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## Consumer acceptability, physicochemical characteristics, and bioactive compounds of sweet potato roots subjected to osmotic dehydration

### Aceitabilidade, características físico-químicas e compostos bioativos de raízes de batata-doce submetidas a desidratação osmótica

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#### Abstract

Sweet potato dehydration is a way of increasing shelf life, modifying and adding value to the final product. However, some of the compounds of nutritional interest may be lost during processing. Thus, this work evaluates different dehydration treatments for sweet potato, and determines the best condition for a quality product. Two sweet potato genotypes (UGA 127 and UGA 34) were first subjected to osmotic dehydration using a 65% sucrose solution or a 2% sodium chloride solution (NaCl), both for 5 hours, being compared with the control treatment. Subsequently, the samples were oven dried at 65 °C for 6 hours. Sweet potatoes were analyzed for sensory characteristics (color, flavor, crispness, aroma, overall acceptability, and purchase intent), physicochemical characteristics (color, titratable acidity, soluble solids), bioactive compounds ( $\beta$ -carotene, phenolic, ascorbic acid), and antioxidant capacity. Potatoes dehydrated with 65% sucrose were well accepted by the tasters. The soluble solids content and soluble solids/titratable acidity ratio were higher for sweet potatoes treated with 65% sucrose. Genotypes differed significantly for luminosity, and the highest average was found for UGA 127, indicating that potatoes processed from this root had a lighter coloration. The content of bioactive compounds varied as a function of the different treatments and genotypes; in general, the highest levels were found in the control and 65% sucrose treatments. Genotype UGA 127 treated with 65% sucrose proved to be a good marketing alternative for small farmers.

**Additional keywords:** antioxidants; *Ipomoea batatas* (L) Lam; osmotic dehydration; sensory analysis.

#### Resumo

A desidratação da batata-doce é uma forma de aumentar o tempo de prateleira, modificar o sabor e agregar valor ao produto final; entretanto, no processamento, parte dos compostos de interesse nutricional pode ser perdida. Neste sentido, o objetivo deste trabalho foi verificar diferentes tratamentos para a desidratação de batatas-doces e determinar a melhor condição para um produto de qualidade. Dois diferentes genótipos (UGA 127 e UGA 34) de batatas-doces foram primeiramente submetidos à desidratação osmótica com solução de sacarose a 65% ou desidratação osmótica com solução de cloreto de sódio (NaCl) a 2%, ambos por 5 horas e comparados com o tratamento-controle. Posteriormente, foram secas em estufa a 65°C por 6 horas. As batatas-doces foram analisadas sensorialmente (cor, sabor, crocância, aroma, aceitação global e intenção de compra), quanto à caracterização físico-química (cor, acidez titulável, sólidos solúveis) e de compostos bioativos ( $\beta$ -caroteno, fenólicos, ácido ascórbico) e capacidade antioxidante. As batatas desidratadas com sacarose a 65% tiveram boa aceitação pelos provadores. O teor de sólidos solúveis e a relação sólidos solúveis/acidez titulável foram maiores para as batatas-doces tratadas com sacarose a 65%. Sobre a luminosidade, houve diferença significativa entre os genótipos, sendo que a maior média encontrada foi para UGA 127, indicando que as batatas processadas a partir desta raiz apresentaram coloração mais clara. O teor de compostos bioativos variou em relação aos diferentes tratamentos e genótipos, sendo em geral as maiores concentrações de compostos bioativos encontradas nos tratamentos-controle e com 65% de sacarose. UGA 127, com 65% de sacarose, mostrou-se como boa alternativa de comercialização para pequenos agricultores.

**Palavras-chave adicionais:** análise sensorial; antioxidantes; desidratação osmótica; *Ipomoea batatas* (L) Lam.

## Introduction

Sweet potato (*Ipomoea batatas* (L) Lam) is native to the Andes, and widely cultivated in South America (Shekhar et al., 2015). It belongs to the family *Convolvulaceae* and is the sixth most consumed food in the world (Wu et al., 2015), after rice, wheat, potato, maize, and cassava (Shekhar et al., 2015).

The sweet potato trade has several advantages due to some peculiar characteristics such as easy adaptability in different growing environments, high weathering resistance, sensory versatility in terms of color, taste, and texture, and its undeniable nutritional value (FAO, 2016; Wu et al., 2015. Suárez et al., 2016).

From the nutritional point of view, sweet potato is rich in various phytochemicals, such as phenolic compounds, anthocyanins, and carotenoids. These phytochemicals and other beneficial molecular components are directly associated with antioxidants that play a key role in the prevention of many chronic diseases (Mcgill et al., 2013; Williams et al., 2013; Lebot et al., 2016; Tian et al., 2016). It also has important levels of other nutrients such as carbohydrates, proteins, fibers, vitamins A, B, C, and E, and minerals such as calcium, potassium, phosphorus, sodium, magnesium, manganese, zinc, copper, and iron (Dincer et al., 2011; FAO, 2012; Kim et al., 2012; Wu et al., 2015; Cai et al., 2016; Trancoso-Reyes et al., 2016).

Roots can be consumed in a variety of ways, in which baking, cooking, and frying are the most common cooking methods. Notwithstanding, it has also been widely used in the industry for the production of various products such as cakes, noodles, chips, and modified starches. Sweet potato processing is a way to increase the shelf life of the vegetable and to modify the flavor to a more attractive preparation, with better acceptability, adding value to the final product and generating income for producers (Yuang, 2016).

A type of processing that has gained space in recent years, especially due to lifestyle changes, is dehydrated food (Megías-Pérez et al., 2014). By removing water from the food, drying or dehydration increases shelf life by inhibiting microbial and enzymatic activity (Oriente et al., 2016). Moreover, most of the dehydrated vegetables and fruits obtained by convection drying first go through bleaching or osmotic dehydration treatment (Villamiel et al., 2015). Osmotic dehydration is widely used to remove water from vegetable tissues by immersion in a concentrated solution. In addition to increasing product shelf life, the advantages of this drying technique compared to others include energy savings, simple process equipment, and shorter processing time (Lenart et al., 2006).

In this sense and due to the constant need for innovation for the strengthening of family farming in food supply, this study developed sweet potatoes dehydrated by different treatments. Aiming to determine the best treatment for a final quality product, with less loss of compounds of nutritional interest, the fol-

lowing were evaluated: sensory acceptability, bioactive compounds content, antioxidant capacity, and physicochemical properties.

## Materials and methods

The sweet potatoes used were grown in an experimental field in Guarapuava-PR. Seedlings from roots (genotypes) UGA 127 and UGA 34 were obtained from the germplasm bank of the Universidade Estadual do Centro-Oeste, produced from small pieces of two-node seedlings, according to methodology proposed by Brune et al. (2005).

According to the Köppen classification, the climate of the region is temperate (Cfb), with average temperature in the coldest month below 18 °C and average temperature in the warmest month above 22 °C (IAPAR, 2014).

## Development of dehydrated potatoes

In the laboratory, sweet potatoes of the two genotypes (UGA 127 and UGA 34) were selected according to size and peel uniformity, being subsequently washed in running water and then immersed in 2% sodium hypochlorite solution for 15 to 20 minutes for sanitization. The potato peels were not removed because they were part of the final product. After being cleaned, the samples were sliced so as to obtain homogeneous slices of approximately 5 mm thickness.

We selected six kilograms (kg) of sweet potatoes from each genotype. Each sweet potato genotype was divided into three lots of two kilograms (kg) each for three different treatments. The treatments consisted of 1) osmotic dehydration with 65% sucrose solution for 5 hours; 2) osmotic dehydration with 2% sodium chloride solution for 5 hours; 3) absence of osmotic dehydration (control treatment). After osmotic dehydration, all samples were immersed in 1% citric acid solution for two seconds to avoid enzymatic browning, being subsequently placed in trays and oven-dried at 65 °C for 6 hours or until reaching a moisture content of less than 12% (Anvisa, 2005). A total of six treatments was obtained.

After osmotic dehydration followed by oven drying, the sweet potatoes were stored in identified plastic containers and closed in vacuum. One week later, they were used for the sensory analysis and for the analysis of physicochemical characteristics and bioactive compounds.

The sweet potatoes obtained were evaluated microbiologically to attest the quality and food safety of the products offered to the tasters. Microbiological analyses were performed using methodologies described in APHA (2001) and Silva et al. (1997), counting coliforms at 35 and 45 °C and Salmonella sp.

## Yield analysis

The sweet potatoes were weighed (digital scale Balmak; maximum capacity of 10 kg and mini-

mum of 20 g) after osmotic dehydration (initial weight). Later, they were oven-dried at 65 °C and dried with the aid of a food dryer, to remove excess solution. After oven drying (final weight), they were weighed again to calculate sweet potato yield according to the formula:

$$\text{Yield (\%)} = \frac{\text{Final weight}}{\text{Initial weight}} 100 \quad (1)$$

### Sensory analysis

Dehydrated sweet potatoes were sensory analyzed after approval of the study protocol (Opinion number: 2.173.514), in accordance with the provisions of the Declaration of Helsinki by the Human Research Ethics Committee of the Universidade Estadual do Centro-Oeste - UNICENTRO. To be included in the research, the participant should be at least 18 years old and accept to perform the sensory analysis by signing the Free and Informed Consent Form (FICF), agreeing to experiment and express his/her satisfaction with the analyzed product. Excluded participants were those under the age of 18 years, those who claimed any allergy to products that were evaluated, or those who did not allow their results to be disclosed or used in the present study.

Sensory tests were conducted in the Sensory Analysis Laboratory, in individual booths with white lighting. The volunteer assessors were selected among students, teachers, and staff of the institution, of both sexes, and without any subordination to the researchers. These were recruited from posters placed throughout the University and through verbal approach by the researchers.

All participants (n = 65) received six samples of dehydrated sweet potatoes and evaluated them for color, flavor, crispness, aroma, and overall acceptability using a 9-point structured hedonic scale ranging from disliked extremely (grade 1) to liked extremely (grade 9), according to Dutcosky's methodology (2011). For the purchase intent test, a 5-point scale was anchored at its extremes with the terms: 1 - certainly would not buy, and 5 - certainly would buy.

Each assessor received a slice of each sample in white plastic plates randomly coded with three-digit numbers, accompanied by water to be used between each test. Samples were offered to the assessors in a sequential monadic way.

The Acceptability Index (AI) of all evaluated attributes was calculated according to Dutcosky, (2011):

$$\text{AI (\%)} = \frac{A}{B} 100 \quad (2)$$

Wherein: A is the average grade obtained for the product, and B is the maximum grade given to the product.

The treatment was considered well accepted when AI was greater than or equal to 70% (Teixeira et al., 1987).

### Physicochemical analysis

Color changes were determined using a Minolta colorimeter with illuminant D65. Values of L\*, a\*, and b\* were obtained; where L\* is luminosity, a\* defines the transition from the green color (-a\*) to the red color (+a\*), and b\* represents the transition from the blue color (-b\*) to the yellow color (+b\*). Hue angle (°H) values were calculated according to the formula °H = tg<sup>-1</sup> (b\*/a\*). Readings were performed in 10 slices of each genotype at three different points. The analysis was performed under high light conditions.

The titratable acidity was performed in triplicate and according to the Association of Official Analytical Chemists (2000), through titration with 0.1 mol L<sup>-1</sup> sodium hydroxide up to pH 8.1. The results were expressed as g of citric acid per 100 g of sample.

The soluble solids content was analyzed in triplicate in a bench refractometer with two to three drops of the sample filtrate; the results were expressed as °Brix. The filtrate was obtained by solubilizing the dehydrated samples in a known volume of distilled water (ratio 1:3, m/v).

The SS/TA ratio was calculated from the data on soluble solids content and titratable acidity.

### Analysis of bioactive compounds

For extraction of the phenolic compounds, the extracts prepared with ethanol:water (80:20) followed the ratio of 1:2 (sample:solvent). The mixture was homogenized in a low-light environment for 30 minutes on a shaker table, being then subjected to a water bath at 37 °C for 30 minutes and subsequent centrifugation for 5 minutes at 2790 g. The supernatant was used for the analysis of phenolic compounds.

The content of phenolic compounds was determined by the Folin-Ciocalteu method as described by Woisky and Salatino (1998), in a spectrophotometer at 740 nm, using gallic acid as the standard for the calibration curve. The results were expressed as mg of gallic acid per 100 g of sample.

The ascorbic acid content was determined by the titration method of AOAC (1984) modified by Benassi and Antunes (1988); the results were expressed as mg of ascorbic acid per 100 g of sample. β-carotene was determined by the spectrophotometric method described by Rodriguez-Amaya (2001); the results were expressed as μg of β-carotene per g of sample.

All analyses of bioactive compounds were performed in three replicates.

### Analysis of antioxidant capacity

Lipophilic and hydrophilic extracts for the analysis of antioxidants were prepared by mixing the homogenized sample 1) with ethanol:water (80:20) solution in the ratio of 1:5 (sample:solvent) for the extraction of hydrophilic compounds, and 2) with hexane in the ratio of 1:5 (solvent:sample) for the extraction of lipophilic compounds. These procedures were

performed in a low-light environment. Extraction was vortexed at room temperature for 1 minute and the resulting extract centrifuged at 2790 g for 5 minutes, followed by removal of the supernatant. This procedure was performed until the supernatant had no apparent dye/pigment (about 4 times). Then the supernatants were pooled, and the volume standardized to 25 mL for subsequent analyses. The analyses were conducted in three replicates.

Antioxidant activity was determined by the ABTS method according to the methodology described by Miller et al. (1996). Trolox, a synthetic antioxidant analogous to vitamin E, was used at 100-2000 µM for the construction of the standard curve. The results of the antioxidant capacity were expressed as µmol of Trolox equivalents per 100 g of sample.

### Statistical analysis

Statistical analysis was performed using SAS 9.0 software. The data obtained from the sensory analysis were submitted to ANOVA in randomized blocks, in which each assessor represents a block. Physico-

chemical analysis, bioactive compounds, and antioxidant activity were performed in a completely randomized design with three replicates. The data were analyzed for normality (Shapiro-Wilk) and homogeneity of variance (Box-Cox). Moreover, the data were subjected to analysis of variance (ANOVA) in a 3x2 factorial arrangement (3 treatments and 2 genotypes). When the results of the F test (ANOVA) were significant, the means were compared by the Tukey test ( $p < 0.05$ ).

### Results and discussion

The osmotic pressure difference between the food and the osmotic solution provides the necessary driving force for the removal of water from the food to the osmotic solution (Fernandes et al., 2009). These mass exchanges between food and solution affect the yield of dehydrated products (Shi, 2008). Table 1 shows the yield results of two sweet potato genotypes dehydrated with different treatments.

**Table 1** – Yield (%) of dehydrated sweet potatoes as function of pre-treatments.

Genotype	Treatment		
	Control	NaCl 2%	Sucrose 65%
UGA 34	31.25	34.54	48.75
UGA 127	32.35	30.00	45.31

Statistical analysis not performed, since these data were not obtained in triplicate

In the present study, sweet potatoes showed yields ranging from 31.25 to 48.75% for UGA 34 and from 30% to 45.31% for UGA 127. In root UGA 34, the control treatment accounted for the lowest yield, whereas root UGA 127 showed lower yield with the 2% NaCl treatment. Furthermore, both genotypes showed higher yield with the 65% sucrose treatment.

Neto et al. (2005) found a similar result, in which treatments with sucrose syrups at 55° and 65° Brix showed lower weight loss. Similar results were also found by Beristain et al. (1990), Lima et al. (2004), and Sousa (2002) during osmotic dehydration of pineapple, banana, and melon, respectively. According to Beristain et al. (1990), this fact occurred due to the difficulty of sucrose diffusion through the cell wall, given its high molecular weight (unlike water molecules, which have their diffusion favored).

Besides weight loss, after osmotic dehydration, sweet potatoes also showed changes in the sensory aspect. Figure 1 shows the sweet potato genotypes submitted to different osmotic dehydration treatments.

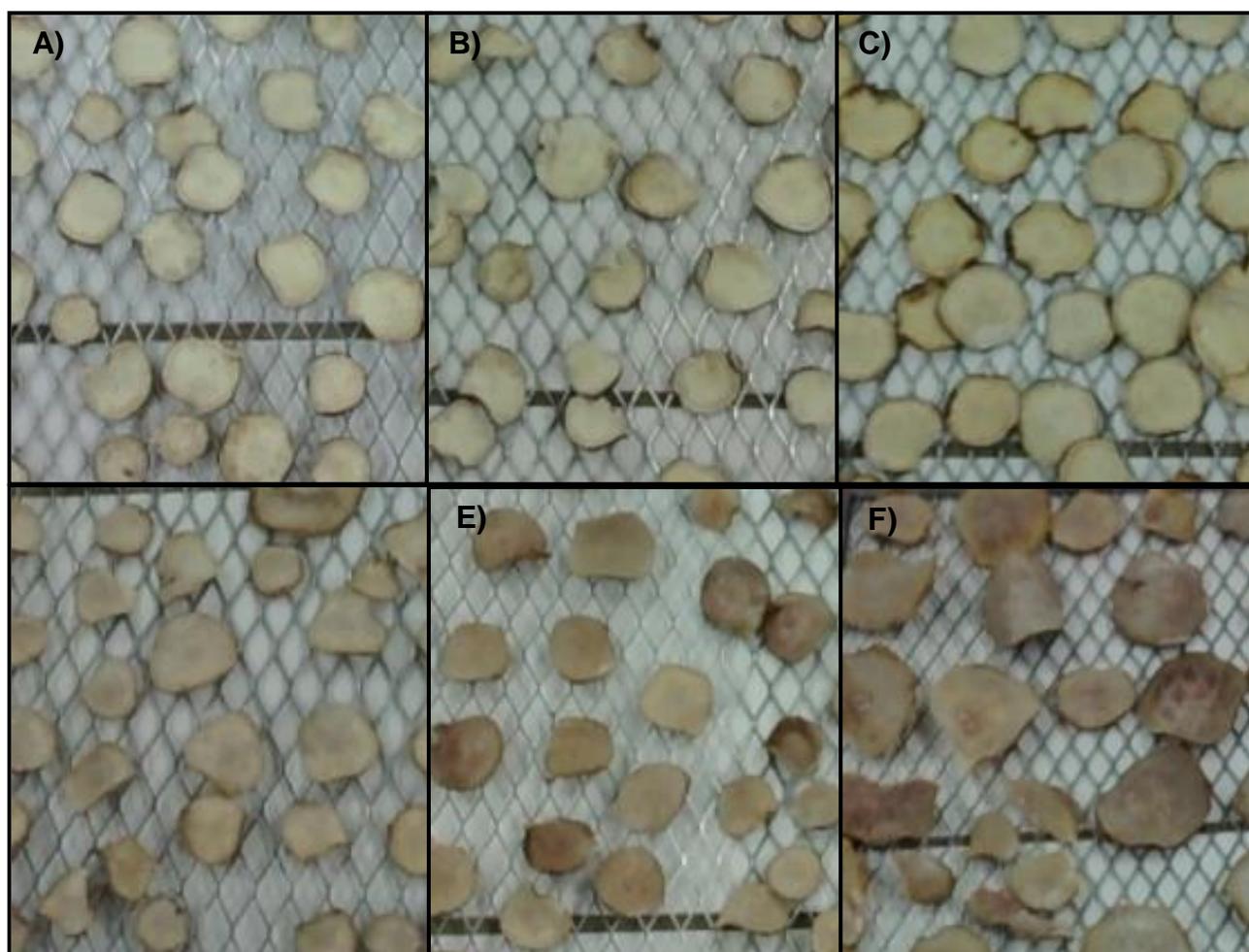
Tables 2 and 3 show the results of the sensory evaluation of dehydrated sweet potato roots. For the attributes flavor and purchase intention there was a significant interaction between treatments and genotypes ( $p < 0.05$ ), whereas for the attributes color, aroma, crispness and overall acceptability there was no

interaction, but only significance was isolated for treatments and genotypes.

For the attributes color, aroma, crispness, and overall acceptability, there was a significant difference between genotypes and between treatments. The highest averages were found for root UGA 127 under the 65% sucrose treatment, with average scores corresponding to “liked slightly”.

When questioned about their purchase intent, assessors showed a greater interest in purchasing sweet potatoes dehydrated with 65% sucrose, from both genotypes. In addition, the purchase intent was higher for root UGA 127 compared to root UGA 34 only in the 2% NaCl treatment. For the other treatments, there were no differences in the intention to purchase the roots.

In general, root UGA 127 had a better acceptability, since in most attributes this root obtained higher grades compared to root UGA 34. This may have occurred in part due to the accelerated enzymatic browning of UGA 34 compared to UGA 127 before and during osmotic dehydration, impairing its appearance (Figure 1). Enzymatic browning is related to the action of polyphenoloxidase (PPO) and peroxidase (POD) enzymes, which use phenolic compounds as substrates and cause undesirable changes in the color, taste, and aroma of plants (Valderrama et al., 2001).



**Figure 1** - Genotypes of sweet potatoes after dehydration. A) UGA 127 without pre-dehydration; B) UGA 127 with 2% NaCl; C) UGA 127 with sucrose solution 65%; D) UGA 34 without pre-dehydration; E) UGA 34 with 2% NaCl; F) UGA 34 with sucrose solution 65%.

**Table 2** - Averages of affective sensory tests and purchase intention (means ± standard deviation) performed for dehydrated sweet potatoes of two genotypes under different treatments.

Attribute	Genotype	Treatment			Mean
		Control	NaCl 2%	Sucrose 65%	
Color	UGA 127	5.61 ± 2	5.61 ± 2	6.57 ± 1	5.93 a
	UGA 34	4.15 ± 2	4.61 ± 2	5.09 ± 2	4.62 b
	Mean	5.11 B	4.88 B	5.83 A	
Aroma	UGA 127	5.63 ± 2	5.11 ± 2	6.13 ± 2	5.91 a
	UGA 34	5.32 ± 2	5.97 ± 2	5.69 ± 2	5.37 b
	Mean	5.48 B	5.54 B	5.91 A	
Flavor	UGA 127	4.80 ± 2 Ca	5.57 ± 2 Ba	7.38 ± 1 Aa	
	UGA 34	4.26 ± 2 Bb	4.18 ± 2 Bb	6.66 ± 2 Ab	
Crispness	UGA 127	6.23 ± 2	6.46 ± 2	6.88 ± 2	6.52 a
	UGA 34	5.49 ± 2	5.58 ± 2	6.58 ± 2	5.88 b
	Mean	5.86 B	6.02 B	6.73 A	
Overall acceptability	UGA 127	5.88 ± 2	6.09 ± 2	7.09 ± 1	6.35 a
	UGA 34	5.00 ± 2	4.80 ± 2	6.12 ± 2	5.31 b
	Mean	5.44 B	5.45 B	6.61 A	
Purchase intention	UGA 127	2.51 ± 1 Ba	2.77 ± 1 Ba	3.75 ± 1 Aa	
	UGA 34	2.26 ± 1 Ba	2.00 ± 1 Bb	3.46 ± 1 Aa	

Means followed by different lowercase and uppercase letters in the same column and row, respectively, differ from each other at 5% probability by the Tukey test

**Table 3** - Acceptability index (AI) for dehydrated sweet potatoes of two genotypes under different treatments.

Attribute	Genotype	Treatment		
		Control	NaCl 2%	Sucrose 65%
Color	UGA 127	62.3	62.3	73.0
	UGA 34	46.1	51.2	56.6
Aroma	UGA 127	62.6	56.8	68.1
	UGA 34	59.1	74.7	63.2
Flavor	UGA 127	60.0	61.9	82.0
	UGA 34	53.3	46.4	74.0
Crispness	UGA 127	69.2	71.8	76.4
	UGA 34	61.0	62.0	73.1
Overall acceptability	UGA 127	65.3	67.7	78.8
	UGA 34	55.6	60.0	68.0

Root UGA 127 treated with 65% sucrose showed an AI greater than 70% for the color attribute; regarding the aroma, this was observed only for root UGA 34 treated with 2% NaCl; for flavor, the 65% treatment in both roots led to an acceptability greater than 70%; regarding crispness, this was observed for root UGA 127 treated with 65% sucrose and 2% NaCl, and for root UGA 34 treated with sucrose. Finally, in overall acceptability, the highest AI was obtained for root UGA 127 treated with 65% sucrose.

For soluble solids, there was significant interaction between treatments and genotypes ( $p < 0.05$ ), whereas for the other characteristics there was no interaction between genotypes and treatments, there

was only significance for treatments and genotypes.

The color directly influences the acceptability of the product (Ductosky, 2011), since it is generally the first criterion used in the acceptance or rejection of the product by the consumer. Thus, it is an important attribute in the food industry (Batista, 1994). If the color is unattractive, the food will most likely not be ingested or proven (Silva et al., 2000). In the present study, the addition of sugar to the potatoes provided them with a color that was more pleasant to the consumers. This color was a slightly darker yellow, as can be observed in Figure 1 and confirmed by the hue and luminosity values (Table 4).

**Table 4** - Soluble solids content (SS), titratable acidity (TA), SS/TA ratio and color (Brightness and Hue) of dehydrated sweet potatoes from two genotypes under different treatments.

Physicochemical analysis	Genotype	Treatment			Mean
		Control	NaCl 2%	Sucrose 65%	
SS (°Brix)	UGA 127	3.92 ± 0.14 Ca	4.33 ± 0.14 Ba	7.66 ± 0.14 Aa	-
	UGA 34	3.75 ± 0 Ba	3.75 ± 0 Bb	6.91 ± 0.14 Ab	-
TA (g 100 g <sup>-1</sup> )	UGA 127	0.37 ± 0.01	0.34 ± 0.02	0.24 ± 0	0.32 a
	UGA 34	0.31 ± 0.06	0.29 ± 0.01	0.21 ± 0.01	0.27 b
	Mean	0.34 A	0.32 A	0.22 B	-
SS/TA	UGA 127	10.37 ± 0.19	12.50 ± 0.65	31.95 ± 0.58	18.28 a
	UGA 34	12.49 ± 2.38	12.77 ± 0.31	33.40 ± 2.00	19.55 a
	Mean	11.43 B	12.64 B	32.68 A	-
Brightness	UGA 127	73.72 ± 3.29	72.02 ± 2.85	70.27 ± 2.58	72.00 a
	UGA 34	57.67 ± 4.01	57.67 ± 3.91	56.17 ± 2.99	57.17 b
	Mean	65.70 A	64.85 A	63.22 A	-
Hue	UGA 127	101.70 ± 1.53	101.98 ± 3.02	97.87 ± 0.97	100.52 a
	UGA 34	87.06 ± 3.47	87.08 ± 6.69	81.97 ± 3.32	85.37 b
	Mean	94.38 A	94.53 A	89.92 B	-

Means followed by different lowercase and uppercase letters in the same column and row, respectively, differ from each other at 5% probability by the Tukey test.

Araújo (2010) evaluated the texture of carrots dried in greenhouse environments and subjected to treatments without osmotic dehydration (A), with 10% NaCl and 50° Brix sucrose (B), and with 50° Brix sucrose (C). Carrots from treatment C had higher acceptability (AI of 72.83%), as observed in this study with sweet potato, for the crispness attribute.

In the same study, Araújo (2010) observed that osmotic dehydration was favorable to the appear-

ance attribute in slices of dehydrated carrots compared to carrots not submitted to this treatment. However, different from the results obtained in our study (in this case, for the color attribute), even though the carrots treated with 50 °Brix solution showed greater acceptability, they did not obtain AI greater than 70%.

Regarding the flavor attribute, the 65% sucrose treatment led to a better acceptance for both genotypes. When comparing genotypes, flavor was

greater for root UGA 127 in all treatments. For this attribute, Araújo (2010) also found that the treatment with sucrose showed higher AI (77.42%) than the treatment with NaCl and sucrose and the treatment without osmotic dehydration.

In addition, acceptability was higher for root UGA 127 with the 65% sucrose treatment, showing AI above 70% for all attributes, except aroma. For root UGA 34, the 65% sucrose treatment led to higher averages in most of the attributes, although acceptability indexes are low, confirming once again the preference for root UGA 127. For both genotypes, osmotic dehydration with 65% sucrose positively influenced acceptability. According to Dalla Rosa et al. (2001), the osmotic dehydration process plays an important role in the sensory quality of the final product, leading to positive changes in color, taste, aroma, and texture.

At first, consumers buy vegetables and fruits based on their visual appearance, and then repeatedly by other sensory factors such as flavor (Echeverría et al., 2015). As a result, consumers are willing to pay more for foods with high sensory quality, which includes especially flavor and sweetness. In this regard, sucrose is the most readily available soluble, used as a standard reference for sweetness (Mikulic-Petkovsek et al., 2016). This association of factors related to sweetness resulted in a greater acceptability in sweet potatoes subjected to 65% sucrose in the present study.

Table 4 shows the results for soluble solids content, titratable acidity, soluble solids/titratable acidity ratio, and color of dehydrated sweet potatoes.

Soluble solids (°Brix) play a relevant role in the quality of fruits and some vegetables, influencing thermophysical, chemical, and biological properties of products. These compounds exert great importance in the control of ingredients to be added to the product and in the final quality (Araújo, 2001; Simões, 1997). Regarding the soluble solids content, the interaction between genotypes and treatments was significant. The 65% sucrose treatment led to a higher soluble solids content for both root UGA 127 and root UGA 34. This was already expected because the addition of sugar in large quantities increases the solids content since sugars are the main components of soluble solids (Azzini et al., 1980). According to Egea & Lobato (2014), sucrose is considered an excellent osmotic agent, especially when osmotic dehydration is used as a preliminary step to convective drying, as it prevents enzymatic browning and the loss of aroma and color. It is expected that the higher the sucrose concentration in the osmotic solution, the higher the solids gain (Queji et al., 2011).

Regarding the differences in soluble solids among genotypes, root UGA 127 showed higher soluble solids content when treated with 2% NaCl and 65% sucrose; however, genotypes did not differ statistically in the control treatment. This higher content for root UGA 127 is probably the result of a higher initial soluble solids content compared to root UGA 34, as

observed for control sweet potatoes.

Titratable acidity (TA) is an indicator of the amount of organic acids present in the fruit, and is important for sensory characteristics since it adds value to the flavor (Guimarães et al., 2014). There was a statistically significant difference for this parameter between treatments and between genotypes; their interaction, however, was not significant. The lowest average TA was found for the 65% sucrose treatment. When comparing among genotypes, root UGA 34 had the lowest average.

Caetano et al. (2012) prepared jellies with whole juice and acerola pulp in the following formulations: T1 (1:1 juice:sugar); T2 (0.6:0.4 juice:sugar); T3 (1:1 pulp:sugar), and T4 (0.6:0.4 pulp:sugar), all with 1% pectin in relation to sugar. The authors observed smaller values for titratable acidity in formulations T1 and T3, which contained more sugar, corroborating the data obtained in this study. The lower average TA for root UGA 34 may be responsible for the more accelerated enzymatic browning of this root compared to UGA 127 before and during osmotic dehydration.

The soluble solids/titratable acidity ratio (SS/TA) is of paramount importance for sensory analysis since it demonstrates the balance between sugar and acidity, determining fruit flavor (Thé et al., 2001). Treatments differed significantly for the SS/TA ratio, whereas genotypes did not differ; the interaction between these factors was not significant. The highest average was found for the 65% sucrose treatment. According to Fernandes et al. (2010), the SS/TA ratio is generally a good indicator of flavor, however, it is not determinative. This can be confirmed in our study, since root UGA 34 obtained a higher SS/TA ratio compared to root UGA 127 (nonsignificant difference), but was not the most preferred sensorially.

Genotypes differed significantly for luminosity. Root UGA 127 had the highest average, indicating that potatoes processed from this root showed a lighter color. Luminosity averages for potatoes dehydrated in the control treatment and in treatments with 2% NaCl and 65% sucrose did not differ statistically among themselves. These results differ from those of Krokida et al. (2000), in which the increase of luminosity was due to the impregnation of sugar during dehydration. Moreover, Argandoña et al. (2002) also observed contrasting results for melons of the cultivar Gold Mine treated with 50, 60, and 70° Brix sucrose, at 30, 40, and 50 °C, which had higher luminosity ( $L^*$ ) values compared to fresh fruit.

The Hue angle indicates the color of a product, 0° red, 90° yellow, 180° green, and 270° blue (García et al., 2015). This characteristic differed significantly between genotypes and between treatments. The highest averages were found for the 2% NaCl and control treatments. Regarding genotypes, UGA 127 showed the highest average. Regarding treatments, the lowest hue angle was verified in the 65% sucrose treatment, due to the addition of sugar, which leaves the sweet potatoes with a slightly darker yellow color

compared to those dehydrated with NaCl and those of the control treatment, probably due to Maillard's reaction. This reaction modifies the sensory characteristics of foods, especially color, after reactions between reducing sugars and amino groups, and may be desirable or undesirable, depending on the product. In this

study, the addition of sugar to the potatoes gave them a color that was more pleasant to the consumers, especially for UGA 127.

The results obtained for bioactive compound contents in dehydrated sweet potatoes are presented in Table 5.

**Table 5** - Content of  $\beta$ -carotene, ascorbic acid, phenolic compounds and lipophilic (L) and hydrophilic (H) antiradicalar activity of dehydrated sweet potatoes of two genotypes under different treatments.

Bioactive compounds	Genotype	Treatment					
		Control		NaCl 2%		Sucrose 65%	
$\beta$ -carotene ( $\mu\text{g g}^{-1}$ )	UGA 127	1.27 $\pm$ 0.21	Ab	1.03 $\pm$ 0.32	Ab	1.25 $\pm$ 0.04	Ab
	UGA 34	1.90 $\pm$ 0.34	Aa	2.05 $\pm$ 0.41	Aa	2.04 $\pm$ 0.85	Aa
Ascorbic acid (mg 100 g <sup>-1</sup> )	UGA 127	34.85 $\pm$ 0.57	Aa	31.87 $\pm$ 2.44	Ba	19.38 $\pm$ 1.42	Ca
	UGA 34	34.35 $\pm$ 4.78	Aa	29.18 $\pm$ 1.71	Bb	16.23 $\pm$ 0.21	Cb
Phenolic compounds (mg 100 g <sup>-1</sup> )	UGA 127	63.64 $\pm$ 2.79	Ab	64.31 $\pm$ 1.34	Aa	60.64 $\pm$ 3.64	Ba
	UGA 34	67.37 $\pm$ 1.74	Aa	43.34 $\pm$ 1.33	Bb	35.90 $\pm$ 0.57	Cb
L ( $\mu\text{mol 100 g}^{-1}$ )	UGA 127	310.68 $\pm$ 34.51	Bb	194.32 $\pm$ 16.56	Ca	433.17 $\pm$ 51.44	Aa
	UGA 34	329.01 $\pm$ 62.26	Ba	186.12 $\pm$ 37.27	Ca	427.88 $\pm$ 25.58	Aa
H ( $\mu\text{mol 100 g}^{-1}$ )	UGA 127	283.69 $\pm$ 16.82	Ab	195.81 $\pm$ 4.46	Cb	271.72 $\pm$ 3.15	Ba
	UGA 34	297.91 $\pm$ 9.15	Aa	205.23 $\pm$ 6.92	Ca	264.48 $\pm$ 4.60	Ba

Means followed by different lowercase and uppercase letters in the same column and row, respectively, differ from each other at 5% probability by the Tukey test

For all bioactive compounds and for antioxidant capacity, the interaction was significant between treatments and genotypes. Regarding  $\beta$ -carotene content, UGA 34 had higher levels for all treatments compared to UGA 127. Among treatments of the same genotype, there was no difference, that is, treatments did not influence  $\beta$ -carotene content. Therefore, all treatments preserved  $\beta$ -carotene contents, which were influenced only by genotype. This maintenance of  $\beta$ -carotene contents is fundamental since it allows the consumer to choose the way he/she wants to consume, without prejudice to the concentration of this compound, which presents provitamin A activity (Campos et al., 2006) and is essential for many physiological activities (Gerster, 1997).

According to Dorais (2007), compounds with antioxidant activity may vary according to the cultivar, crop management, stage of maturity at harvest, and environmental factors such as luminosity and temperature.

Food-based strategies, including the use of sweet potatoes as a rich source of provitamin A carotenoids such as  $\beta$ -carotene, are promising tools for eradicating vitamin A deficiency (VAD) in developing countries (Low et al. 2001; Haskell et al., 2004; Van et al., 2006; Low et al., 2007). Knowing that sweet potato is a rich source of  $\beta$ -carotene and considering the genotypes with the highest concentration of this bioactive compound, it is possible to outline fundamental strategies for health promotion, such as the reduction of VAD.

Regarding ascorbic acid contents, root UGA 127 differed significantly in the treatments with 2% NaCl and 65% sucrose. The sweet potatoes of the control treatment, both from UGA 127 and UGA 34 genotypes, showed higher ascorbic acid content, fol-

lowed by potatoes treated with 2% NaCl and, finally, potatoes treated with 65% sucrose. In this case, the treatments did not favor the retention of ascorbic acid, probably due to its water solubility and the losses to the solution water during treatments that lasted for 6 hours.

Regarding the concentration of phenolic compounds, for root UGA 127, potatoes from the control treatment and those treated with 2% NaCl showed higher phenolic compound contents. For root UGA 34, in turn, potatoes of the control treatment showed a higher concentration of phenolic compounds.

The lower concentration of ascorbic acid and phenolic compounds after osmotic dehydration demonstrates that high levels of sugar, and probably of salt, hinder the retention of these compounds. It is important to know this result since, besides presenting a reducing chemical behavior, ascorbic acid acts as an antioxidant, aiding in the accumulation of iron in the bone marrow, spleen and liver, in the production of collagen, in the maintenance of resistance to bacterial and viral diseases, in the formation of bones and teeth, in the maintenance of blood capillaries, among others (Le Couteur et al., 2006). Phenolic compounds also reduce the effects caused by oxidative stress due to their antioxidant function, consequently reducing the risk of several diseases such as cardiovascular diseases and some types of cancer (Joshiyura et al., 2009; Crowe et al., 2011; Wootton-Beard et al., 2011).

Regarding antioxidants, some are hydrophilic, such as ascorbic acid, while others are clearly lipophilic, such as vitamin E. Phenolic compounds (flavonoids) and carotenoids ( $\beta$ -carotene) also have antioxidant activity (Gawlik-Dziki, 2012; Vetrani et al., 2012). Each of them has its own function in the organism, acting in different places, but working together (Jia et al., 1998; Marinova et al., 2008; Yang et al., 2009).

For lipophilic antioxidant capacity, the highest concentrations were found with the 65% sucrose treatment, followed by the dehydrated sweet potatoes from the control treatment and those treated with 2% NaCl. There was no difference between genotypes in relation to the treatments with 2% NaCl and 65% sucrose. For the control treatment, in turn, root UGA 34 had higher antioxidant activity.

Regarding hydrophilic antioxidant capacity, potatoes of the control treatment had the highest concentrations of antioxidant compounds, for both genotypes, followed by potatoes treated with 65% sucrose and, finally, potatoes treated with 2% NaCl. Genotype UGA 34 showed higher values of antioxidant activity compared to UGA 127 in the 2% NaCl and control treatments. For the 65% sucrose treatment, there was no difference between genotypes.

In the study of Abreu (2010), tomatoes were subjected to osmo-convective drying (OCD), which is preceded by osmotic dehydration, similar to the present study. In their case, different immersions were used: OCD1 (5% NaCl), OCD2 (10% NaCl), OCD3 (5% NaCl + 10% sucrose), OCD4 (10% NaCl + 5% sucrose), OCD5 (5% sucrose), and OCD6 (10% sucrose). The tomatoes subjected to osmo-convective drying in the different immersions generally had a higher preservation of antioxidant compounds, similarly to the present study, showing that this may be a more adequate method to preserve the antioxidant potential of tomato.

According to Alakali et al. (2006), the most common dehydrating agent for fruits is sucrose, which is also considered a good osmotic agent, as it prevents enzymatic browning and the loss of aroma. This prevention is due to the presence of a layer of the disaccharide, formed on the surface of the dehydrated product. This layer constitutes an obstacle to the contact with oxygen, minimizing or preventing enzymatic browning, besides having a positive influence on the maintenance of flavoring substances and some bioactive compounds of the food.

In the case of genotypes, it is fundamental to identify those with the highest levels of bioactive compounds, considering their importance for health promotion. In general, the content of bioactive compounds varied between the treatments and genotypes of dehydrated sweet potatoes.

## Conclusion

The results indicate that the osmotic treatment with 65% sucrose for root UGA 127 was well accepted by the tasters. The addition of sucrose improved the consumer acceptability of the color, aroma, flavor, and crispness of the product when compared to the sweet potatoes from the control and 2% NaCl treatments. The 65% sucrose treatment showed the highest soluble solids content and the highest SS/TA ratio, which may have influenced the preference of tasters for this treatment.

As for the contents of phenolic compounds,  $\beta$ -carotene, ascorbic acid, and antioxidant activity, the sweet potatoes showed variations among all the treatments, the same occurring among the genotypes. The control treatment showed higher values especially for ascorbic acid and hydrophilic antioxidant capacity, regardless of genotype. However, the products of this treatment were not preferred from the sensory point of view. In this sense, according to the results of the sensory analysis, root UGA 127 treated with 65% sucrose proved to be a good value-adding alternative for small farmers. Moreover, this genotype/treatment interaction appears to be promising for the preservation of compounds of nutritional interest.

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