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Development and sensorial acceptance of biofortified dehydrated cassava chips

Desenvolvimento e aceitação sensorial de *chips* desidratado de mandioca biofortificada

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Abstract

Cassava is the food base for millions of people in tropical Africa, Latin America and Asia. However, cassava commercial varieties are deficient in vitamin A and the consumption of biofortified cassava, which has a higher concentration of β-carotene in the roots, represents an alternative to prevent this deficiency. Dehydrated products are an integral part of many consumers' diet, which have preferred healthier and lower calorie foods. This study aimed to develop a dehydrated product of cassava (dehydrated chips) from biofortified varieties. The dehydrated chips were elaborated from the following biofortified cassava genotypes: BRS Dourada, BRS Gema de Ovo, BRS Jari and hybrid 2003 14-11. For obtaining the dehydrated chips, cassava roots were washed, sanitized, peeled, sliced to a thickness of 0.8 mm, blanched and dehydrated at 65 °C. First, dehydrated chips were prepared with no added flavoring, from roots of four cassava genotypes harvested at 12 months after planting, in order to select the two most suitable for dehydrated chips production based on sensory acceptance. In the second stage, dehydrated chips were produced with the addition of onion and parsley flavoring, from the two genotypes selected in the previous step. The BRS Jari variety and hybrid 2003 14-11 showed highest total carotenoid content, 10.54 $\mu g\ g^{-1}$ and 6.92 $\mu g\ g^{-1}$, respectively, and β-carotene, 8.93 $\mu g\ g^{-1}$ and 4.98 $\mu g\ g^{-1}$, respectively. For carotenoids and β-carotene retention there was no significant difference among the dehydrated chips prepared with four biofortified cassava genotypes, which showed average values of 76% and 67%, respectively. Dehydrated chips made with the BRS Jari and hybrid 2003 14-11 had highest average for flavor attribute and did not differ on the crispness and overall acceptance and classified between "like slightly" and "like moderately". Despite the addition of "onion and parsley" flavoring, there has been no greater acceptance by consumers. Dehydrated cassava chips made with the BRS Jari variety and the hybrid 2003 14-11 showed good sensorial acceptance and higher total carotenoid and β-carotene contents, thus being biofortified varieties suitable for the elaboration of this product.

Key words: β-carotene. Drying. *Manihot esculenta* Crantz. Sensory evaluation.

Resumo

A mandioca é a base alimentar para milhões de pessoas das regiões tropicais da África, América Latina e Ásia. Contudo as variedades comerciais de mandioca são deficientes em vitamina A e o consumo de mandioca biofortificada, que apresenta maior concentração de β-caroteno nas raízes, representa uma

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alternativa para prevenir essa deficiência. Os produtos desidratados são uma parte integrante da dieta de muitos consumidores, os quais têm preferido alimentos mais saudáveis e de menor valor calórico. O objetivo desse estudo foi desenvolver um produto desidratado de mandioca (*chips* desidratados) a partir de variedades biofortificadas. Os *chips* desidratados foram elaborados a partir de raízes dos seguintes genótipos de mandioca biofortificados: BRS Dourada, BRS Gema de Ovo, BRS Jari e o híbrido 2003 14-11. Para a obtenção dos *chips* desidratados, as raízes de mandioca foram lavadas, sanitizadas, descascadas, fatiadas com 0,8 mm de espessura, branqueadas e desidratadas a 65 °C. Na primeira etapa, os *chips* desidratados foram elaborados sem adição de aromatizante, a partir de raízes de quatro genótipos de mandioca, colhidos aos 12 meses após o plantio, a fim de selecionar os dois melhores para a produção dos *chips* desidratados com base na aceitação sensorial. Na segunda etapa, foram elaborados *chips* desidratados com adição de aromatizante sabor cebola e salsa, a partir dos dois genótipos selecionados na etapa anterior. A variedade BRS Jari e o híbrido 2003 14-11 apresentaram os maiores teores de carotenoides totais, 10,54 µg g^{-1} e 6,92 µg g^{-1}, respectivamente, e de β-caroteno, 8,93 µg g^{-1} e 4,98 µg de g^{-1}, respectivamente. Para a retenção dos carotenoides totais e do β-caroteno não houve diferença significativa entre os *chips* desidratados elaborados com os quatro genótipos de mandioca biofortificados, que apresentaram valores médios de 76% e 67%, respectivamente. Os *chips* desidratados elaborados com a variedade BRS Jari e o híbrido 2003 14-11 apresentaram as maiores médias para o atributo sabor e não diferiram entre si quanto à crocância e aceitação global, sendo classificados entre os termos “gostei ligeiramente” e “gostei moderadamente”. Apesar da adição do aromatizante sabor “cebola e salsa”, não houve uma maior aceitação pelos consumidores. Os *chips* desidratados de mandioca elaborados com a variedade BRS Jari e o híbrido 2003 14-11 apresentaram boa aceitação sensorial e elevada retenção de carotenoides totais e de β-caroteno sendo, portanto, variedades biofortificadas adequadas para a elaboração desse produto.

Palavras-chave: β-caroteno. Desidratação. *Manihot esculenta* Crantz. Avaliação sensorial.

Introduction

Cassava *(Manihot esculenta* Crantz) is widely cultivated as the main source of energy for millions of people in tropical regions of Africa and Latin America (GÁRCIA-SEGOVIA et al., 2016; NAMBISAN, 2011).

Cassava varieties normally grown and marketed are deficient in micronutrients such as vitamin A, iron and zinc, which limit their use as the only food in the diet considering the importance of these micronutrients. This is the main cause of hidden hunger in most of sub-Saharan Africa (OLURANTI et al., 2016). Due to cassava’s importance in the diet of these populations, which often present health problems caused by vitamin A deficiency, the consumption of cassava varieties with higher levels of β-carotene may be a sustainable way of preventing this deficiency (OLURANTI et al., 2016; CEBALLOS et al., 2012).

In this sense, the varieties BRS Dourada and BRS Gema de Ovo were recommended by Embrapa Cassava & Fruits in 2005 and BRS Jari launched in 2009 as sweet varieties with higher levels of pro-vitamin A than commercial varieties of white pulp (ARAUJO; ALMEIDA, 2013).

The culinary cassava consumption is quite diverse and it can be cooked, roasted, fried, in the composition of more sophisticated dishes (MORETO; NEUBERT, 2014) and in the development of new products, such as breakfast cereals and snacks.

Snacks are products with a long shelf life, accessible, cheap and easy to eat, requiring no further preparation. They are part of many consumers’ diet, constituting an important portion of daily nutrients and calories intake (OMIDIRAN et al., 2016). Among snacks, the cassava chips obtained by frying process, considerably increases the fat content and the caloric value of the final product, however, there is a tendency of consumers opting for healthier and lower calorie foods.

Dehydration is a unitary operation that aims to reduce the water present in food, reducing and inhibiting both chemical and enzyme reactions and microbial growth, which are responsible for their deterioration (GONÇALVES et al., 2017). Although different dehydration processes are used by the food industry, convective drying is the most common process due to its operation simplicity and accessible technology (MEGÍAS-PÉREZ et al., 2014).

The production of chips by dehydration process using biofortified cassava varieties can be an excellent alternative for obtaining a product with high nutritional value and meeting consumers' demand for healthier foods. However, during the drying process food changes may occur and it is necessary to know the total carotenoid and β-carotene stability during processing.

Based on the above, this study aimed at developing dehydrated chips from biofortified cassava varieties.

Material and Methods

Raw material

Four cassava genotypes were selected for the preparation of dehydrated chips: BRS Dourada, BRS Gema de Ovo, BRS Jari and hybrid 2003 14-11. The plants of these genotypes were cultivated at Embrapa Cassava & Fruits in Cruz das Almas, Bahia, Brazil. At least 10 healthy roots of each genotype were harvested, of which five were used for processing and five for the raw material characterization analyzes. The roots were processed and prepared for analysis on the same day of harvest.

Preparation of dehydrated cassava chips

Processing was performed in two steps. First, dehydrated chips were prepared with no added flavoring, from roots of four cassava genotypes harvested at 12 months after planting, in order to selecting the two most suitable for dehydrated chips production based on sensory acceptance. In the second stage, dehydrated chips were produced with the addition of onion and parsley flavoring, from the two genotypes selected in the previous step. The genotypes used in the second stage were harvested at 14 months of planting.

For dehydrated chips preparation, the roots were washed with water, sanitized with sodium hypochlorite (50 mg L^{-1} of active chlorine) for five minutes, peeled and sliced to 0.8 mm in a slicer. Cassava slices (500 g) were blanched for two minutes at 100 °C in a solution containing 5 L of water, 50 mL of vegetable oil and 85 g of sodium chloride. After blanching, the slices were removed from solution, immersed in ice water for thirty seconds to stop cooking and drained to remove water. Then the slices were placed on trays and air-dried in forced air circulation (air drier Pardal PE 60, Petrópolis, Brazil) at a temperature of 65 °C for about 3 h and 30 min. The product was packed in polyethylene terephthalate / aluminum / polyethylene (PET / AL / PE) with approximately 150 g of dehydrated chips. The same process was carried out for the preparation of the onion and parsley flavored product, but in the blanching solution, 70 g of sodium chloride and 75 g of the flavoring were added. The product was stored for 15 days prior to analysis.

Physicochemical analysis

The quantification of total carotenoids and β-carotene in the raw material and the dehydrated chips was performed according to the method described by Rodriguez-Amaya and Kimura (2004). The total carotenoids were extracted with acetone, partitioned with petroleum ether and quantified by spectrophotometry (Spectrophotometer Biospectro 220, Curitiba, Brazil) at 450 nm using the β-carotene absorption coefficient in petroleum ether (2592). For the identification and quantification of β-carotene and its isomers 9-cis-β-carotene and 13-cis-β-carotene, 5 mL of the extract used in the spectrophotometer reading for total carotenoids was transferred to a glass tube covered with aluminum foil and dried under nitrogen flow. The standards, β-carotene and its isomers were analyzed on high performance liquid chromatography (HPLC Waters Alliance 2695, Milford, USA) using the C30 column (Waters YCM carotenoid S-3, 4.6 x 250 mm, reverse) and UV / visible photodiode array detector between 350 and 600 nm using Empower software. The mobile phase solvent was the solution of 8 mL of methanol: 2 mL of HPLC grade methyl t-butyl ether. The mobile phase flow rate was 0.8 ml min^{-1} and 25 µL of the ethereal extract from the sample was injected. The column temperature was 30 °C, with a total analysis time of 60 minutes. Immediately prior to injection, the dried extract was fully diluted in 100 µL of acetone and transferred to a 2 mL amber vial for analysis.

The apparent carotenoid retention in the dehydrated chips was calculated from the concentration of this compound, on the raw material dry basis, after the dehydration.

The moisture from the roots was obtained after drying in forced air circulation oven at 60 °C to constant weight and dehydrated chips moisture at infrared balance (Infrared moisture analyzer Gehaka IV 2500, São Paulo, Brazil) for 6 minutes. The yield in pulp and the final product were calculated based on the weight of the cassava roots with peel, the peeled roots and the weight of the product after dehydration.

Sensory analysis

Dehydrated chips made with the roots of the four genotypes were evaluated for sensory acceptance by 59 judges. The test was performed in individual booths under white light. The evaluator received each sample (three slices of product) codified with a random three digit number, in a monadic and sequential manner in the complete block design, totaling four samples.

The sensory attributes of color, appearance, flavor, crispness and overall acceptance were evaluated using a hedonic scale of nine points, the extremes of which were "like extremely" and "dislike extremely". In addition to the sensorial acceptance test, the intensities of the attributes salty taste (1-little salty to 9- very salty) and fibrous appearance (1-little fiber to 9- much fiber) were evaluated. Product purchase intent was evaluated using the terms "I would buy", "I would not buy" and "I would buy with a different taste", and for the latter option the evaluator was asked to suggest a taste of preference. Sensory analysis of cassava onion and parsley flavored chips was performed by 75 judges, who evaluated the same attributes mentioned above.

The project was approved by the Committee of Ethics in Research of the Multidisciplinary Institute in Health, of the Federal University of Bahia, with the emission of a Presentation Certificate of Ethical Appreciation (CAAE nº. 23109213.9.0000.5556).

Statistical analysis

The experiments were conducted in a completely randomized design, with four treatments/varieties and three replications, in the first stage, and with two treatments/varieties and three experimental replicates in the second stage. The results were submitted to variance analysis and genotypes means were compared by the Tukey test at 5% probability, using the SISVAR statistical program (FERREIRA, 2010). The purchase intention data was presented as a percentage.

Results and Discussion

There was no significant difference ($p>0.05$) among the four cassava genotypes for pulp and chips yield, with an average value of 70.7% and 25.3%, respectively (Table 1). These results are in agreement with Vilpoux and Cereda (2004), who reported that the losses with the skin, cortex and tips vary in average 25 to 35% of the total root weight, surpassing the 40% for finer roots, while the yield of the fried chips on an industrial scale is 21%.

Table 1. Characteristics of fresh roots and dehydrated chips obtained from four cassava genotypes harvested at 12 months after planting.

				Content (wet basis)			
	Genotypes	YIELD	UM	CT	BETA	CIS13	CIS9
Cassava root	BRS Dourada	72.8a	62.84c	4.69b	3.49b	0.42a	0.29b
	BRS Gema de Ovo	68.9a	56.42d	3.32b	1.73b	0.39a	0.82a
	BRS Jari	71.8a	75.18a	10.54a	8.93a	0.42a	0.37b
	Hybrid 2003 14-11	69.5a	71.75b	6.92ab	4.98ab	0.41a	0.64a
F		1.51^{ns}	199.23**	6.57*	8.12**	0.11^{ns}	19.91**
CVe (%)		3.64	1.57	33.46	39.03	15.65	17.93
Chips	BRS Dourada	28.3a	5.45a	7.66b	4.97b	1.13b	0.60b
	BRS Gema de Ovo	31.7a	6.42a	4.95b	2.42b	0.68b	1.16b
	BRS Jari	19.0a	5.75a	27.92a	20.13a	3.25a	1.93a
	Hybrid 2003 14-11	22.3a	5.13a	23.93a	15.23a	3.05a	2.21a
F		4.00^{ns}	0.78^{ns}	70.40**	38.50**	31.54**	21.13**
CVe (%)		19.02	17.22	13.83	20.72	18.83	15.91
				Apparent carotenoid retention (%)			
Chips	BRS Dourada			67.7a	59.9a	101.0a	87.0a
	BRS Gema de Ovo			69.4a	65.3a	80.4a	65.4a
	BRS Jari			73.5a	62.3a	208.5ab	151.0a
	Hybrid 2003 14-11			92.1a	79.0a	247.2b	113.7a
F				2.68^{ns}	2.04^{ns}	7.78*	2.75^{ns}
CVe (%)				13.25	13.06	29.04	36.08

Means followed by the same letter do not differ by Tukey test at 5% of significance; **significant at 1% probability by F test; *significant at 5% probability by the F test; ^{ns}not significant by F test; CVe: experimental variation coefficient; YIELD: yield in pulp or product; UM: moisture (%); CT: total carotenoid (μg g^{-1}); BETA: β-carotene (μg g^{-1}); CIS13: 13-cis-β-carotene (μg g^{-1}); CIS9: 9-cis-β-carotene (μg g^{-1}).

Regarding moisture, the pulp of BRS Jari variety showed the highest value, followed by the hybrid 2003 14-11 and the BRS Dourada variety (Table 1). The significant differences in moisture observed among genotypes were probably due to the genetic nature, since these genotypes were planted in the same place, and under the same conditions. These results were lower than those obtained by Ceni et al. (2009) for BRS Dourada and BRS Gema de Ovo, 70% and 66% respectively.

There was no significant difference (p>0.05) among dehydrated chips regarding moisture content, which is desirable and demonstrates the standardization on dehydration step to obtain a crispy product, with an average value of 5.7% (Table 1).

The total carotenoid content in the raw material ranged from 3.32 μg g^{-1} (BRS Gema de ovo) to 10.54 μg g^{-1} (BRS Jari) (Table 1). The results are similar to those observed by Carvalho et al. (2012) for hybrid 2003 14-11 and the BRS Dourada variety (named Dendê) for total carotenoids, 7.03 μg g^{-1} and 3.19 μg g^{-1} respectively.

In relation to β-carotene concentration, the genotype BRS Jari presented the highest level (Table 1), a fact that is associated to the yellower pulp of this genotype. Carvalho et al. (2012) evaluated hybrid 2003 14-11 and BRS Dourada variety, and observed β-carotene concentrations similar to those obtained in this work (5.37 and 2.38 μg g^{-1}, respectively).

The highest β-carotene/carotenoid ratio was observed for genotype BRS Jari (84%), followed by BRS Dourada (74%), hybrid 2003 14-11 (72%) and BRS Gema de Ovo (52.0%). These results are similar to those reported by Carvalho et al. (2012) for the hybrid 2003 14-11 (75%) and BRS Dourada (76%).

Regarding the isomers, there was no significant difference ($p>0.05$) among genotypes for the concentration of 13-cis-β-carotene in the roots, with the average value of 0.41 μg g^{-1}. As for 9-cis-β-carotene, the varieties BRS Dourada and BRS Jari presented the lowest values (Table 1). Oliveira et al. (2010) evaluated 12 varieties of yellow bitter cassava pulp, which showed β-carotene levels similar to this study (1.37 to 7.66 μg g^{-1}), but higher for 13-cis-β-carotene (0.22 to 1.24 μg of g^{-1}) and 9-cis-β-carotene (from 0.28 to 1.61 μg of g^{-1}).

The dehydrated chips presented total carotenoid content between 4.95 and 27.92 μg g^{-1}, varying according to cassava genotypes (Table 1). The dehydrated chips obtained from BRS Jari variety and hybrid 2003 14-11 had highest carotenoids and β-carotene concentrations. Despite the carotenoid degradation during processing, the concentration of these compounds in dehydrated chips is superior when compared with the fresh roots due to water removal in the drying process.

Vitamin A is an essential nutrient needed in small amounts by humans for the normal functioning of the visual system, growth and development, maintenance of epithelial cellular integrity, immune function and reproduction. These dietary needs for vitamin A are normally provided for as preformed retinol and provitamin A carotenoids (FAO/WHO, 2004). Vitamin A equivalency of β-carotene (VEB) is defined as the amount of ingested β-carotene in μg that is absorbed and converted into 1 μg retinol (vitamin A) in the human body (VAN LOO-BOUWMAN et al., 2014) and the VEB for a mixed vegetable diet was estimated to be 6 μg β-carotene to 1 μg retinol. This VEB of 6:1 for a mixed diet is referred to as the retinol equivalents and is used in many food composition tables. Estimates for the vitamin A recommended safe intakes for male and female adults are 600 μg and 500 μg retinol daily, respectively (FAO/WHO, 2004).

A study with biofortified cassava porridge in Colombia reported a VEB of 2.80 μg β-carotene to 1 μg retinol (LIU et al., 2010). Another study with biofortified cassava porridge in the USA determined a VEB of 4.2:1 when provided with added oil and a VEB of 4.5:1 when provided without added oil (LA FRANO et al., 2013). Considering a VEB of 4.5 μg β-carotene to 1 μg retinol and an intake of 600 μg retinol daily, the consumption of 180 g of dehydrated chips obtained from BRS Jari variety and hybrid 2003 14-11 is sufficient to supply the vitamin A requirement.

The carotenoid retention depends on the genotype and the processing performed. Processing breaks the plant matrix, including cellular compartments and protein binding that serve to protect and stabilize carotenoids (OLURANTI et al., 2016). In fresh root, carotenoids occur predominantly in the *all trans* configuration, however, the process may lead to the formation of *cis* isomers that have different biological properties, such as decreased provitamin A, the bioavailability and antioxidant capacity (SCHIEBER; CARLE, 2005). In the dehydrated chips produced with genotypes BRS Jari and hybrid 2003 14-11, highest 13-cis-β-carotene and 9-cis-β-carotene concentrations are observed. Regarding the apparent retention of these isomers, there is high retention of over 100% for dehydrated chips produced with these genotypes due to modification of *all trans* structure for *cis* occurring after processing (Table 1). The differences in apparent carotenoid retention observed among genotypes can be attributed to the carotenoids contents initially found and the own genotype.

For apparent carotenoids and β-carotene retention there was no significant difference ($p>0.05$) among the dehydrated chips prepared, which showed average values of 76% and 67%, respectively (Table 1). These results are higher than those obtained by Oliveira et al. (2010), which evaluated the total carotenoids degradation on 5 cassava genotypes processed in the form of flour and observed apparent retention between 29 and 67%. Oluranti et al. (2016) observed the apparent retention of four fermented cassava products (gari, pupuru, fufu and lafun type flours) produced in different ways from three genotypes and obtained lower retention values compared to this study. Chávez et al. (2006) evaluated the true retention of total carotenoids in three genotypes submitted to different processes (cooked cassava, gari type flour, shade-dried, sun-dried and oven-dried slices) and observed greater retention in the oven-dried slices processed at 60 °C for 24 hours (71.9%), followed by the shade-dried slices for 6 to 7 days (59.7%) and cooked cassava (55.7%). Carvalho et al. (2012) studied true retention of total carotenoids and β-carotene on seven cooked cassava genotypes and obtained values similar to the present study, from 66.7% to 85.0% and 32.9% to 82.3%, respectively. The high apparent carotenoids retention on dehydrated chips obtained in this study indicate the possibility of using cassava biofortified for the development of this product, as a means to minimize vitamin A deficiency.

Dehydrated chips made with BRS Jari, BRS Dourada and hybrid 2003 14-11 did not differ (p>0.05) in color acceptance and were ranked between the hedonic terms “like slightly” and “like moderately” (Table 2). Color is an important attribute of quality and directly related to product acceptability (DOYMAZ et al., 2006). Thus, if color is attractive, food will likely to be ingested or at least tasted by consumers (SILVA et al., 2000).

Table 2. Acceptance and intensity attributes of dehydrated chips made with four cassava genotypes.

Genotypes	Sensory acceptance					Intensity attributes	
	Color	Appearance	Flavor	Crispness	Overall acceptance	Salty taste	Fibrous appearance
BRS Dourada	6.7ab	6.5a	4.8b	5.6b	5.4b	2.7b	5.1a
BRS Gema de ovo	6.4b	6.3a	5.1b	5.9ab	5.6ab	2.4b	4.4a
BRS Jari	6.9ab	6.6a	5.9a	6.5ab	6.3a	3.8a	4.9a
Hybrid 2003 1411	7.2a	6.6a	6.1a	6.7a	6.4a	3.7a	5.3a
F	2.94*	0.37^{ns}	7.95**	3.65*	5.47**	6.99**	1.69^{ns}
CVe (%)	22.29	24.24	31.92	32.78	28.49	63.95	45.07

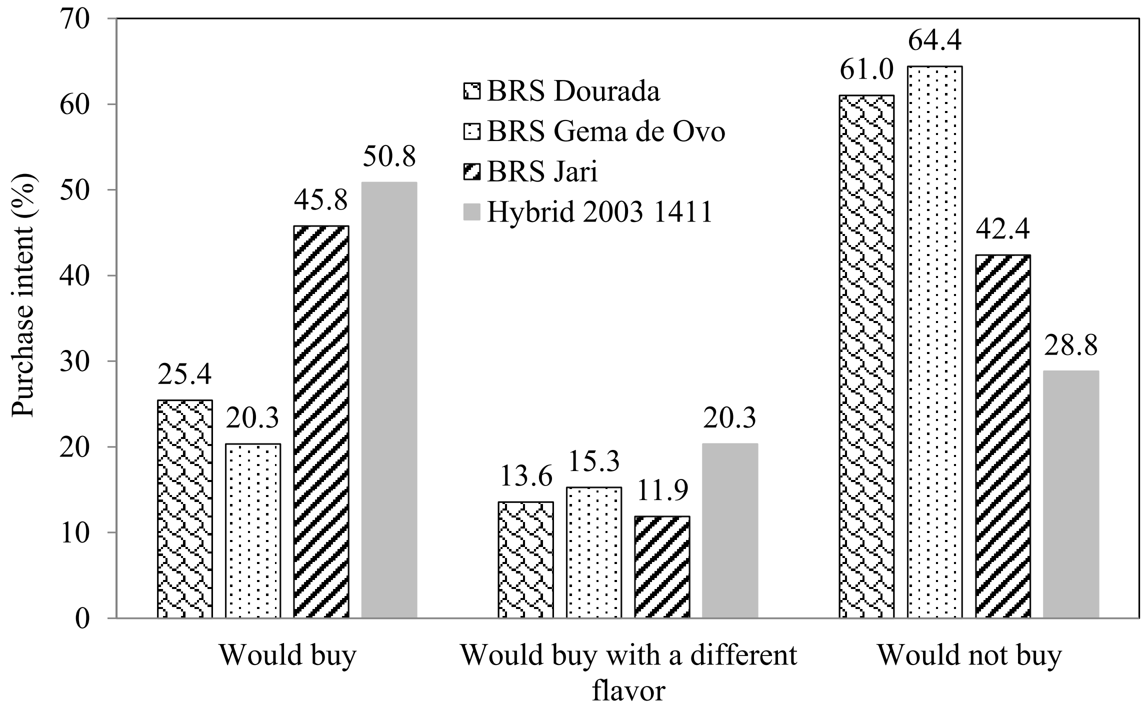
Values are the mean acceptance: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely. Values are the mean attributes: salty taste 1-little salty to 9- very salty and fibrous appearance 1-little fiber to 9- much fiber. Means followed by the same letter do not differ by Tukey test at 5% of significance; **significant at 1% probability by F test; *significant at 5% probability by the F test; ^{ns}not significant by F test; CVe: experimental variation coefficient.

For the appearance attribute, there was no significant difference (p>0.05) among dehydrated chips and the average value was 6.5 (Table 2). Dehydrated chips made with the BRS Jari variety and hybrid 2003 14-11 had highest average for flavor attribute and did not differ (p>0.05) on the crispness and overall acceptance and classified between “like slightly” and “like moderately”. The acceptance values obtained in this work for the BRS Jari genotypes and hybrid 2003 14-11 are similar to those reported by Grizotto and Menezes (2002) for cassava chips elaborated with IAC Mantiqueira and IAC 576.70 varieties, receiving grades between 4.9 and 6.3 for the global acceptance and appearance attributes.

In terms of attribute intensity, the four products were considered “low salted” by consumers. The biggest salty flavor intensities were found in dehydrated chips made with BRS Jari and hybrid 2003 14-11 showing that consumers prefer products with higher salt taste, as these were the most accepted by consumers. There was no significant difference (p> 0.05) among the elaborated products regarding fibrous appearance, and these were considered with intermediate fiber intensity (Table 2).

In assessing purchase intention, dehydrated chips made of the BRS Jari and hybrid 2003 14-11 genotypes were the most well accepted, with 45.8% of purchase intent for BRS Jari and 50.8% for the 2003 hybrid 14- 11 (Figure 1). Adding to the category "would buy" and "would buy with different flavor", 57.7% and 71.1% of the evaluators would buy dehydrated cassava chips made of the BRS Jari and hybrid 2003 14-11, respectively. From the total number of evaluators who pointed out that "would only buy with a different flavor", only ten made suggestions of preferred flavors. Two judges suggested as preferred the "onion and parsley" flavor, three judges indicated the "parsley" flavor and three the "onion" flavor to purchase the product. Based on this result, "onion and parsley" flavor was selected in order to achieve greater acceptance of the product.

Figure 1. Purchase intent of dehydrated cassava salty chips made with four genotypes.



From the results of sensory acceptance and β-carotene content, the BRS Jari genotypes and hybrid 2003 14-11 were selected for the preparation of "onion and parsley" flavored dehydrated chips.

For the preparation of "onion and parsley" flavored chips, the roots were harvested at 14 months after planting. It was found that BRS Jari statistically presented ($p \leq 0.05$) higher moisture (73.69%), plus the highest carotenoids (7.85 μg g^{-1}) and β-carotene (5,91 μg g^{-1}) concentrations as compared to hybrid 2003 14-11 (Table 3). There was no significant difference ($p > 0.05$) between the two genotypes for the concentrations of 13-cis-β-carotene and 9-cis-β-carotene and the average value was 0.42 μg g^{-1} and 0.82 μg g^{-1}, respectively.

When comparing the total carotenoid and β-carotene contents of these genotypes harvested at 12 months (Table 1) and at 14 months (Table 3), it was verified that there was the tendency to decrease the concentration of these compounds in the roots harvested at 14 months. This result indicates that for these genotypes, it is ideal using roots harvested at 12 months in order to obtain a final product with higher content of provitamin A. Cassava chemical composition is influenced by several factors such as: variety, age at harvest, cultivation practices, environmental conditions during the growing season (FRANCK et al., 2011; ORTIZ et al., 2011). Ortiz et al. (2011) studying 54 cassava genotypes at 8, 10 and 12 months of harvest observed an increase in the concentration of total carotenoids and β-carotene from 8 to 10 months of age, followed by a reduction from 10 to 12 months; regarding β-carotene percentage, a reduction with the increase of age was observed. These results corroborate those observed in this study.

Table 3. Characteristics of fresh roots and "onion and parsley" flavored chips made from genotypes BRS Jari and hybrid 2003 14-11, harvested at 14 months of age.

			Content (wet basis)			
	Genotypes	UM	CT	BETA	CIS13	CIS9
Cassava root	BRS Jari	73.69a	7.85a	5.91a	0.43a	0.68a
	Hybrid 2003 14-11	65.99b	5.11b	2.83b	0.41a	0.95a
F		186.33**	44.69**	84.15**	0.08^{ns}	0.90^{ns}
CVe (%)		0.99	7.74	9.41	25.35	42.71
Chips	BRS Jari	5.66a	25.71a	17.66a	1.20a	3.79a
	Hybrid 2003 14-11	6.42b	13.63b	7.63b	0.58b	2.77a
F		12.26*	10.90*	13.60*	10.23*	2.60^{ns}
CVe (%)		4.44	22.78	26.34	26.57	23.47
			Apparent carotenoid retention (%)			
Chips	BRS Jari		93.1a	83.4a	83.7a	204.3a
	Hybrid 2003 14-11		97.1a	98.2a	54.7a	112.9a
F			0.05^{ns}	1.27^{ns}	1.37^{ns}	1.49^{ns}
CVe (%)			23.90	17.73	43.89	57.82

Means followed by the same letter do not differ by Tukey test at 5% of significance; **significant at 1% probability by F test; *significant at 5% probability by the F test; ^{ns}not significant by F test; CV: experimental variation coefficient; UM: moisture (%); CT: total carotenoid (μg g^{-1}); BETA: β-carotene (μg g^{-1}); CIS13: 13-cis-β-carotene (μg g^{-1}); CIS9: 9-cis-β-carotene (μg g^{-1}).

Dehydrated chips made with BRS Jari (Table 3) showed higher total carotenoid content (25.71 μg g^{-1}) and β-carotene (17.66 μg g^{-1}). In relation to the apparent retention, there was no significant difference ($p>0.05$) among the genotypes, with mean values of 95.1% and 90.8%, for total carotenoids and β-carotene, respectively. The retention of 9-cis isomers were above 100%, indicating that the processing has promoted the modification of the *all trans* structure for isomer 9-cis-β-carotene.

Despite the addition of "onion and parsley" flavoring, there has been no greater acceptance by consumers, and dehydrated chips made by the two genotypes were classified between the hedonic terms "like slightly" and "like moderately" to the sensory attributes appearance, flavor, crispness and global acceptance (Table 4). Only on the color attribute, the chips prepared with the BRS Jari obtained higher grades and was ranked between the terms "like moderately" and "like very much".

Table 4. Acceptance and intensity of sensory attributes of onion and parsley flavored chips.

Genotypes	Sensory acceptance					Intensity attributes	
	Color	Appearance	Flavor	Crispness	Overall acceptance	Onion and parsley flavor	Fibrous appearanc
BRS Jari	7.4a	7.0a	6.6a	6.9a	6.7a	5.3a	5.8a
Hybrid 2003 1411	7.0b	6.8a	6.2a	6.7a	6.4a	4.7a	5.6a
F	6.03*	1.42^{ns}	1.94^{ns}	0.48^{ns}	1.79^{ns}	3.84^{ns}	0.65^{ns}
CVe (%)	14.72	15.80	24.76	24.48	21.52	40.02	33.94

Values are the mean acceptance: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely. Values are the mean attributes: onion and parsley flavor 1-little flavor to 9- very flavor; and fibrous appearance 1-little fiber to 9- much fiber. Means followed by the same letter do not differ by Tukey test at 5% of significance; *significant at 5% probability by the F test; ^{ns}not significant by F test; CVe: experimental variation coefficient.

Regarding the intensity of the sensorial attributes, there was no significant difference (p>0.05) among the elaborated products, and the consumers considered the intensity of the attributes "onion and parsley flavor" and "fibrous appearance" to be intermediate.

The mean values of sensory acceptance, between 6 and 7 ("like slightly" and "like moderately"), received by the two products, suggest that they can be accepted in the consumer market from a sensorial point of view (HAUTRIVE et al., 2008). This is showed by the results obtained by purchase intent test, in which 66.6% (n = 50) of the evaluators would buy the "onions and parsley" flavored chips made with the variety BRS Jari and 60.0% (n = 45) would buy the product elaborated with the hybrid 2003 14-11.

Conclusion

Dehydrated cassava chips made with the BRS Jari variety and the hybrid 2003 14-11 showed good sensorial acceptance and higher total carotenoid and β-carotene contents, thus being biofortified varieties suitable for the elaboration of this product.

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