FONSECA MJO; SOARES AG; FREIRE JUNIOR M; ALMEIDA DJ; ASCHERI JLR. 2008. Effect of extrusion-cooking in total carotenoids content in cream and orange flesh sweet potato cultivars. *Horticultura Brasileira* 26: 112-115.

Effect of extrusion-cooking in total carotenoids content in cream and orange flesh sweet potato cultivars

Marcos José de O Fonseca[1]; Antonio G Soares[1]; Murillo Freire Junior[1]; Dejair L de Almeida[2]; José Luiz R Ascheri[1]

[1]Embrapa Agroindústria de Alimentos, Av. das Américas 29501, 23020-470 Rio de Janeiro-RJ; [2]Embrapa Agrobiologia, Antiga Rod. Rio-São Paulo, km 47, 23851-970 Seropédica-RJ; mfonseca@ctaa.embrapa.br

ABSTRACT

Sweet potato (*Ipomoea batatas*) is a food crop that supplies energy, minerals and vitamins C and B. Some cultivars are very rich in carotenoids (pro-vitamin A). In this study were evaluated and compared the total carotenoids content of two cultivars and the losses on the dehydrated extruded sweet potato flour. Samples from organic and conventional crops were analyzed, in the form of fresh and dehydrated extruded samples. Total carotenoids content of the fresh product, expressed on wet basis, was of 437 µg 100 g^{-1} for the cream cultivar and 10,12 µg 100 g^{-1} for the orange cultivar. After dehydration, losses of total carotenoids were of 41% and 38%, respectively. The fresh orange cultivar presented high total carotenoids content in comparison to the cream cultivar. The extruded orange sweet potato flour showed the lowest losses in total carotenoids. Therefore, the processed flour of orange sweet potato could be used to obtain pre-gelatinized extruded flour with high total carotenoids content.

Keywords: *Ipomoea batatas*, organic crop, total carotenoids, β-carotene, extrusion-cooking.

RESUMO

Effect of extrusion-cooking in total carotenoids content in cream and orange flesh sweet potato cultivars

A batata-doce (*Ipomoea batatas*) é um alimento fonte rico em energia, minerais, vitaminas C e B. Algumas cultivares são ricas em pró-vitamina A. O objetivo do presente trabalho foi avaliar e comparar o conteúdo de carotenóides totais em duas cultivares de batata-doce e determinar suas perdas na obtenção da farinha desidratada e processada por extrusão. Foram analisadas amostras de sistema de cultivo orgânico e convencional, tanto as frescas como as extrusadas desidratadas. O conteúdo de carotenóides totais do produto fresco, expressos em base úmida, foi de 437 µg 100 g^{-1} para a cultivar creme e de 10,120 µg 100g^{-1} para a cultivar alaranjada. Após o processo de desidratação das amostras, as perdas de carotenóides totais foram de 41% para a batata-doce creme e 38% para a alaranjada, respectivamente. Os resultados indicaram alto conteúdo de carotenóides totais para a cultivar alaranjada fresca, quando comparado com a cultivar creme. A amostra de farinha de batata-doce extrusada apresentou menor perda de carotenóides totais. Desta forma, verifica-se que a farinha de batata-doce alaranjada pode ser utilizada na obtenção de uma farinha pré-gelatinizada com alto conteúdo de carotenóides totais.

Palavras-chave: *Ipomoea batatas*, cultivo orgânico, carotenóides totais, β-caroteno, extrusão.

(Recebido para publicação em 27 de novembro de 2006; aceito em 20 de fevereiro de 2008)

Sweet potato (*Ipomoea batatas*) has already reached the 6th or 7th most produced food crop in the world (FAO, 2007). In Brazil sweet potato is the 4th most consumed vegetable crop. Sweet potato is a great crop because it is relatively easy to grow, relatively free of pests and diseases, has relatively high yield, and is always a good source of carbohydrates (Miranda, 1995). Its ability to grow in poor soils makes the sweet potato an especially good crop for tropical soils where fertilizer is not easily available. Sweet potatoes can be cultivated throughout tropical and warm temperate regions wherever there is sufficient water to support their growth (Martin, 1998). Because of its drought tolerance, sweet potato is called a hot weather crop. Phuc *et al.* (2001) indicated that sweet potato is one of the main tuberous roots produced in developing countries.

Sweet potato is a source of energy, minerals and vitamins C and B. Some cultivars are rich in carotenoids (Reddy & Sistrunk, 1980; Picha, 1985).

Vitamin A deficiency is an endemic public health problem in many regions of the developing world. Four measures had been taken to decrease this problem on these countries: 1) supplementation; 2) fortification; 3) diet diversification; 4) health measures to reduce nutrient wastage (Underwood, 1998). Food-based approaches, specifically the diet diversification, are the most sustainable measures toward a permanent conquest of insecure vitamin A nutrition (Swai, 1993; Bulux *et al.*, 1996). For many populations around the world, carotenoids, from vegetables, represent 80-85% of its pro-vitamin A diet (De Pee, 1996). Despite its source as vitamin A, carotenoids are still of great interest due to its antioxidant potential, reducing the probability of cancer and degenerative illnesses (Sies & Stahl, 1995). Mangles (1993), Hart & Scott (1995) and Mueller (1997) verified that the sweet potato, as well as other vegetables, is also an important source of xanthophylls. Studies carried out by Wang *et al.* (1994) and Mertz *et al.* (1997) indicated the possibility of metabolic conversion from 9-cis-β-carotene into 9-cis-retinoic acid, the last one being considered as a potential medicine for treatment of certain types of tumor.

In 1999, at the FAO conference for Austral Africa, the National Institute of Agronomic Investigation (INIA) presented the program of the orange fresh sweet potato, rich in pro-vitamin A. It was a primary example how the INIA would start the integration of the nutritional concern on its agricultural research and extension programs. This was one of the adopted strategies to fight against the vitamin A deficiency of the poor people into Austral Africa region (Low *et al.*, 2003).

Sweet potato is a versatile crop with multiple uses. It could be used as a substitute for rice and corn, besides being a potential source of raw materials for industrial uses and food delicacies. Sweet potato has been processed as feeds, flour, starch, and pectin for local and export markets. The flour is further processed into fermented products such as soy sauce and alcohol (Ramesh *et al.*, 2006). Iwe *et al.* (1998) showed that sweet potato could be used in extruded products due to its high nutritional value.

Carotenoids present in fresh tissue are very stable. However, when those products are processed, carotenoids become very unstable by the action of heat, light and oxygen. Carotenoids can be partially isomerized or totally degraded, depending on the applied time and temperature conditions during the processing of carrot juice (Marx *et al*, 2003). The objective of this work was to compare the total carotenoids contents of cream and orange sweet potato cultivars and to evaluate its losses from fresh to dehydrated and extrusion product.

MATERIAL AND METHODS

The experiment was carried in Embrapa Agrobiologia, located in Seropédica, Rio de Janeiro State, Brazil. Sweet potato cv. Rosinha de Verdan (cream colour) (Daros *et al.*, 2002) and cv. IAPAR 69 (orange) were grown under organic system and after harvest roots were analyzed in the fresh, dehydrated and extruded form.

Drying of the samples was carried out in a forced air oven at 65ºC during 5 hours. The dehydrated samples were grinded in hammer mill with a 20 mesh bolter.

After that, all the sweet potato flour was extruded. Mixtures were prepared by mixing 50% of sweet potato flour with 50% of rice flour of both cultivars. Extrusion was performed on a Brabender single screw extruder, model DS 20. The process conditions were described in Table 1. From each sample we used 1000 grams and the final moisture was achieved by adding distilled water calculated from moisture content of each dehydrated sample.

Table 1. Extrusion-cooking process conditions used for developing mixture of pre-gelatinized sweet potato and rice flours (Processo de extrusão usado no preparo de farinha de batata-doce pré-gelatinizada misturada com farinha de arroz). Rio de Janeiro, Embrapa Agroindústria de Alimentos, 2006.

Sample	Screw speed (rpm)	Feeder flow rate (rpm)	Moisture content (%)
1) Orange sweet potato flour	170	10	10
2) Orange sweet potato flour	180	15	10
3) Cream sweet potato flour	170	10	10
4) Cream sweet potato flour	180	15	10
5) 50% of orange sweet potato/50% of rice flour	170	10	13
6) 50% of orange sweet potato/50% of rice flour	180	15	13
7) 50% of cream sweet potato/50% of rice flour	170	10	13
8) 50% of cream sweet potato/50% of rice flour	180	15	13
Barrel temperature	**Zone 1**	**Zone 2**	**Zone 3**
	70°C	**100°C**	**120°C**
die: 3mm; screw: 5:1			

After mixing water, all samples were kept under room temperature during one night before the extrusion.

The total carotenoids content was obtained using the method described by Rodriguez-Amaya (2001). Two grams of the homogeneous sweet potato sample were transferred to a mortar containing a small amount of hyflosupercel and ground with 50 mL of cold acetone and then filtered under suction through a Buchner funnel with filter paper Whatman nº 1. The mortar, pestle and the residue were rinsed with acetone and the extract was transferred to a separator funnel. This rinsing was repeated three times. Petroleum ether was added to the extract and rinsed with distilled water. Carotenoids were collected from ethereal extract and then passed through a glass funnel containing anhydrous sodium sulfate to remove the water. The quantification, in ethereal extract, was carried out by Analytik Jena spectrophotometry - Model SPECORD 205 at 450 nm. Petroleum ether was used as a blank sample.

The statistical analyses were performed using the software STATISTICA version 5.1 edition 98 (Statsoft, 1995).

RESULTS AND DISCUSSION

The total carotenoids content, in the fresh product, was of 437 μg 100 g^{-1} for the cream cultivar and 10,120 μg 100g^{-1} for the orange one, calculated in b-carotene equivalent. Lako *et al.* (2006) studied cultivars from conventional system crop and found 15,000-19,000 μg 100g^{-1} of total carotenoids content for orange sweet potato and 480-570 μg 100 g^{-1} for cream variety. Total carotenoids content found by K´osambo *et al* (1998) from conventional system crop were 200 μg 100 g^{-1} for cream sweet potato and 8,800 μg 100 g^{-1} for orange sweet potato. The results of this work were very similar and in accordance with the previous reports. Therefore, it seems that there is no influence from the cropping system on total carotenoids content.

The total carotenoids content in the flour products were 1,587 μg 100 g^{-1} and 29,397 μg 100 g^{-1} for cream and orange cultivars, respectively ($p<0.05$). During the dehydration process occurred losses of carotenoids content of 41% for the cream and 38% for the orange cultivar. The flour yields were 25.8% for cream and 25.3% for the orange cultivar, without significant differences ($p>0.05$).

Before the dehydration process, the sweet potato tubers were cut into slices and then submitted to a thermal shock (65ºC). Therefore, the exposure to oxygen and the thermal shock were the decisive factors for carotenoids losses during the process. However, even though 38% of the carotenoids were lost, the amount of total carotenoids was high, indicating that the orange sweet potato has an important nutritional value.

Table 2. Total carotenoids content of extruded flours and losses from fresh raw material (teor total de carotenóides de farinha extrudada e perdas de material fresca). Rio de Janeiro, Embrapa Agroindústria de Alimentos, 2006.

Sample	Total carotenoids content (μg.100g^{-1})	Loss (%)
Orange sweet potato flour	21,200b ± 102	27.9 a
Orange sweet potato flour	23,276a ± 99	20.8 b
Cream sweet potato flour	628b ± 96	60.4 a
Cream sweet potato flour	935 a ± 120	41.0 b
50% of orange sweet potato/50% of rice flour	10,328n..s. ± 98	2.6 n.s.
50% of orange sweet potato/50% of rice flour	10,199n.s. ± 101	3.8 n.s.
50% of cream sweet potato/50% of rice flour	715ns. ± 90	9.9 b.
50% of cream sweet potato/50% of rice flour	665ns. ± 90	16.2 a.

^{ns}There is no statistical difference for LSD test (p<0.05) (^{ns}não há diferença estatística para teste LSD(p<0.05)).

The results from the extrusion-cooking process indicated that there were statistical different losses of total carotenoids content (LSD<0.05) (Table 2). For sweet potato flour without mixture, there were 20.8% and 27.9% for the orange variety and 41.0% and 60.4% for the cream one. The losses were lower in mixed flours than in the single sweet potato flour, with 2.6% and 3.8% of losses for the orange variety and 9.9% and 16.2% for the cream one. Losses of total carotenoids content were very small on the samples mixing flour with rice. Possibly this occurs due to the rice flour composition, with 9% of protein, 0.75% of crude fiber and around 1% of lipids. These elements could form a carotene-lipid-protein net protecting carotenoids from thermic denaturation (Borrelli *et al*, 2003). The β-carotene being a lipid octaprenoids, probably occur an interaction with rice lipids (Grosjean, *et al*, 2000).

Losses of total carotenoids content were higher in the extruded products with low feeder flow rate and low screw speed. This can be explained by the long retention time of sample, on the barrel, during the extrusion process. Camire *et al*. (1990) verified that the correct conditions process has influence on prevention losses of important constituents of extruded products, minimizing these losses during the process.

It was also observed that total carotenoids content in single pre-gelatinized orange sweet potato flour were 21,200 μg 100 g^{-1} and 23,276 μg 100 g^{-1} for the two different conditions. These values are still very high, indicating that this product is a very good source of pro-vitamin A. Total carotenoids content of 50% orange sweet potato flour mixing with 50% of rice flour were also a very good source of pro-vitamin A, with values between 10,199 μg 100 g^{-1} and 10,238 μg 100 g^{-1}.

The results indicated that the fresh orange sweet potato variety showed high total carotenoids content in comparison to the cream variety. It seems that there is no influence of cropping system on total carotenoids content. The sweet potato flour from orange variety could be used to obtain the extruded pre-gelatinized product with high nutritional value.

REFERENCES

BORRELLI GM; DE LEONARDIS AM; FARES C; PLATANI C; DI FONZO N. 2003. Effects of modified processing conditions on oxidative properties of semolina dough and pasta. *Cereal Chemistry* 80: 225-231.

BULUX J; QUAN DE SERRANO J; PÉREZ R; LÓPEZ CY; SOLOMONS NW. 1996. Studies on the bioconversion and bioavailability of β-carotene in Guatemalan school children. *European Journal Clinical Nutrition* 50: 76-77.

CAMIRE ME; CAMIRE A; KRUMBAR K. 1990. Chemical and nutritional changes in foods during extrusion. *CRC Critical Reviews of Food Science and Nutrition*. 29: 35-57.

DAROS M; AMARAL JUNIOR AT; PEREIRA TNS; LEAL NR; FREITAS SP; SEDIYAMA T. 2002. Caracterização morfológica de acessos de batata-doce. *Horticultura Brasileira* 20: 43-47.

DE PEE S. 1996. *Food based approaches for controlling vitamin A deficiency: studies in breast feeding women in Indonesia*. Landbouwerniversiteit Wagmeningem, Germany. ISBN 90-8504-492-8. 116p.

FAO Statistical Yearbook. 2007. Food Agricultural Organization. Rome, Italy, v.1. 250p.

GROSJEAN E; POINSOT J; CHARRIÉ-DUHAUT A; TABUTEAU S; ADAM P; TRENDEL J; SCHAEFFER P; CONNAN J; DESSORT D; ALBRECHT P. 2000. A heptacyclic polyprenoid hydrocarbon in sediments: a clue to unprecedented biological lipids. *The Royal Society of Chemistry. Chemistry. Communication*. p. 923-924.

HART DJ; SCOTT KJ. 1995. Development and evaluation of HPLC method for analysis of carotenoids in foods and the measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. *Food Chemistry* 54: 101-111.

IWE MO; WOLTERS I; GORT G; STOLP W; VAN ZUILICHEM DJ. 1998. Behavior of gelatinization and viscosity in soy-sweet potato mixtures by single screw extrusion: a response surface analysis. *Journal of Food Engineering* 38: 369-379.

K´OSAMBO LM; CAREY EE; MISRA AK; WILKER J; HAGEMIMANA V. 1998. Influence of age, farming site and boiling on Pro-Vitamin A content in sweet potato (*Ipomoea batatas* (L.) Lam.) storage roots. *Journal of Food Composition and Analysis* 11: 305-321.

LAKO J; TRENERRY CV; WAHLQVIST M; WATTANAPENPAIBOON N. SOTHEESWARAN S; PREMIER R. 2006. Phytochemical flavonols, carotenoids and the antioxidant properties of a wide selection of Fijian fruit, vegetables and other readily available foods. *Food Chemistry* 90: 315-329.

LOW J; WALKER T; KAPINGA R; HIJMANS R; REYNOSO D; EWELL P; ZHANG D. 2003. The potential impact of beta-carotene rich sweet potatoes on vitamin A intake in Sub-Saharan Africa. In: HARVEY WJ; TAYLOR, TM. (eds). *Report of the XXI International Vitamin A Consultive Group (IVACG)*. Marrakech, Marrocos. 10p

MANGLES AR. 1993. Carotenoids content of fruits and vegetables: an evaluation of analytical data. *Japanese Agriculture Development Association* 93: 284-296.

MARTIN FW. 1998. *Sweet potato*. Florida: Echo Technical Note. 7p.

MARX M; STUPARIC M; SCHIEBER A; CARLE R. 2003. Effects of thermal processing on trans-cis-isomerization of β-carotene in carrot juices and carotene-containing preparation. *Food Chemistry* 83: 609-617.

MERTZ JR; SHANG E; PIANTELOSI R; WEI S; WOLGEMUTH DJ; BLANER WS. 1997. Identification and characterization of stereospecific human enzyme that catalyzes 9-cis-retinol oxidation. *Journal Biological Chemistry* 272: 11744-11749.

MIRANDA JEC. 1995. A cultura da batata-doce. Brasília, DF: Embrapa, 95 p. (Plantar hortaliças; 30). ISBN 8585007605.

MUELLER H. 1997. Determination of the carotenoids content in selected vegetables and fruits by HPLC and photodiode array detection. *European Food Research and Technology* 204: 88-94.

PHUC BHN; LINDERB JE; OGLE B; THOMKE S. 2001. Determination of the nutritive value of tropical biomass products for monogastrics using rats. Part 2: Effects of drying temperature. *Asian-Australasian Journal Animal Science* 14: 994-1002.

PICHA DH. 1985. Crude protein, minerals and carotenoids in sweet potatoes. *Journal Food Science* 50: 1768-1769.

RAMESH YA; MANISHAGUHA RN; THARANATHAN RS; RAMLEKE RS. 2006. Changes in characteristics of sweet potato flour prepared by different drying techniques. *Lebensmittel Wissenchaft und Technologie* 39: 20-26.

REDDY NN; SISTRUNK WA. 1980. Effect of cultivar size, storage and cooking method on carbohydrates and nutrients of sweet potatoes. *Journal Food Science* 45: 682-684.

RODRIGUEZ-AMAYA DB. 2001. *A guide to carotenoids analysis in foods*. Washington: Ilsi. 64p.

SIES H; STAHL W. 1995. Vitamin E and C, β-carotene, and other carotenoids as antioxidants. *American Journal Clinical Nutrition* 62(suppl):1315S-1321S.

SWAI REA. 1993. Diet diversification: Tengeru activities on vitamin A rich foods. *Report of the XV International Vitamin A Consultive Group (IVACG) Meeting*. Washington, D.C. United States, IVACG/ILSI. 99p..

STATSOFT INCORPORATION. 1995. Statistica for windows computer program manual. Version 5.1, edition 98, Tulsa, Oklahoma, USA.

UNDERWOOD BA. 1998. Micronutrient malnutrition. Is it being eliminated? *Nutrition Today* 33:121-129.

WANG XD; KRINSKY NI; BENOTTI PN; RUSSEL RM. 1994. Biosynthesis of 9-cis retinoic acid from 9-cis carotene in human intestinal mucosa in vitro. *Archive of. Biochemistry and Biophysics* 313: 150-155.