Stability of Biofortified Sweet Potato Flour

Rosa M. V. ALVES[1*], Danielle ITO[2], Jose Luiz Viana de CARVALHO[3], Werito Fernandes de MELO[4] , Ronoel Luiz de Oliveira GODOY[5]
CETEA /ITAL– Packaging Technology Center of ITAL
EMBRAPA - Food Technology
[1]rosa@ital.sp.gov.br; [2]danielle@ital.sp.gov.b; [3]jlvc@ctaa.embrapa.br, [4]werito@cnph.embrapa.br, [5] ronoel@ctaa.embrapa.br

Abstract. Sweet potatoe has great economic and social importance in Brazil. Sweet potato flour with high level of β-carotene can replace wheat flour to make products used as school food, as mother-child support, thus contributing to reduce malnutrition in poor countries. The purpose of this study was to survey information on the effect of the type of package and packaging system of the product to preserve carotenoids in biofortified sweet potato flour. The flour was packed with and without vacuum in packs with different barriers to oxygen, water vapour and light (PET/Al/LDPE, PETmet/LDPE, LDPE/PA/LDPE and LDPE) and stored at 25°C/75%RH with and without exposure to light. It was observed quick consumption of the residual oxygen of the headspace in vacuum packages, particularly in those with low oxygen transmission rate by the material (PET/Al/LDPE, PETmet/LDPE). Losses of 50% total carotenoids and ß-carotene occurred in the flour of the LDPE and PETmet/LDPE without vacuum after 50-day storage and in LDPE/PA/LDPE with vacuum after 90 days with or without exposure to light. Under vacuum and in PETmet/LDPE, contents of carotenoids in flour were slightly reduced and were preserved in PET/Al/LDPE up to 360 days of storage. The results indicate that the key factors to preserve carotenoids in biofortified sweet potato flour are: to reduce the oxygen level in the headspace of the package via application of vacuum and the use of packaging materials with oxygen barrier in the order of greatness achieved with PET with metallization barrier.

Keywords: Biofortified sweet potato flour; flexible packages; barrier properties; oxygen level in the headspace; retention of carotenoids, shelf life.

Introduction

Sweet potatoes are one of the most commonly grown vegetables in North-eastern Brazil where the climate, with long periods of drought, restricts production of other kinds of crops. It is an easy, unsophisticated culture adapted to systems of low technological level of small family properties and to vegetable gardens in schools and communities. It also allows prolonged harvesting [1].

Sweet potato flour made from roots with high level of β-carotene is a source of vitamin A which has beneficial effects on human health such as improvement on immunity and reduction of degenerative illnesses such as cancer, cardiovascular and macular degenerations [2-4]. Sweet potato flour can partially replace wheat flour in production of cakes, biscuits and other products used in school feeding and mother-infant support [5].

Biofortified products are being developed in Brazil and other countries in Central America, África and Ásia to fight against malnutrition, which means lack of micronutrients (vitamin A, iron and zinc) which are essential for the health. Although the poorer population, mainly in rural areas, use corn, cassava and sweet potato as their basic food, but if these products are not biofortified they do not supply essential micronutrients found in more nutritional foods such as vegetables, milk, fruit and meat offer, mainly if not ingested in enough amounts [6, 7].

Aiming at to contribute for vitamin A supply for poor populations in different countries, programs like the AgroSalud and Harvest Plus, for many years, have searched for improvement of cultures, through selection and key genes cross, in order to obtain biofortification in the field. In Brazil the activities on these programs are coordinated by EMBRAPA. The sweet potato is one of the cultures focused by the program.

Complementing these developments it was verified the necessity of raising information on the effect of the light, the level of permeability to the oxygen and of the presence of oxygen in the headspace of the packaging, on the loss of carotenoids, and color in the biofortified sweet potato flour in order to define suitable packing.

According to literature, carotenoids are susceptible to isomerization and oxidation during food processing and storage. The practical consequences of these reactions are loss of product color and activity as vitamin A and the formation of volatile compounds that impart desirable or undesirable flavor in some foods. The enzymatic oxidation occurs in great extension before the thermal treatment, and the non enzymatic oxidation occurs in processed foods, which is expected in the case of the flour. It was also noticed that loss of carotenoids during storage process is basically influenced by the storage temperature and time, transmission of light and oxygen permeability of the packaging. The residual of oxygen in the package headspace is also critical and which can be minimized by vacuum packaging or by inert atmospheres [3, 8, 9].

The objective of this study was to raise information about the effect of the type of package material and vaccum filling the product in the preservation of the carotenoids in biofortified sweet potato flour.

Materials and Methods

Product

Sweet potato (*Ipomoea batatas* (L.) Lam.) roots, cultivar Beauregard, produced at the Experimental Field of EMBRAPA Vegetables, Gama, DF – Brazil were peeled, sliced and scraped, dried at 65°C and grounded in a mill with holes of 200μm. At the beginning of the study the flour showed 5.8% (dry basis) of humidity and 185μg carotenoids total /g fresh roots.

Package

Table 1 describes four types of packaging materials studied and all of them with 110g content of biofortified sweet potato flour. The packaging material was described by thickness, oxygen transmission rate (OTR) and water vapor transmission rate (WVTR).

The stability of biofortified sweet potato in the dark

The stability of biofortified sweet potato flour was evaluated in packages described above and stored in the dark at 25±2°C / 75±5% RH. Periodically, samples were analyzed according to the residual oxygen rate in the headspace, product evaluation as for appearance, water activity and level of carotenoids.

The oxygen in the headspace was quantified with an Agilent gas chromatograph, model 7890, operating with a thermal conductivity detector, at 150°C, column (molecular sieve 13 X) at 50°C and injector at 70°C. The chromatograph results were analysed by Chemstation Program - Agilent version B 03.01, based in standard-curves made with gas calibration.

Water activity (Aw) of in sweet potato was determined by hygrometer based in psychrometric – Decagon – Aqualab, with resolution 0.001Aw, at 24.0±1°C [10].

The sweet potato flour initial color was evaluated externally in the transparent packages and after opening all of them.

The total carotenoids and β-carotene in the samples were determined by weight of 1-2g of sweet potato flour, macerated with celite, the carotenoids were extracted with acetone and partitioned to petroleum ether as described by RODRIGUES-AMAYA [2]. The quantification of total carotenoids was made through analysis of absorbance at 450nm in spectrophotometer Shimadzu UV-VIS model UV-1800.

Table 1. Main characteristics of evaluated packages.

Package Material	**Properties**	**Package filling and storage**	
PET/Al/LDPE	11µm/9µm/66µm OTR < 0.05* WVTR <0.01	With vacuum Storage in the dark	
PETmet/ LDPE	12µm/58µm OTR – 1.04* WVTR – 0.93	With vacuum Storage in the dark	
		Without vacuum Storage in the dark	
LDPE/PA/ LDPE	23µm/16µm/20µm OTR – 71.71** WVTR – 7.04	With vacuum Storage in the dark	
		With vacuum Storage under light	
LDPE	80µm OTR – 2,504 WVTR – 4.94	Without vacuum Storage in the dark	

PET = polyester; Al = aluminum foil; LDPE = low density polyethylene; PA = polyamide (Nylon)

OTR - Oxygen transmission rate (cm^3 (STP).m^{-2}.day^{-1}) at 23°C, 1 atm and (*) dry conditions or (**) 75% RH

WVTR – Water vapor transmission rate (g water.m^{-2}.day^{-1}) at 38°C and 90% RH

The analysis of the extract for quantifying β-carotene was made in Waters HPLC Chromatographic with column C_{30} (YMC carotenoid S-3 250x4.6mm, 3µm), with gradient elution in methanol/methyl tert-butyl ether (ether varied from 20 to 90% in 28min) as mobile phase, flow 0.8 mL/min, detector photodiode array with scanning of 300 a 550nm, temperature of the column 33°C and external standard.

Stability of sweet potato flour in the light

LDPE / PA / LDPE vacuum packages with biofortified sweet potato flour were stored in lab at 23±2°C/70±5% RH and daily exposed during 10 hours under 200 lux (4 Sylvania white fluorescent lamps – daylight / 40W) on the ceiling of the laboratory, at about 2 meters distance from the samples. The same trials described for dark stability were applied in these tests (under light).

Results and discussion

The results of residual oxygen in the packages headspace during storage at 25°C/75% RH (Table 2) indicate that packages with vacuum, the amount of residual oxygen was smaller and was consumed faster by oxidation reaction in the packages with lower oxygen transmission rates (PET/Al/LDPE, PETmet/ LDPE) than in LDPE/PA/LDPE packages. When the volume was lower than 0.6mL it was not possible to quantify the percentage of oxygen.

Table 2. Level of oxygen in the headspace (%v/v) of the biofortified sweet potato flour package, stored at 25ºC/75%RH.

Package		Time of storage (days)							
		0	55	90	145	180	235	280	360
PET/Al/LDPE **With** vaccum	A VI	21.0	-	-	(1)	-	(1)	-	(1)
PETmet/ LDPE **With** vacuum	A VI		21.4 21.3-21.4	-	(1)	(1)	(1)	-	(1)
PETmet/LDPE **Without** vacuum	A VI		15.8 15.8-15.9	12.9 11.5-14.4	12.9 12.8-13.1	12.2 11.3-13.2	10.8 9.7-12.0	10.0 9.0-11.0	8.7 5.7–11.9
LDPE/PA/LDPE **With** vacuum **Dark**	A VI		21.2 21.0-21.4	20,4 20,3-20,4	20.9 20.8-21.0	(1)	(1)	(1)	(1)
LDPE/PA/LDPE **With** vacuum **Light**	A VI		21.6 21.5-21.6	21.7 21.6-21.7	21.6 21.5-21.6	(1)	(1)	-	(1)
LDPE **Without** vacuum	A VI		21.3 21.0-21.6	21.2 21.2-21.2	20.7 20.6-20.9	-	20,7 20,7-20,8	20.6 20.3-20.8	20.3 20.3-20.4

A - Average results of two packages of sweet potato flour; VI – variation interval
(1) V<0,6ml – it was not possible to determined the oxygen level

The packages in which the flour was packet without vacuum, the internal atmosphere maintained the air composition (21%O2) during all the period of the study due to high oxygen transmission rate in the LDPE film (Table 1) and it was gradually reduced in PETmet/ LDPE package because part of the oxygen consumed in oxidation reactions is not replaced by permeation through the package material, due to its good oxygen barrier properties as showed at Table 1.

In the evaluations for water activity in the product showed in Figure 1 it is possible to notice the increase of water activity of the flour packed in packages with higher water vapor transmission rate of the LDPE and LDPE/PA/LDPE as previously showed at Table 3. In these packages, the 0.43 water activity described in literature as being the level which better preserve carotenoids in dry carrots [11] it was achieved after 55 days of storage 25ºC/75% RH. In PETmet/LDPE packages the water activity or 0.43 was achieved after 235 storage days and in aluminum laminated package, the sweet potato flour water activity has not had any change during 360 days of storage at 25ºC/75%RH.

In visual evaluation of the samples during the study, it was realized a similar orange color in all sweet potato flour in PET/Al/LDPE and PETmet/LDPE packages, both with vacuum, in all storage periods evaluated. In the other hand, LDPE (without vacuum) was the material which least preserved the color of the product in all the evaluations.

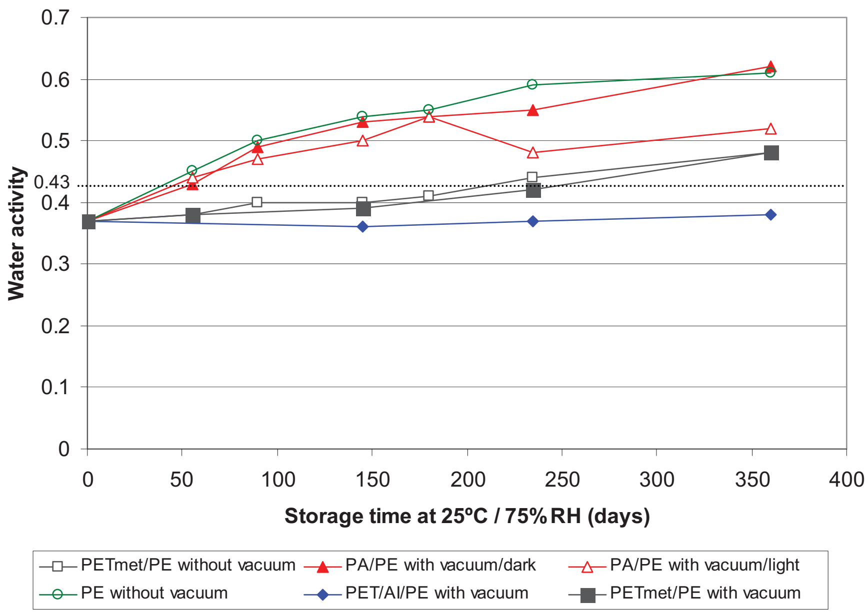


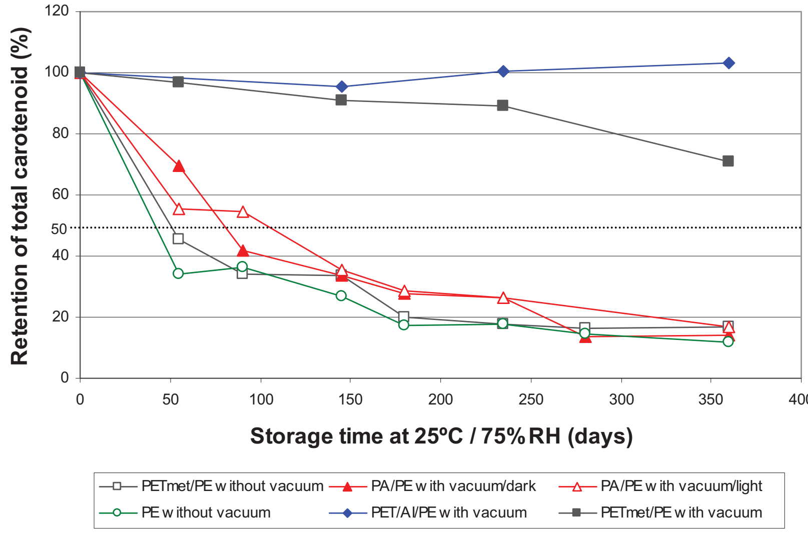
Figure 1. Water activity of sweet potato flour stored at 25ºC/75%RH.

Throughout storage period, LDPE/PA/LDPE with vacuum packages which were exposed or not exposed to light preserved the color of sweet potato flour slightly better than the PETmet/LDPE packages without vacuum, demonstrating that the effect of residual oxygen in the package headspace is more critical than the oxygen permeability of the package material even if the water activity in the flour, packaged in film coex LDPE/PA/LDPE, was higher than in the PETmet/LDPE packages, due to a higher WVTR of LDPE/PA/LDPE compared to PETmet/LDPE packages.

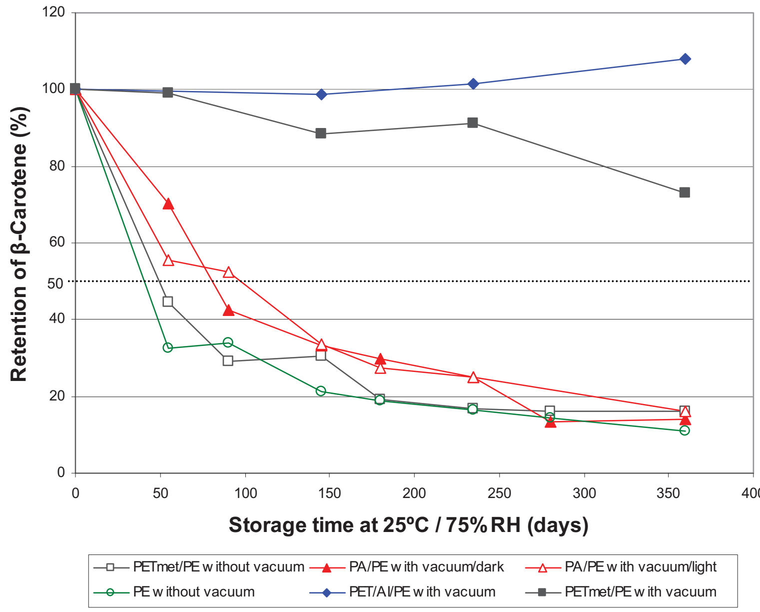
Figure 2 shows the biofortified sweet potato flour appearance after 360 storage days.

Figure 2. The appearance of the biofortified sweet potato flour after 360 storage days at 25ºC/75%RH.

Figures **3a** and **3b** show the results for total carotenoids and β -carotene retention, respectively, calculated on the amount detected on the product on the 0 day of the storage. It is observed that at the 50th day of storage a loss of approximately 50% of total carotenoids and β-carotene occurred in packages LDPE e PETmet/LDPE without vacuum respectively. These results are in accordance with the ones observed by MACEDO et al. [12] which realized a loss of 50% of total carotenoids in biofortified sweet potato packaged in LDPE and storage in the dark at 25ºC/75%RH.



(a)



(b)

Figure 3. Retention of total carotenoids (a) and β-carotene (b) in biofortified sweet potato flour stored at 25ºC/75%RH.

Losses of 50% of total carotenoid and β-carotene were also observed in coex film LDPE/PA/LDPE at approximately 90 days of storage at 25°C/75%RH. However in the coex package it was observed a loss of color in the product when in contact with the surface of the package due to the light exposure. Homogenizing all the content of the package it was observed that the level of carotenoids in the product was a lower in the packages stored under light than the packages stored in the dark, probably because the laboratory temperature (storage under light) was in average lower (between 21ºC and 25ºC) than in the climatized chamber (storage in the dark, between 23°C and 27ºC). The light has also had no important interference in the loss of freeze-dried carotenoid pigment extracted from sweet potato, carrot and orange peel during 120 days of storage under fluorescent light at 25°C compared to the samples kept in the dark [13, 14].

On PETmet/LDPE with vacuum, the level of carotenoids slightly diminished and was maintained in PET/Al/LDPE with vacuum until 360 storage days at 25°C/75%HR.

Based on the obtained results, the retention of 50% of carotenoids in biofortified sweet potato flour, packaged in the different packaging material/ systems occurred after the following periods when stored at 25°C/ 75%RH:

- 50 days in LDPE e PET/met/LDPE without vacuum;
- 90 days in LDPE/PA/LDPE with vacuum with and without light exposition (200lux for 10 hours daily);
- Superior to 360 days in PETmet/LDPE with vacuum.

CONCLUSIONS

Based on the evaluations to different package material and packaging systems for the biofortified sweet potato flour, it was verified that the determining factors for the preservation of the level of carotenoids for periods longer than 3-4 months is the reduction of oxygen in the headspace of the package by vacuum and the use of packaging material with high oxygen barrier (OTR near 1.0ml (STP).m^{-2}.day^{-1}, at 23°C, 75%RH and 1atm the partial pressure gradient permanent gas).

Acknowledgement

The authors thank the Embrapa – Monsanto Research Fund for the financial support.

References

[1] FONTES, R. R.; VILELA, N. J. The current status of brazilian vegetable crops and future opportunities. **Acta Horticulturae**. Disponível em: <http: www.actahort.org/books/607>. Acesso em: 22 mar. 2008.

[2] RODRIGUES-AMAYA, D. B. **A guide to carotenoid analysis in foods.** Washington: ILSI - International Life Sciences Institute, 2001. 64 p.

[3] RODRIGUES-AMAYA, D. B.; KIMURA, M.; GODOY, H. T.; AMAYA-FARFAN, J. Updated Brazilian database on food carotenoids: factors affecting carotenoid composition. **Journal of Food Composition and Analysis**, San Diego, n. 21, p. 445-463, 2008.

[4] VAN JAARSVELD, P. J.; MARAIS, D. W.; HARMSE, E.; NESTEL, P.; RODRIGUES-AMAYA, D. B. Retention of β-carotene in boiled, mashed orange-fleshed sweet potato. **Journal of Food Composition and Analysis,** San Diego, n. 19, p. 321-329, 2006.

[5] RODRIGUEZ-AMAYA, D. B.; NUTTI, M. R.; CARVALHO, J. L. V. Carotenoids of sweet potato, cassava, and maize and their use in bread and flour fortification. In: PREEDY, R. R.; WATSON, R. R.; PATEL, V. B. (Ed.). **Flour and breads and their fortification in health and disease prevention.** London, Burlington, San Diego: Academic Press, Elsevier, 2011. Chapter 28, p. 301-311.

[6] BALL, Anna-Marie. **Biofortificação**: Novas culturas contra a fome oculta. Disponível em: <http://spore.cta.int/index.php?option=com_home&id_publication=11&lang=pt>. Acesso em: 29 nov. 2010.

[7] KRISTOF, Nicolas D. **Bless the orange sweet potato**. The New York Times: Reprints, November, 24, 2010. Disponível em: http://www.nytimes.com/2010/11/25/opinion/25kristof.html?_r=1&scp=1&sq=bless %20the%20orante%20sweet%20potato&st=cse. Acesso em: 1 dez. 2010.

[8] RODRIGUES-AMAYA, D. B. Changes in carotenoids during processing and storage of foods. **Archivos LatinoAmericanos de Nutrition**, Venezuela, v. 49, n.1-S, p.38-47, 1999.

[9] LESKOVÁ, E.; KUBÍKOVÁ, J.; KOVÁCIKOVÁ, E.; KOSICKÁ, M.; PORUBSKÁ, J.; HOLCÍKOVÁ, K. Vitamin losses: retention during heat treatment and continual changes expressed by mathematical models. **Journal of Food Composition and Analysis**, San Diego, n. 19, p. 252-276, 2006.

[10] DECAGON DEVICES. **Aqua lab – model CX-2-Water activity meter**.[s.l.s.d.]. 73 p. (Operator's Manual Version 3.0).

[11] RODRIGUES-AMAYA, D. B. Stability of carotenoids during the storage of foods. In: CHARALAMBOUS, G. **Shelf life studies of foods and beverages: chemical, biological, physical and nutritional aspects.** Amsterdam: Elsevier Science Publishers, 1993, p.591-627.

[12] MACEDO, J.R.; CARVALHO, P.G.B.; LEASTRO, D.A.; ALVES, N.S.; SILVA, J.B.C.; NUTTI, M.; CARVALHO, J.L.V. Carotenoid retention in sweet potato flour during storage. In: MEETING OF MICRONUTRIENT FORUM, 2., 2009, Beijing. *Poster...* Beijing , 2009, 2p.

[13] ÇINAR, I. Carotenoid pigment loss of freeze-dried plant samples under different storage conditions. **Lebensmittel – Wissenschaft und - Technologie**, n. 37, p. 363-367, 2004.

[14] ÇINAR, I. Stability studies on the enzyme extracted sweet potato carotenoproteins. **Food Chemistry**, New York, n. 89, p. 397-401, 2005.