Impact of storage under ambient conditions on the vitamin content of dehydrated vegetables

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Abstract

The consumption of dehydrated vegetables, which provides an important source of vitamins, is increasing worldwide. Dehydrated vegetables are located on non-refrigerated shelves in food shops and, therefore, it is of utmost importance to understand the modifications that take place in the content of these labile micronutrients at the ambient conditions currently found in food shops. The present study discusses the effect of storage for 3, 6, 9 and 12 months on the content of thiamin and vitamin C in different commercial and pilot plant dehydrated garlic, onions, potatoes and carrots in darkness at room temperature under vacuum conditions. The content of β-carotene under these conditions was also studied in dehydrated carrots. Thiamin remained stable over the first 3 months of storage (~90% retention), while long-term storage led to larger losses (retention of 85% in garlic and 45% in commercial carrots after 12 months of storage). The content of vitamin C drastically decreased during the storage period and even disappeared in some dried onions and carrots following 12 months of storage. Storage for 6 months at ambient conditions preserved 80-90% of the β-carotene content in dehydrated vegetables, while long-term storage led to significant β-carotene degradation (retentions between 43 and 81%). These results suggest that vitamins are

gradually lost during storage at the practical conditions in food shops and will thus provide relevant information concerning dried vegetables so manufacturers may calculate shelf life under established storage conditions.

Keywords: dried vegetables, storage, thiamin, vitamin C, β-carotene.

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INTRODUCTION

There is solid epidemiological evidence that demonstrates the benefits of a diet rich in fruits and vegetables to prevent cardiovascular diseases, cancer, hypertension, diabetes and obesity. Carrots, potatoes, garlic and onions are among the most popular vegetables not only because of their availability in food markets, but also because of their vitamin content and flavouring properties.

Fresh vegetables are the best source of vitamins and, among them, vitamin C is one of which they contain important amounts; it is a potent antioxidant involved in essential biological functions that reduce the damage caused by free radicals to cell membranes. Furthermore, vegetables provide B complex vitamins such as thiamin (vitamin B_1) that is essential for the metabolism of carbohydrates and branched-chain amino acids. Likewise, it is implicated in neurotransmission and nerve conduction. In addition, carrots are one of the highest dietary sources of β-carotene, which is the precursor of vitamin A, and has antioxidant, immunomodulatory and anti-carcinogenic properties (Machlin, 1984; Mataix, 2002). Since vegetables are seasonal and abundantly available at particular times of the year, a large amount of wastage can occur during the growing season due to a lack of adequate storage facilities. Vegetables are highly perishable, therefore, their preservation can increase their shelf-life and make them available in the off-season.

Drying is an ancient method for food preservation that has been successfully applied in fruits and vegetables to minimize their biochemical, chemical and microbiological deterioration by reducing moisture to levels which allow safe storage over a long period of time (Mujumdar, 2007). Dried vegetables have emerged to fulfil consumer demands for healthy and safe plant foods that are easy to prepare.

The dehydrated vegetables market provides consumers with long shelf-life foods that are easily stored and ready for rehydration. Different commercially available dehydrated vegetables are increasingly being used in the preparation of different food products and commercial restaurants, as well as in healthy oil-free snack foods (Lin et al. 1989).

Manufacturers usually recommend a shelf-life of one year for commercial dried vegetables. Since dried plant foods are located in non-refrigerated shelves in food shops and vitamins are very labile micronutrients it is important to acquire knowledge concerning the vitamin content of dried vegetables stored at the practical conditions currently found in food stores, which may sometimes be as long as 12 months. There is previous research regarding the effect of storage on the content of some vitamins in common vegetables. Negi and Roy (2000) found a noticeable decrease in the β-carotene and ascorbic acid content of carrots stored at room temperature. Similarly, Bechoff et al. (2011) observed a total carotenoid loss of 84% during storage of sweet potato for 4 months at ambient on-farm conditions. However, to date, there is a lack of data regarding the effect of practical storage conditions in the thiamin content of dried vegetables. In addition, no information has been found concerning the effect of storage on the content of vitamin C in common dried plant foods, such as onions, garlic or potatoes.

Therefore, the objective of the present work was to study the effect of storage at ambient conditions after 3, 6, 9 and 12 months on the content of thiamin and vitamin C in different commercial and laboratory dehydrated garlic, onions, potatoes and carrots, as well as β-carotene in commercial and laboratory dehydrated carrots in order to simulate the conditions that are usually found in food shops.

MATERIAL AND METHODS

Material

The samples for analysis were dehydrated onions, garlic and potatoes from different sources. Source 1: commercial dehydrated garlic (GC) (Carmencita, Novelda, Alicante, Spain), onions (OC) (Dulcros, Madrid, Spain) and potatoes (PC) (Nomen, Tortosa, Tarragona) purchased from El Corte Ingles supermarket (Madrid, Spain) within 12 months of the shelf-life found on the label. GC had shape of little squares; the shape of OC was of thin strips; and the PC sample was potato puree. GC and OC samples were packed into capped glass vessels while PC sample was purchased in aluminiumplastic bags under vacuum conditions. Source 2: dehydrated garlic, onions, potatoes and carrots were kindly provided by Vegenat S.A., Badajoz, a Spanish company devoted to the commercialization of dehydrated foods; they provided the samples in aluminium-plastic bags under vacuum conditions. Dehydrated garlic had laminated shape (GV); dehydrated chopped onions were provided both in small strips (< 0.5 cm) (OSV) and large strips (>0.5 cm) (OLV); dehydrated potatoes were had a laminar shape (PV); and carrots were presented in laminated shape (10x10x2 mm) (CFV) and expanded shape (6x6x6 mm) (CEV). Source 3: dehydrated onions, garlic, potatoes and carrots were experimentally prepared in the pilot plant of our Institute. Fresh good quality vegetables were purchased at El Corte Ingles, Madrid; they were hand peeled and washed. Garlic was chopped into four parts; onions and potatoes were laminated into thin strips; and carrots were sliced into ~4 mm thickness and ~24 mm diameter. Garlic, onions and carrots were blanched by immersion in boiling water for 1 min (sample: water ratio was 1:30), cooled in ice-bath water and dehydrated by freeze-drying (GP, OP and CP, respectively). Potatoes, however, were blanched by steaming them with boiling water for 10 min, and then cooled in ice-bath water and dehydrated by freeze-drying (PP).

For storage studies, the commercial and pilot-prepared dehydrated vegetables were packed into plastic bags under vacuum conditions in different batches, covered with aluminum foil to protect them from light exposure and stored at room temperature for 3, 6, 9 and 12 months, thus simulating the storage conditions in a food shop. Maximum, minimum and mean temperatures during storage are shown in Table 1. Month 0 was considered the storage starting time. Just before analysis, samples were finely ground using a thermostated laboratory grinder (IKA A10, Janke & Kundel).

Methods

Determination of thiamin. Thiamin was extracted and subsequently quantified by high performance liquid chromatography (HPLC) (Prodanov et al., 1997). For quantification, a chromatographic system Alliance Separation Module 2695 (Waters Associates, Milford, USA) was used. 50 µL of the extract were injected and thiamin was separated into a µBondapak C_{18} column (300 x 3.9 mm i.d.) connected to a Porasil B Bondapak C_{18} guard column (20 x 3.9 mm i.d., Waters) at 35 ºC. Mobile phase consisting of methanol (Scharlau)/ water (milli Q)/acetic acid (Sharlau, Spain) (31/68.5/0.5), containing 5 mM sodium hexasulfonate (Sigma-Aldrich, Steinhein, Germany) was pumped at a flow rate of 1.2 mL/min. The content of thiamin was then quantified using a postcolumn derivatization in a Waters 470 scanning fluorescence detector (Waters Associates, Milford, USA) set up at λ_{exc}= 360 nm and λ_{em}= 435 nm and a personal computer running the Empower 2 chromatographic software for Microsoft Windows (Waters Associates, Milford, USA). The calibration curve was obtained with the thiamin standard (Sigma-Aldrich, Steinheim, Germany) being processed in a similar manner to the samples, plotted and adjusted by using the method of least squares. The regression coefficient was greater than 0.990. Extractions were performed in duplicate per batch and results were expressed as µg/100g of dry matter (d.m.).

Determination of vitamin C. Vitamin C was extracted as described by Frias et al. (2005) and quantified by capillary zone electrophoresis. To quantify the vitamin C content, a fused silica capillary TSP075375 (47 cm x 75 µm) purchased from Composite Metal Services LTD (The Chase, Hallow, Worcester, UK), a P/ACE system 2050 (Beckman Instruments, Fullerton, CA, USA) and UV detection at 254 nm were used. Vitamin C was quantified from a calibration curve built with pure ascorbic acid standard (Sigma-Aldrich, Steinheim, Germany) and with the response factor relative to an internal standard. Extractions were performed in duplicate per batch and results were expressed as mg/100 g of dry matter (d.m.).

Determination of β-carotene. The content of β-carotene in dried vegetables under analysis was extracted following the procedure described by Lavelli et al. (2007). β-carotene was quantified by HPLC using a Vydac 201TP54 C18 reverse column (250 x 4.6 mm) (GraceVydac, Symta, Spain), equipped with a C18 precolumn (100 x 4.6 mm) (ACE, Symta, Spain). The chromatographic system included an Alliance Separation Module 2695 (Waters Associates, Milford, USA), a photodiode array detector PAD 2998 (Waters Associates, Milford, USA) set at 450 nm, and a personal computer running the Empower II chromatographic software for Windows (Waters). Chromatographic separation was performed with methanol (Scharlau)/stabilized THF (95:5) as the eluent under isocratic conditions, at a 1.0 mL/min flow rate and at room temperature. Quantification was carried out by the external standard method, using a commercial standard of β-carotene (Sigma-Aldrich, Steinheim, Germany). The purity of β-carotene was measured spectrophotometrically at 453nm (Riso and Porrini, 1997) and concentrations of standard solutions were corrected accordingly. Extractions were carried out in duplicate per batch and results were expressed as mg/100 g of dry matter (d.m.).

Statistical analysis. Data provided are the mean of three determinations of each experimental replicate. Data were subjected to multifactor ANOVA using the least-squared difference test (LSD) with the Statgraphic 5.0 Program (Statistical Graphics Corporation, Rockville, MD, USA) for Windows.

RESULTS AND DISCUSSION

Thiamin content

The content of thiamin in commercial and pilot-prepared dehydrated garlic and the effect of storage are shown in Table 2. The thiamin content of the dehydrated garlic before storage ranged from 275.30 µg/100 g d.m. in GV to 330.69 µg/100 g d.m. in GP, and significant differences ($P \leq 0.05$) were found between them. Storage of dehydrated garlic at room temperature in darkness led to losses in the content of thiamin; there were retentions between 92-95% in the 3rd month of storage and between 85-87% in the 12th month (Table 2, Figure 1).

Thiamin content in dehydrated onions before storage ranged from 166.85 µg/100 g d.m. in OP to 217.80 µg/100 g d.m. in OC (Table 3). The storage of these samples for 3-12 months caused different reductions in their thiamin content depending on the onion source. The content of thiamin of OSV, OLV and OP underwent a gradual but slight decrease during the 12 storage months (retentions ranging from 95 - 99% in the 3rd month to 84 - 91% in the 12th month), whilst the content of thiamin in OC decreased sharply during storage (a retention of 79% in the 3rd month and 44% in the 12th month) (Table 3, Figure 1).

The initial content of thiamin in dehydrated potatoes ranged from 46.95 µg/100 g d.m. in PC sample to 169.31 µg/100 g d.m. in PV sample (Table 4). After storage for 3 months, the thiamin content of dried potatoes decreased by only 3-6%. However, a longer storage period led to different stability depending on the origin of the sample and only 59-79% of the thiamin content was retained after 12 months (Table 4, Figure 1).

The content of thiamin in dehydrated carrots before storage ranged from 121.59 µg/100 g d.m. in CFV carrots to 174.78 µg/100 g d.m. in PC (Table 5). The stability of this vitamin was quite high after 3 storage months irrespective of the type of dried carrot under study, and 92-94% of the initial value was retained. However, storage up to 6 months at ambient conditions led to retention of 88 % in CP, whilst only 70% of the thiamin content was retained in commercial dehydrated carrots. A longer storage period led to gradual losses of thiamin and 54%, 62% and 65% of the initial content was found in CFV, CEV and CP, respectively, at the end of the storage time (Table 5, Figure 1).

The content of thiamin in dehydrated garlic, onions, potatoes and carrots are within the amounts found in the Food Composition and Nutrition Tables (Gubler et al. 1984) for dried vegetables. However, no literature data has been found related to the effect of storage conditions on thiamin content of dried vegetables. Temperature and pH are key factors affecting the stability of thiamin. Although this vitamin is quite stable on heating and oxidating below a pH of 5.5, above this pH, it is destroyed relatively rapidly by heating and, at a pH of 7, it can easily be degraded, even at room temperature (Souci et al. 2008). The pH of the dehydrated vegetables studied here was slightly acidic (between 5.9-6.3 for garlic, 6.0-6.4 for onions, 5.9-6.2 for carrots and 5.9-6.2 for dried carrots); the temperatures during storage ranged between 13.4 and 25 ºC during the first trimester (mean temperature of 20.4ºC), between 19 and 28 ºC in the second trimester (mean temperature of 23.1ºC), between 20.6 and 31.5 ºC in the third trimester (mean temperature of 24.8ºC), and between 18.7 and 30.1 ºC in the fourth one (mean temperature of 24.1ºC) (Table 1). Although these pHs were slightly higher than 5.5 and the samples were stored at mild temperatures, the stability of thiamin gradually declined during short-term storage and more significantly during long-term storage. Our results suggest that thiamin is not fully retained in dried vegetables when they are stored at practical conditions in food shops for long periods of time of up to 12 months.

Vitamin C content

Tables 2-5 show the content of vitamin C in dehydrated vegetables and the changes during storage at ambient conditions in darkness. Vitamin C was not detected in commercial dried garlic purchased in a local market or in those samples provided by the drying food industry (GC and GV, respectively). However, dried garlic experimentally prepared in our pilot plant (GP) showed a content of 14.13 mg/100 g d.m. Vitamin C content of GP underwent a sharp reduction after 3 months of storage and only 58% of the initial content was retained. Long-term storage led to larger losses of vitamin C and retentions of only 29 and 17% of the original content were kept after 6, 9 and 12 months, respectively (Table 2, Figure 2).

The content of vitamin C in dehydrated onions at the initial storage time was widely variable and ranged from 17.50 mg/100 g d.m. in OLP to 55.91 mg/100 g d.m. in OP (Table 3). The storage at ambient conditions sharply affected the content of vitamin C and depended on the onion origin. Vitamin C in OP decreased slightly after 6 months of storage and 93% was retained, but there was a sharp decrease after 9 months of storage (46% retention) and no vitamin C was detected at the end of the storage period. Dried onions provided by the food industry only had 65 and 81% vitamin C retention in the 3rd storage month (for OSV and OLV, respectively), and underwent a gradual loss up to the 12th month (retentions of 29 and 46%, respectively). However, the OC sample stored for 3 months contained only 42% of the initial vitamin C amount;

after 6 and 9 months, there was a retention of 36 and 26%, respectively; and it totally disappeared after 12 months (Table 3, Figure 2).

The content of vitamin C in freshly obtained dried potatoes ranged from 17.26 g/100 g d.m. in PV to 58.26 mg/100 g d.m. in PP (Table 4). This vitamin was relatively stable during the first 3storage months (82-89% of the initial content was retained). After that time, the vitamin C continued its degradation and only 49, 32 and 27% was maintained after 12 months in PC, PV and PP, respectively (Table 4, Figure 2).

The vitamin C of dried carrots also showed a wide range of values before storage. CP sample presented the highest content (30.54 mg/100 g d.m.) followed by CFV (25.95 mg/100 g d.m.) and CEV (19.29 mg/100 g d.m.). The storage of dehydrated carrots at ambient conditions led to significant ($P \leq 0.05$) reductions of vitamin C, even in the 3rd month of storage, where retentions of 82, 84 and 65% of the initial concentration in CFV, CEV and CP, respectively, were found (Table 5, Figure 2). After 6 and 9 months of storage, the stability of vitamin C decreased steadily (retentions of 73 and 47% for CFV, 80 and 58% for CEV, and 49 and 36% for CP, respectively). After long-term storage, only ~40% of the initial vitamin C was maintained in commercial samples, whilst it was completely lost in CP (Table 5 Figure 2).

The vitamin C content found for the studied dried vegetables are within the range of values collected in the Food Composition and Nutrition Tables (Gubler et al. 1984) and within those reported by other authors for dried carrots (Negi and Roy, 2000; Frias et al. 2010). To our knowledge, there is scarce information about the effect of storage on vitamin C content in dehydrated vegetables. Our results are in accordance with those found by Negi and Roy (2000) which reported the total spoilage of vitamin C in dehydrated carrots stored at 15.0-37.5 ºC (practical conditions) after 9 months. It is well known that vitamin C is the most labile of all the vitamins and thus is easily degraded at high temperatures. Therefore, the differences within results found in the present work may be due to the different experimental temperatures registered during storage (13.4 to 31.5 ºC, Table 1).

The degradation of ascorbic acid could be attributed to browning reactions through spontaneous thermal decomposition under both aerobic and anaerobic conditions in dehydrated vegetables (Namiki, 1988) and its degradation products also participate with amino acids in Maillard browning (Molnar-Perl and Friedman, 1990). In fact, there is evidence that in orange drinks, ascorbic acid is the most reactive constituent in the formation of browning pigments, which is accelerated in the presence of oxygen and amino acids, thus limiting the shelf life of this product (Kacem et al. 1987). Ascorbic acid browning leads to the destruction and loss of this important vitamin and to the production of furfurals as a result of degradative transformations, thereby contributing to the loss of the nutritional value of dehydrated products. In addition, these compounds induce deterioration in color, flavor and taste during long-term storage of dehydrated products (Molnar-Perl and Friedman, 1990).

β-carotene content

The content of β-carotene in dehydrated carrots under study as well as of their retention percentages during storage are shown in Table 5. The initial valueof β-carotene in carrots dried at laboratory conditions (CP) was 50.67 mg/100 g d.m which was similar to that of the commercial extruded carrots (CEV) (48.64 mg/100 g d.m.), but which was considerably higher than that of the flaked carrots (CFV) (23.36 mg/100 g d.m.) provided by the drying food company. The content of β-carotene in dried carrots varies widely in the scientific literature with values ranging from 25 mg/100 g (Negi and Roy, 2000) to 50.0 mg/100 g (Kacem, 1987; Lavelli et al. 2007; Soria et al., 2009); they are within the range presented by Souci et al., (2008) in the Food Composition and Nutrition Tables. In CEV and CP carrots stored for 3 months, the content of β-carotene underwent a slight reduction and as much as 95% was retained, while in CFV only 80% was kept. After that time, the content of β-carotene decreased gradually and, at 12 months, only 43, 76 and 81% of the initial β-carotene content was retained (FC, EC and CP, respectively) (Table 5, Figure 3). These results are consistent with the findings of Zhao and Chang (1995), who found a continuous decrease in the β-carotene of dried carrots during long-term storage under practical conditions. Similarly, Negi and Roy (2000) observed steady reductions of β-carotene in dried carrots after storage at ambient conditions (15.0-37.5 ºC) for 6 months and its total disappearance after 9 months. Likewise, Bechoff et al., (2010) demonstrated that losses of carotenoids in sweet potato were critical during storage for 4 months in customary on-farm storage conditions in many developing countries.

One of the most important factors that contribute to β-carotene reduction during storage of dried carrots is the product moisture. The water content in dry matrices may increase the oxidation rate which implies higher susceptibility of β-carotene toward degradation. Lavelli et al. (2007) indicated that during storage of dehydrated carrots at 40 ºC, β-carotene decreased following a pseudo-first-order kinetics and, upon plotting the first-order rate constants against water activity (Aw) showed an U-shaped curve typical of most oxidative reactions. In the Aw range of 0.341-0.537, corresponding to 6-11% moisture, carotenoids showed the maximum stability (Lavelli et al, 2007) ; in the present work , the moisture content of the stored carrots under investigation are within such a range (7.2, 9.2 and 10%, for CFV, CEV and CP, respectively). Dried vegetable foods usually contain between 5 and 15% water content; this final content would prevent undesirable biochemical changes and subsequent contamination and spoilage.

In addition, the differences found in vitamin contents among the dried vegetables studied in the present work could also be attributed to the differences among varieties:, vegetable age, shape and size together with the matrix structure that might affect not only the vitamin stability during storage, but also the quality attributes of dried vegetables (Devahastin and Niamnuy, 2010; Słupski et al., 2010).

CONCLUSIONS

Dehydrated vegetables are a source of vitamins but their content depends on storage conditions. Thiamin and vitamin C in dehydrated vegetables were not fully retained during storage at the ambient conditions usually found in food stores. In general, thiamin was relatively well preserved during the first 3 storage months (retentions above 80% of the initial content) although afterwards it gradually decreased to almost 60% of the initial content during the 12 months of storage. Vitamin C, however, was quite unstable and was totally spoiled in some of the samples at the end of the storage period. β-carotene gradually decreased during the storage of carrots at ambient conditions and retentions between 43-80% were obtained following 12 months of storage. These results suggest that the vitamin content of dried vegetables can be easily degraded during a long storage period at the ambient conditions usually found in food shops and, hence, the shelf life of dried plant foods would be significantly reduced.

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LEGENDS TO FIGURES

Figure 1. Effect of storage under ambient conditions on the thiamin content of dehydrated vegetables

Figure 2. Effect of storage under ambient conditions on the vitamin C content of dehydrated vegetables

Figure 3. Effect of storage under ambient conditions on the β-carotene content of dehydrated carrots

Table 1. Maximum, minimum and mean temperature during the storage of dehydrated vegetables.

Storage time (months)	T max (ºC)	T min (ºC)	T mean (ºC)
0	23.8	16.8	19.6
1	25.0	18.0	21.4
2	24.1	13.4	19.7
3	24.8	17.6	20.8
4	25.0	19.8	22.1
5	26.9	18.9	22.9
6	27.9	22.2	24.3
7	30.7	22.0	25.6
8	29.9	20.9	24.2
9	31.5	20.6	24.7
10	30.1	23.2	25.4
11	28.2	20.7	24.0
12	24.9	18.7	22.6

Table 2. Effect of storage under ambient conditions on thiamin and vitamin C content of dehydrated garlic.

Dehydrated garlic	Storage time (months)	Thiamin (µg/100 g d.m.)	Vitamin C (mg/100 g d.m.)
GC	0	303.57±1.09 e2	ND
	3	286.48±3.23 d	ND
	6	283.67±3.35 d	ND
	9	263.40±1.19 b	ND
	12	258.68±1.80 a	ND
GV	0	275.30±2.18 c1	ND
	3	252.60±8.41 b	ND
	6	251.92±3.33 b	ND
	9	247.22±2.16 b	ND
	12	239.57±3.86 a	ND
GP	0	330.69±1.41 d3	14.13±0.20 e
	3	314.54±7.17 c	8.21±0.46 d
	6	314.71±1.24 c	4.04±0.25 c
	9	291.61±2.26 b	3.49±0.23 b
	12	283.10±7.83 a	2.41±0.23 a

Values are the mean ± SD. Different letter in the same column for each vegetable indicates significant difference (P≤0.05). Different number between vegetables at 0 time storage indicates significant difference (P≤0.05).

Table 3. Effect of storage under ambient conditions on thiamin and vitamin C content of dehydrated onions

Dehydrated onions	Storage time (months)	Thiamin (µg/100 g d.m.)	Vitamin C (mg/100 g d.m.)
OC	0	217.80±0.91 e3	34.36±1.09 e
	3	174.84±1.98 d	14.55±0.85 d
	6	145.36±1.91 c	12.29±0.75 c
	9	129.51±0.65 b	8.88±0.23 b
	12	125.02±0.87 a	NDa
OSV	0	194.62±4.32 b2	21.49±1.11 e
	3	193.36±2.97 b	13.92±0.52 d
	6	191.85±1.28 b	11.93±0.81 c
	9	190.96±2.71 b	9.92±0.20 b
	12	176.37±1.86 a	6.20±0.22 a
OLV	0	191.74±8.24 c2	17.50±1.18 e
	3	185.68±2.52 b	14.19±0.57 d
	6	181.58±1.33 b	12.46±0.51 d
	9	174.48±1.62 a	11.02±0.94 b
	12	169.15±1.62 a	8.10±0.38 a
OP	0	166.85±3.94 d1	55.91±0.75 e
	3	157.89±2.91 c	53.95±0.93 d
	6	157.38±1.26 c	51.76±1.06 c
	9	146.55±4.29 b	25.42±1.77 b
	12	140.69±4.73 a	ND a

Values are the mean ± SD. Different letter in the same column for each vegetable indicates significant difference (P≤0.05). Different number between vegetables at 0 time storage indicates significant difference (P≤0.05).

Table 4. Effect of storage under ambient conditions on thiamin and vitamin C content of dehydrated potatoes.

Dehydrated potatoes	Storage time (months)	Thiamin (µg/100 g d.m.)	Vitamin C (mg/100 g d.m.)
PC	0	46.95±0.56 d1	20.74±0.27 e2
	3	45.63±1.02 cd	17.51±0.41 d
	6	45.12±0.86 c	14.72±0.69 c
	9	41.96±0.91 b	13.43±0.47 b
	12	27.78±1.22 a	10.11±0.39 a
PV	0	169.31±5.00 c3	17.26±0.81 d1
	3	164.78±7.40 c	15.29±1.02 c
	6	168.93±4.88 b	13.56±0.99 b
	9	156.08±1.30 b	12.84±0.40 b
	12	133.22±6.40 a	5.54±0.75 a
PP	0	156.13±3.78 e2	58.26±3.54 e3
	3	146.34±2.77 d	48.03±1.92 d
	6	131.71±4.77 d	45.51±1.01 c
	9	125.45±1.33 b	25.23±0.62 b
	12	108.01±2.26 a	15.50±1.12 a

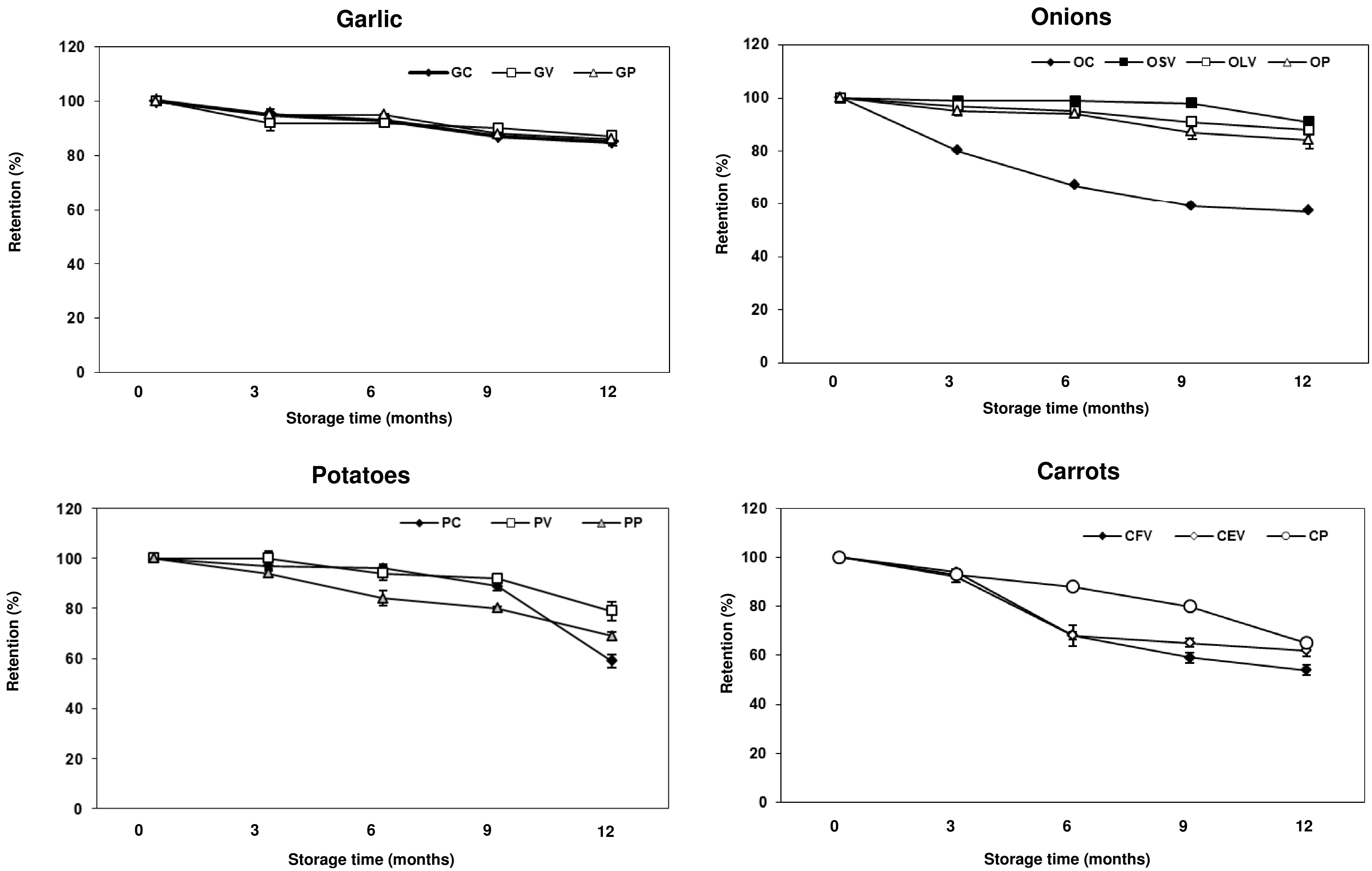
Values are the mean ± SD. Different letter in the same column for each vegetable indicates significant difference (P≤0.05). Different number between vegetables at 0 time storage indicates significant difference (P≤0.05).

Table 5. Effect of storage under ambient conditions in thiamin, vitamin C and β-carotene content of dehydrated carrots

Dehydrated carrots	Storage time (months)	Thiamin (μg/100 g d.m.)	Vitamin C (mg/100 g d.m.)	β-carotene (mg/100 g d.m.)
CFV	0	121.59±1.37 e1	25.95±1.36 e2	23.36±0.49 d1
	3	114.31±1.47 d	21.34±1.32 d	18.66±0.81 c
	6	83.25±5.31 c	18.92±1.06 d	18.09±0.26 c
	9	71.46±2.60 b	12.24±1.04 b	16.28±0.40 b
	12	65.61±2.35 a	10.39±0.42 a	10.01±0.24 a
CEV	0	151.63±4.85 d2	19.29±1.76 d1	48.64±0.26 d2
	3	138.87±3.54 c	16.21±0.94 c	46.58±0.32 c
	6	103.17±2.11 b	15.52±1.01 c	44.32±0.15 b
	9	97.97±2.54 ab	11.11±0.64 b	38.34±1.80 a
	12	93.32±3.98 a	8.02±0.24 a	37.17±1.15 a
CP	0	174.78±2.67 e3	30.54±1.77 e3	50.67±0.85 d3
	3	162.62±3.15 d	19.95±0.99 d	48.39±0.85 c
	6	154.42±3.28 c	14.81±0.81 c	45.71±1.49 b
	9	139.31±1.63 b	12.30±0.86 b	42.53±0.83 a
	12	114.08±2.49 a	ND a	41.06±1.18 a

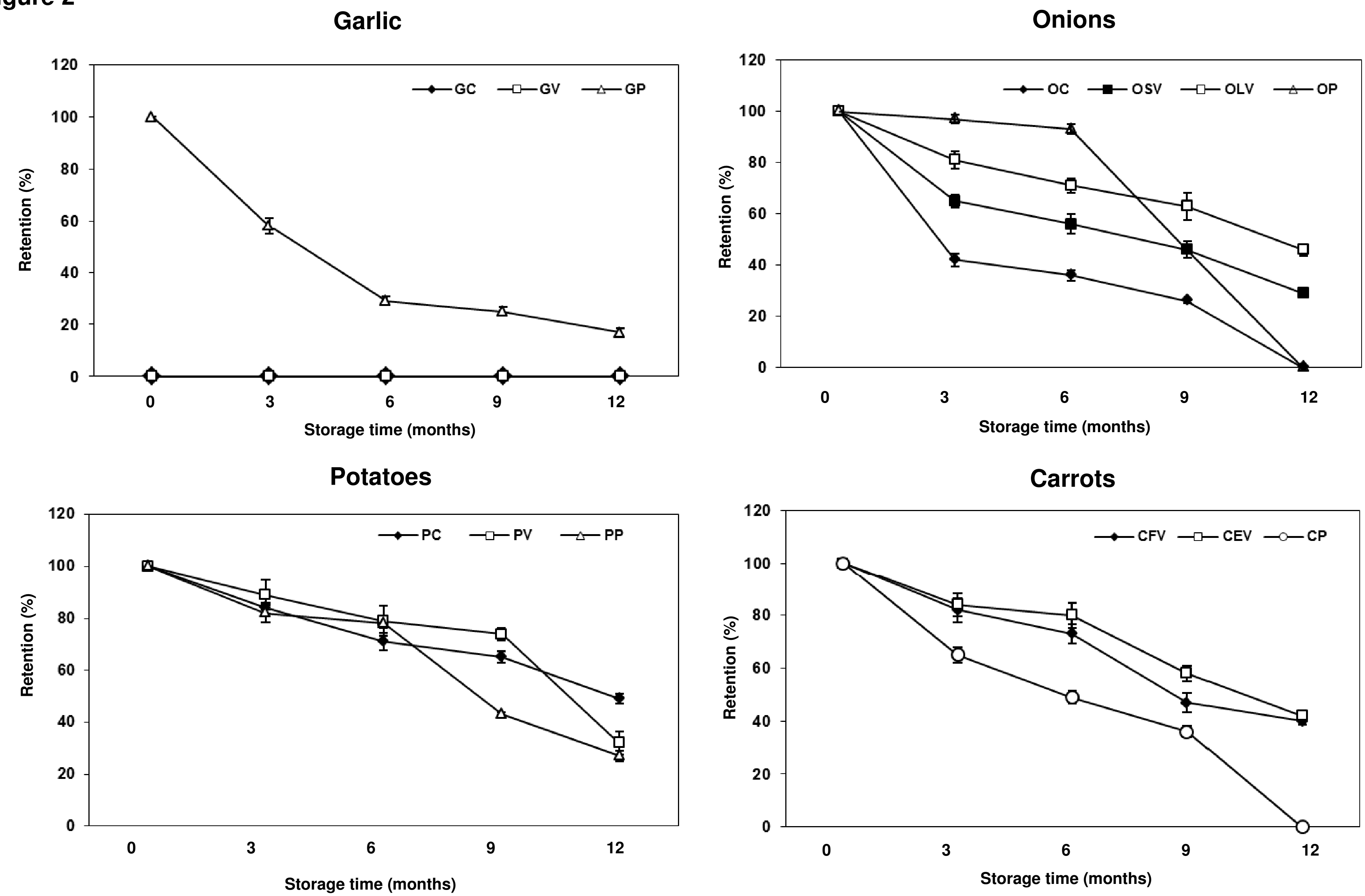
Values are the mean ± SD. Different letter in the same column for each vegetable indicates significant difference (P≤0.05). Different number between vegetables at 0 time storage indicates significant difference (P≤0.05).

Figure 1



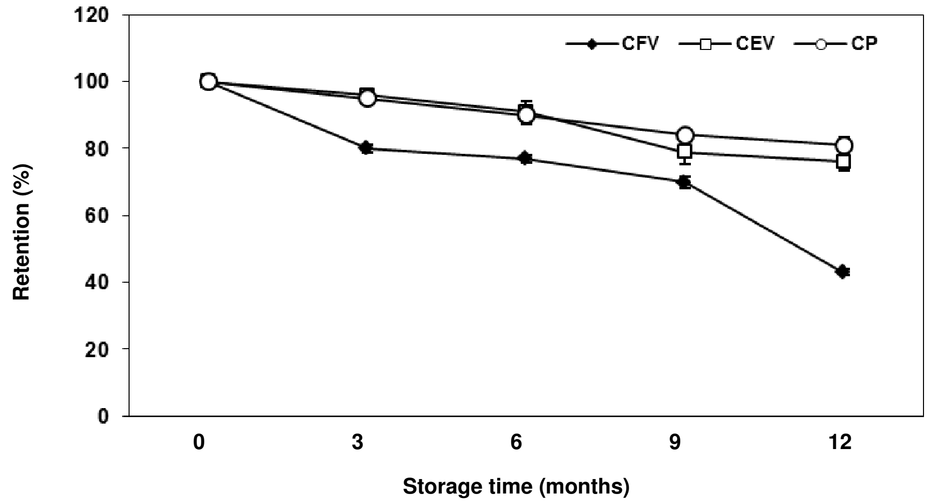
GC: commercial dried garlic; GV: Dried garlic from Vegenat; GP: dryed garlic processed in pilot plant; OC: commercial dried onion; OSV: dried onions in small strips from Vegenat; OLV: dried onions in large strips from vegenat; OP: dried onions processed in pilot plant; PC: commercial dried potatoes; PV: dried patatoes from Vegenat; PP: dried potatoes processed in pilot plant; CFV: laminated dried carrots from Vegenat; CEV: expanded dried carrots from Vegenat; CP: dried carrots processed in pilot plant.

Figure 2



GC: commercial dried garlic; GV: Dried garlic from Vegenat; GP: dryed garlic processed in pilot plant; OC: commercial dried onion; OSV: dried onions in small strips from Vegenat; OLV: dried onions in large strips from vegenat; OP: dried onions processed in pilot plant; PC: commercial dried potatoes; PV: dried patatoes from Vegenat; PP: dried potatoes processed in pilot plant; CFV: laminated dried carrots from Vegenat; CEV: expanded dried carrots from Vegenat; CP: dried carrots processed in pilot plant.

Figure 3



CFV: laminated dried carrots from Vegenat; CEV: expanded dried carrots from Vegenat; CP: dried carrots processed in pilot plant