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Variation in Content of Carotenoids and Vitamin C in Carrots

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Abstract

Carrots are the most popular and wide-spread of all root vegetables, and are the principal source of carotenoids in human diet. The purpose of this study was to examine differences between cultivars and the effect of storage regarding the carotenoid and vitamin C content in carrots. Six carrot cultivars were used in this study, ranging from early to late ones. Observed carotenoid content ranged from 60 mg kg^{-1} to 134 mg kg^{-1}. Significantly higher levels of carotenoids were found in late and moderately late cultivars in comparison to early ones. Vitamin C content in these cultivars ranged from 54 mg kg^{-1} to 132 mg kg^{-1}. Significantly higher contents of vitamin C were also found in the late cultivars. 30-day storage resulted in a significant reduction in vitamin C content, on average of 47%. There was also a reduction in the carotenoids content, but to a lesser extent, on average of 11%.

Keywords: nutritional value, carrots, cultivars, storage

Introduction

Carrot is a root vegetable, and is in demand throughout the whole year. The average carrot consumption in the Czech Republic in 2008 was 6.2 kg per person (Czech Rep., 2008). Carrots in general are one of the best sources of β-carotene in our diet, and provide 17% of the total β-carotene intake in human nutrition (Alasalvar *et al*., 2001). Carrots also contain a wide spectrum of other antioxidant substances, such as phenolic compounds, and also vitamin C, which is one of the most important compounds to be found in vegetables.

There were reported differences between cultivars regarding the content of carotenoids (Alasalvar *et al*., 2001; Karkleliene *et al.,* 2007; Vulsteke, 1996), and also vitamin C (Bratu *et al*., 2006; Lee and Kader, 2000; Pokluda, 2003). Vitamin C in carrots ranges from 21 mg kg^{-1} (Pokluda, 2003) to 775 mg.kg^{-1} (Lachman *et al*., 2000), and carotenoids from 50 mg kg^{-1} (Kopec, 1998) to 159 mg.kg^{-1} (Müller, 1997). Since carrots are important source of vitamin C and carotenoids in the human diet, it is appropriate to determine to what extent these compounds are lost during storage. Singh *et al*. (2001) mentioned vitamin C and carotenoid losses after storage, with higher losses for vitamin C. Favell (1998) noted a 15% decrease of vitamin C after 14 days storage at 4°C. The potential decrease of carotenoid levels after storage was also reported by Lee (1986).

The aim of this study was to determine the contents of vitamin C and carotenoids in 6 different carrot cultivars and to study the effect of a 30-day storage period on the contents of these compounds.

Materials and methods

Six carrot cultivars, ranging from early to late (Tab. 1), were grown during the years 2004 and 2005 in fields belonging to Mendel University at the Faculty of Horticulture in Lednice (GSP location 48°47'36.858"N, 16°47'49.526"E). Tab. 2 shows average temperatures and total rainfalls during the growing season in each year and long-term seasonal averages. The carrots seeds were sown directly into the plots in the middle of April. Soil analyses showed high levels of all soil nutrients except nitrogen. The nitrogen fertilization, as well as other agronomic practices were in accordance with standard recommendations for growing carrots (Malý and Petříková, 1998). The harvest was made by hand in agricultural terms, with the early cultivars being harvested in July and the late cultivars being harvested in September. Only the late cultivars ´Olympia´, ´Tinga´ and ´Nerac F1´ were placed in

Tab. 1. Experimental cultivars

Cultivar	Characteristics	Registration	Breeding
´Delicia´	very early cultivar	1966	Sempra Praha
´Kráska´	semi-early, type Berlicum	1996	Ing. Jitka Hrubešová
´Stupická k rychlení´	early cultivar, type Nantés	1954	Moravoseed
´Nerac F1´	semi-late, type Nantés	1995	Bejo Zaden
´Olympia´	late cultivar	1973	Seva-Flora
´Tinga´	late cultivar, type Flakkee	1998	Moravoseed

Note: Cultivars came from Czech Rep., ´Nerac F1´ from Holland

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Tab. 2. Average monthly air temperatures (°C) and rainfall totals (mm) during the growing season in years 2004 and 2005 and the values of long-term seasonal

Year	Average air temperature (°C)						Rainfall totals (mm)					
	IV	V	VI	VII	VIII	IX	IV	V	VI	VII	VIII	IX
2004	11.5	13.7	17.6	19.7	20.3	14.8	16.2	27.7	99.4	58.9	31.6	44.0
2005	11.2	15.7	18.4	20.2	18.4	16.0	47.1	77.1	51.2	101.5	87.2	22.1
Long-term seasonal 1961-1990	9.7	14.5	17.5	19.1	18.5	14.7	34.7	57.7	66.4	59.8	50.0	37.3

storage, where they stayed for 30 days at a temperature of 2-3°C, with 90% relative humidity.

The determinations of vitamin C and carotenoid contents in the carrots were carried out in the Department of Vegetable and Flower Production in Lednice, each determination being replicated three times. These observations were made immediately after harvest and again after 30-days of storage. Vitamin C was determined by HPLC, total carotenoid content by colorimetry (Holm,1954; Ecom Ltd., 1998). Analysis of variance and Tukey's test (Unistat 5.1) were employed in the statistical evaluation of the data.

Results and discussion

Vitamin C and carotenoid levels in six different cultivars of carrots, including both early and late cultivars, were examined in two successive years. The resulting values are shown in Tab. 3.

The highest values of vitamin C were observed in cv. ′Olympia′ (132 mg kg^{-1}), the lowest vitamin C levels were found in cv. ′Stupická k rychlení′ (54 mg kg^{-1}). The average vitamin C level in the carrots was 84 mg kg^{-1}. Statistical analysis showed significantly higher vitamin C in the late cultivars ′Olympia′ and ′Tinga′ compared to the early

Tab. 3. Average (mean ± S.D.) vitamin C and carotenoids content in carrot cultivars

2004						
Cultivar	Compound (mg.kg^{-1})				Loss after storage (%)	
	Vitamin C	Vitamin C after storage	Carotenoids	Carotenoids after storage	Vitamin C	Carotenoids
′Delicia′	61 ± 16.96 a	-	84 ± 9.33 a	-	-	-
′Kráska′	73 ± 21.49 ab	-	95 ± 33.00 ab	-	-	-
′Stupická k rychlení′	54 ± 20.99 ab	-	92 ± 9.47 a	-	-	-
′Nerac F1′	88 ± 7.03 b	47 ± 8.68*	134 ± 14.98 b	123 ± 13.30	47	8
′Olympia′	132 ± 32.65 c	43 ± 12.68*	141 ±21.95 b	120 ± 49.58	67	15
′Tinga′	100 ± 31.52 abc	41 ± 7.74*	114 ±12.32 b	110 ± 25.92	59	4
Mean	85		110		58	9
2005						
Cultivar	Compound (mg.kg^{-1})				Loss after storage (%)	
	Vitamin C	Vitamin C after storage	Carotenoids	Carotenoids after storage	Vitamin C	Carotenoids
′Delicia′	62 ± 9.13 a	-	61 ± 1.36 a	-	-	-
′Kráska′	88 ± 8.64 b	-	77 ± 5.40 a	-	-	-
′Stupická k rychlení′	61 ± 5.60 a	-	60 ± 14.13 a	-	-	-
′Nerac F1′	72 ± 5.04 b	51 ± 6.94*	127 ± 9.53 b	104 ±9.95 *	29	18
′Olympia′	103 ± 13.77 c	63 ± 6.05*	97 ± 8.72 c	91 ± 9.83	39	6
′Tinga′	117 ± 14.67 c	70 ± 9.52*	105 ± 13.32 c	88 ± 6.53 *	40	16
Mean	84		88		36	13

Note: Different letters express significant differences between cultivars for $P \leq 0,05$; * Significant differences after storage for $P \leq 0,05$.; Levels of vitamin C varied significantly between the two years in which this study was made.

cultivars ′Delicia′, ′Kráska′, ′Stupická k rychlení′ and the medium-late cultivar ′Nerac F1′.

After 30 days of storage there was an average decrease in vitamin C of 47%. Statistical analysis showed a significant difference in vitamin C levels in carrots before and after storage (Tab. 3). The losses of vitamin C ranged from 29% (cv. ′Nerac F1′) to 67% (cv. ′Olympia′).

The average total carotenoid content in the carrots, measured immediately after harvest, was 98 mg kg^{-1}. The highest value for carotenoids was observed in the late cv. ′Olympia′ in 2004 (141 mg kg^{-1}), and the lowest value was observed in 2005 in the early cv. ′Delicia′ (61 mg kg^{-1}) (Tab. 3). In 2005, lower values of carotenoids were observed in all cultivars. Statistical analysis showed significantly higher levels of carotenoids in the late cvs. ′Olympia′ and ′Tinga′ and medium-late ′Nerac F1′, compared to the early cvs. ′Delicia′, ′Kráska′ and ′Stupická k rychlení′ (Tab. 3). The early carrot cultivars contained on average 76 mg.kg^{-1} of carotenoids, whereas the late cultivars contained on average 120 mg kg^{-1} of carotenoids.

After 30 days of storage the late carrot cultivars showed a decrease in total carotenoids of about 11% on average, dropping to an average value of 106 mg kg^{-1}. A significant difference in carotenoid content before and after storage was confirmed. The highest decrease of carotenoid content was noted in cv. ′Nerac F1′ (18%), the lowest losses were noted in cv. ′Tinga′ (4%).

Among the six early to late carrot cultivars used in this study, the late cultivars had higher levels of both vitamin C and also of carotenoids. In the case of vitamin C, the range of observed values was very wide, reflecting the differences known to exist between the various cultivars (Singh *et al.*, 2001; Iqbal *et al.*, 2006). The values for carotenoids were in line with previously published observations (Kopec, 1998; Gebczynski, 2006).

Variations in the vitamin C content of different carrot cultivars has been observed before (Alasalvar *et al.*, 2001; Lee and Kader, 2000). Significantly higher levels of vitamin C in the late cvs. ′Olympia′ and ′Tinga′ were reported by Pokluda (2003), although Bratu *et al.* (2006) reported higher levels of vitamin C in early carrot cultivars (75 mg.kg^{-1}) compared to late cultivars (31-46 mg.kg^{-1}). Similarly, varietal differences in carotenoid content were also confirmed, in line with many similar previous observations (Alasalvar *et al.*, 2001; Karkleliene *et al.*, 2007; Vulsteke, 1996). Analyses showed differences in the carotenoid content between early and late cultivars, as did Müller (1997), who observed higher carotenoid content in older and bigger carrot roots (159 mg.kg^{-1}) in comparison with younger carrots (95 mg.kg^{-1}). Fritz and Weichmann (1979) also observed higher β-carotene content in late-harvested carrots.

Lower carotenoid values in the year 2005 were apparently caused by lower temperatures during the growing season-temperatures were on average 2°C lower in August 2005 in comparison with August 2004, and this could be determinant for the final carotenoid levels in carrots, which were harvested in September. Similar effects of ambient temperature on carotenoid levels in carrots have been noted before Rosenfeld *et al.* (1999), Alasalvar *et al.* (2001).

Carrots stored for 30 days at a temperature of 2-3°C and 90% relative humidity showed a 47% decrease in vitamin C and an 11% decrease in carotenoids. Similar results were reported by Singh *et al.* (2001), who observed a 49% decrease in vitamin C (from 146 mg kg^{-1} to 75 mg kg^{-1}) and an 11% decrease in β-carotene after 30 days of storage, so it would appear that in comparison with β-carotene, the losses of vitamin C in stored carrots are always considerably higher. Favell (1998) reported an 85% decrease in the initial vitamin C content in carrots stored at 4°C for 14 days.

The choice of cultivar and storage are very important factors affecting vitamin C and carotenoid levels in carrots. In comparison with vitamin C, carotenoids are less sensitive to losses in storage, a fact confirmed in this study.

Conclusions

This work confirms the existence of important differences between carrot cultivars regarding vitamin C and carotenoid contents. Higher amounts of these nutritionally important compounds were observed in late cultivars compared to early cultivars. After 30 days of storage the levels of both compounds were significantly lower. Higher losses were noted for vitamin C.

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