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Changes in Carotenoid Content of Carrots During Growth and Post-Harvest Storage

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ABSTRACT

Up to 3 weeks before harvest time the provitamin A carotene content of carrots increased as they matured, and then decreased. During post-harvest storage at 2°C and 90% relative humidity (RH), the levels of alpha- and beta-carotene, which made up over 85% of the total carotene, increased slowly during the first 100-day storage, but decreased thereafter. Treatment of carrots with 2-(4-chlorophenylthio)triethylamine HCl (CPTA) resulted in reduction of total carotenoids and inhibited the enzymatic cyclization of neurosprene, with concomitant increase in the lycopene content during storage. The biosynthesis of carotenes in carrots during storage appears to follow the established pathways for tomatoes.

INTRODUCTION

Many reports have shown that the carotenoid content of carrots increases during growth in the field and storage following the harvest. As a result, canned carrots prepared with mature carrots have been reported to have higher vitamin A value than fresh young carrots. Brown (1947) reported that the carotene content of carrots increased up to approximately 100 days after planting, then remained fairly constant until harvested at 135 days. Carotene levels in carrots also increased during storage up to 20 weeks at 0 to 4 °C, then remained fairly constant for an additional 10 weeks

Food Chemistry 0308-8146/86/$03·50

(Brown, 1949). These, as well as the reports of others (Rygg, 1949), were based on total carotene analyses which do not present an accurate value for vitamin A. The first objective of this study, therefore, was to measure the level of individual provitamin A carotenoids during growth and storage of carrots. The herbicide, 2-(4-chlorophenylthio)triethylamine HCl (CPTA) was reported to affect the carotenoid biosynthesis of citrus fruits (Yokoyama *et al.*, 1971, 1972) and mung bean seedlings (Valadon & Mummery, 1982). While the biosynthesis of carotenoids in certain plant foods, especially tomatoes, is well understood (Porter & Lincoln, 1950), little work has been done with carrots. The operative pathways during storage of this vegetable are now of particular interest. Thus, the second objective was to elucidate the biosynthetic pathway of carotenoids during storage of carrots and to determine the effects of CPTA on carotenoid generation.

MATERIALS AND METHODS

Carrots

Three carrot cultivars, Spartan Classic, K-strain and Nantes, were grown on New York muck soil during 1981 and 1982. Samples of fresh carrots were taken every two weeks during the growing season, starting 60 days after planting. Following cleaning, the carrots were held at −23 °C until analysis.

Storage

Storage studies were conducted on 125 kg of commercially produced Nantes cultivar. Immediately after harvest, the carrots were placed in the open plastic containers and stored in a 2 °C room with 90% relative humidity (RH). At different time intervals during the winter months, 5 kg samples were selected randomly for analysis. These samples were placed in No. 303 cans under vacuum and held at −23 °C until analysis.

In the study of carotenoid biosynthesis during storage, carrots (variety: PY 60) were immersed for 10 min in a solution containing 0·2% CPTA plus 500 ppm Tween 80. The carrots were then stored at 2 °C and 90% RH for 100 days.

Analysis

The carotenoids were extracted and separated by column chromatography as described previously (Ogunlesi & Lee, 1979) and the individual carotenes were measured quantitatively using spectrophotometric procedures (Sweeney & Marsh, 1970; Davies, 1976). All analyses were replicated twice and the carotene contents were expressed on the basis of either original fresh weight or dry weight.

RESULTS AND DISCUSSION

Carotenoid composition of carrots at harvest is shown in Table 1. More than 90% of the total carotenoids are made up of hydrocarbon carotenes consisting of alpha- and beta-carotene, with small amounts of phytofluene, zeta-carotene, beta-zeacarotene, gamma-carotene and neurosporene. This result is similar to those published previously (Baloch *et al.*, 1977; Ogunlesi & Lee, 1979).

During the growing season the level of most carotenes increased up to harvest time (140 days after planting). However, the beta-carotene content of K-strain and Nantes, and the alpha-carotene content of K-strain and Spartan Classic, reached a maximum at 110 days and then decreased, as shown in Fig. 1. Brown (1947) observed that the total carotene content of carrots grown in the State of Wyoming increased up

TABLE 1
The Carotenoid Content of Carrots at Harvest[a]

Carotenoids	*μg/g dry weight*	*Relative %*
Hydrocarbon	727	93–96
Monohydroxy	5	<2
Polyhydroxy	4	<2
Phytoene	47	6
α-Carotene	247	32
β-Carotene	414	53
ζ-Carotene	46	6
β-Zeacarotene	11	1
γ-Carotene	6	<1
Neurosporene	5	<1

[a]Average of three cultivars at harvest.

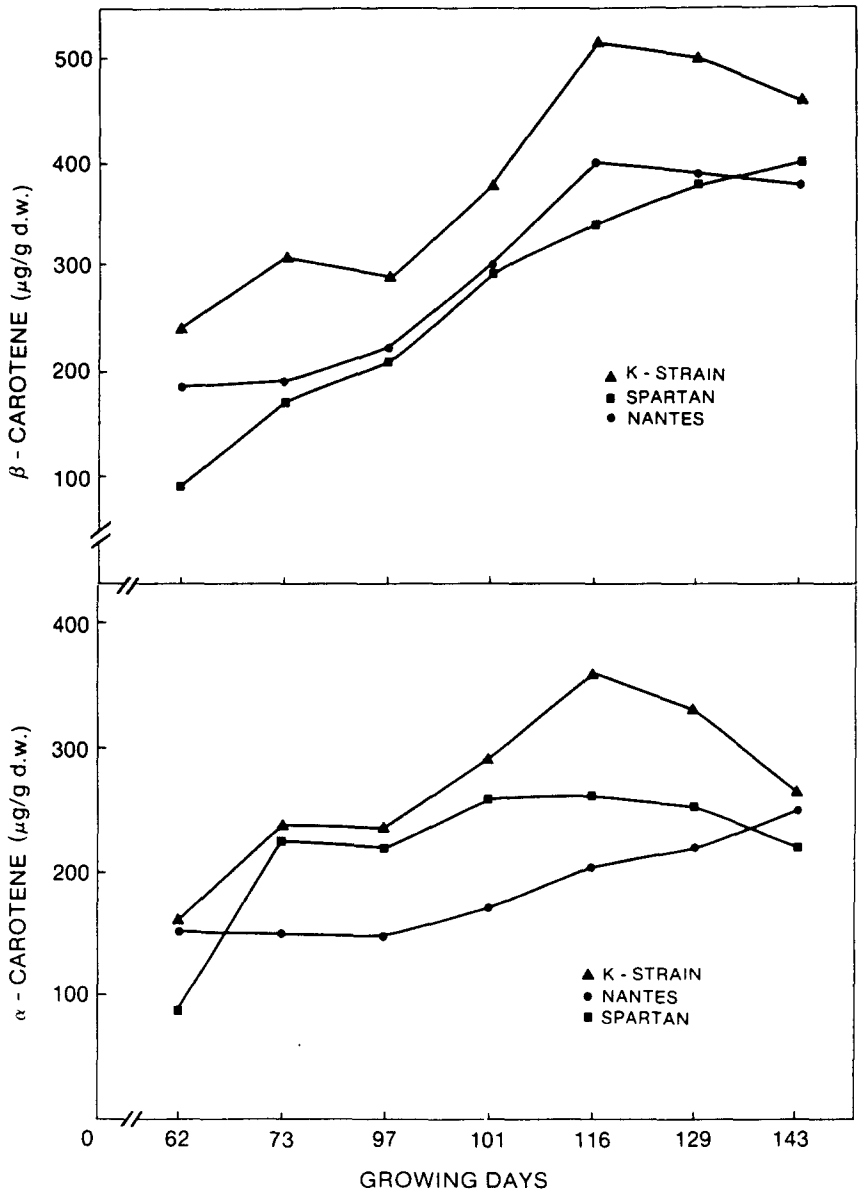

Fig. 1. Changes in the alpha- and beta-carotene contents of three carrot cultivars during growth.

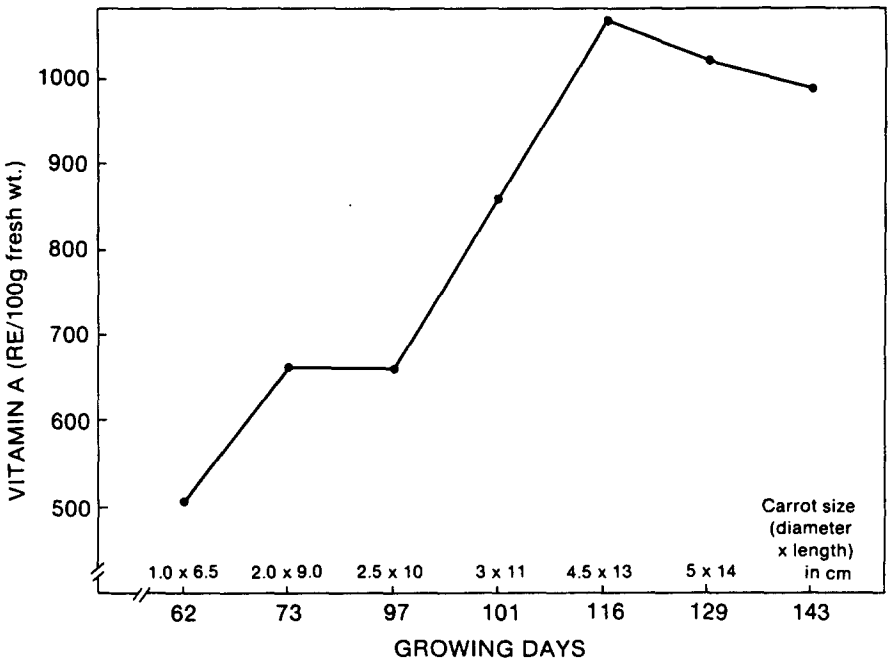

Fig. 2. Changes in vitamin A value of carrots during growth.

to 100 days after planting, but remained constant until harvested at 135 days. He indicated that environmental factors influence the carotene content.

Since alpha- and beta-carotene are the major provitamin A carotenes in carrots, their changes during the growing season had a significant effect on the vitamin A value. Based on retinol equivalent (RE) calculations of provitamin A carotenes, including alpha-, beta- and gamma-carotene and beta-zeacarotene, the average vitamin A value of three cultivars reached a maximum of 1070 RE/100 g fresh weight at 116 days and decreased to 990 RE/100 g at harvest time (Fig. 2).

Table 2 shows the change in provitamin A carotenes during storage of carrots. The content of alpha- and beta-carotene increased slowly for up to 100–125 days and then decreased. Beta-zeacarotene and gamma-carotene, which are known to be precursors of beta-carotene in the biosynthetic pathway of some fruits and vegetables, also increased and reached a maximum level at 125 days and 50–70 days, respectively. Phytoene and phytofluene, which are also known as precursors of beta-zeacarotene, were detected only after 70 days. Their increase paralleled

TABLE 2
Change in Provitamin A Carotenes of Carrots During Storage[a]

Carotene	*Storage Days*						
	5	*27*	*50*	*70*	*100*	*125*	*155*
α-Carotene	21·1	21·4	22·1	22·5	25·5	21·5	18·5
β-Carotene	54·9	58·9	61·3	62·3	62·8	63·1	58·2
β-Zeacarotene	0·7	0·8	1·3	1·1	1·2	1·6	1·6
γ-Carotene	0·8	0·9	1·9	1·9	1·3	1·5	1·3

[a] Expressed as μg/g fresh weight.

an increase in beta- and alpha-carotene. Figure 3 shows the overall change in the vitamin A value of carrots during storage.

The treatment of carrots with CPTA resulted in reduction of total carotenoids during 100 days' storage. Table 3 shows that alpha- and beta-carotene, beta-zeacarotene and neurosporene decreased, while the zeta-carotene and lycopene contents increased significantly, during storage. The increase of lycopene and simultaneous decrease of neurosporene suggests that there is a rapid turnover of neurosporene → lycopene as

TABLE 3
Effects of CPTA on Carotenoids of Carrots During 100 Days Storage

Carotenoids	*Control*	*CPTA*
Total	275·0	205·2
Hydrocarbon	214·8	180·3
Monohydroxy	1·9	1·6
Polyhydroxy	1·4	1·2
Phytoene	17·1	21·3
Phytofluene	1·2	3·1
α-Carotene	55·0	36·6
β-Carotene	161·9	116·7
ζ-Carotene	8·7	11·6
β-Zeacarotene	3·8	2·9
γ-Carotene	2·6	2·8
Neurosporene	1·2	—
Lycopene	<1·0	4·3

[a] Expressed as μg/g fresh weight.

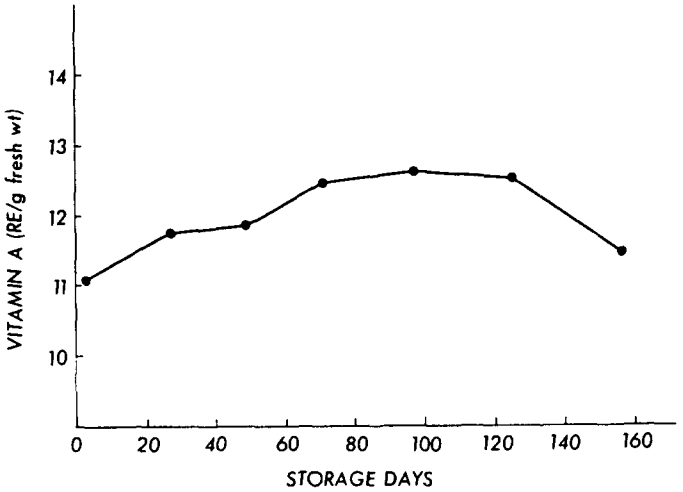

Fig. 3. Changes in vitamin A value of carrots during storage.

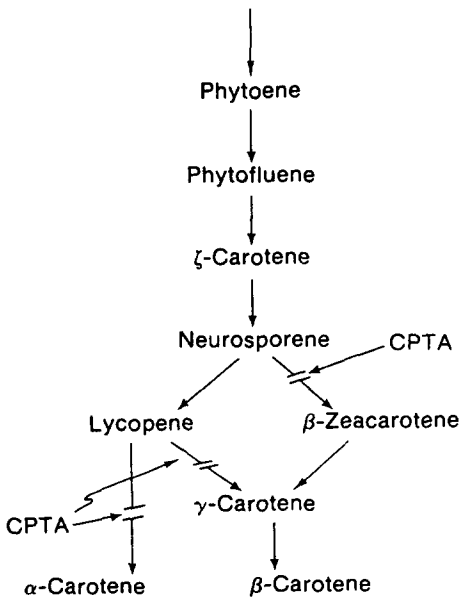

Fig. 4. The possible sites of CPTA action on carotenoid biosynthesis in carrots.

shown in Fig. 4 (Porter & Anderson, 1962). It appears that CPTA inhibits the enzymatic cyclization of neurosporene and affects the synthetic pathway neurosporene → beta-zeacarotene → gamma-carotene → beta-carotene. The effect of CPTA on the increase in lycopene content was previously reported for citrus fruits (Yokoyama *et al.*, 1971, 1972) and mung bean seedlings (Valadon & Mummery, 1982). These observations suggested that the biosynthesis of carotenes in carrots during storage appears to follow the pathway reported in tomatoes (Porter & Anderson, 1962).

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