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EFFECT OF NATURE SEAL® ON MAINTAINING CAROTENE IN FRESH-CUT CARROTS

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Abstract. **Studies showed that application of Nature Seal® (NS) reduces 'white blush' formation on fresh-cut carrots (*Daucus carotova*) during postharvest storage. Since carrots are a major contributor of vitamin A in the human diet, it is vital to assess the impact of these treatments on vitamin A preservation. Two experiments were carried out to evaluate the effect of Nature Seal on maintaining provitamin A carotenoids in fresh-cut carrots. Fresh-cut carrots were dipped in NS1000, or NS1020, drained, and kept in plastic bags for three or four weeks at 1°C or 10°C. Both α-carotene and β-carotene contents were measured. The results showed that NS1000 and NS1020 slowed down carotene loss in fresh-cut carrots, as compared to untreated or water treated control.**

The market for fresh-cut carrot is expanding quickly in recent years. To make fresh-cut carrots, carrots are washed, trimmed and peeled. These wounding procedures increase respiratory rate (Kahl and Laties, 1989) and induce ethylene synthesis (Rhodes and Wooltorten, 1978; Yang and Pratt, 1978). Activities of phenylalanine ammonia-lyase (PAL, EC4.3.1.5) and peroxidase (POD, EC 1.11.1.7) (Howard and Griffin, 1993) were also induced by the wounding. These wounding-induced metabolic changes generate two major problems for the industry, white discoloration (white-blush) and carotene loss. Lignin formation occurred and corresponded with development of white discoloration (Howard and Griffin, 1993). The application of Nature Seal® 1000 (NS1000), a cellulose based product, reduced 'white blush' formation during extended postharvest storage (Sargent et al., 1994; Howard and Dewi, 1995).

Carrots are the most important vegetable source of provitamin A. Generally, β-carotene accounted for 45-80%, α-carotene accounted for 15-40% of total carotenoids in carrots. The fresh-cut industry is using NS1000 to retard the 'white blush' formation of cut carrots, but it is not clear how the treatment affects carotene content during storage. NS1020 is effective for controlling discoloration of cut apple and potato (Baldwin et al., 1996). Its effect on controlling discoloration and carotene loss of cut-carrots is not known. These experiments evaluated the effect of NS1000 and NS1020 on carotene preservation of fresh-cut carrots stored in plastic bags at 1°C or 10°C for 3 - 4 weeks.

Materials and Methods

Experiment 1

Fresh-cut carrots were prepared according to industry procedures within two days after harvest, and shipped overnight in coolers from California (Grimmway Farms, Salinas, CA) to the University of Kentucky. The carrot samples were carefully selected for quality and uniformity and placed into the following treatment groups: Untreated control, NS1000 and NS1020. Nature Seal was applied by dipping for 10 seconds, then the coated carrots were drained for 4 hours at 1°C, 85% RH. Carrots (70 g/bag) packed in plastic film bags were stored at 1°C, 92% RH for 4 weeks in the absence of light. Two bags from each treatment were removed each week for the determination of carotene contents.

Samples were rapidly ground in liquid nitrogen and stored at -80°C for further analysis. Two replicates and two sub-samples were measured for each treatment. Carotenoids were extracted by using hexane/acetone (60:40) solution. The α-carotene and β-carotene were separated and qualitatively estimated by reverse-phase high performance liquid chromatograpyh (HPLC) using β-cryptoxanthin (Hoffmmann-La Roche Inc., Nutley, New Jersey) as an internal standard. Separation was performed by using a C_{18} column (Rainin Instrument Co. Inc., Emryville, CA) of 4.6 × 250 mm length and 5 um particle size, with the mobile phase of acetonitrite/methylen chloride/octonol (90/25/0.1, v/v/v/) running isocratically at a flow rate of 1 ml/min. The detection of β-cryptoxanthin, α-carotene and β-carotene was carried out by using a UV/VIS detector (Waters 486, Tunable Absorbance Detector) at the wavelength of 450 nm. The data were calculated to mg carotene per 100 g dry weight. Total carotene is the sum of α-carotene and β-carotene. The data were analyzed as a randomized completed block factorial. Means were separated by Duncan's multiple range test at 1% level.

Experiment 2

Fresh-cut carrots packed at W. M. Bolthouse Farm were obtained from a local retail store. Carrots in different bags were mixed, and then randomly divided to three groups. They were dipped in NS1000, NS1020 or in water for 20-30 seconds, then drained and packed in plastic film bags. The carrots were stored at 10°C for 18 days and 21 days. Samples were shipped to Webb Technology Group by over-night express for total carotene content analysis.

Results and Discussion

In the first experiment, fresh-cut carrots were kept at 1°C for four weeks and carotene contents were measured once a week. The results were presented in table 1, 2 and 3.

Table 1 is the result of analysis of variance for α-carotene and β-carotene contents. The variance between the two replicates was significant and was separated from the treatment effect by the analysis method. Both storage time and Nature Seal treatment significantly affect carotene contents. The interaction between storage time and coating was not significant. Therefore, only the main effect means were separated.

Table 2 is the main effect mean of storage time. Both α-carotene and β-carotene contents decreased during the four weeks at 1°C. The rate of α-carotene losses was higher from the first to second and second to third weeks than that during the first week and the third to fourth weeks (15-18 vs. 6-7 mg

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Table 1. Result of analysis of variance for carotene contents in fresh-cut carrots stored at 1°C for four weeks. Data were obtained from experiment 1 and were analyzed as randomized completed block factorial.

Source of Variance	F value		
	α-carotene	β-carotene	Total carotene
Replication	38**[z]	18**	37**
Storage time	47**	52**	67**
Coating	12**	14**	19**
Time × Coating	0.3 NS	0.5 NS	0.2 NS

[z]**Significant at 1% level. NS: Not significant.

Table 2. Effect of storage time on carotene content in fresh-cut carrots stored at 1°C. Data are from experiment 1 and are means of three coating treatments. Mean separations within columns are by Duncan's multiple range test at 1% level.

Storage time (week)	Carotene content (mg/100 g dry wt)		
	α-carotene	β-carotene	Total carotene
0	83	97	180
1	77 A	88 A	165 A
2	62 B	64 B	126 B
3	44 C	54 BC	98 C
4	37 C	44 C	81 C

per 100 g dry weight per week). The rate of β-carotene loss was higher during the second week than at other storage periods (24 vs. 10-11 mg per 100 g dry weight per week).

Table 3 is the main effect mean of coating treatment. Both of NS1000 and NS1020 resulted in higher α-carotene and β-carotene contents than those of untreated control. No major difference was observed between NS1020 and NS1000 treatment.

Table 4 is the total carotene content in carrots stored at 10°C for 18 and 21 days measured by Webb Technology Group. Total carotene content in NS1000 or NS1020 treated samples were about 150% as high as that in water treated samples. The data were not statistically analyzed because only one replicate was measured.

Carotene is degradated by oxidation, including chemical oxidation, photo oxidation and enzymatic oxidation. The oxidation is affected by oxygen concentration, temperature, pH, water content and light. Nature Seal treatments do not have any effect on temperature and light. They do provide a low pH, water-cellulose film on carrot surfaces. This film holds more water on the surface for a longer period and drops the pH on the surface. The water layer is important for retarding white discoloration and carotene loss. It was observed that the white-blush appeared after, not before, the carrot surfaces were dry (data not published). An absorbent, reported to absorb moisture and ethylene, elevated lignin content in fresh-cut carrots (Howard and Griffin, 1993). The water layer is also a barrier for oxygen diffusion. Oxygen has to dissolve in the water layer first before it is able to contact

Table 3. Effect of Nature Seal on carotene content in fresh-cut carrots stored at 1°C for four weeks. Data are means of four storage times obtained from experiment 1 and are separated within columns by Duncan's multiple range test at 1% level.

Treatment	Carotene content (mg/100 g dry wt)		
	α-carotene	β-carotene	Total carotene
Untreated	46 A	53 A	99 A
NS1000	57 B	65 B	122 B
NS1020	61 B	70 B	131 B

Table 4. Effect of Nature Seal on total carotene content in fresh-cut carrots stored for 18 and 21 days at 10°C

Treatment	Total carotene (mg/100g dry wt)	
	18 days	21 days
Uncoated	159[z]	173
NS1000	239	301
NS1020	264	286

[z]The total carotene content was measured by Webb Technology Group. Data were not statistically analyzed.

carrot tissue. The solubility of oxygen in water is 4.89 g/100 ml at 0°C, which is much lower than that in air (21%). The low pH of Nature Seal may inhibit activities of oxidative enzymes which catalyze carotene degradation and lignin biosynthesis. NS1020 contains more ingredients than NS1000, such as soy protein, $CaCl_2$ and ascorbic acid and other antioxidants. It is effective for inhibiting discoloration of cut apple and potato (Baldwin et al. 1996). It is not more effective for control of discoloration and carotene loss in carrot than NS1000. This result suggests that carotene loss and white discoloration of cut carrot are not affected by the antioxidants and other ingredients present in NS1020.

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