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STORAGE AND QUALITY FEATURES OF CARROTS AND CORN GROWN UNDER ORGANIC AND CONVENTIONAL AGRICULTURAL PRACTICES

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ABSTRACT Conscious of their health, the demand for organic vegetables is sought by consumers in many parts of the world including Canada. Saskatchewan has the potential of producing high-quality organic vegetables cost-effectively and in a sustainable manner .Preliminary vegetable production research is being undertaken at the Canada-Saskatchewan Irrigation Development Centre (CSIDC), Outlook, to develop efficient agronomic practices and storage management for producing high-quality vegetables under irrigation. This paper presents the interactive effects of field production and storage practices for corn and carrots. Carrots and corn were grown under organic and conventional agricultural practices. Controlled atmosphere (CA) and refrigerated storage of the harvested produce were compared. The carrots and corn were stored at a temperature of 4^{o}C and relative humidity of 80.4% to 92.5% for CA storage and 83.9% to 93.6% for refrigerated storage. Some of the carrot samples were blanched using a microwave oven before storage. For the CA storage, the set-points for CO_2 and O_2 were 5% and 3%, respectively. The moisture content, storage losses, total soluble solids, hardness, toughness, and color of the stored carrots and corn were measured periodically. The conventional corn stored under refrigerated conditions had the highest mass loss. At the end of each storage period, the total soluble solids for the CA stored samples were higher compared to the refrigerated samples. At the end of the first storage period, the hardness values for organic samples were higher compared to the conventional stored corn samples. However, the converse was observed at the end of the second storage period. At the end of the first storage period, the color difference was higher for the conventional corn stored under CA conditions compared to the other stored samples. For the non-blanched carrots, the mass loss was higher for the organic carrots stored under refrigerated conditions. Marketability of the conventional carrots was higher compared to the organic samples. The storage method had significant effect on the color difference during storage, except during the third storage period. There were no clear effects of storage time and storage method on the total soluble solids of the stored carrots. There were no clear effects of storage time and storage method on the hardness of the stored carrots. Storage method did not have any effect the toughness of the stored carrots. Blanching of carrots may not be suitable for CA and refrigerated storage.

Keywords: vegetables, storage, controlled-atmosphere, blanching, quality

INTRODUCTION

In conventional agricultural food production, pesticides, insecticides, and herbicides are utilized to control pests, insects and weeds to optimize yields. The residues from these chemical applications may constitute a threat to human health and the environment. Some chronic diseases such lymphoma, leukemia, dementia, Parkinson,s have been linked to the residues from these chemical applications (Alavanja et al. 2004). Conscious of their health, some consumers are resorting to organically grown produce. As a result, the demand for organically grown vegetables and fruits has seen a rapid expansion of the industry in Europe and North America and the need to develop the industry in Saskatchewan. Agricultural practices such as composting, crop rotations and other environmental friendly cultural practices are employed in organic vegetable production compared to conventional. In 2005, the retail sales of organic produces were estimated to be 750 million to one billion dollars.

Saskatchewan government has embarked on an initiative to develop Saskatchewan-grown vegetables and fruits to be consumed locally and for export. Saskatchewan is well positioned to compete effectively in the fruit and vegetable market. Saskatchewan has competitive advantage which with low land cost, extensive water resources, less disease incidence due to low relative humidity and accessibility to North American market. A major constraint facing the developing of a vegetable industry in Saskatchewan is that the province has a short growing season from May to September, and harvested products need to be stored properly to prolong their shelf-life. Fresh harvested vegetables may be cooled and be stored below zero (frozen) or above zero (chilled) conditions to reduce biochemical, physical and microbial degradation and therefore maintain the quality of the products.

Controlled atmosphere (CA) and refrigerated storage systems are being investigated to store the produce when harvested. Controlled atmosphere may be used synergistically with chilled storage to extend the shelf-life and maintain the nutritive value of vegetables by further reducing biochemical and microbial activities during storage (Yackel et al., 1971; Harvey, 1978; Ke and Kader, 1992; Paradis et al., 1996; Lopez-Galvez et al., 1996; Sanchez-Mata et al., 2003). In controlled atmosphere storage, the composition of the gases surrounding the product is automatically controlled throughout the storage life of the product (Jayas and Jeyamkondan, 2002). Controlled atmosphere storage studies on vegetables and fruits have been conducted by researchers (Yackel et al., 1971; Robinson et al., 1975; Ke et al., 1990; Carlin et al., 1990; Luo and Mikitzel, 1996; Hurst et al., 1997; Gil et al., 1997). Yackel et al. (1971) studied the effect of CA and air storage on mold growth in fruit. The fruit were stored at 1^{o}C, in a controlled atmosphere of 10.5% CO_2 and 2.0% O_2. They found less mold in the CA storage compared to air storage. Luo and Mikitzel (1996) examined the effect of controlled atmosphere and air storage on decay, weight loss, color and soluble solids content of green bell peppers. They found that after 2 weeks of storage, the air-stored peppers had 33% decay compared to 9% for the CA-stored peppers. CA storage retained color better than air-stored pepper.

The present project, conducted at the Canada-Saskatchewan Irrigation Diversification Centre, is a preliminary investigation designed to study (i) the feasibility of growing vegetables cost effectively and in a sustainable manner using organic management practices, and (ii) develop storage management practices to extend shelf life while maintaining nutritive and quality characteristics.

The objectives of this investigation were to determine the effects of CA and refrigerated storage on quality characteristics (hardness, toughness, color, total soluble solids and moisture content) of carrot and corn grown under organic and conventional agricultural practices**.**

MATERIALS AND METHODS

Materials Vegetable products used in the storage studies consisted of organic and conventional grown corn and carrots.

Controlled Atmosphere Equipment A research-scale controlled atmosphere (CA) storage equipment obtained from Horticultural Research and Development Center, Saint-Jean-sur-Richelieu, Quebec was installed at the Canada-Saskatchewan Irrigation Diversification Centre (CSIDC), Outlook, Saskatchewan. The CA equipment consists of personal computer, data acquisition system, gas analyser, thermocouples, solenoid valves, rigid plastic mini-chambers, expansion bag, CO_2 scrubbers and gas (N_2, CO_2 and compressed air) cylinders. Detailed description of this CA storage equipment is provided by Goyette et al. (2002).

Storage Procedure For each test, the mini-chambers were washed and disinfected before the products were placed in them. A corrugated plastic piece was placed at the bottom of the chamber and a perforated plastic plate was placed on top of it. A ventilating pipe was inserted through a hole in the perforated plate. The produce was placed on top of the plate. About 200 ml of water was poured into the chamber. A Plexiglas cover was used to cover the chamber and C-clamps were used to tightening the cover. Plastic tubes for supplying the gases were connected to the cover. Thermocouples were inserted to measure the temperature in the chambers. Water was poured onto of the cover to seal the chamber from the surrounding air.

The set-points for CO_2 and O_2 were 5 and 3%, respectively. Each chamber was manually flushed with pure N_2 for 5 min and then CO_2 was injected for 20 s. The control software was started to control the injection of N_2 and compressed air. Excess CO_2 was circulated through the scrubber to be absorbed by soda lime.

The storage test was performed with corn grown under conventional and organic conditions. The corn samples were stored under CA and refrigerated conditions from September 10 to November 12, 2009. The corn samples were weighed on October 13, 2009 and November 12, 2009. For all the tests, the refrigerated storage room was maintained at a temperature of 4^oC and the relative humidity of ranged between 87.9% to 88.2% for CA storage and 83.9% to 91.7% for refrigerator storage.

Organic and conventional carrots were washed with water. The samples stored were either blanched or non-blanched. About 1.5 kg sample size was blanched each time for 10 min. Figure 1 shows microwave blanching of carrot samples. Blanched and non-blanched carrot samples were placed in the mini-chambers and totes for controlled atmosphere and refrigerated storage, respectively. For refrigerated storage, about 200 ml of water was poured into beakers and placed in each tote to maintain high humidity around the samples. Figure 2 shows the refrigerated storage of carrots in a tote, and Figure 3 shows the carrots in the CA storage chamber at the CSIDC. The weights of the samples were measured before placing them in the chambers and after they were removed from storage. The weight of the carrot samples that flaccid or spoiled was measured and combined as spoilage. The samples were stored from October 22, 2009 to February 17, 2010. For all the tests, the refrigerated storage room was maintained at a temperature of 4^{o}C and the relative humidity of ranged from 80.4% to 92.5% for CA storage and 89.0% to 93.6% for refrigerator storage.

Moisture content The moisture content of the corn and carrots were determined after drying at 105^{o}C for 24 h in a forced convection oven. Moisture content was determined in duplicate and the average is presented.

Total soluble solids content Total soluble solids of the carrots and corn were determined by using a digital refractometer (Pocket Refractometer PAL-2, ATAGO Company, Limited, Tokyo, Japan). The carrots were ground in a blender and the juice was squeezed onto the refractometer using a garlic press. For the corn, the samples were not ground. The samples were placed in a garlic press and squeezed. Three measurements were taken from each sample.

Hardness The hardness and toughness of the corn and carrots were measured using a texture analyzer (Texture Technologies Corp., Scarsdale, NY). A 2 mm probe was used and the corn samples were penetrated to a depth of 3 mm at a test speed of 0.5 mm/s. For the carrots, the samples were penetrated to a depth of 15 mm at a speed of 0.5 mm/s. The bioyield point was used to determine the hardness of the samples, and the area under the curve was used as an indication of the toughness of the samples.

Color parameters The color of the samples was measured using Hunterlab Color Analyzer (Hunter Associates Laboratory Inc., Reston, VA, U.S.A.). The chromaticity of stored carrots was determined by measuring their respective ‘L’, ‘a’, and ‘b’ coordinates. A carrot was cut into half perpendicular to its length. The color of the cut surface was measured. The ‘L’ values range from minimum ‘L’ which is zero (black) to maximum ‘L’ which is 100 (white). Positive ‘a’ value is red and negative value is green. Also, positive ‘b’ value is yellow and negative ‘b’ is blue. After initial calibration against standard black and white surface plates, four measurements were taken from each sample. Color delta values, ΔL, Δa and Δb, were calculated according to the following equations:

$$\mathbf{\Delta a = a - a_t} \tag{1}$$

where 'L', 'a', and 'b' are the measured values of the specimen and L_t, a_t, b_t are values of the target color. The target colors in this experiment are 'L', 'a', and 'b' of the fresh carrots before storage, taken on October 10, 2008 for the CA stored carrots and on November 7, 2008 for refrigerated samples. For the Δa, a positive value indicates the sample is redder than the target or standard sample and a negative value indicates that the sample is lighter than the target. The total color difference (ΔE) was calculated using the L, a, b color coordinates and as defined by the Equation 4 (Maruyama et al. 2001).

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \qquad (2)$$

Storage losses The percentage mass loss or gain was calculated from the difference in mass of the sample at the beginning of storage to end of each storage period. For example, from September 10, 2009 to October 13, 2009 is one period and October 13, 2009 to November 12, 2009 is another period.

$$\%\text{Mass loss or gain} = 100 * \frac{(M_b - M_e)}{M_b} \qquad (3)$$

where, M_b is the mass of the samples at the beginning of each storage period and M_e is the mass at the end of the that particular storage period.

RESULTS AND DISCUSSION

Corn storage losses The percentage mass loss or gain of corn stored under CA and refrigerated conditions are presented in Table 1. At the end of the first storage period, the percentage mass loss ranged from 2.16% to 2.95% for the stored samples. The conventional corn stored under refrigerated conditions had the highest mass loss. At the end of the second storage period (Nov. 12, 2009), the corn samples stored CA conditions had gained mass compared to the samples stored under refrigerated conditions which had lost mass.

Moisture content of stored corn Table 2 presents the moisture content of the corn samples at the beginning of the storage and at the end of each storage period. The moisture content of the samples was lower at the beginning and increased during storage. At the beginning of the storage, there was significant difference between the organic and the conventional corn with conventional corn having a higher moisture content of 80.2%. Szymanek (2009) determined the moisture content of sweet corn harvested at different times and reported the moisture content to range from 77.41% to 69.83%. The moisture content decreased with harvesting time.

Stored corn total soluble solids Table 3 presents the total soluble solid content of the corn samples at the beginning of the storage and at the end of each storage period. The total soluble solid contents of the samples were high at the beginning of storage and decreased during storage. There were significant differences among the samples. The organic corn had higher total soluble solid content at the beginning of storage compared to the conventional corn. At the end of each storage period, the total soluble solids for the CA stored samples were higher compared to the refrigerated samples.

Color characteristics of stored corn The color characteristics of the corn samples are presented in Table 4. There was no color difference between the organic and conventional corn samples at the beginning of storage. At the end of the first storage period, the color difference was higher for the conventional corn stored under CA conditions compared to the other stored samples. At the end of the second storage period, there were no significant differences among the stored corn samples.

Hardness and toughness of stored corn Table 5 presents the results of the corn hardness and toughness at the beginning and during each storage period. There was no difference in corn hardness at the beginning of storage. The corn hardness decreased at the end of the first storage period and then increased at the end of the second storage period. At the end of the first storage period, the hardness values for organic samples were higher compared to the conventional stored corn samples. However, contrary was observed at the end of the second storage period. Szymanek (2009) reported the hardness of sweet corn to range from 9.11 to 17.23 N.

The conventional corn sample was tougher at the beginning of storage. The toughness of the stored samples decreased with storage time. The conventional corn samples produced higher toughness values compared to the organic samples. At the end of the second storage period, there were no differences in the toughness of the stored corn samples.

Carrot storage losses The percentage mass loss or gain for the carrot samples stored under CA and refrigerated conditions is presented in Table 6. At the end of the first storage period, the blanched samples had higher mass loss compared to the non-blanched samples. The blanched sample stored under refrigerated conditions had higher mass loss compared CA stored samples. Mass loss was lower for the CA stored samples compared to the refrigerated after the first storage period. For the non-blanched carrots, the mass loss was higher for the organic carrots stored under refrigerated conditions. After the first storage period, the mass loss increased for the carrots stored under refrigerated conditions. The non-blanched carrots stored under CA environment showed mass loss and gain during the storage period.

Istella et al. (2006) stored different varieties of carrot at temperatures of 4 – 10^{o}C and relative humidity of 85% - 90% in unsealed polyethylene bags. They reported that at the end of 112 days of storage the percentage weight loss ranged from 15% to 35% depending on the carrot variety and the dry matter had increased in all varieties.

Moisture content of the stored carrots The moisture content of the carrot samples at the beginning and during storage is presented in Table 7. The moisture content of the blanched carrots was slightly lower compared to the non-blanched carrots at the beginning of storage. There was not increase or decrease in the moisture content of the stored samples.

Marketable stored carrots Marketable carrots at the end of each storage period are presented in Table 8. At end of the first storage period, all the blanched samples had decayed. Blanching carrot samples before storage may not be suitable. The non-blanched carrots stored under refrigerated conditions had higher marketable carrots at the end of the first storage period compared to the CA stored. The marketability of the conventional carrots was higher compared to the organic samples. After the first storage period, the non-blanched organic carrots produced the lowest marketability at the end of each storage period.

Color characteristics of the stored carrots The color characteristics of the carrots before storage and during storage are presented in Table 9. The results indicate that there was significant difference between the blanched and non-blanched carrots before storage. The blanched samples became darker and lost some of their reddish color. The color loss was higher for the conventional, blanched carrots. The storage method had significant effect on the color difference during storage, except during the third storage period ending in January 28, 2010 (97 storage days) where the storage methods did not have any effect on the color difference. Figure 4 shows the appearance of refrigerated and CA stored carrots at the end of 117 storage days.

Total soluble solids of the stored carrots Table 10 presents the total soluble solids before storage and during storage of the blanched and non-blanched carrots. Blanching had significant effect on the total soluble solid content. Blanching produced higher total soluble solids compared to non-blanching. The results indicate that there were no clear effects of storage time and storage method on the total soluble solids of the stored carrots. The variation in the total soluble solids during storage might be due to variation in the sample size and growth conditions. Sandhu et al. (1988) reported total soluble solids for carrots ranging from 8.46 to 9.98 ^{o}Brix.

Hardness of the stored carrots The hardness of blanched and non-blanched carrots before and during storage is presented in Table 11. Blanching had significant effect on the hardness of the carrots. The blanched carrot samples produced higher hardness compared to non-blanching. There were no clear effects of storage time and storage method on the hardness of the stored carrots. Bourne and Comstock (1981) determined the hardness of raw carrots and reported a hardness value of about 212.5 N for a sample size of 10.0 mm cube for a 50% degree of compression. Budrewicz et al. (2005) also reported the hardness of different varieties of carrot which ranged from 146.83 to 304.75 N for 10.0 mm cubes with 50% degree of compression.

Toughness of the stored carrots The toughness of blanched and non-blanched carrots before and during storage is presented in Table 12. Blanching had significant effect on the toughness of the carrots. The blanched carrot samples produced lower toughness values compared to non-blanching. Storage method did not have any effect the toughness of the stored carrots. The toughness of the stored carrots rose to higher values at the end of fourth storage period, 117 storage days, compared to previous storage periods.

CONCLUSIONS

1. The conventional corn stored under refrigerated conditions had the highest mass loss. At the end of each storage period, the total soluble solids for the CA stored samples were higher compared to the refrigerated samples. At the end of the first storage period, the hardness values for organic samples were higher compared to the conventional stored corn samples. However, the converse was observed at the end of the second storage period. At the end of the first storage period, the color difference was higher for the conventional corn stored under CA conditions compared to the other stored samples.

2. For the non-blanched carrots, the mass loss was higher for the organic carrots stored under refrigerated conditions. Marketability of the conventional carrots was higher compared to the organic samples. The storage method had significant effect on the color difference during storage, except during the third storage period. There were no clear effects of storage time and storage method on the total soluble solids of the stored carrots. There were no clear effects of storage time and storage method on the hardness of the stored carrots. Storage method did not have any effect the toughness of the stored carrots.
3. Blanching of carrots may not be suitable for storage. The marketability of the blanched and stored carrot was reduced to zero after the first storage period.

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Table 1. Percentage mass loss or gain of stored corn.

Sample	Storage type	Days of storage	
		34	64
		Mass loss/gain (%)	Mass loss/gain (%)
Conventional	CA	2.38	-3.98
Organic	CA	2.16	-2.45
Conventional	Refrigerated	2.95	4.20
Organic	Refrigerated	2.32	2.24

Table 2. Moisture content of the stored corn.

Sample	Storage type	Days of storage		
		0	34	64
		Moisture content (% wb)		
Conventional	CA	80.2b	83.3a	80.5a
Organic	CA	78.2a	81.7a	82.9b
Conventional	Refrigerated	80.2b	84.6a	84.0b
Organic	Refrigerated	78.2a	82.8a	84.7b

Means with same letters in the same column are not significantly different at 5% level.

Table 3. Total soluble solid content of the corn stored under various conditions.

Sample	Storage type	Days of storage		
		0	34	64
		Total soluble solids (% wb)		
Conventional	CA	14.4a	12.9b	9.4c
Organic	CA	15.6b	12.4b	9.3c
Conventional	Refrigerated	14.4a	9.1a	5.5b
Organic	Refrigerated	15.6b	9.3a	4.4a

Means with same letters in the same column are not significantly different at 5% level.

Table 4. Color characteristics of the stored corn samples.

Sample	Storage type	Initial color characteristics			Days of storage	
		Sept. 10, 2009			34	64
		L	a	b	Color difference (ΔE)	
Conventional	CA	67.82a	5.36a	25.57a	5.56b	6.11a
Organic	CA	67.92a	5.38a	24.65a	3.96a	4.78a
Conventional	Refrigerated	67.82a	5.36a	25.57a	3.92a	5.32a
Organic	Refrigerated	67.92a	5.38a	24.65a	4.49ab	6.56a

Means with same letters in the same column are not significantly different at 5% level.

Table 5. Hardness and toughness of the stored corn.

Sample	Storage type	Days of storage			Days of storage		
		0	34	64	0	34	64
		Hardness (N)			Toughness (N mm)		
Conventional	CA	3.61a	2.92ab	5.11b	18.56b	14.11b	7.84a
Organic	CA	3.68a	3.31b	3.57a	16.09a	6.87a	6.21a
Conventional	Refrigerated	3.61a	2.52a	3.73a	18.56b	13.95b	7.33a
Organic	Refrigerated	3.68a	3.22b	3.58a	16.09a	7.04a	7.17a

Means with same letters in the same column are not significantly different at 5% level.

Table 6. Percentage mass loss o gain during the storage of carrots samples.

Sample	Storage type	Days of storage			
		35	59	97	117
		Mass loss/gain (%)	Mass loss/gain (%)	Mass loss/gain (%)	Mass loss/gain (%)
Conventional no blanching	CA	0.52	0.48	0.56	0.18
Conventional blanched	CA	3.53			
Organic no blanching	CA	0.86	-0.33	-0.93	0.08
Organic blanched	CA	3.77			
Conventional no blanching	Refrigerated	0.86	1.39	2.59	2.59
Conventional blanched	Refrigerated	7.62			
Organic no blanching	Refrigerated	0.22	1.79	3.90	5.50
Organic blanched	Refrigerated	5.70			

Table 7. Moisture content of the stored carrots.

Sample	Storage type	Days of storage				
		0	35	59	97	117
		Moisture content (%)				
Conventional no blanching	CA	90.2ab	91.1a	91.2ab	91.0ab	90.7a
Conventional blanched	CA	89.7ab				
Organic no blanching	CA	90.7b	90.3a	91.6b	91.5b	91.1a
Organic blanched	CA	89.3a				
Conventional no blanching	Refrigerated	90.2ab	91.2a	90.3a	90.5a	90.5a
Conventional blanched	Refrigerated	89.7ab				
Organic no blanching	Refrigerated	90.7b	90.7a	91.3b	90.1a	90.3a
Organic blanched	Refrigerated	89.3a				

Means with same letters in the same column are not significantly different at 5% level.

Table 8. Marketable carrots at the end of each storage period.

Sample	Storage type	Days of storage			
		35	59	97	117
		Marketable (%)	Marketable (%)	Marketable (%)	Marketable (%)
Conventional no blanching	CA	91.61	94.71	92.72	90.97
Conventional blanched	CA	0.00			
Organic no blanching	CA	92.19	80.96	83.28	86.75
Organic blanched	CA	0.00			
Conventional no blanching	Refrigerated	95.35	92.13	96.47	96.03
Conventional blanched	Refrigerated	0.00			
Organic no blanching	Refrigerated	94.36	69.85	72.53	68.41
Organic blanched	Refrigerated	0.00			

Table 9. Color characteristics of the stored carrots samples.

Sample	Storage type	Initial color characteristics			Days of storage			
		Oct 22, 2009			35	59	97	117
		L	a	b	Color difference (ΔE)			
Conventional no blanching	CA	49.59b	31.94d	24.83c	1.90a	3.84b	2.65a	3.65a
Conventional blanched	CA	44.31a	24.64a	20.69a				
Organic no blanching	CA	48.52b	29.72c	23.72b	2.90bc	3.47ab	2.77a	3.52a
Organic blanched	CA	45.38a	27.66b	22.96b				
Conventional no blanching	Refrigerated	49.59b	31.94d	24.83c	3.00c	2.50a	2.60a	4.47ab
Conventional blanched	Refrigerated	44.31a	24.64a	20.69a				
Organic no blanching	Refrigerated	48.52b	29.72c	23.72b	2.15ab	3.97b	2.40a	5.22b
Organic blanched	Refrigerated	45.38a	27.66b	22.96b				

Means with same letters in the same column are not significantly different at 5% level.

Table 10. Carrot total soluble solids

Sample	Storage type	Days of storage				
		0	35	59	97	117
		Total soluble solids (%Brix)				
Conventional no blanching	CA	8.4ab	8.0ab	7.5a	7.8a	8.5a
Conventional blanched	CA	8.7b				
Organic no blanching	CA	7.7a	8.4b	7.6ab	7.4a	7.8a
Organic blanched	CA	8.6b				
Conventional no blanching	Refrigerated	8.4ab	7.5a	8.4b	7.8a	8.3a
Conventional blanched	Refrigerated	8.7b				
Organic no blanching	Refrigerated	7.7a	8.3ab	7.4a	8.7b	8.3a
Organic blanched	Refrigerated	8.6b				

Means with same letters in the same column are not significantly different at 5% level.

Table 11. Hardness of carrot samples before and during storage.

Sample	Storage type	Days of storage				
		0	35	59	97	117
		Hardness (N)				
Conventional no blanching	CA	11.56a	11.81a	12.80ab	11.59a	12.47a
Conventional blanched	CA	15.33b				
Organic no blanching	CA	11.73a	11.67a	11.72a	11.65a	12.94a
Organic blanched	CA	14.75b				
Conventional no blanching	Refrigerated	11.56a	11.93a	14.02b	14.06b	13.59a
Conventional blanched	Refrigerated	15.33b				
Organic no blanching	Refrigerated	11.73a	12.52a	12.22ab	12.11a	12.24a
Organic blanched	Refrigerated	14.75b				

Means with same letters in the same column are not significantly different at 5% level.

Table 12. Toughness of carrot samples before and during storage.

Sample	Storage type	Days of storage				
		0	35	59	97	117
		Toughness (N mm)				
Conventional no blanching	CA	159.8b	152.1a	156.0a	151.3a	320.0a
Conventional blanched	CA	97.9a				
Organic no blanching	CA	151.6b	153.9a	153.5a	150.7a	309.3a
Organic blanched	CA	109.4a				
Conventional no blanching	Refrigerated	159.8b	156.6a	164.3a	158.2a	328.9a
Conventional blanched	Refrigerated	97.9a				
Organic no blanching	Refrigerated	151.6b	155.7a	151.0a	150.4a	316.4a
Organic blanched	Refrigerated	109.4a				

Means with same letters in the same column are not significantly different at 5% level.

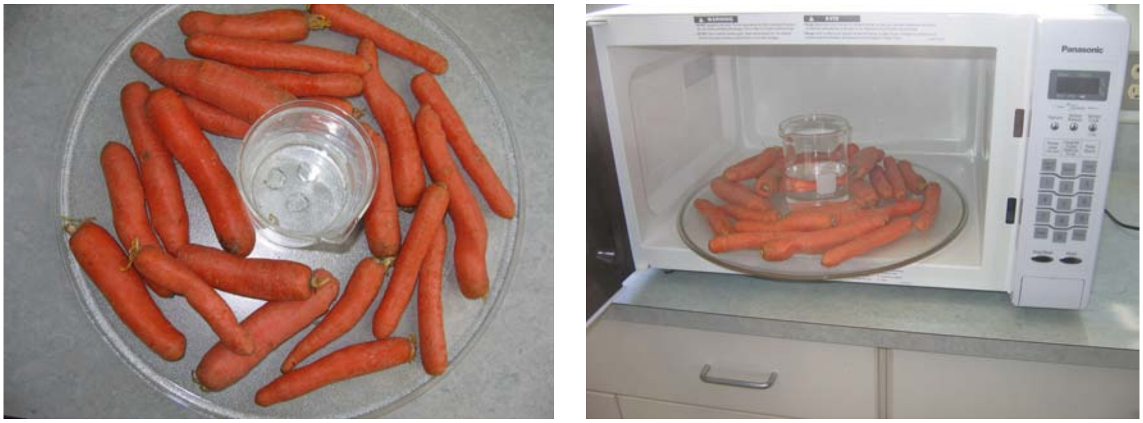

Figure 1. Microwave blanching of carrot samples

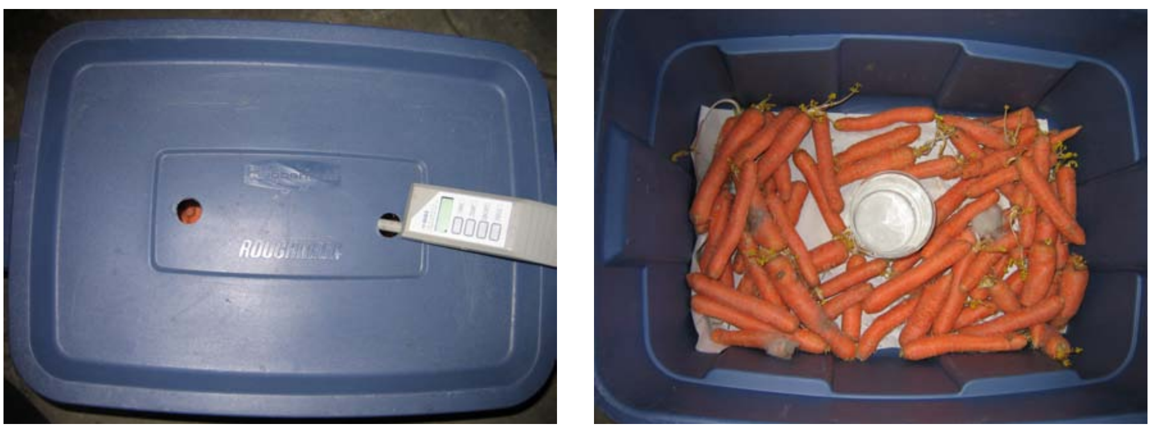

Figure 2. Refrigerated storage of carrots.

Figure 3. Controlled atmosphere storage of carrots.

	
Refrigerated stored	CA stored

Figure 4. Appearance of refrigerated and CA stored carrots at the end of 117 storage days.