

The Effect of Different Storage Conditions and Package Size on Storage Duration of Carrots *

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Abstract:The effects of different storage temperatures and packing size on the storage period of the Nandor F₁ carrot cultivar are reported. Storage temperatures were at a controlled 0° and 5° C and at ambient temperature with assisted ventilation. Product was stored in 2-, 5-, 10-, and 20-kg perforated polyethylene (PE) bags for these experiments; control carrots were placed in each of the three temperatures but were not packed. At monthly intervals the stored carrots were evaluated for the following: total soluble solids, carotene content, weight loss, sprouting, rooting, and sensory quality. Results show that the unpacked carrots placed in 5°C refrigeration could be stored for up to two months. Unpacked controls stored in ventilated conditions or at 0° C could be stored for as long as three months. Carrots packed in PE bags and placed in ventilated conditions could be stored for up to four months, while plastic-packed product placed in 0° C refrigeration lasted for as long as six months. Sprouting and weight loss were found to increase as storage temperature increased, whereas TSS was observed to decrease in contrast. For all storage conditions the carotene content of carrots stored in PE bags was uniformly higher at the end of the storage period than at the beginning of the storage period.

Key Words: Carrot, storage, packaging, sprouting, rooting, caroten content

Farklı Depo Koşulları ve Ambalaj Büyüklüğünün Havucun Muhafaza Süresine Etkisi

Özet :Araştırmada Nandor F₁ havuç çeşidinin muhafaza süresine depo sıcaklığı ve ambalaj büyüklüğünün etkileri incelenmiştir. Bu amaçla havuçlar hasattan sonra yıkanarak 2, 5, 10 ve 20 kg'lık delikli polietilen torbalar içerisine konularak 0°, 5°C sıcaklıktaki soğutuculu depolar ile soğutucusuz depoya yerleştirilmiştir. Kontrol amacı ile kullanılan örnekler aynı depo ortamlarında açıkta plastik kasalar içerisinde muhafaza edilmişlerdir. Aylık aralıklarla depodan alınan örneklerde; suda eriyebilir toplam kuru madde, karoten miktarı, ağırlık kaybı, köklenme ve filizlenme oranları ile duyu kalite değerlendirmesi yapılmıştır. Sonuçlar 5°C'de kontrol grubunun 2 ay muhafaza edilebileceğini, bu sürenin soğutucusuz ve 0°C'deki soğutuculu depoda 3 aya çıktığını göstermiştir. Soğutucusuz depo ile 0°C'deki soğutuculu depoda PE torbalarda muhafaza edilen havuçlar ise sırası ile 4 ve 6 ay süresince önemli bir kalite kaybına uğramamışlardır. Sonuçlar depo sıcaklığı yükseldikçe filizlenme ve ağırlık kaybının arttığını, suda eriyebilir toplam kuru madde miktarının ise azaldığını ortaya koymuştur. Karoten miktarı tüm depo koşullarında ambalajlı örneklerde depolama süresi sonunda hasat zamanına göre artış göstermiştir.

Anahtar Kelimeler: Havuç, muhafaza, ambalajlama, köklenme, filizlenme, karoten miktarı

Introduction

In the carrot production areas of Turkey, the most common storage method which farmers employ is to leave the mature product unharvested in the field during the winter period and harvest only when the product is about to be sold. Another storage method involves placing harvested carrots into holes which are then overlaid with soil. These storage methods can result in crop losses estimated to be as high as 25-30%, with damage mostly occurring when there is soil freezing (Yanmaz et al. 1995). The delicate structure of the carrot root makes it particularly sensitive to mechanical damage which can occur during soil freezing.

Kader et al. (1985) have classified carrots as members of the non-chilling sensitive group of vegetables, along with broccoli, cabbage, onion, and pea. It has been determined that the freezing point of carrot root is -1.68° C, so it is assumed that storage

temperatures can be set as low as this value. A 0° C storage temperature and 95-100% relative humidity are recommended by many as optimum storage conditions for carrot (Ryall and Lipton 1972, Debner et al. 1980, Salunkhe and Desai 1984, Kader et al. 1985, Kozukue et al. 1985, Embrechts and Schoneveld 1988). Gor'kovenko (1992) has pointedly recommended a 1-2° C storage temperature and 80-85% relative humidity as the optimal conditions for carrot storage. There is wide agreement that a stable storage temperature is essential.

Changes in the postharvest quality of carrot product are evaluated by a number of established criteria (Snowdon 1991). Observation of shriveling and softening of root tissue are attributable to dehydration of the root. Other measures of quality include discoloration, sprouting, rooting, tissue cavitation, altered taste as increased bitterness, and postharvest disease.

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The principal factors which can be used to estimate the length of postharvest life of carrots include the time of harvest of the product, stage of maturity at harvest, and the handling and storage conditions. Insofar as carrot handling, the typical procedure involves product washing, topping, chemical treatment, and packaging prior to storage or immediate marketing.

This study is intended to observe what effects of temperature and the size of package have on the storage life of carrot. Data are reported for the several criteria given above as the basis of assessing carrot postharvest quality.

Material and Method

These experiments were conducted using the Nandor F₁ carrot cultivar grown at a privately held farm in the Middle Anatolia region. Three different storage temperatures were used for these experiments:

- (i) an ambient-temperature storage area with assisted ventilation; temperature records were kept and showed a range of 0.5° to 7.5° C throughout the storage period;
- (ii) a refrigerated storage room set at 0° C and relative humidity kept between 85-90%;
- (iii) a refrigerated storage room set at 5° C and relative humidity kept between 85-90%.

Carrots were harvested in november and then trimmed, washed and packed into 2-, 5-, 10-, and 20-kg perforated polyethylene (PE) bags which has 4, 8, 12, and 16 holes and 3 mm each, respectively. The plastic film of the bags showed a permeability to O₂ of 9092 cm³ /m² over 24h at 25°C. The permeability to CO₂ was 24800 cc/m² over 24 h at 25°C. Moisture vapor transmission at 90% RH and 37.8° C was 21.7g over 24h (TSE-Izmir). Controls for these studies were placed only on plastic trays without PE packing and then stored in the three different storage rooms. At one-month intervals ten carrots for each replicate were removed from each of the storage area, and data were recorded for the following criteria: (i) total weight loss, (ii) degree of sprouting, (iii) degree of rooting, (iv) total soluble solids, and (vi) carotene content, determined according to Chan and Caveletto (1982). In addition, the product sensory quality was assessed for taste and appearance by a trained panel using a 5-point scoring system, the scores representing the following judgments: 5, excellent; 4, good; 3, acceptable; 2, bad; 1, very bad. Scoring for appearance were done considering tissue cavitation, cracking of the root surface, hollowness, and shrivelling. All data gathering involved experimental determinations of triplicate data sets with 10 carrots used in each data set. The Duncan test was used to measure whether differences in data were statistically significant, a probability of less than 5% ($P < 0.05$) considered the criterion asserting differences to be significant (Düzgüneş 1963).

Results and Discussion

Weight loss: Increased weight losses were observed for carrots stored under all conditions in these

experiments (Table 1). Packaging in perforated PE bags decreased weight loss in carrots during storage period. The data showed that the rate of weight loss was predictably not as great for packaged product as opposed to unpackaged controls. Weight loss was also effected by storage temperature. While weight loss determined as 1-5% after six month in 0° C this value was 1.3-15% after four months in ventilated stores. Carrots packed into 2-kg perforated PE bags showed the least weight loss compared to all other treatments.

Weight loss attributable to changes in the tissue water content was the most important factor affecting postharvest life of carrots according to relevant studies. In these studies postharvest life of unpacked carrots stored in a ventilated room and in the 0°C room was ended largely due to significant weight loss attributable to shriveling and tissue cavitation. It has been shown that a 16.8% weight loss can occur with carrots placed for six days at room temperature, while nearly double (29%) the weight loss occurs under warmer conditions over the same period (Ram et al. 1981). Relative humidity ranged between 36-59% in this study. The packing of topped carrots appears to have an effect on reducing such weight losses (Salunkhe and Desai 1984). Geeson (1985) also reported increased weight loss and softening of tissue with an increased storage temperatures; weight loss was 0.4-0.8% during a 9-month storage period at 0° C with no softening, but increased to 1.5 to 2.0% during 4 to 5- month storage period at accompanied by softening at 5°C.

Sprouting rate: Table 2 shows the degree of sprouting occurring during storage. Sprouting is observed to increase for all carrots over the six-month storage period. At the end of the first month of storage, the rate of sprouting ranged between 20-38% for carrots stored in the ventilated store and at 5° C while sprouting was not noticeable over two month of storage at 0°C room. While half of the carrots showed sprouts after five or six months of storage in the 0°C, half the carrots in the 5° C room had sprouted after only two months and half of the carrots in the ventilated room had sprouted after only three months. Sprouting was observed to be rather low in carrots stored in 5-kg PE bags in ventilated storage, and unpacked controls were found to have not sprouted at all under these conditions probably due to water loss. Less sprouting was observed for carrots packed into larger PE bags (10 and 20 kg bags) than for smaller bags (2 and 5 kg), but the differences were not statistically significant. This could be due to increased moisture present in the packages in 0°C because of high humidity. With increased package sizes, moisture accumulation in the packages might also increase because of an increased amount of product within the bags. In addition higher CO₂ concentrations in the large-sized packages might induce less sprouting than in small ones. Embrechts and Schoneveld (1988) have recommended the use of plastic film as providing the best results in avoiding quality loss in carrots during storage. According to Hardenburg et al. (1986) and Gnaegiu et al. (1978) film bags for carrots should be perforated to allow ventilation and to prevent development of off-odors and off-flavors.

Table 1. Weight loss (%) changes of carrots during storage at 0°C, 5°C and ventilated store*

Storage conditions	Package size (kg)	Storage duration (month)					
		1	2	3	4	5	6
0°C	Unpacked	22.05 b	40.25 b	53.2 b	-	-	-
	2	0.24 d	0.47 e	0.5 d	0.77 e	0.82 b	0.92 b
	5	0.64 d	0.7 e	1.98 d	3.09 bc	4.49 a	6.07 a
	10	0.47 d	0.63 e	1.63 d	2.41 cd	4.14 a	5.08 a
	20	0.25 d	0.74 e	1.47 d	1.72 de	3.49 a	4.91 a
5°C	Unpacked	12.78 c	25.52 c	-	-	-	-
	2	0.59 d	1.84 e	-	-	-	-
	5	0 d	0.18 e	-	-	-	-
	10	1.01 d	1.64 e	-	-	-	-
	20	0.24 d	0.73 e	-	-	-	-
Ventilated	Unpacked	27.25 a	56.08 a	66.64 a	-	-	-
	2	0.5 d	0.96 e	0.96 d	1.34 de	-	-
	5	0.55 d	0.86 e	2.39 d	3.67 b	-	-
	10	0.47 d	1.12 e	2.1 d	2.94 bc	-	-
	20	0.53 d	8.02 d	8.56 c	14.70 a	-	-

*Differences in data within a colon were statistically significant, a probability of less than 5% ($P < 0.05$)

Table 2. Sprouting rates (%) of carrots during storage at 0°C, 5°C and ventilated store*

Storage conditions	Package size (kg)	Storage duration (month)					
		1	2	3	4	5	6
0°C	Unpacked	0 c	0 c	0 c	-	-	-
	2	4.77 bc	4.77 c	4.77 c	4.77 c	66.67 a	80.93 ab
	5	0 c	0 c	0 c	0 c	57.10 a	90.47 a
	10	4.77 bc	4.77 c	19.07 b	23.84 c	57.13 a	57.13 b
	20	0 c	0 c	0 c	4.77 c	61.90 a	66.63 b
5°C	Unpacked	0 c	14.30 b	-	-	-	-
	2	38.13 a	61.90 a	-	-	-	-
	5	33.37 a	57.13 a	-	-	-	-
	10	19.07 ab	61.87 a	-	-	-	-
	20	28.60 a	47.60 a	-	-	-	-
Ventilated	Unpacked	0 c	0 c	0 c	-	-	-
	2	38.10 a	42.87 a	70.19 a	76.17 a	-	-
	5	23.83 ab	42.90 a	42.90 b	42.90 b	-	-
	10	38.13 a	61.87 a	57.13 a	85.70 a	-	-
	20	38.10 a	47.63 a	71.40 a	80.93 a	-	-

*Differences in data within a colon were statistically significant, a probability of less than 5% ($P < 0.05$)

Rooting rate: For the four-month storage period in the 0°C room, no root formation was observed. However more than half of the product were rooted after six months of storage. Rooting was also not observed for unpackaged controls in the first two months at 5°C, whereas root formation ranging between 19.1-28.6% was seen within this time period for carrots packed into PE bags and stored at this temperature (Table 3). This difference between the control and the packed product was significant. Ram et al. (1981) and Richard (1985) also reported an increase in root formation of carrot samples stored under high humidity. For carrots stored in the ventilated area, root formation was not observed in carrots stored in the 20-kg PE bags until after two months. After a four-month period in the ventilated store, the degree of rooting had reached 38.13% for carrots stored in 5-kg PE bags and 71.4% for 10-kg bags. In particular the differences in rooting rate between carrots

stored in 5-kg and 10-kg PE bags at the end of this storage period were found to be significant (Table 3).

Total soluble solid content: Changes in TSS content are given in Table 4. Changes in TSS content for carrots stored at 5°C under all conditions showed no significant differences over a two-month period. In contrast TSS content rapidly increased in carrots stored in the ventilated and in the 0°C controlled temperature. The rate of increase in TSS content was observed to be lower for the packed carrots in these two storage environments compared to the unpacked controls.

At the lower storage temperatures the changes in TSS was not as dramatic. On the other hand this quality parameter was significantly increased in the control carrots stored in refrigerated and ventilated stores, which may be attributable to an increased water loss. Changes

Table 3. Rooting rates (%) of carrots during storage at 0°C, 5°C and ventilated store*

Storage conditions	Package size (kg)	Storage duration (month)					
		1	2	3	4	5	6
0°C	Unpacked	0 c	0 b	0 c	-	-	-
	2	0 c	0 b	0 c	0 c	47.63 a	80.93 a
	5	0 c	0 b	0 c	0 c	42.87 a	71.14 a
	10	0 c	0 b	0 c	0 c	33.33 a	52.40 a
	20	0 c	0 b	0 c	0 c	52.37 a	66.63 a
5°C	Unpacked	0 c	0 b	-	-	-	-
	2	9.43 b	28.60 a	-	-	-	-
	5	0 c	19.07 a	-	-	-	-
	10	0 c	19.07 a	-	-	-	-
	20	0 c	19.07 a	-	-	-	-
Ventilated	Unpacked	0 c	0 b	52.40 a	-	-	-
	2	0 c	0 b	38.13 b	47.63 b	-	-
	5	0 c	0 b	0 c	38.13 b	-	-
	10	23.83 a	23.83 a	28.60 b	71.40 a	-	-
	20	0 c	23.83 a	23.83 b	42.87 b	-	-

*Differences in data within a colon were statistically significant, a probability of less than 5% ($P < 0.05$)

Table 4. Total soluble solids content (%) of carrots during storage at 0°C, 5°C and ventilated store*

Storage conditions	Package size (kg)	Storage duration (month)					
		1	2	3	4	5	6
0°C	Unpacked	9.50 a	10.83 b	12.62 b	-	-	-
	2	8.00 b	8.20 c	8.50 c	8.27 a	7.80 a	8.00 a
	5	8.17 b	8.27 c	8.03 c	7.82 a	7.40 a	7.77 ab
	10	8.00 b	7.97 c	8.08 c	8.13 a	7.62 a	7.75 ab
	20	7.83 b	8.08 c	7.65 c	8.03 a	7.55 a	7.45 b
5°C	Unpacked	8.17 b	8.58 c	-	-	-	-
	2	8.33 b	7.98 c	-	-	-	-
	5	8.40 b	7.93 c	-	-	-	-
	10	8.23 b	8.18 c	-	-	-	-
	20	8.50 b	8.07 c	-	-	-	-
Ventilated	Unpacked	9.33 a	11.98 a	17.62 a	-	-	-
	2	8.00 b	7.83 c	8.47 c	8.00 a	-	-
	5	8.07 b	8.20 c	8.15 c	8.00 a	-	-
	10	8.23 b	8.03 c	8.13 c	7.47 a	-	-
	20	8.40 b	7.88 c	8.12 c	8.12 a	-	-

*Differences in data within a colon were statistically significant, a probability of less than 5% ($P < 0.05$)

** Total soluble solids content (%) of carrots at day 0 was 8.5%.

in the TSS did not show a significant decrease from the harvest value and this might be due to a low temperature, decreased water loss and increased carbon dioxide concentrations inside the packages or a combinations of these factors.

Carotene content: Except for the unpacked controls, carotene content did not show much variation over the storage period. In general carotene content rose quickly during initial storage period, then declines by a steady rate over the rest of the storage period. Despite this overall decline in carotene content, Table 5 shows that carotene content was higher at the end of the storage period compared to the carotene content of product at the beginning of storage, and this result is independent of storage temperature and type of packaging.

Carrots are popularly understood to be a rich source of vitamin A among vegetables. Results of these experiments showed that carotene content increases at the beginning the overall of storage, and then slightly

decreases through to the end of the storage period under all conditions of storage.

Sensory quality: The sensory quality of carrots was judged in terms of taste and appearance (Table 6 and 7). Scores on product taste began to fall uniformly after the first month of storage for carrots stored under all conditions. Unpacked carrots stored at 5°C showed appearance scores falling below the level of acceptability by the end of the second month. The level of acceptability regarding taste and appearance is any mean score falling below 3. Taste scores were seen to decrease faster for carrots stored in PE bags than for unpacked controls. Carrots stored at 0°C did not fall below the level of taste acceptability until after six months. Product stored in the ventilated area did not fall below acceptability until after third month.

Unpacked controls stored under either refrigerated or ventilated conditions showed a degree of shriveling at the end of two months such that their market value was

judged to have been lost (Table 6). In contrast carrots stored in PE bags at the 0°C room maintained its appearance over a six-month storage period. Carrots placed in the ventilated storage maintained an acceptable appearance quality score for four months. Differences in appearance scores of carrots stored in PE bags of different sizes, all other parameters remaining constant, were not found to be statistically significant.

Although taste scores decreased during storage, the package size did not have a statistically significant effect on this parameter. Increased bitterness which is attributable to the formation of isocoumarin, and the greater decrease in the taste quality of unpacked samples might be due to their exposure to greater amounts of ethylene in the atmosphere (Carlton et al. 1961, Hardenburg et al. 1986, Lafuente et al. 1989).

Conclusion

Results of this study generally showed the major factors affecting storage life are water loss, sprouting and

rooting. The greatest crop loss for carrots stored in the ventilated storage rooms. Since this storage room underwent a large range of temperature fluctuation, it is possible this variable alone could account for the loss.

All experimental results showed that carrots can be stored for as long as 3 to 6 months at different temperatures and in various packages without showing a high degree of quality loss. The results in the present study suggest that the best conditions are storage at 0°C in 5 or 10 kg perforated PE bags, which can be done for as long as 6 months. In the event that ventilated stores are to be used, storage in plastic bags can be extended to as long as 3 to 4 months. Fluctuation in the ambient temperature of ventilated storage areas should be minimized as much as possible to prevent water loss, rooting, and sprouting of product which would otherwise reduce the quality. On the other hand continuous 5°C temperature was found very high for carrot storage because of increased weight loss, sprouting, rooting and taste loss.

Table 5. Carotene content ($\mu\text{g/g}$, DM) of carrots during storage at 0°C, 5°C and ventilated store*

Storage conditions	Package size (kg)	Storage duration (month)					
		1	2	3	4	5	6
0°C	Unpacked	466.7 b	202.7 cde	172.4 bc			
	2	685.6 ab	219.0 cde	277.2 abc	424.5 a	302.4 a	305.1 a
	5	511.5 ab	158.9 de	353.1 ab	305.3 a	308.4 a	344.6 a
	10	652.2 ab	182.7 cde	340.8 a	272.9 a	334.0 a	261.6 a
	20	550.1 ab	120.4 e	283.8 abc	309.9 a	253.3 a	356.5 a
5°C	Unpacked	494.1 b	169.4 de	-	-	-	-
	2	1242.3 c	204.1 cde	-	-	-	-
	5	817.8 ab	201.3 cde	-	-	-	-
	10	662.6 ab	243.4 cde	-	-	-	-
	20	669.4 ab	139.3 e	-	-	-	-
Ventilated	Unpacked	828.4 ab	295.9 bcd	159.0 c	-	-	-
	2	548.8 ab	324.3 abc	239.8 abc	286.0 a	-	-
	5	595.3 ab	397.7 ab	235.2 abc	363.7 a	-	-
	10	575.9 ab	450.4 a	244.2 abc	290.9 a	-	-
	20	499.8 b	401.8 ab	392.6 a	331.0 a	-	-

*Differences in data within a colon were statistically significant, a probability of less than 5% ($P < 0.05$)

** Caroten content at day 0 was 250.9 $\mu\text{g/g}$, DM.

Table 6. General appearance scores of carrots during storage at 0°C, 5°C and ventilated store*

Storage conditions	Package size (kg)	Storage duration (month)					
		1	2	3	4	5	6
0°C	Unpacked	3	2	1	-	-	-
	2	5	5	5	5	5	4
	5	5	5	5	5	5	4
	10	5	5	5	5	5	4
	20	5	5	5	5	5	4
5°C	Unpacked	4	2	-	-	-	-
	2	5	3	-	-	-	-
	5	5	3	-	-	-	-
	10	5	3	-	-	-	-
	20	5	3	-	-	-	-
Ventilated	Unpacked	3	1	1	-	-	-
	2	4	4	4	4	-	-
	5	5	5	4	4	-	-
	10	4	4	4	3	-	-
	20	4	4	4	3	-	-

* General appearance score at day 0 was 5 points.

Table 7. Taste scores of carrots during storage at 0°C, 5°C and ventilated store*

Storage conditions	Package size (kg)	Storage duration (month)					
		1	2	3	4	5	6
0°C	Unpacked	4	3	3	-	-	
	2	4	4	4	3	3	3
	5	4	4	4	3	3	3
	10	4	4	4	3	3	2
	20	4	3	4	3	4	2
5°C	Unpacked	4	2	-	-	-	-
	2	4	2	-	-	-	-
	5	3	3	-	-	-	-
	10	3	2	-	-	-	-
	20	3	2	-	-	-	-
Ventilated	Unpacked	3	3	2	-	-	-
	2	4	4	4	3	-	-
	5	4	4	4	3	-	-
	10	4	4	3	3	-	-
	20	4	3	3	3	-	-

* Taste score at day 0 was 5 points.

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