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Impact of Storage Conditions on Grape Tomato Quality

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Abstract

Storage and ripening recommendations for tomatoes are well known, but quality problems associated with poor temperature management continue to occur during distribution. Grape and cherry tomatoes, also called 'snacking' tomatoes, now constitute about 24% of the value of all tomatoes sold in U.S. supermarkets. New marketing opportunities, such as grape tomatoes in trays of fresh-cut vegetables, expose fruit to temperatures of 5°C or below often in combination with modified atmospheres, conditions at odds with postharvest recommendations for good tomato quality. Several studies were conducted on different varieties of grape tomatoes. 1-MCP only slightly retarded ripening and delays to cool affected subsequent color and water loss. Storage at 10°C resulted in excellent quality fruit. At 5°C, near ripe grape tomatoes were of marketable quality for 18 days. Storage at 5°C resulted in minimal weight loss, no lycopene synthesis, decreases in sugar concentrations and retention of Vitamin C concentrations. However, if fruit were transferred from 5°C to warmer temperatures, typical chilling injury symptoms (decay, poor color formation) occurred. Controlled atmospheres of 3 or 10% oxygen with 0, 7, 12 or 18% carbon dioxide at 5°C provided little benefit but were tolerated by grape tomatoes for up to 3 weeks based on visual appearance, discoloration, decay, off-odors, and changes in composition (sugars, Vitamin C, and ethanol and acetaldehyde concentrations). Although not ideal, near ripe high quality grape tomatoes do perform well as components of fresh-cut vegetable trays at low temperature under controlled atmospheres not recommended for tomatoes.

INTRODUCTION

Fresh-market tomatoes are a popular and versatile fruit vegetable, making significant contributions to human nutrition throughout the world for their content of sugars, acids, vitamins, minerals, lycopene and other carotenoids, among other constituents (Simonne et al., 2006; Toor and Savage, 2006). The small size snacking tomatoes (cherry, grape types) contain high concentrations of sugars and acids, major contributors to tomato flavor, and now comprise about 24% of retail sales of tomatoes in the U.S. (Anon., 2008).

Postharvest recommendations indicate that tomatoes, including cherry and grape tomatoes, should be stored at 10°C or higher to avoid chilling injury (Jimenez et al., 1996; Roberts et al., 2002) and even 10°C may be detrimental to tomato flavor quality (Maul et al., 2000). Chilling injury symptoms include failure to ripen and develop full color and flavor, irregular color development, excessive softening, surface pitting, and increased decay (Cantwell, 2008; Sargent and Moretti, 2004, Suslow and Cantwell, 2000). Low oxygen (3-5%) atmospheres retard tomato ripening while high levels of carbon dioxide (>5%) are considered damaging for tomatoes. Low O_2 injury is characterized by uneven

ripening and off-flavors due to increases in ethanol and acetaldehyde. Carbon dioxide concentrations higher than 5% may cause surface discoloration, softening, and uneven coloration (Leshuk and Saltveit, 1990; Sargent and Moretti, 2004).

The synthesized compound, 1-methylcyclopropene (1-MCP) is a potential regulator of the ripening of many climacteric fruits including tomatoes (Watkins, 2008). The effects of 1-MCP on ripening of a cherry tomato cultivar (Opiyo and Ting, 2005) and a grape tomato cultivar (Ergun et al., 2006) were slight to moderate.

Cherry and grape tomatoes are sometimes held at lower than recommended temperatures. Also cherry and grape tomatoes are routinely used as components on fresh-cut vegetables trays under modified atmospheres, with expected shelf-life of 14-18 days at 2-5°C. A few studies have characterized changes in small tomatoes stored at below recommended temperatures alone or in combination with modified atmosphere packaging (Akbudak et al., 2007; Ilic and Fallik, 2007).

The objectives of this study was to further characterize the storage performance of grape tomatoes stored at a range of temperatures and to especially document quality changes at 5°C in combination with high carbon dioxide atmospheres.

MATERIALS AND METHODS

Grape tomato samples from 7 cultivars were obtained from commercial growers in California and Mexico, shipped under cool conditions (10-13°C) and received within 2-4 days of harvest. Fruit were sorted for defects, and rinsed in chlorinated water (150 ppm NaOCl). Fruit were sorted into 3 maturity/ripeness categories (Stage 3=turning, yellowish, stage 4=pink-orange and stage 5=orange-red). Fruit were stored in commercial vented clamshells with a minimum of 15 fruit per replicate. The impact of delays to cool was evaluated on fruit in clamshells held at 30°C 30%RH for up to 18 hours followed by storage at 10°C. For 1-MCP treatment, color stage 4 fruit were treated 12 hr at 20°C with 500ppb 1-MCP, and stored 8 days at 20°C. Controlled atmospheres were prepared from mixing humidified gases and were maintained within 5% of the indicated concentrations.

Fruit were analyzed for weight loss, subjective quality, color, firmness and composition. Visual quality was scored on a 9 to 1 scale, where 9=excellent, fresh appearance, 7=good, 5=fair, 3=fair, 1=unusable. Typical aroma, off-odors, and flavor were scored on 1 to 5 scales, where 1=none, 2=slight, 3=moderate, 4=almost typical aroma or moderately severe, and 5=maximum or severe. Decay, discoloration or other defects were scored on a 1 to 5 scale, where 1=none, 2=slight defect but product salable, 3=moderate, product useable but not salable, 4=moderately severe and 5=severe, unusable. L*, a* and b* color values were measured with a Minolta color meter, and hue calculated as $\tan^{-1}$ (b*/a*). Firmness was measured as the force to compress the fruit a distance of 5 mm using a flat cylinder (Ø25mm) moving at 0.5 mm/sec.

Fruit were blended in a homogenizer, the juice filtered and a few drops used for direct measurement of % soluble solids on a digital refractometer. Another aliquot was used for determination of total sugars by a phenol-sulfuric colorimetric assay. Ten mL juice was titrated with 0.1N NaOH to an 8.1 pH endpoint and %T.A. calculated as citric acid. For ethanol and acetaldehyde, 8g chopped tissue was frozen at -80°C, then incubated at 65°C and ethanol and acetaldehyde were determined from 1mL head space samples by FID GC. Ascorbic acid and dehydroascorbic acid were determined on cold 2% oxalic acid extracts, filtered and frozen at -80°C for subsequent analysis by HPLC.

RESULTS AND DISCUSSION

Grape tomato harvested at 3 color stages (3=turning, 4=pink-orange, 5=orange-red) ripened into well colored fruit with a similar rate of water loss during ripening at 20°C (Table 1). Fruit harvested at stage 3 had lower firmness, soluble solids, acidity, and sugars at the ripe stage than fruit harvested at more advanced stages (Table 1). On average, Vitamin C concentrations were not different among these 3 stages of maturity.

The small grape tomatoes are very susceptible to water loss during handling and storage and symptoms of shrivel and dehydration and softening are highly correlated with weight loss (data not shown). Weight loss of near ripe grape tomatoes in vented plastic consumer packaging contributed to changes in overall visual quality and firmness loss (Figure 1). Visual quality (evaluated at storage temperature) was maintained by storing the grape tomatoes at 10°C for 12 days or at 5°C for up to 18days. Ripe fruit generally are considered more tolerant to chilling temperatures than fruit initiating the ripening process. Color change continued slowly in fruit stored at 10°C at a much lower rate than at 15 and 20°C. After an initial change in hue (due to a lag of temperature affecting lycopene synthesis), color change was stopped at 5°C (Figure 1D). Soluble solids and acid concentrations generally declined during storage (Figure 1). Acid loss was greater in fruits at 20°C than at the other storage temperatures. There was an increase in soluble solids at 20°C which was not associated with an increase in sugars (data not shown).

Exposing fruit to periods up to 18 hours at 30°C had little impact on visual quality or firmness during storage at 10°C but exposures of 6 hours or longer affected red color development (Figure 2). Temperatures above 25°C are known to retard lycopene development in tomatoes (Sargent and Moretti, 2004; Cantwell, 2008).

A 1-MCP treatment at pink-orange stage (stage 4) slightly retarded color development and firmness changes of seven cultivars (Table 2). In one cultivar, 1-MCP resulted in a blotchy appearance. Decay, shrivel, weight loss and discoloration were not affected by 1-MCP treatment (data not shown). These results are similar to those of Ergun et al. (2006) in which a small but significant extension of shelf-life was achieved when grape tomato fruit at advanced stages of ripeness were treated with 1-MCP.

Grape tomato (cv Merlot) quality slowly declined at 5°C (Figure 3) and this was associated with a perceived discoloration or darkening. There were some differences in visual appearance among the tomatoes stored in air or the controlled atmospheres after 15 days. There was generally a decrease in overall tomato aroma and an increase in off-odor and off-flavor on day 15 (with higher off-odor and off-flavor scores for fruit stored in air) (Figure 3). Decreases in volatiles of grape tomatoes under low temperatures should be similar to changes documented in round tomatoes (Maul et al., 2000). However, because of the high sugar and acid composition of grape tomatoes, the contribution of aroma volatiles to flavor perception may be less than in round tomatoes (Malundo et al., 1995).

There was an overall trend to darkening (decreasing L* values) with increased time at 5°C, and chroma and hue values remained relatively constant (data not shown). Ethanol concentrations in grape tomatoes in controlled atmospheres increased with time but were relatively low compared to those in other vegetables under the same atmospheres (Table 3). The most notable increases in ethanol and acetaldehyde were observed in the tomatoes stored in 3%O_2 +12 or 18%CO_2. Sugar concentrations decreased 30% in the tomatoes stored in air and somewhat less in the CA-stored fruit. Vitamin C concentrations (Table 3) remained stable at 5°C under all storage atmospheres. Retention of Vitamin C in tomatoes stored at low temperatures was also reported by Toor and Savage (2006).

CONCLUSIONS

Although grape tomatoes have high levels of sugars and acid, maturity at harvest is still important to ensure good composition and flavor at the table-ripe stage. Grape tomatoes should be harvested at a 'pink' or more advanced stage of maturity/ripeness. The long standing recommended temperature and atmosphere storage conditions for tomatoes also apply to grape tomatoes. Because of their small size, grape tomatoes have a high rate of water loss in the vented clamshells used at retail when held at ambient temperatures. Water loss is a major contributor to decreased quality (softening and shrivel), but can be minimized if the grape tomatoes are held at 10°C. Grape tomatoes used in cut vegetable trays will tolerate 2-3 weeks at 5°C since the products are not transferred to warm temperatures. Decline in some attributes (sugars, acids, aroma) occurs with time, but Vitamin C concentrations are very stable. Although not recommended, near ripe high quality grape tomatoes tolerate a range of high carbon dioxide atmospheres (7-18% CO_2 in combination with 3 or 10% O_2) for 3 weeks at 5ºC.

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Tables

Table 1. Composition of grape tomato harvested at 3 stages of maturity and ripened at 20°C. Color or maturity stage 3=turning, yellowish, stage 4= pink-orange and stage 5=orange-red fruit. Data are averages of 3 replicates of a composite sample of 15 fruit.

Cultivar and Initial color	Red color hue	Firmness N	Weight loss %/day	Soluble solids %	Sugars mg/ml juice	Titratable acidity %	Vitamin C mg/100g
Color 3							
Ahern 299	37.4	12.6	1.1	6.2	30.5	0.58	83.1
Amsterdam	38.2	12.1	1.2	5.5	30.1	0.51	92.6
Harris LI-34	34.9	11.1	1.2	4.7	23.2	0.49	103.4
Hazera1319	35.5	9.1	1.4	5.9	28.4	0.67	111.7
Rotterdam	34.6	12.8	1.5	6.2	29.2	0.60	82.8
TC900	34.7	8.7	--	5.5	22.2	0.65	87.4
TC 1260	37.4	14.1	1.3	7.1	30.3	0.66	108.5
Average	**35.8**	**11.5**	**1.3**	**5.9**	**27.7**	**0.59**	**95.6**
Color 4							
Ahern 299	35.6	14.1	1.1	6.7	32.3	0.65	82.2
Amsterdam	38.3	14.1	1.2	6.0	30.7	0.53	90.4
Harris LI-34	37.9	13.2	1.3	6.8	26.7	0.71	110.1
Hazera1319	34.7	11.3	1.4	7.6	32.6	0.87	104.7
Rotterdam	35.2	14.7	0.9	6.5	33.6	0.61	93.2
TC900	35.8	11.5	--	6.8	25.1	0.79	90.2
TC 1260	36.5	16.4	1.2	6.8	31.9	0.64	105.8
Average	**36.3**	**13.6**	**1.2**	**6.7**	**30.4**	**0.68**	**96.7**
Color 5							
Ahern 299	36.9	15.1	1.1	7.1	33.2	0.56	105.0
Amsterdam	39.2	13.0	1.4	7.5	33.6	0.57	85.8
Harris LI-34	39.6	14.0	1.3	6.8	27.5	0.62	121.2
Hazera1319	35.2	11.7	1.6	8.4	37.3	0.86	108.2
Rotterdam	37.0	15.7	1.0	7.5	36.3	0.65	93.0
TC900	36.7	10.3	--	7.0	27.0	0.69	85.7
TC 1260	39.2	15.8	1.3	8.1	35.8	0.71	96.5
Average	**37.7**	**13.7**	**1.3**	**7.5**	**32.9**	**0.67**	**99.3**
LSD.05	2.1	1.5	0.1	0.8	2.8	0.09	13.7

Table 2. Color and firmness values for 7 cultivars of grape tomatoes (color stage 4) stored at 20°C for 8 days after no treatment or treatment with 500 ppb 1-MCP. Data are based on 3 replicates of 15 fruit each.

Cultivar	Firmness, N		Red color, Hue		Observations
	Control	1-MCP	Control	1-MCP	
Ahern 299	12.0	14.1	33.3	37.5	1-MCPappears less red than control
Amsterdam	11.8	13.7	37.2	39.4	1-MCP slightly less red than control
Harris LI-34	10.9	12.0	36.4	38.3	Both appear the same
Hazera 1319	9.1	9.7	33.6	35.1	Control dark red; 1-MCP bright red
Rotterdam	12.4	14.0	34.2	38.6	1-MCP appears less red than control
TC900	8.7	8.2	34.6	36.4	25-30% 1-MCP blotchy ripening
TC 1260	12.9	17.0	36.1	39.2	Control fruit red; 1-MCP fruit orange-red
Average	11.1	12.7	35.1	37.8	
LSD.05	0.9	0.9	1.2	1.2	

Table 3. Sugar, ethanol, acetaldehyde, and Vitamin C concentrations of near ripe grape tomatoes (cv Merlot) stored in air or controlled atmospheres after 18 days at 5°C. Data are averages of 3 replicates.

Atmosphere %O2+%CO2	Days	Sugar mg/ml juice	Ethanol µmole/100g	Acetaldehyde µmole/100g	Vitamin C mg/100g
Initial	0	37.6	41.2	6.1	42.3
Air	12	28.4	24.5	2.2	40.5
3 + 7	12	32.9	49.8	8.2	41.2
3 + 12	12	32.2	132.8	16.6	38.0
3 + 18	12	35.9	140.8	14.3	42.8
10 +12	12	33.2	51.4	3.2	37.9
Air	18	26.1	60.5	2.9	43.2
3 + 7	18	31.9	83.3	10.9	38.9
3 + 12	18	31.8	118.5	17.7	40.0
3 + 18	18	32.7	186.1	21.5	39.1
10 +12	18	31.9	122.2	6.9	38.8
LSD.05		5.6	32.5	4.4	3.8

Figures

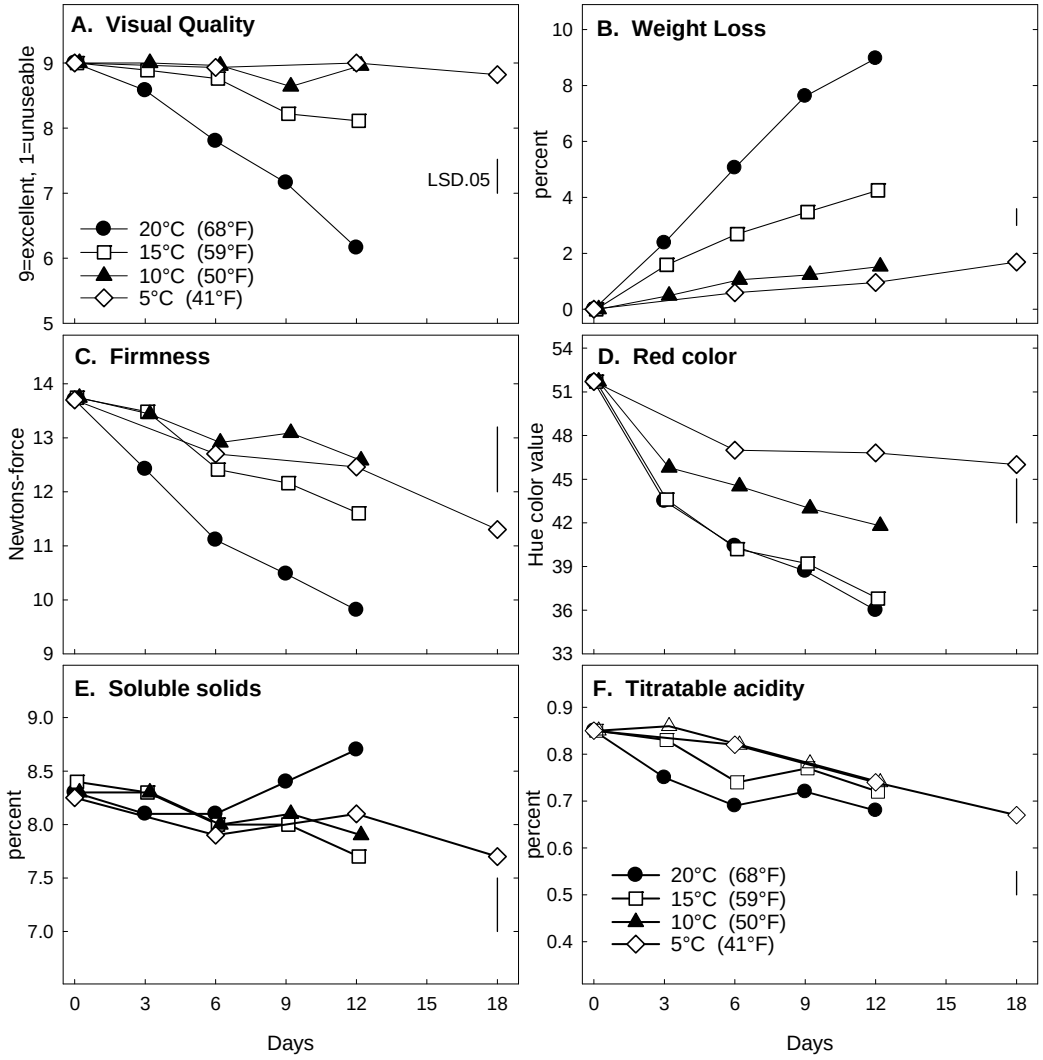

Figure 1. Visual quality, weight loss, firmness, color, soluble solids and acidity of grape tomatoes (cv. Amsterdam) stored in consumer packages at 4 temperatures. RH values averaged 36, 55, 69 and 84% at 20, 15, 10, and 5ºC, respectively. Data are averages of 3 replicates of 15 fruit each. Vertical bars indicate LSD.05.

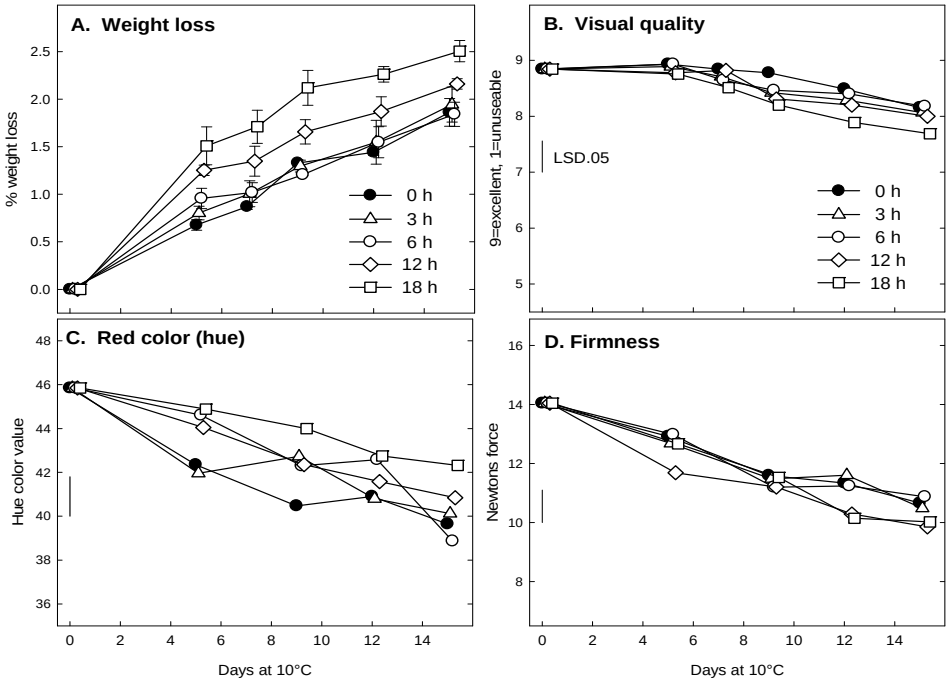

Figure 2. Weight loss, visual quality, red color and firmness of grape tomatoes (cv Amsterdam in clamshells) at 10°C after 0, 3, 6, 12 or 18 hours exposure to 30°C. Data are averages of 3 replicates of 15 fruit each. Vertical bars indicate LSD.05.

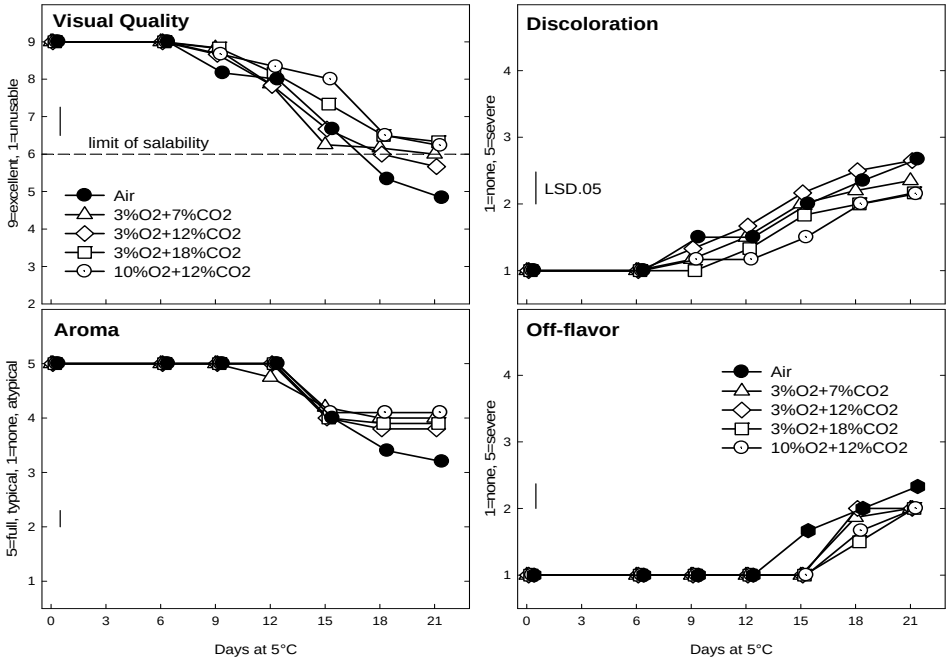

Figure 3. Visual quality, discoloration, aroma and off-flavor scores for grape tomatoes (cv Merlot) stored in air or controlled atmospheres at 5°C. Data are averages of 3 replicates. Vertical bars indicate LSD.05.