Tolerance of Grape Tomatoes to Controlled Atmospheres at Low Temperature

M. Cantwell and M. Saltveit
Mann Laboratory, Dept. Plant Sciences
University of California, Davis
CA 95616
USA

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Abstract

Grape and cherry tomatoes comprise about one quarter of retail tomato sales in the United States and are also important components in fresh-cut mixed vegetable trays. The latter require low temperatures and packaging which can produce a range of modified atmospheres (MA) to achieve 14 days of shelf-life. Postharvest handling recommendations for good tomato quality do not usually include low temperatures or MA. Storage studies were conducted to ascertain the effect of low temperatures and MA on grape tomato quality. Grape tomatoes (orange-red or more advanced color) can be stored in clamshells for up to 18 days at 5°C and still be of marketable quality if kept cold. Continuous storage at 5°C in air resulted in minimal weight loss (a significant cause of quality loss in grape tomato stored at warmer temperatures), and retention of vitamin C levels, but no lycopene synthesis, and decreased sugar concentrations. However, if fruit were transferred from 5 or 10°C to warmer temperatures (i.e., 20°C), typical chilling injury symptoms (decay, poor color formation) occurred on fruit stored at 5°C but not at 10°C. Controlled atmospheres (CA) of 3 or 10% O_2 with 0, 7, 12 or 18% CO_2 provided little or no benefit, but were tolerated by grape tomatoes for up to 21 days at 5°C. These results are based on evaluation of visual appearance, discoloration, decay, aroma, off-odors, flavor, and changes in concentrations of lycopene, sugars, vitamin C, ethanol and acetaldehyde. Although not ideal, near-ripe high quality grape tomatoes perform well as components of fresh-cut vegetable trays at low temperatures and under atmospheres not usually recommended for tomatoes.

INTRODUCTION

Offerings in the fresh market tomato category have become greatly diversified. The small size snacking tomatoes (cherry and grape types) contain high concentrations of sugars and acids, major contributors to tomato flavor, and now comprise over 20% of retail sales of tomatoes in the US (Anon., 2008; Calvin et al., 2012). These tomatoes are popular and versatile and make significant contributions to human nutrition for their content of sugars, acids, vitamins, minerals, lycopene and other carotenoids, among other constituents (Simonne et al., 2006; Toor and Savage, 2006).

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). With small fruited tomato cultivars, weight loss and symptoms of shrivel become important quality parameters, and lower storage temperatures can mitigate this quality problem (Cantwell et al., 2009).

Low O_2 (3 to 5%) atmospheres retard tomato ripening, while high levels of CO_2 (>5%) are damaging to tomatoes (Suslow and Cantwell, 2004). Low O_2 injury is characterized by uneven ripening and off-flavors due to increased levels of ethanol and acetaldehyde. Concentrations of CO_2 higher than 5% may cause surface discoloration, softening, and uneven coloration (Leshuk and Saltveit, 1990; Sargent and Moretti, 2004).

Cherry and grape tomatoes are sometimes held at lower than recommended temperatures when used as components in fresh-cut vegetables trays. These trays have an expected shelf-life of 14 to 18 days at 2 to 5°C and are often constructed to produce a modified atmosphere (MA). A few studies have characterized changes in small tomatoes stored at below recommended temperatures alone, or in combination with MA and heat treatments to reduce decay and chilling sensitivity (Akbudak et al., 2007; Ilic and Fallik, 2007).

The objective of this study was to further characterize the storage performance of grape tomatoes stored at low temperatures and in controlled atmospheres (CAs) containing high CO_2 concentrations. Fruit were evaluated as they would be used on a fresh-cut vegetable tray, i.e., without transfer to warmer temperatures.

MATERIALS AND METHODS

Three experiments were conducted. Grape tomatoes were obtained from commercial growers in Culiacan, Mexico. The storage temperature experiment used 'Amsterdam' fruit that were harvested 2 days before the experiment began. The CA experiments used 'Sweetheart' from a November harvest and 'Merlot' from a January harvest 4 and 6 days, respectively, before the experiments began. The fruit were shipped to the lab in 5 kg bulk packs at 10 to 13°C. Fruit were sorted for defects, rinsed in chlorinated water (100 ppm NaOCl pH 7.0), drained and air dried. Fruit were near orange-red when stored (color stage 5.0 to 5.5; where 5 indicates orange-red and 6 indicates full red).

Fruit were stored in commercial vented clamshells with a minimum of 15 fruit per replicate for the storage temperature test. For the CA experiments, fruit were stored in perforated plastic bags inside containers through which the CA flowed. The flow rate was adjusted to keep the CO_2 level below 0.5% for fruit held at 5°C in air. Controlled atmospheres were prepared by mixing humidified air, N_2 and CO_2 and were maintained within 5% of the indicated concentrations.

Fruit were analyzed for weight loss, subjective quality, color, firmness and composition. Fruit were subjectively evaluated at ambient temperature (ca. 20°C) within 30 min of removal from storage by 3 trained evaluators. Visual quality was scored on a 9 to 1 scale, where 9 = excellent, fresh appearance, 7 = good, 5 = fair, 3 = fair, 1 = unusable; intermediate values were used when appropriate and a score of 6 was considered the limit for marketable quality. Typical aroma, off-odors, and flavor were scored on a 1 to 5 scale, where 1 = none, 2 = slight, 3 = moderate, 4 = almost typical aroma or moderately severe, and 5 = maximum or severe. For aroma and off-odors, fruit were cut in half and immediately scored. 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. Fruit were warmed to ambient temperature for measurement of color and firmness and these measurements were completed within 2 h after removal from storage. 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 (25 mm in diameter) moving at 0.5 mm/s on a TA-XT Texture Analyzer.

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 of juice was titrated with 0.1 N NaOH to an 8.1 pH endpoint and % titratable acidity (TA) was calculated as citric acid. For fermentative volatiles, 8 g of chopped tissue was frozen at -80°C in stoppered test tubes until analysis when samples were incubated at 65°C and ethanol and acetaldehyde were determined from 1.0 ml head space samples by FID GC. Vitamin C (ascorbic acid and dehydroascorbic acid) were determined on cold 2% oxalic acid extracts, filtered and frozen at -80°C for subsequent analysis by HPLC.

Data are based on 3 replicates per treatment per evaluation. Data were analyzed by

ANOVA with mean separation by calculation of LSD.05.

RESULTS AND DISCUSSION

Storage Temperatures

Small grape tomatoes are very susceptible to water loss during handling and storage, and symptoms of shrivel, dehydration, and softening are highly correlated with weight loss. Weight loss of near ripe grape tomatoes in vented plastic consumer packaging contributed to changes in overall visual quality and firmness loss (Fig. 1). Visual quality was maintained by storing the grape tomatoes at 10°C for 12 days or at 5°C for up to 18 days. 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 but at a much lower rate than color change at 15 and 20°C. After an initial change in hue (due to a lag effect of temperature on lycopene synthesis), color change was stopped at 5°C. Soluble solids concentrations decreased only slightly with time except in fruit at 20°C in which an increase was noted. However, this was not associated with an increase in sugar concentrations (data not shown), and was likely related to the high weight loss at that temperature. TA decreased within 3 days in fruit held at 20°C, but after 12 days, the % TA had decreased to similar values in all fruit. Grape tomato fruit held continuously at 5°C performed well and retained marketable quality for over 2 weeks.

Controlled Atmospheres

In the first CA test at 5°C, grape tomato quality decreased with time mainly due to an increase in shriveling and dehydration (Fig. 2), while in the second CA test, discoloration, but not shrivel contributed to a loss of visual quality (Fig. 3). After 15 days, some CA conditions resulted in higher visual quality scores than for fruit stored in air. In both tests, fruit in air reached the limit of salability by about day 15, while some fruit in CA were of marketable appearance after 18 days. Almost all fruit were below marketable quality by 21 days. Generally, there was little perceived difference in visual appearance among the 4 CAs, although these fruit were scored slightly better after 18 days than fruit stored in air. In the first CA test there was also an increase in decay after 12 days in air stored fruit, while decay was minimal in tomatoes stored in the 4 CA conditions (data not shown); there was no decay observed in the second CA test.

Tomato aroma scores decreased notably after day 12 in both CA experiments. There were some differences among storage treatments, but in both experiments, air stored fruit were given the lowest aroma scores by day 18. There were increases in off-odor (data not shown) and off-flavor scores after day 15, but no significant differences were observed among the 5 storage conditions in either CA experiment. 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; Simonne et al., 2008).

The color values for grape tomato were quite variable but showed an overall trend to darkening (decreasing L* value) with increased storage time and these changes were independent of storage atmosphere (data not shown). Chroma and hue values remained relatively constant during storage with the exception of tomatoes stored 18 days in air in which hue values decreased significantly (i.e., there was increased red color).

In both CA experiments, average sugar concentrations decreased about 14% after 12 days and were similar among storage treatments (Tables 1 and 2). Sugar concentrations of grape tomatoes in the second CA test were higher initially than those in the first experiment, but changes during storage were greater.

Grape tomatoes have high vitamin C concentrations and these were quite stable over the 18 days storage at 5°C (Tables 1 and 2). There were no important differences in vitamin C content of grape tomatoes in relation to the storage atmospheres in the first CA experiment. In the second CA experiment, there were small differences on day 18 with fruit from 3 of the 4 CA conditions having lower vitamin C concentrations than the air-stored fruit (Table 2).

In the first CA experiment, ethanol concentrations increased considerably in the CO_2 atmospheres with 3% O_2 (Table 1), while there were only moderate increases in grape tomatoes stored in air or the 10% O_2 atmosphere. There were small increases in acetaldehyde, and the changes paralleled the changes in ethanol among the 5 storage conditions. Ethanol concentrations changed less with time in the second CA test. The most notable increases in ethanol and acetaldehyde were observed in the tomatoes stored in 3% O_2 + 12 or 18% CO_2 or the 10% O_2 + 12% CO_2 atmospheres, while there were minimal increases in the grape tomatoes stored in air or the 7% CO_2 atmosphere.

CONCLUSIONS

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. The long standing recommended temperature and atmosphere storage conditions for tomatoes also apply to grape tomatoes. However, grape tomatoes used in fresh-cut vegetable trays will tolerate 2 to 3 weeks at 5°C since the products are not transferred to warm temperatures prior to consumption. A decline in some attributes (sugars, acids, and aroma) occurs with time, but vitamin C concentrations are very stable. High CO_2 CA are not generally recommended for tomatoes, but near ripe high quality grape tomatoes tolerated a range of high CO_2 atmospheres (7 to 18% CO_2 in combination with 3 or 10% O_2) for 3 weeks at 5°C.

Literature Cited

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Tables

Table 1. Sugar, ethanol, acetaldehyde, and vitamin C concentrations of near ripe grape tomatoes of 'Sweetheart' stored in air or controlled atmospheres at 5°C (CA experiment 2). Data are averages of 3 replicates of 15 fruit each.

Atmosphere % O_2 + % CO_2	Days	Sugar (mg/ml juice)	Ethanol (µmol/100 g)	Acetaldehyde (µmol/100 g)	Vitamin C (mg/100 g)
Initial	0	32.0	43.7	6.5	45.8
Air	12	28.0	71.1	8.7	47.4
3 + 7	12	27.0	40.6	10.0	39.0
3 + 12	12	27.8	84.7	15.2	48.6
3 + 18	12	26.7	139.4	17.5	50.5
10 + 12	12	27.5	72.3	10.2	42.2
Air	18	28.1	134.8	2.6	45.3
3 + 7	18	28.8	487.1	15.5	50.7
3 + 12	18	29.8	562.2	13.9	48.7
3 + 18	18	25.7	491.7	15.4	47.1
10 + 12	18	28.7	266.2	6.9	49.1
LSD.05		4.8	56.0	3.4	ns

Table 2. Sugar, ethanol, acetaldehyde, and vitamin C concentrations of near ripe grape tomatoes of 'Merlot' stored in air or controlled atmospheres at 5°C (CA experiment 2). Data are averages of 3 replicates of 15 fruit each.

Atmosphere % O_2 + % CO_2	Days	Sugar (mg/ml juice)	Ethanol (µmol/100 g)	Acetaldehyde (µmol/100 g)	Vitamin C (mg/100 g)
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

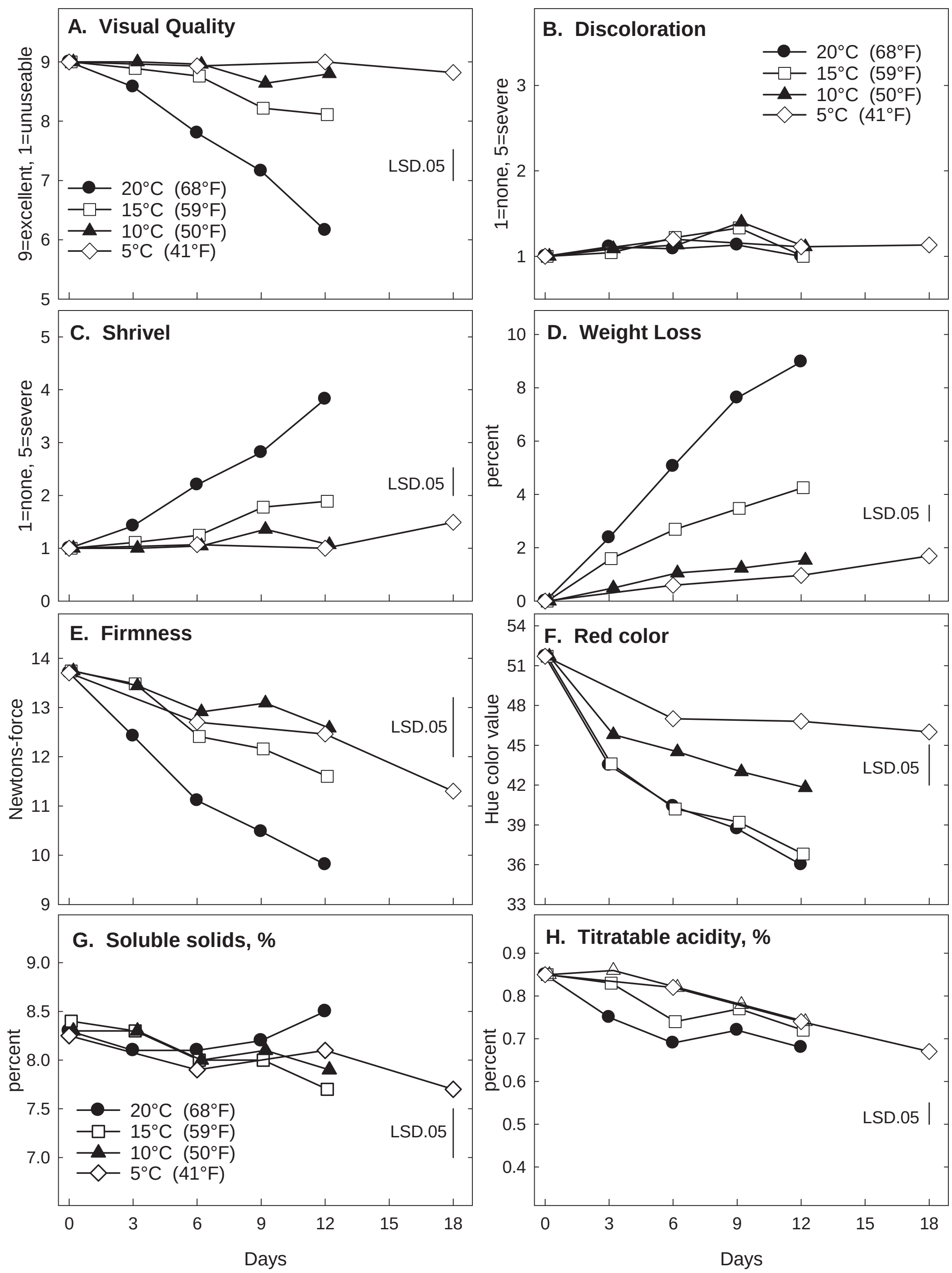

Fig. 1. Quality attributes of grape tomatoes ('Amsterdam') stored in clamshell packages at 4 temperatures. RH values averaged 36, 55, 69 and 84% at 20, 15, 10, and 5°C, respectively. Data are averages of 3 replicates of 15 fruit each. Vertical bars indicate LSD.05.

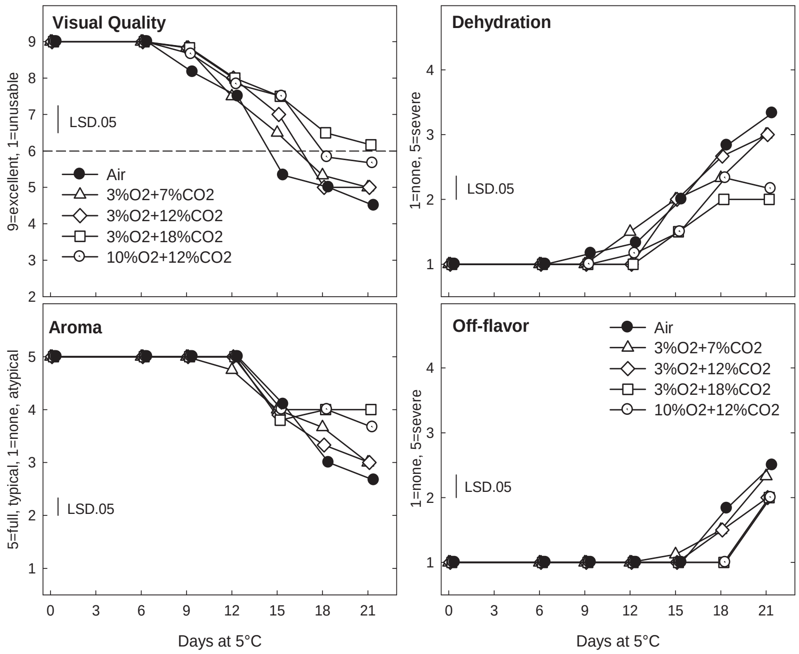

Fig. 2. Quality attributes of grape tomatoes ('Sweetheart') stored in air or controlled atmospheres at 5°C (CA experiment 1). A visual quality score of 6 indicates the limit of marketable quality. Vertical bars indicate LSD.05.

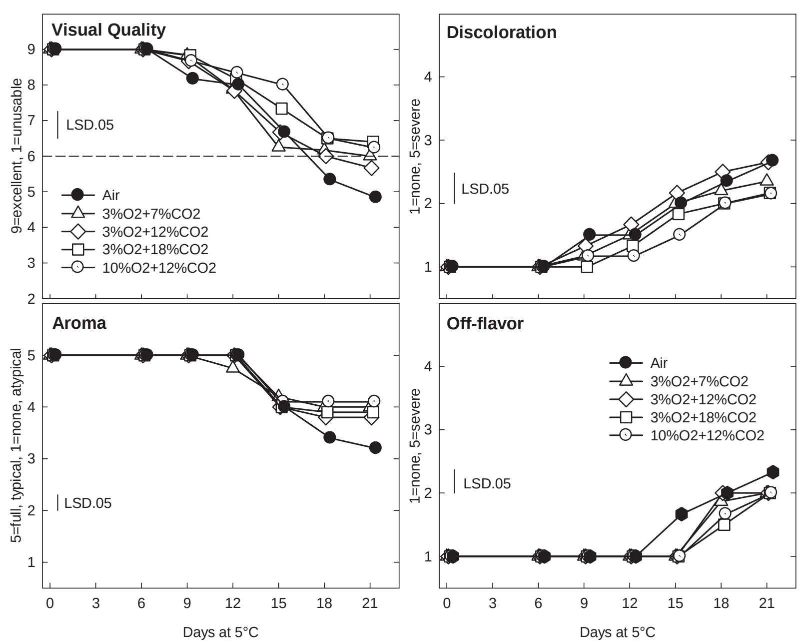

Fig. 3. Quality attributes of grape tomatoes ('Merlot') stored in air or controlled atmospheres at 5°C (CA experiment 2). A visual quality score of 6 indicates the limit of marketable quality. Vertical bars indicate LSD.05.