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PREDICTING FLAVOR POTENTIAL FOR GREEN-HARVESTED TOMATO FRUIT

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Abstract. **Fresh market tomato data collected over a 36 month harvest period show the existence of a strong linear relationship (R^2 = 0.837) between physiological maturity at harvest and length of ethylene exposure required to initiate fruit ripening. The proportion of fruit rated as immature-green (M1) ranged between 17% and 51% (31.3% average) for nine harvest dates. Two separate "difference from control" sensory tests were conducted using untrained panelists and two commercial tomato cultivars ('Agriset-761' and 'CPT-5'). 'Agriset-761' and 'CPT-5' fruit which required 3 or 5 days of ethylene treatment to initiate ripening were rated significantly different than the control samples (1 day ethylene gassing) in overall tomato flavor. Significant differences were detected in pH, titratable acidity, total sugars, or ascorbic acid content were documented for 'Agriset-761' tomato fruit that required 1, 3 or 5 days ethylene gassing. 'CPT-5' samples, on the other hand, showed significant differences only in titratable acidity among the ethylene gassing treatments. Flavor volatile concentrations showed significant differences in five out of 15 compounds quantified for 'Agriset-761' samples (acetone, hexanal, 2 + 3-methylbutanol, 2-isobutylthiazole, and β-ionone), while eight out of 15 compounds showed significant differences for 'CPT-5' samples (hexanal, 2 + 3-methylbutanol, *trans*-2-heptenal, 6-methyl-5-hepten-2-one, 2-isobutylthiazole, β-ionone, geranylacetone and ethanol). The differences in flavor attributed to the variation in physiological maturity at harvest could be predicted using ethylene gassing as a nondestructive screening tool.**

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Introduction

Tomato (*Lycopersicon esculentum* Mill.) is considered one of the major vegetable crops in terms of worldwide popularity and characteristic flavor (Wang et al., 1996). Despite tomato's popularity, numerous publications in the past 20 years have noted a rising concern among consumers regarding poor tomato flavor (Stevens, 1985; Kader et al., 1977). Tomato breeders typically develop new cultivars with traits such as superior yields, disease resistance, uniform color and extended firmness during ripening. Fruit flavor was seldom a primary goal for breeding programs (Petro-Turza, 1987); however, in the past decade, breeding for flavor has become an important consideration for the IFAS tomato breeding program led by Dr. J. W. Scott. Dissatisfaction with fresh market tomatoes has been attributed to inferior flavor and aroma, possibly affected by cultivar, cultural practices, growing conditions, maturity stage at harvest, and inadequate or inappropriate postharvest handling practices (Stevens, 1985; Kader et al., 1977; Baldwin et al., 1991).

Traditionally, tomatoes are grown in Florida during winter months and shipped to distant markets. Most are harvested at a green stage and ripening is enhanced through exposure to ethylene gas under controlled conditions. Due to the lack of accurate visible indicators of physiological maturity, commercial green harvest operations must rely almost entirely on fruit size as harvest index. It has been proposed that immature-harvested tomato fruits will never ripen properly (Brecht et al., 1991) and/or develop their full flavor potential.

The characteristic flavor of tomato fruits is the result of a complex mixture of soluble sugars, free acids, amino acids, minerals and aroma volatile compounds (Baldwin et al., 1991). Although over 400 volatile compounds have been identified in tomato fruits, less than 20 compounds are considered of importance to flavor, based on their odor thresholds. Among the important esters, aldehydes, alcohols, and ketones present in tomato flavor hexanal, *cis*-3-hexenal, *trans*-2-hexenal, 2 + 3 methylbutanol, ethanol, methanol, acetone, 6-methyl-5-hepten-2-one, geranylacetone, 2-isobutylthiazole, *trans*-2-heptenal, and β-ionone have been reported to be of considerable importance (Petro-Turza, 1987; Buttery et al., 1987; Baldwin et al., 1991). The complex interactions between the numerous volatile compounds, present in very small concentrations, gives tomatoes their characteristic flavor (Lever-Garcia, 1977).

The objective of the present study was to use difference/discrimination sensory tests to document the presence and extent of flavor differences in tomato fruits which required up to 5 days of exogenous ethylene (100 µliter/liter C_2H_4 @ 20°C) prior to attaining breaker stage (<10% red color) (USDA, 1976). In addition, a polynomial regression model was developed to predict ethylene gassing response time (in days) based on the distribution of maturity classes (M1-M4) (Kader and Morris, 1976) at harvest.

Materials and Methods

Plant Materials. A total of nine tomato harvests were conducted during the 1996 and 1997 harvest seasons in commercial tomato fields at different locations throughout the state of Florida (Table 1) to document the relationship between harvest maturity and ripening response under ethylene gas treatment. Fruit were harvested at green stage following commercial harvesting guidelines, then transported to Gainesville on the day of harvest. Tomatoes were sorted for defects and then placed inside sealed chambers where a humidified ethylene/air mixture (100 µliter/liter C_2H_4) was administered using a flow-through system. A sample of 30 to 100 green fruit from each harvest was set aside prior to ethylene gassing to determine the physiological maturity based on the development of locule gel (M1-M4) according to Kader and Morris (1976). After 1 day, 3 and 5 days of ethylene treatment, tomatoes that attained breaker stage were removed from the gassing chamber and placed at 20°C and 95% RH for subsequent ripening to table-ripe stage prior to quality analyses.

Tomatoes were considered at table-ripe stage upon reaching full red skin coloration and yielding slightly to the touch (3-mm deformation using a constant 9.8 Newton force for 5 sec). Only tomato fruit from cultivars 'Agriset-761' and 'CPT-5' harvested on 4/25/96 from experimental plots at Collier farms in Naples FL were used to document chemical composition and flavor quality changes due to harvest maturity.

Physical quality measurements. In order to document any consistent trait characterizing fruit from the different ethylene gassing requirements, fruit mass (g), fruit equatorial diameter (mm) and locule gel content (% fresh weight) data were collected. In addition, the number of days fruits required to attain the table-ripe stage (as previously defined) was also recorded.

Chemical composition analyses. Upon reaching the table-ripe stage, samples from the three ethylene gassing treatments (1 day, 3 days, and 5 days to reach breaker stage) were collected for chemical composition and volatile profile analyses. The chemical composition assays (n = 15 fruits/treatment) were pH, titratable acidity (as % citric acid), soluble solids content (°Brix), vitamin C (mg ascorbic acid/kg fresh weight), and total sugars (% of fruit fresh weight). For pH, titratable acidity and soluble solids content analyses, tomato samples were homogenized for 30 sec. at high speed using a Waring blender, then centrifuged at 18,000 g_n and 4°C for 20 min. The resulting supernatant was filtered and used for chemical composition analyses.

For the vitamin C assays, tomato homogenate (2 g/sample) were stabilized using 20-mliter of acid mixture (6% HPO_3 containing 2N acetic acid) prior to centrifugation. Vitamin C and total soluble sugars contents were analyzed using spectrophotometric methods adapted from Terada et al. (1978) and Dubois et al. (1956), respectively. Four samples of

Table 1. Physiological maturity class (M1 to M4) at harvest and response time to ethylene exposure (in days) to attain breaker stage for seven tomato cultivars harvested at five commercial operations in the state of Florida.

			Maturity at Harvest Distribution (%)				Ethylene Gassing Requirement (%)		
Harvest Date	Cultivar	Growing Area	M4	M3	M2	M1	1-Day	3-Days	5-Days
4/25/96	Agriset-761	Naples	10.0	38.0	27.0	25.0	16.6	59.7	23.7
4/25/96	CPT-5	Naples	26.5	25.9	27.1	19.5	18.7	61.6	19.7
4/25/96	BHN-102	Naples	16.0	30.0	37.0	17.0	16.3	61.3	22.4
3/24/97	Solimar	Del Ray Beach	4.2	36.5	11.4	47.9	4.8	26.6	68.6
5/15/97	Solar Set	Bradenton	8.9	10.5	26.9	53.7	8.6	53.0	38.4
6/16/97	Agriset-761	Gainesville	12.0	32.0	36.0	20.0	16.4	61.7	21.9
7/30/97	Mountain Spring	Quincy	6.9	17.2	34.5	41.4	23.9	70.1	6.0
9/26/97	BHN-189	Quincy	10.4	6.9	51.7	31.0	18.0	60.7	21.3
11/17/97	Solar Set	Gainesville	6.6	16.7	50.0	26.7	3.6	64.3	32.1

homogenate (40 mliter) were each combined with 10 mliter saturated $CaCl_2$ solution, cryogenically frozen using liquid nitrogen and stored at -80°C for GC analyses. All remaining homogenate (ca. 1000 mliter) from each cultivar and treatment was frozen and stored at -20°C until sensory analysis.

Gas chromatographic analysis. Tomato volatile compounds were identified and quantified by GC using a headspace analysis technique (Baldwin et al., 1991). Each sample was thawed under running tap water, and a 2-mliter sample was withdrawn and placed inside a 6-mliter vial and sealed with a crimp-top and Teflon-silicone septum. Vials were rapidly heated and incubated at 80°C for 15 min before injection to a Perkin Elmer HS-6 headspace-sampler heating block. The analysis was carried out using a Perkin Elmer Model 8500 gas chromatograph equipped with a 0.53 mm × 30 m polar stabilwax capillary column (1.0-μm film thickness, Restek Corp., Bellefonte, Pa.) and a flame ionization detector. Initial column temperature was held at 40°C for 6 min, then raised to 180°C at a rate of 6°C/min where it was held constant for an additional 8 min. Previous research (Baldwin et al., 1991) identified 16 important aroma volatile compounds (acetaldehyde, acetone, methanol, ethanol, 1-penten-3-one, hexanal, *cis*-3-hexenal, 2 + 3-methylbutanol, *trans*-2-hexenal, *trans*-2-heptenal, 6-methyl-5-hepten-2-one, *cis*-3-hexenol, 1-nitro-2-phenylethane, geranylacetone, 2-isobutylthiazole, and β-ionone) based on their positive log-odor values determined by Buttery et al. (1987). The GC peaks for the aroma volatile compounds of interest were quantified in μL/L using standard curves as determined by enrichment of bland tomato homogenate with authentic volatile compound standards.

Difference/Discrimination sensory tests. A "Difference from control" test was chosen for its ability to identify overall differences between samples (when compared against a control sample) while allowing panelists to rate the extent of those differences by including a hidden control sample within the treatments. Samples from 'Agriset-761' and 'CPT-5' were presented to a group of 30 untrained panelists on two separate panel sessions, one session for each cultivar. Samples from fruits that required 1-day ethylene gassing to attain breaker stage were chosen as controls.

Panelists were asked to rate the degree of difference they perceived between the control sample and three other samples (1-day "hidden control", 3-days and 5-days ethylene gassing requirement). A 12 point scale with verbal descriptors on either end was used to rate the extent of difference in the sensory test ballots (1 = no difference and 12 = extremely different). All samples were presented in plastic cups labeled with random numbers and presented in random order to panelists to avoid biased results. Following the sensory test sessions, the results from the ballots were computed, and in both cases, some degree of panelist screening was required when panelists rated the hidden control (1 day of ethylene gassing) extremely different than the control sample (1 day of ethylene gassing).

Statistical analyses and polynomial regression model. The chemical composition parameters and sensory test data were analyzed for statistical significance using ANOVA and Duncan's Multiple Range Test for separation of means at the 5% level. Harvest maturity distribution (expressed in %) was related to the number of days required for tomatoes to initiate ripening (breaker stage). In order to develop a regression model, it was assumed that immature-green fruit would require longer ethylene exposure to initiate ripening. Harvest maturity and ethylene response required to initiate ripening distributions were paired into three groups.

Percent M1 (immature-green) was compared to % fruit requiring 5 or more days of ethylene gassing, % M2 (partially mature-green) and M3 (mature-green) were combined and compared % of fruit requiring 3-days ethylene gassing. Finally, % M4 (advanced mature-green) fruit was compared to % fruit requiring 1-day ethylene gassing. The statistical relationship between the resulting comparisons was estimated with a third-order polynomial regression equation, which yielded the best fit to the experimental data (R^2) (STATISTICA v4.5, Statsoft Corp., 1994).

Results

There was considerable variation in the distribution of tomatoes classified as immature-green (M1), partially mature-green (M2), mature-green (M3) and advanced mature-green (M4) for the nine harvest dates and seven tomato cultivars (Table 1). However, the distribution of maturity classes at harvest was highly correlated to the number of days ethylene gassing required to reach breaker stage ($R^2 = 0.837$) (Fig. 1). In general, M1 fruit required longer ethylene gassing exposure (5 days) whereas M4 fruit required the shortest period (1-day).

Fruit mass varied significantly for both 'Agriset-761' and 'CPT-5' fruit. However, no consistent trend related to harvest maturity was evident. 'Agriset-761' tomatoes requiring 1-day ethylene gassing had significantly lower mass than those requiring 3- or 5-days ethylene gassing (195.5, 216.8 and 230.6 g, respectively) (Table 2). On the other hand, 'CPT-5' fruit requiring 3-days ethylene gassing had significantly greater mass when compared to tomatoes gasses for either 1 or 5 days (242.7, 195.2 and 204.9 g, respectively). Tomato fruit equatorial diameters were positively related to fruit mass, where significantly greater diameters were found in the treatments with greater fruit mass (Table 2). Locular gel content (% fresh weight basis) showed no significant difference among treatments for either cultivar. Both cultivars required approx-

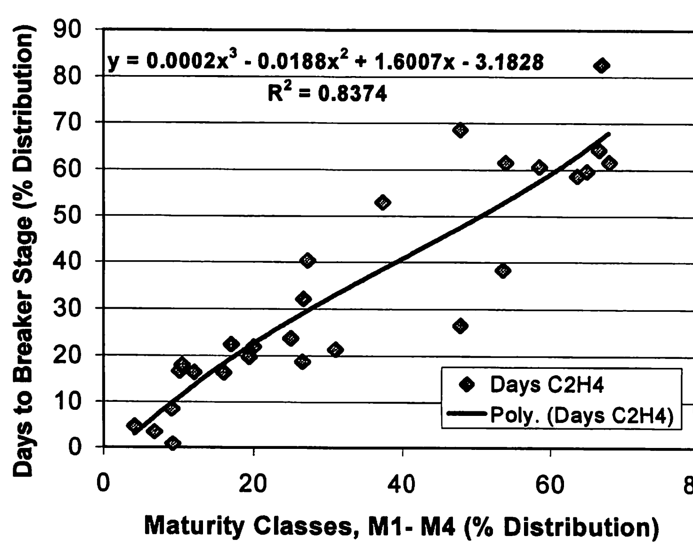

Figure 1. Polynomial regression equation describing the relationship between physiological maturity class at harvest (M1 to M4) (% distribution) and the period of ethylene gassing requirement to reach breaker stage (% distribution).

Table 2. Ripe tomato physical quality measurements for green-harvested 'Agriset-761' and 'CPT-5' tomatoes requiring 1-, 3- or 5-days ethylene gassing to attain breaker stage.

Fruit quality parameters	Pr > F[z]	Ethylene Gassing Requirement 1-Day	3-Days	5-Days
		'Agriset-761'		
Mass (g)	0.001	195.70 b	216.79 a	230.62 a
Equatorial Diameter (mm)	0.013	78.00 b	80.25 ab	82.38 a
Breaker to Table-Ripe (Days)	0.648	10.56 a	10.19 a	10.81 a
Deformation (mm)	0.148	3.96 a	4.18 a	3.91 a
Locule gel content (% fresh weight)	0.429	18.94 a	20.65 a	19.86 a
		'CPT-5'		
Mass (g)	0.001	195.23 b	242.68 a	204.91 b
Equatorial Diameter (mm)	0.001	78.63 b	85.81 a	81.25 b
Breaker to Table-Ripe (Days)	0.209	11.06 a	11.19 a	10.25 a
Deformation (mm)	0.123	4.00 a	3.94 a	4.26 a
Locule gel content (% fresh weight)	0.788	21.59 a	21.21 a	20.33 a

[z]Means for parameters with different letters within rows were significantly different at the 5% level (n = 15 fruit).

imately 10.5 days from breaker (following ethylene treatment) to table-ripe stage (Table 2).

The "difference from control" sensory tests with untrained panelists found significant differences in overall tomato flavor due to ethylene gassing requirement for both cultivars (Table 3). The panelists found lesser degree of difference between samples requiring 1-day gassing (hidden control and control samples) while the degree of difference was significantly higher between either 3-day or 5-day ethylene gassing samples and the 1-day controls.

Significant differences in pH, titratable acidity, total sugars and ascorbic acid content were found for 'Agriset-761' fruits. In general, significantly lower pH values, found in 1-day ethylene gassing samples, concurred with significantly higher titratable acidity content (Table 4). Fruit requiring 5-days ethylene gassing had significantly higher pH values while total sugars were significantly lower than either 1- or 3- days gassing requirement. Ascorbic acid content was significantly lower for 1-day fruit when compared to either 3-day or 5-day samples (9.96, 14.10 and 14.30 mg/kg fresh weight, respectively) (Table 4). In contrast, 'CPT-5' fruit showed significant chemical composition differences only in titratable acidity, where fruit requiring 3-days ethylene gassing had significantly higher citric acid contents than 1- or 5-days ethylene gassing samples (0.86%, 1.04% and 0.94% citric acid, respectively) (Table 4).

The concentrations of five flavor volatile compounds from ripe 'Agriset-761' samples were significantly different between the ethylene gassing requirements of the green-harvested fruits. Significantly higher concentrations of acetone, hexanal and 2 + 3-methylbutanol were found in fruit requiring extended ethylene gassing (5-days), whereas, 2-isobutylthiazole and β-ionone decreased significantly (Table 5). In 'CPT-5' fruit, significant differences in nine out of fifteen important flavor volatile compounds quantified were found. Tomatoes requiring extended ethylene treatments showed increased production of hexanal, trans-2-heptenal, 6-methyl-5-hepten-2-one, 2-isobutylthiazole, 1-nitro-phenylethane and

Table 3. Results from "difference from control" sensory tests conducted using ripe tomato homogenate from 'Agriset-761' and 'CPT-5' cultivars. Degree of difference ratings were based on a 12 point scale with verbal descriptors ranging from 1 (not different from control) to 12 (extremely different from control).

	Pr > F[z]	Ethylene Gassing Requirement 1-Day	3-Days	5-Days
'Agriset- 761'	0.0008	3.85 a	6.65 b	6.80 b
'CPT-5'	0.0001	3.00 a	5.90 b	7.35 b

[z]Means for tomato fruit sensory scores with different letters within rows were significantly different at the 5% level (n = 30 panelists).

Table 4. Ripe tomato chemical composition parameters for green-harvested 'Agriset-761' and 'CPT-5' fruit requiring 1-, 3- or 5-days ethylene gassing to attain breaker stage.

Chemical Composition Parameters	Pr > F[z]	Ethylene Gassing Requirement 1-Day	3-Days	5-Days
		'Agriset-761'		
pH	0.0013	4.23 b	4.28 ab	4.34 a
Soluble Solids Content (°Brix)	0.0563	3.85 a	4.02 a	3.45 a
Titratable Acidity (% Citric acid)	0.0260	0.91 a	0.81 ab	0.73 b
Total Sugars (% fresh weight)	0.023	1.93 ab	2.29 a	1.69 b
Ascorbic Acid (mg/kg fresh weight)	0.032	9.96 b	14.10 a	14.30 a
		'CPT-5'		
pH	0.230	4.25 a	4.28 a	4.23 a
Soluble Solids Content (°Brix)	0.265	3.90 a	3.90 a	4.35 a
Titratable Acidity (% Citric acid)	0.022	1.04 a	0.86 b	0.94 ab
Total Sugars (% fresh weight)	0.237	1.80 a	2.13 a	2.35 a
Ascorbic Acid (mg/kg fresh weight)	0.135	10.69 a	13.00 a	14.33 a

Table 5. Concentrations for 15 important flavor volatile compounds from ripe 'Agriset-761' fruit requiring 1-, 3-, or 5-days ethylene gassing to attain breaker stage.

Flavor Volatile Compounds[z]	Ethylene Gassing Requirement 1-Day	3-Days	5-Days
Acetone	0.82 b	0.77 b	1.69 a
Methanol	297.01 a	285.35 a	268.32 a
Ethanol	52.07 a	55.77 a	84.65 a
1-penten-3-one	0.30 a	0.24 a	0.25 a
Hexanal	13.24 ab	12.24 b	18.41 a
Cis-3-hexenal	11.06 a	8.20 a	11.03 a
2 + 3-methylbutanol	2.14 b	2.18 b	3.54 a
Trans-2-hexenal	8.32 a	6.56 a	9.23 a
Trans-2-heptenal	0.05 a	0.05 a	0.05 a
6-methyl-5-hepten-2-one	0.85 a	0.68 a	0.83 a
Cis-3-hexanol	0.05 a	0.05 a	0.05 a
2-isobutylthiazole	0.14 b	0.13 b	0.10 a
1-nitro-phenylethane	0.20 a	0.20 a	0.20 a
Geranylacetone	6.54 a	8.14 a	5.39 a
β-ionone	0.17 ab	0.45 a	0.12 b

[z]Flavor volatile compound concentrations are expressed in μliter/liter. Means for flavor volatile concentrations with different letters within rows are significantly different at the 5% level (n = 4 samples/treatment).

geranylacetone (Table 6). Meanwhile, increased production of ethanol, 2 + 3-methylbutanol and β-ionone was observed in fruit that required 3-days ethylene gassing.

Discussion

The strong relationship between tomato maturity at harvest (M1-M4) and the duration of ethylene gassing required to initiate ripening demonstrated that ethylene gassing could perhaps be utilized as a nondestructive tool to determine the physiological maturity of a population of green tomato fruit at harvest. The proportion of immature-green (M1) fruit (17% to 53.7%) correlated to the proportion of fruit requiring 5 or more days of ethylene treatment (6% to 68.6%). Chomchalow (1991) reported an average of 41% immature-green tomatoes during several commercial harvests; such a proportion is comparable to the 31.3% average found in this study.

The lack of dependable visual indicators of physiological maturity for green tomatoes was demonstrated by the inconsistent results relating fruit mass or diameter to maturity at harvest. Such physical properties as mass, volume or density would be easily measured by modern optical sorting equipment available at commercial tomato packinghouses. The rate of tomato ripening, following ethylene gassing treatment, was not significantly influenced by the physiological maturity of the fruit. However, if the length of the ethylene treatment required for ripening initiation was considered, those fruit that required longer ethylene treatments would apparently have a longer postharvest life.

Sensory tests demonstrated that untrained panelists could detect overall ripe flavor differences for both cultivars as a function of their green-harvest maturity. Previous researchers (Kader et al., 1977; Watada and Aulenbach, 1979) have alluded to such sensory differences related to fruit maturity at harvest. There was a trend of increased degree of difference from the control (1-day gassing) with increased ethylene gassing requirement to initiate ripening. Descriptive sensory panels have revealed that fruit requiring extended ethylene treatments resulted in significantly reduced ripe tomato aroma, flavor and sweetness, increased sourness and green/grassy flavor notes when compared to brief ethylene requirement and ripe-harvested fruit (Maul et al., unpublished).

The perceived sensory differences were supported by significant changes in tomato fruit chemical composition. 'Agriset-761' tomatoes harvested at immature-green stage had higher pH values, lower titratable acidity and total sugars at table-ripe stage. 'CPT-5' tomatoes, on the other hand, showed significant changes in titratable acidity only. The magnitude of pH and acidity variations required for sensory perception have been reported by Gould (1978). Changes in pH greater than 0.16 units and of 0.1% for titratable acidity would be required for sensory detection. Therefore, differences in overall flavor could be partly attributed sugar and/or acid composition changes for both cultivars.

Several panelists noted "unpleasant", "metallic", "strange" or "lingering" off-flavors in tomato samples requiring extended ethylene treatments. Hayase et al. (1984) reported tomatoes picked at an unripe stage and ripened postharvest occasionally presented off-flavors, substantially weakening their characteristic tomato flavor. There is limited quantitative evidence for the characterization of individual flavor volatiles and their contribution to overall fresh tomato flavor/aroma (Goodenough, 1990). Nonetheless recent publications have reported significant flavor volatile concentration differences found in different tomato cultivars (Baldwin et al., 1991) and postharvest treatments (McDonald et al., 1996).

'Agriset-761' tomatoes showed significant changes in five out of 15 important flavor volatiles quantified, while 'CPT-5' tomatoes showed concentration differences in nine out of 15 compounds. For both cultivars, concentrations of 2 + 3-methylbutanol, geranylacetone and β-ionone were significantly affected by fruit maturity at harvest. In general, volatile compound concentrations increased in fruit requiring longer ethylene treatments to initiate ripening. In contrast, McDonald et al. (1996) reported reductions in six flavor volatile compounds requiring 1-day ethylene treatment (when compared to non-gassed controls); changes in concentrations of hexanal, 6-methyl-5-hepten-2-one, geranylacetone and 2 + 3-methylbutanol were also observed in the present study. Significant reductions in 6-methyl-5-hepten-2-one, 2-isobutylthiazole and geranylacetone found in 'Solimar' tomatoes requiring extended ethylene treatment (Maul et al., 1998) further supports the relevant effect of harvest maturity on ripe tomato flavor/aroma.

Changes in the concentrations of 2-isobutylthiazole, a flavor volatile unique to tomato fruit, are noteworthy due to the compound's low odor threshold concentrations of 2 ppb in aqueous solutions (Buttery et al., 1987) and 36 ppb in bland tomato homogenate (Tandon, 1998). In aqueous solutions with concentrations above 50 ppb, 2-isobutylthiazole has been reported to impart "medicinal", "rancid" and "metallic" aroma notes (Kazeniac and Hall, 1970). The task of identifying individual flavor volatiles responsible for the overall flavor differences and off-flavors/off-odors perceived by the untrained panelists would require further studies employing descriptive sensory tests using trained panelists.

In conclusion, the changes in chemical composition and flavor volatile compounds documented for 'Agriset-761' and 'CPT-5' tomatoes induced significant sensory perception differences. Volatile compounds such as 2 + 3-methylbutanol, geranylacetone, hexanal and β-ionone consistently showed

Table 6. Concentrations for 15 important flavor volatile compounds from ripe 'CPT-5' fruit requiring 1-, 3-, or 5-days ethylene gassing to attain breaker stage.

	Ethylene Gassing Requirement		
Flavor Volatile Compounds[z]	1-Day	3-Days	5-Days
Acetone	1.01 a	1.72 a	1.23 a
Methanol	268.50 a	301.65 a	282.44 a
Ethanol	70.20 ab	100.48 a	38.53 b
1-penten-3-one	0.28 a	0.28 a	0.33 a
Hexanal	17.66 b	16.84 b	25.34 a
Cis-3-hexenal	8.80 a	11.30 a	9.51 a
2 + 3-methylbutanol	2.29 b	3.15 a	2.80 b
Trans-2-hexenal	10.41 a	8.83 a	10.23 a
Trans-2-heptenal	0.06 ab	0.05 b	0.07 a
6-methyl-5-hepten-2-one	0.93 ab	0.75 b	1.11 a
Cis-3-hexanol	0.06 a	0.06 a	0.05 a
2-isobutylthiazole	0.13 ab	0.11 b	0.14 a
1-nitro-phenylethane	0.22 b	0.21 b	0.32 a
Geranylacetone	6.64 b	7.83 ab	8.87 a
β-ionone	0.13 b	0.22 a	0.17 ab

[z]Flavor volatile compound concentrations are expressed in μliter/liter. Means for flavor volatile concentrations with different letters within rows are significantly different at the 5% level (n = 4 samples/treatment).

significant concentration changes in this study and confirming results published elsewhere, thus, suggesting their relative susceptibility to the effects of harvest maturity. The development of regression models, such as this polynomial model relating harvest maturity and ripening response time under ethylene treatment (Fig. 1), could help commercial green-harvest operations to optimize harvesting and ethylene gassing schedules to minimize the proportions of potentially inferior flavored immature-green fruit.

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CONSUMER PREFERENCES FOR 'FUYU' PERSIMMONS GROWN IN NORTH-CENTRAL FLORIDA[1]

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Abstract. **'Fuyu' non-astringent persimmons (*Diospyros kaki* L.) were harvested at two ripeness stages from a commercial orchard in Chiefland, Florida. Fruit from Harvest 1 (13 October, 1997) were picked at the earliest ripeness stage for commercial harvest (mostly yellow with a slightly green tint) and were stored at 1°C and about 85% relative humidity for 15 days. Fruit from Harvest 2 (28 October) were picked mid-season (full yellow). The same day of Harvest 2 fruits from both harvests were stored overnight at 20°C. Consumer taste tests were performed 29 and 30 October at two Gainesville supermarkets. Shoppers (n = 104) were presented peeled, unlabeled wedges and asked to rate several quality attributes on a scale of 1 (Dis-**

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