Effect of Harvest Maturity on the Final Fruit Composition of Cherry and Large-fruited Tomato Cultivars

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Abstract. Fruit of 2 cherry tomato (Lycopersicon esculentum var. cerasiforme Aef.) cultivars [‘Large Red Cherry’ (‘LRC’) and ‘Small Fry’ (‘SF’)] and 2 large-fruited tomato (Lycopersicon esculentum Mill.) cultivars (‘Duke’ and ‘Sunny’) were harvested green, ripened at 23°C, and analyzed for sugars and organic acids 6 days after breaker stage. Both fructose and glucose concentration increased in ‘LRC’ and ‘SF’ fruit with less-mature harvested fruit. Maturity at harvest had no effect on the concentration of either sugar in ‘Duke’ or ‘Sunny’ fruit. ‘LRC’ had the highest fructose and glucose concentration among cultivars. Increased citric acid concentration was found with less-mature harvested fruit, except in ‘LRC’. Malic acid concentration within cultivars was similar in the fruit harvested more mature, but decreased with less-mature fruit in ‘Duke’ and ‘Sunny’. ‘LRC’ and ‘SF’ fruit had more citric and malic acid than ‘Duke’ or ‘Sunny’. Cherry tomato cultivars had a higher percentage of locular tissue than the large-fruited cultivars.

Vine-ripened tomato fruit are generally better in overall quality and flavor than those harvested mature-green and room-ripened (2, 13, 23). The majority of large-fruited and cherry tomatoes grown in the United States and Mexico, however, are picked green for economic reasons and to withstand current methods of handling and transportation. Commercially harvested green fruit require one to 3 weeks at 20°C to ripen, indicating the wide range of maturity of green fruit picked at any given harvest.

Sugars and organic acids are major contributors to overall flavor intensity (7, 11, 21, 22). It is not known if the individual sugars and organic acids attain the same levels in room-ripened tomato fruit harvested at different stages of maturity and how the levels compare to vine-ripened fruit. Kader et al. (13) found no significant difference in total reducing sugar content between vine-ripened ‘Cal-Ace’ tomatoes and those harvested green and room-ripened. Some workers found no differences in pH and soluble solids content between mature-green harvested, room-ripened fruit and vine-ripened fruit (2, 23), whereas others reported vine-ripened fruit to have higher pH and soluble solids (13–15). Titratable acidity was reported to be higher (23), similar (2, 13), or lower (12, 14, 15) in vine-ripened vs. mature green-harvested and room-ripened fruit. Differences in flavor volatiles have been reported between vine-ripened and room-ripened tomatoes (4, 13, 19, 23).

The objective of this study was to determine if the individual sugar and organic acid levels in green-harvested, room-ripened cherry and large-fruited tomatoes are different in fruit picked at different stages of maturity and to compare these amounts to vine-ripened (table-ripe stage) fruit.

Materials and Methods

Fruit source. Two cherry tomato cultivars [‘Large Red Cherry’ (‘LRC’), ‘Small Fry’ (‘SF’)] and 2 large-fruited fresh market cultivars (‘Duke’ and ‘Sunny’) were grown at the LSU Hill Farm, Baton Rouge, La., during Spring 1984 following commercially recommended cultural practices.

Harvest maturity study. Green fruit of marketable size from each cultivar were picked on 8 June and ripened at 23°C, 75% RH, under cool-white fluorescent lights. Sugars and organic acids were determined 6 days after the breaker stage (incipient color at the stylar end) in cherry tomato fruits that took 1, 3, 5, 7, 9, 11, 13, 15, or 17 days after harvest to reach breaker stage, and in large-fruited tomato fruits that took 1, 3, 5, 7, 9, or 11 days after harvest to reach breaker stage. Attention was given to selecting fruit of similar size among harvest maturities but, unavoidably, the less mature the fruit, the smaller the size. Vine-ripened fruit were harvested on 20 June at the table-ripe stage for a reference comparison to those harvested green and room-ripened. Five replications of 10 fruits from each maturity class were analyzed.

Sugar and organic acid analyses. The 10 whole fruit (cherry cultivars) or 10 equal and opposite selected quarters (large-fruited cultivars) from each replication were homogenized in a Waring blender for 1 min. Exactly 20 g of homogenate was boiled in about 100 ml of 80% ethanol for 15 min, cooled, and filtered through Whatman #4 paper. The residue and original container were washed with additional 80% ethanol and brought to a final volume of 100 ml. About 5 ml was filtered through a 0.45-μm membrane and 20-μl samples were injected into separate HPLC systems; one for sugars, the other for organic acids.
Sugars were quantified with a Beckman 341 HPLC equipped with a refractive index detector and Bio-Rad Aminex HPX-87C column heated to 75°C. The mobile phase was H₂O at a flow rate of 1.2 ml·min⁻¹.

Organic acids were quantified with a Beckman 341 HPLC equipped with an ultraviolet detector (214 nm) and Bio-Rad HPX-87H column heated to 75°C. The mobile phase was 0.0008 N H₂SO₄ at a flow rate of 0.8 ml·min⁻¹.

Tissue portions. Fifteen table-ripe fruit from each cultivar were weighed, cut in half, and the locular portion (placenta, seeds, and jelly) was separated from the pericarp, which included the septa. Weights of the locule and pericarp portions were determined and expressed as a percentage of the whole fruit weight.

Results and Discussion

Fruit appearance. Fruit from all green maturity classes ripened to a saleable red color stage, based on subjective visual observations. ‘Duke’ and ‘Sunny’ fruit, which required 11 days, and cherry tomatoes, which required more than 13 days to reach the breaker stage, were less red after ripening than vine-ripened fruit. Slight shriveling was observed in cherry tomato fruit requiring 15 and 17 days to turn color. ‘Duke’ and ‘Sunny’ fruit requiring 9 and 11 days to turn color had, after ripening, less internal red pigmentation and more hard white pericarp and septa tissue than fruit harvested more mature.

Sugar content. Concentrations of fructose (Fig. 1) and glucose (Fig. 2) declined in the less-mature harvested fruit of cherry tomatoes that had been room-ripened. Fructose and glucose concentrations in fruit of the room-ripened, large-fruited cultivars were similar, regardless of harvest maturity, indicating that sugar content in green-harvested ‘Duke’ and ‘Sunny’ fruit would not be affected adversely by premature vine detachment from one to 11 days before breaker stage. Both cherry tomato cultivars required vine attachment for maximum sugar development. Of all cultivars, fruit of ‘LRC’ had the highest levels of monosaccharides at any given harvest maturity. Among the large-fruited cultivars, ‘Sunny’ had slightly more fructose and glucose than ‘Duke’. ‘SF’ had the lowest fructose concentration of all cultivars in fruit, which required 3 days or longer to reach the breaker stage, and the lowest glucose concentration of all cultivars in room-ripened, green-harvested fruit.

The fructose and glucose concentration in breaker minus one-day harvested fruit was less than the concentration found in vine-ripened fruit (Table 1), indicating that tomato fruit must remain attached to the vine until the table-ripe stage for attainment of highest sugar levels. The sugar content of green-harvested fruit was expectedly lower than vine-ripened fruit because of premature elimination of photosynthate translocation from the leaves coupled with respiratory loss of existing sugar. Several workers found more reducing sugars in vine-ripened fruit than in those picked at the mature-green or breaker-stage in large-fruited types (1, 12, 13) and in a cherry cultivar (13). McCollum and Skok (17) found labeled ¹⁴C-glucose applied to the leaf continued to be translocated into fruits up to 10 days after the breaker stage, even though increased glucose was translocated into developing green fruit.

Fructose was the major sugar in all cultivars, whether vine-ripened or picked green and room-ripened (Table 1). In other tomato cultivars, the free sugars also consisted mainly of fructose and glucose, with fructose present in a slightly increased amount (6, 8, 20). In vine-ripened fruit, the cherry tomato cultivars had a much higher concentration of both monosaccharides than the large-fruited cultivars, which was in agreement with previous studies (13, 22).

Fructose : glucose ratio was similar among vine-ripened and green-harvested fruit of different maturities and cultivars, except that ‘SF’ fruit had a slightly higher ratio in the less-mature fruit (Table 2). Perhaps similar pathways of sugar metabolism were followed in vine-ripened and room-ripened fruit.

Sucrose was found in very small amounts in green-harvested (Fig. 3) and vine-ripened fruit (Table 1), in agreement with the amounts reported by Davies and Kempton (7). The relation between sucrose concentration and fruit maturity at harvest was
Table 1. Sugar and organic acid concentration comparison between vine-ripened (VR) tomato fruit and breaker minus one day green-harvested, room-ripened (RR) fruit.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Fructose VR (percentage of fresh wt)</th>
<th>RR</th>
<th>Glucose VR (percentage of fresh wt)</th>
<th>RR</th>
<th>Sucrose VR (percentage of fresh wt)</th>
<th>RR</th>
<th>Organic acid Citric VR (percentage of fresh wt)</th>
<th>RR</th>
<th>Malic VR (percentage of fresh wt)</th>
<th>RR</th>
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<tbody>
<tr>
<td>LRC</td>
<td>2.00</td>
<td>1.78*</td>
<td>1.67</td>
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<td>0.03</td>
<td>0.05*</td>
<td>0.55</td>
<td>0.64</td>
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<tr>
<td>SF</td>
<td>1.77</td>
<td>1.33*</td>
<td>1.40</td>
<td>0.78*</td>
<td>0.03</td>
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<td>0.77</td>
<td>0.73</td>
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<td>0.10*</td>
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<tr>
<td>Duke</td>
<td>1.36</td>
<td>1.25</td>
<td>1.09</td>
<td>0.95*</td>
<td>0.04</td>
<td>0.03</td>
<td>0.38</td>
<td>0.37</td>
<td>0.07</td>
<td>0.05</td>
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<tr>
<td>Sunny</td>
<td>1.46</td>
<td>1.28*</td>
<td>1.20</td>
<td>1.03*</td>
<td>0.02</td>
<td>0.03</td>
<td>0.41</td>
<td>0.44</td>
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<tr>
<td>LSD (5%)</td>
<td>0.16</td>
<td>0.18</td>
<td>0.17</td>
<td>0.14</td>
<td>0.01</td>
<td>0.01</td>
<td>0.11</td>
<td>0.13</td>
<td>0.02</td>
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*Significant differences within rows between single comparisons of VR and RR components indicated by asterisk, based on Student’s t test, 5% level.


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<tr>
<th>Harvest maturity</th>
<th>Fructose : glucose</th>
<th>LRC</th>
<th>SF</th>
<th>Duke</th>
<th>Sunny</th>
<th>Fructose + glucose : citric + malic</th>
<th>LRC</th>
<th>SF</th>
<th>Duke</th>
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<td>4.0</td>
<td>5.5</td>
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<td>LSD (5%)</td>
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<td>0.2</td>
<td>NS</td>
<td>NS</td>
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more variable than that of the monosaccharides (Fig. 3). Less mature fruit generally contained increased sucrose, except for ‘LRC’, which had the most sucrose in fruit harvested at breaker minus 3 days. Sucrose concentration was similar between vine-ripened and breaker minus one day harvested fruit in all cultivars except ‘LRC’, which had more sucrose in room-ripened fruit (Table 1).

Organic acid content. The less mature the fruit were at harvest, the higher the citric acid concentration was after ripening, except in ‘LRC’, which had a similar citric acid concentration in fruit from all harvest maturities (Fig. 4). The cherry tomato cultivars had more citric acid than the large-fruited cultivars. In contrast to these results, Hall (10) found less locule acidity and no difference in pericarp acidity in large-fruited cultivars from less mature green-harvested fruit. Cultivar differences in acid content at harvest and different rates of organic acid change during the ripening period may explain the contrasting results. Organic acid accumulation in detached fruit is determined by metabolite levels at the time of detachment. Sakiyama and Stevens (18) found detached immature-green fruit to increase in titratable acidity at a higher rate than attached fruit.

Concentration of citric acid, the major organic acid, was similar between breaker minus one day-harvested fruit and vine-ripened fruit (Table 1) in all cultivars. ‘SF’ and ‘LRC’ had higher concentrations of citric acid than ‘Sunny’ and ‘Duke’ in

Fig. 3. Sucrose concentration in room-ripened tomato fruit picked at different stages of green maturity. Bars represent se of the mean.
Fig. 4. Citric acid concentration in room-ripened tomato fruit picked at different stages of green maturity. Bars represent ±SE of the mean.

The change in malic acid concentration with fruit maturity differed between cultivars. In ‘Duke’ and ‘Sunny’ fruit, no difference in malic acid was found between fruit requiring one to 7 days to reach the breaker stage, but less mature fruit had less malic acid after ripening. In green-harvested ‘SF’ fruit, malic acid concentration was similar regardless of whether it took one or 17 days to reach the breaker stage, and fairly similar amounts were found between fruits of the different harvest maturities in ‘LRC’ also. Malic acid concentration was higher in green-harvested cherry tomatoes than in the large-fruit cultivars.

Malic acid concentration was less in vine-ripened fruit than in breaker minus one day harvested fruit in the cherry tomato cultivars, but was similar among the large-fruited types (Table 1).

Sugar : acid ratio. Sugar : acid ratio is often used to estimate quality but the quantitative amount of sugar and acids should also be reported with the ratio, since different cultivars of a similar sugar : acid ratio may be perceived as quite different in flavor characteristics (22). The sugar : organic acid ratio decreased in less-mature fruit in all cultivars (Table 2). In cherry tomatoes, this decrease was the result of a decreasing sugar concentration, while organic acids remained stable or slightly increased. In large-fruit cultivars, the decrease was the result of a stable sugar concentration and increasing citric acid. Vine-ripened fruit had the highest sugar : acid ratio because of the greatest sugar concentration. Among cultivars, ‘SF’ fruit had the lowest sugar : acid ratio because of low sugar content coupled with a high citric acid concentration. The other 3 cultivars had similar ratios for vine-ripened fruit, but ‘Duke’ had a higher ratio and ‘LRC’ a lower ratio for green-harvested fruit. Under the assumption that high sugar : acid ratios improve flavor characteristics, less desirable flavor would exist in less-mature green-harvested fruit, especially ‘SF’.

Tissue portion. The cherry tomato cultivars had a higher percentage of locular tissue (34–37% of total fruit weight) than the large-fruit cultivars (20–23% total fruit weight). There was no significant difference between cultivars of the same type. Previous workers also found similar locular values (20–25%) for large-fruit cultivars (2) and 35% for a cherry cultivar (20). Differences between cultivars in fruit composition may be attributed to genetic differences and to different proportions of pericarp to locule tissue. It has been established that the locule fraction contains more titratable acidity (3, 7, 9, 15, 16, 20), more citric acid and more or similar malic acid (5, 16, 20), and less glucose and similar fructose (20) compared to the pericarp portion.

Sugar and organic acid composition differed between cherry and large-fruit tomato types, cultivars within types, and harvest maturity. The results indicated that sugar content in ‘LRC’ and ‘SF’ fruit would be more adversely affected by premature vine detachment than in ‘Duke’ or ‘Sunny’. Maximum sugar development in all cultivars required vine attachment until the table-ripe stage. Vine-ripened fruit of both cherry tomato cultivars were higher in sugars and organic acids than the large-fruit types. Green harvested, room-ripened ‘SF’ fruit contained the lowest total sugar concentration among cultivars. Sensory evaluations are needed to establish the relationship between composition and flavor, although sugar and organic acid levels may be useful indicators of flavor quality.

Literature Cited


3. Brecht, P.E., L. Keng, C.A. Bisogni, and H.M. Munger. 1976. Effect of fruit portion, stage of ripeness and growth habit on...
chemical composition of fresh tomatoes. J. Food Sci. 41:945–948.


**Relationship of Netted Muskmelon Fruit Water Loss to Postharvest Storage Life**

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Additional index words. Cucumis melo, senescence, β-carotene, quality, shrink-wrap film, carbohydrates, firmness, postharvest decay, electrolyte leakage

**Abstract.** ‘Maggot 45’ muskmelon fruit, (Cucumis melo L. var. reticulatus Ser.) either shrink-film-wrapped to maintain a water-saturated microatmosphere or nonwrapped, were stored in 4°C, 85–95% RH, and were sampled at 10-day intervals for 40 days postharvest. Fruits maintained in a water-saturated microatmosphere via shrink-wrap exhibited no significant change in percentage of dry weight, firmness, soluble sugars, β-carotene, or a loss of membrane integrity throughout 40 days storage. Shrink-wrap fruit had a 1% reduction in fresh weight, and a decline in appearance rating and surface browning by 40 days postharvest but were generally rated as excellent to good salable quality. Unwrapped fruit maintained in 85–95% RH exhibited progressive decline in appearance, surface browning, percentage of dry weight, soluble sugars, mesocarp firmness, and loss of membrane integrity. No change was observed in β-carotene. Nonwrapped fruit had a 5.7% reduction in fresh weight within 20 days postharvest and were generally rated as fair to poor salable quality. Mesocarp membrane integrity during postharvest storage was highly dependent on percentage of fresh weight loss over time for both shrink-film-wrapped and nonwrapped muskmelon fruit.

Hard, ripe, netted muskmelon fruit have a normal postharvest storage life of about 14 days (10) and become soft and shiveled even when stored under cool, high-humidity conditions. Evidence suggests that the open, netted rind serves as the site for transpiration, and thus contributes to the relative short storage life of reticulatus fruit (unpublished data). Softening and storage life are highly correlated with declining water potentials in non-climacteric citrus and bell pepper fruit (3). Therefore, maintaining fruit in a water-saturated microatmosphere should delay changes related to senescence, such as deterioration of membrane integrity and softening (2). It has been suggested for cli-