Mature Fruit Vegetables

Tomatoes

- Maturity at harvest critical for quality
- Chilling sensitive, but variable in sensitivity
- Ethylene can control ripening
- Moderate respiration rates; can be stored

Marita Cantwell, UC Davis
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Ch. 33 Postharvest Technology Book

Tomato Quality Attributes

- Size, shape
- Condition
  - no damage
  - no decay
- Texture
  - Firmness, mealiness, juiciness, slice integrity
- Color
  - Red color and lycopene content
- Flavor and Composition
  - Sugars
  - Acids
  - Aroma volatiles
  - Vitamins

Tomato matur-

Maturity & Ripening Stages

1. GREEN: The tomato surface is completely green. The shade of green may vary from light to dark.

2. BREAKERS: There is a definite break of color from green to bruised fruit. Tannish-yellow, pink or red or 10% or less of the tomato surface.

3. TURNING: Tannish-yellow, pink or red color shows on over 10% but not more than 30% of the tomato surface.

4. PINK: Pink or red color shows on over 30% but not more than 90% of the tomato surface.

5. LIGHT RED: Pinkish-red or red color shows on over 60% but red color covers not more than 90% of the tomato surface.

6. RED: Red means that more than 90% of the tomato surface, in aggregate, is red.

http://www.tomato.org/
http://www.fioridatomatoes.org/

PROBLEMATIC!

Tomato mature-green & breaker stages

<table>
<thead>
<tr>
<th>Immature</th>
<th>MG1</th>
<th>MG2</th>
<th>MG3</th>
<th>Br</th>
</tr>
</thead>
</table>

http://www.tomato.org/food/color.html

Ripening mutants retard the ripening process

Example: Tomato rin mutant
Firmness Classes for Tomatoes

<table>
<thead>
<tr>
<th>Firmness Class</th>
<th>Description</th>
<th>Firmness (Newtons force to compress 5 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very firm</td>
<td>yields slightly to considerable finger pressure</td>
<td>30-50</td>
</tr>
<tr>
<td>Firm</td>
<td>yields slightly to moderate finger pressure</td>
<td>20-30</td>
</tr>
<tr>
<td>Moderately firm</td>
<td>--</td>
<td>15-20</td>
</tr>
<tr>
<td>Moderately soft</td>
<td>yields readily to moderate finger pressure</td>
<td>10-15</td>
</tr>
<tr>
<td>Soft</td>
<td>yields to slight finger pressure</td>
<td>10</td>
</tr>
<tr>
<td>Very soft</td>
<td>yields very readily to slight finger</td>
<td>5</td>
</tr>
</tbody>
</table>

Other Textural Characteristics

<table>
<thead>
<tr>
<th>Slice Integrity</th>
<th>Mealiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newton = 9.81 kp-force or 4.45 pound-force</td>
<td></td>
</tr>
</tbody>
</table>

Tomato Color

Carotenoids
- β- and other carotenones
- Lycopene (90%)

Other Textural Characteristics

Slice Integrity

<table>
<thead>
<tr>
<th>Tomato Color</th>
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<tbody>
<tr>
<td>Hue</td>
</tr>
<tr>
<td>Pink-Orange</td>
</tr>
<tr>
<td>Orange-Red</td>
</tr>
<tr>
<td>Red</td>
</tr>
<tr>
<td>Dark Red</td>
</tr>
</tbody>
</table>

Lycopene in the pericarp, mg/kg FW

Typical Objective Color Values for Tomatoes

ACIDS

<table>
<thead>
<tr>
<th>Flavor and Sugar: Acid Ratio</th>
</tr>
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<tbody>
<tr>
<td>ACIDS</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Moderate to High</td>
</tr>
<tr>
<td>Low</td>
</tr>
</tbody>
</table>

Soluble solids measured by a refractometer = sugars, but also organic acids, soluble pectins, anthocyanins, phenolic compounds, ascorbic acid

Flavor and Sugar: Acid Ratio

- Sugars (4-8%)
- Acids (0.2-0.8%)
- Aroma volatiles (ppm)

We estimate flavor by measuring sugars (soluble solids) and acids (titratable acidity)
**Tomato Type & Composition, U.S. Retail**

<table>
<thead>
<tr>
<th>Tomato Type</th>
<th>% Soluble Solids</th>
<th>% Titratable Acidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grape</td>
<td>7.55</td>
<td>0.62</td>
</tr>
<tr>
<td>Cherry</td>
<td>6.25</td>
<td>0.67</td>
</tr>
<tr>
<td>Orange Cluster</td>
<td>4.70</td>
<td>0.44</td>
</tr>
<tr>
<td>Round</td>
<td>4.65</td>
<td>0.33</td>
</tr>
<tr>
<td>Roma</td>
<td>4.65</td>
<td>0.51</td>
</tr>
<tr>
<td>Round Cluster</td>
<td>4.30</td>
<td>0.35</td>
</tr>
</tbody>
</table>

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<th>% Soluble Solids</th>
<th>% Titratable Acidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherry</td>
<td>7.10</td>
<td>0.77</td>
</tr>
<tr>
<td>Campari</td>
<td>6.30</td>
<td>0.58</td>
</tr>
<tr>
<td>Romanita</td>
<td>0.30</td>
<td>0.44</td>
</tr>
<tr>
<td>Grape</td>
<td>5.60</td>
<td>0.61</td>
</tr>
<tr>
<td>Round greenhouse</td>
<td>4.50</td>
<td>0.36</td>
</tr>
</tbody>
</table>

**Composition of Ripe Grape Tomato**

**Harvested at 3 Stages of Maturity**

<table>
<thead>
<tr>
<th>Initial Maturity Stage</th>
<th>Weight fruit, g</th>
<th>Red color, hue</th>
<th>Firmness, N force</th>
<th>Soluble solids, %</th>
<th>Sugars mg/mL</th>
<th>Titratable acidity, %</th>
<th>Vitamin C mg/100mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4.9</td>
<td>36.8</td>
<td>11.5</td>
<td>5.9</td>
<td>27</td>
<td>0.59</td>
<td>96</td>
</tr>
<tr>
<td>4</td>
<td>5.7</td>
<td>36.3</td>
<td>13.6</td>
<td>6.7</td>
<td>30</td>
<td>0.66</td>
<td>97</td>
</tr>
<tr>
<td>5</td>
<td>5.9</td>
<td>37.7</td>
<td>13.7</td>
<td>7.5</td>
<td>33</td>
<td>0.67</td>
<td>99</td>
</tr>
</tbody>
</table>

**Minimum harvest stage should be Stage 4 (pink-orange)**

Average 7 cvs, Cantwell, 2003

**Checker boarding**

Should never be a problem with vine ripe tomatoes!

**At Packhouse**

**At Distribution**

**Storage of Tomatoes**

- 12.5°C (55°F)
- No lower than 10°C (50°F)
- 2-3 weeks
- Controlled atmospheres
  - 3% O2, <3% CO2
  - Relative humidity ~85%

**Avoid chilling temperatures for tomatoes**

Too low temperature (<10°C <50°F)
- Reduces flavor
- Affects ability to ripen
- Increases decay
Low temperatures reduce aroma volatiles. 
\textit{z-3} hexanal as example of important volatile.

Table-ripe tomatoes stored for 6 days
\begin{table}[h!]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
Storage temperature, °C & 5 & 10 & 15 & 20 \\
\hline
\textit{z-3} hexanal, ppm & 6.0 & 9.8 & 9.3 & 9.9 \\
\hline
\end{tabular}
\end{table}

More recent research shows that 10°C is too low for good aroma profile.

Cantwell, UC Davis, unpublished.

It is quite common that tomatoes are held at 45°F. Results in decay and poor color.

Cv Bobcat, round field-grown variety
2006 Ara and Cantwell.

Most of the fruit stored longer than 1 week at 5 and 7.5°C (41 and 45°F) had decay and did not ripen.

Fruit stored at 0°C and 7.5°C that didn’t decay, lacked the ability to develop red color.

Round Tomato (cv Bobcat) stored 4 weeks + 2 days
\begin{table}[h!]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Storage Temperature & 10°C (50°F) & 7.5°C (45°F) & 5°C (41°F) \\
\hline
\end{tabular}
\end{table}

Tomato Ripening & Temperature

15°C allows ripening to continue but at much slower rate than at 20°C
Similar to ripening bananas and other fruits

Tomatoes ripen into similar quality in temperature range from 12.5-20°C

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Initial color</th>
<th>Days to FR</th>
<th>Weight loss %</th>
<th>Firmness N</th>
<th>Red color %</th>
<th>SS %</th>
<th>Sugar mg/100g</th>
<th>TA %</th>
<th>Vit. C mg/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2</td>
<td>13</td>
<td>4.3</td>
<td>27.0</td>
<td>35.0</td>
<td>4.0</td>
<td>18.3</td>
<td>0.26</td>
<td>29.8</td>
</tr>
<tr>
<td>12.5</td>
<td>16</td>
<td>11</td>
<td>3.4</td>
<td>23.0</td>
<td>35.9</td>
<td>4.0</td>
<td>20.8</td>
<td>0.26</td>
<td>27.4</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>22</td>
<td>3.0</td>
<td>28.5</td>
<td>39.4</td>
<td>4.2</td>
<td>19.5</td>
<td>0.26</td>
<td>29.9</td>
</tr>
<tr>
<td>12.5</td>
<td>4</td>
<td>4</td>
<td>2.2</td>
<td>25.5</td>
<td>37.2</td>
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<td>0.29</td>
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</tr>
<tr>
<td>20</td>
<td>4</td>
<td>18</td>
<td>2.2</td>
<td>26.3</td>
<td>37.6</td>
<td>4.1</td>
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<tr>
<td>Average 20°C</td>
<td>9</td>
<td>3.0</td>
<td>24.6</td>
<td>37.8</td>
<td>4.0</td>
<td>19.7</td>
<td>0.27</td>
<td>25.8</td>
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Impact of Temperature on Tomato Ripening
Respiration, Ethylene and Color
Avoid Ripening above 20°C

Storage for grape tomatoes is somewhat different due to water loss; High quality grape tomatoes on salad trays at 5°C okay for 14-18 days

Shelf-life/Storage/Ripening Conditions
✓ Temperature and ripening of different tomato types; update conventional tomato chart
✓ Impact of lower than recommended storage temperature; slight chilling; differences among varieties
✓ Ripening Temperature and ethylene treatment
✓ Temperature and RH - Impact on firmness and gloss

Table 1. Effect of temperature on ripening rates of conventional tomatoes.

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<td>10</td>
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<td>7</td>
</tr>
<tr>
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<td>13</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Turning</td>
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<td>10</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Pink</td>
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Visual quality of packaged grape tomatoes after 9 days.

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Respiration µL CO₂. g⁻¹h⁻¹
Ethylene production nL. g⁻¹h⁻¹

Days from Breaker Stage

Color Score (1=green, 6=table-ripe)

Impact of Temperature on Tomato Ripening
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Respiration during Ripening
Ethylene Production during Ripening

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<td>3</td>
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<td>2</td>
</tr>
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</table>

Visual quality of packaged grape tomatoes after 9 days.

Storage for grape tomatoes is somewhat different due to water loss; High quality grape tomatoes on salad trays at 5°C okay for 14-18 days

Tomatoes and 1-MCP (SmartFresh™)

- 300ppb 1-MCP at 20°C ~ 12.5°C Storage
- 1-MCP is a powerful regulator of tomato fruit ripening
- Easy to overdose and have poor final quality (red fruit)
- Important to determine where 1-MCP can add value to the tomato category


Ethylene Treatment for Ripening MG fruit

- Ethylene concentration: 10-100 ppm
- Temperature: 15-25°C (60 to 77°F)
- Relative humidity: 90-95%
- Duration: 24 to 72 hours
- Air circulation: sufficient for distribution of ethylene in ripening room
- Ventilation: sufficient to prevent accumulation of CO2 which reduces effectiveness of ethylene
**Checker boarding**

Should never be a problem with vine ripe tomatoes!

**Vine-ripe Greenhouse Tomato**

Why did they have variability? What changes did they make?

---

**Tomato quality**

- Variety and maturity at harvest
- Minimize physical injury
- Storage: temperature & duration
  - 12.5°C (55°F), No lower than 10°C (50°F)
  - 2-3 weeks
- Ripening conditions
  - Temperature 15-20°C
  - High humidity
  - If MG fruit, 100 ppm ethylene 3 days

---

**Sensory Evaluation Project**

Fruit with decay and other defects.

<table>
<thead>
<tr>
<th>Tomato type</th>
<th>Number fruit evaluated</th>
<th>% decay</th>
<th>% defects</th>
<th>Type of defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>MG ripened</td>
<td>480</td>
<td>1.0</td>
<td>11.9</td>
<td>Poor color, sunburn, too soft</td>
</tr>
<tr>
<td>Field-grown</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinks</td>
<td>360</td>
<td>10.8</td>
<td>8.9</td>
<td>Poor color, excessively soft</td>
</tr>
<tr>
<td>Field-grown</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hothouse</td>
<td>140</td>
<td>1.5</td>
<td>2.1</td>
<td>Shriveling, mechanical damage</td>
</tr>
<tr>
<td>TOV</td>
<td>260</td>
<td>0.0</td>
<td>4.0</td>
<td>Immature fruit, poor color</td>
</tr>
</tbody>
</table>

Test #2. Tomatoes packed commercially; VR field fruit not in commercial box
Quality Criteria for Marketing Chiles and Peppers

- Shape, size and color typical of cultivar
- Bright glossy appearance;
- Green stem & calyx
- No decay, damage, defects
- Firm, little water loss
- Flavor and pungency typical of cultivar

Color changes During ripening Of peppers

Bell peppers generally do not respond to ethylene
Temperature has the greatest effect on color change or ripening.
Holding at 25-29°C (77-84°F) maximizes rate of color change.

To maximize quality and shelf-life of colored peppers, harvest at no more than 80-90% color; color change continues after harvest even under typical storage temperatures.

Storage Conditions for Peppers

- High RH reduces water loss but may increase superficial decay on stems
- Avoid condensation, will favor bacterial decay on damaged areas
- Temperature: 5-10°C (41-50°F); 7.5°C (45°F) is best
- Shelf-life: 2-3 weeks
- CA not provide much benefit; low O2 retards color change
Chilling Injury Symptoms on Peppers and Chiles

Ripe peppers are more chilling tolerant than green peppers
Lim et al., 2007. HortScience 42:1659; 14d 1°C (A) +2d 20°C (B)

Percent weight loss
0.0 0.5 1.0 1.5 2.0 2.5
B. Weight Loss
9=excellent, 7=fair, 5=poor

A. Visual Quality

12.5°C  55°F
10°C  50°F
7.5°C  45°F
5°C  41°F
2.5°C  36°F

LSD.05

Days
7 1 4 2 1 8

Total capsaicinoids (mg/100g DW)
0 20 40 60 80

C. Capsaicin Content

Jalapeño Peppers
stored at 5 temperatures for up to 4 weeks (evaluated without transfer)
No significant changes in capsaicin content of Jalapeño peppers with time or storage temperature—in chiles of marketable quality
Similar results with Habanero and Serrano chiles—no significant Changes in capsaicin content

Field Pack Operations

Field Harvest: defect sorting
Plastic totes into refrigerated trailer for transport to packing house

3 productions systems, Mexico
Photos Jose Aguiar, UCR
GREENHOUSE PEPPERS

- Peppers transferred to shallow trailer
- Gentle dry dump
- Singulation for weight sizer
- Water spray to remove dust (chlorinated)
- Sponge rollers to remove excess water

Hand packing

Weight sizer

Volume sizer

Weight loss in bell pepper fruits during periods of direct sun exposure, with storage for 7 days at 7.5°C and finally total weight loss after additional 2 days at 20°C to simulate marketing.

<table>
<thead>
<tr>
<th>Minutes at Sun Exposition</th>
<th>% Weight Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>20</td>
<td>1.0</td>
</tr>
<tr>
<td>30</td>
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<td>3.0</td>
</tr>
<tr>
<td>70</td>
<td>3.5</td>
</tr>
<tr>
<td>80</td>
<td>4.0</td>
</tr>
<tr>
<td>90</td>
<td>4.5</td>
</tr>
<tr>
<td>100</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Weight loss, Appearance and Firmness

- Delays to cool should be less than:
  - 9 hours at 20-25°C (68-77°F)
  - 6 hours at 37°C (99°F)

Pepper Shriveling Rating Scale

- Weight loss:
  1 = 2%
  2 = 4-5%
  3 = 7-8%
  4 = 10-12%
  5 = 15-17%

Importance of water loss

- <3% no visual effect, texture
- 3-5% visual quality affected
- >5% shrivel, lose salability

Water loss is cumulative

Salable Weight
Fresh Appearance
Texture

Repacking Peppers at Distribution Center, 2010