Mature Fruit Vegetables

- Peppers, Chiles
- Tomatoes
- Winter squash, pumpkins
- Melons

- 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
micantwell@ucdavis.edu
http://postharvest.ucdavis.edu
Tomato Quality Attributes

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

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.floridatomatoes.org/
http://www.tomato.org/
Checker boarding

Should never be a problem with vine ripe tomatoes!
Tomato photos: http://www.tomato.org/food/color.html

<table>
<thead>
<tr>
<th>Time</th>
<th>Relative Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red color</td>
<td>Yellow color</td>
</tr>
<tr>
<td>Aroma</td>
<td>Flavor</td>
</tr>
<tr>
<td>Sugars</td>
<td>Soluble pectins</td>
</tr>
<tr>
<td>Polymerized phenolics</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Respiration</th>
<th>Ethylene</th>
</tr>
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<table>
<thead>
<tr>
<th>Time</th>
<th>Respiration</th>
<th>Ethylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>MG</td>
<td>Breaker</td>
<td>Turning</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>0 µL CO₂/g-h</td>
<td>0 µL C₂H₄/g-h</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Days at 20°C from Breaker stage

Ripening mutants retard the ripening process

Example: Tomato rin mutant
Experimental LSL round tomato variety, 2008

Fruit harvested at different ripeness stages and held 10 days at 20°C

Air | 100 ppm Ethylene

Firmness Classes for Tomatoes

<table>
<thead>
<tr>
<th>Firmness Class</th>
<th>Description</th>
<th>Firmness (Newton) 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 pressure</td>
<td>5</td>
</tr>
</tbody>
</table>

1 Newton = 9.81 kg-force or 4.45 pound-force
Tomato Texture: Slice Integrity

<table>
<thead>
<tr>
<th>Juice Loss</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very firm</td>
<td>0-2%</td>
</tr>
<tr>
<td>Firm</td>
<td>2-5%</td>
</tr>
<tr>
<td>Moderately firm</td>
<td>5-8%</td>
</tr>
<tr>
<td>Moderately soft</td>
<td>5-8%</td>
</tr>
<tr>
<td>Soft</td>
<td>8-10%</td>
</tr>
<tr>
<td>Very soft</td>
<td>&gt;10%</td>
</tr>
</tbody>
</table>

Tomato Color

Carotenoids
- \( \beta \)- and other carotenes
- Lycopene (90%)

Pigment extraction, Objective color values
Good red color in tomatoes:

Hue less than 40

Typical Objective Color Values for Tomatoes

<table>
<thead>
<tr>
<th></th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>chroma</th>
<th>hue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pink-Orange</td>
<td>49.6</td>
<td>16.6</td>
<td>30.9</td>
<td>35.0</td>
<td>61.8</td>
</tr>
<tr>
<td>Orange-Red</td>
<td>46.2</td>
<td>24.3</td>
<td>27.0</td>
<td>36.3</td>
<td>47.9</td>
</tr>
<tr>
<td>Red</td>
<td>41.8</td>
<td>26.4</td>
<td>23.1</td>
<td>35.1</td>
<td>41.2</td>
</tr>
<tr>
<td>Dark Red</td>
<td>39.6</td>
<td>27.5</td>
<td>20.7</td>
<td>34.4</td>
<td>37.0</td>
</tr>
</tbody>
</table>
Tomato Flavor

*Depends on content of:*

- Sugars (4-6%)
- Acids (0.2-0.6%)
- Aroma volatiles (ppm)

We estimate flavor by measuring sugars (soluble solids) and acids (titratable acidity)

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Tomato Type & Composition

**Group 2**

<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>4.25</td>
<td>0.31</td>
</tr>
<tr>
<td>Round Cluster</td>
<td>4.20</td>
<td>0.35</td>
</tr>
</tbody>
</table>

2006 Test#2
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

**z-3 hexanal as example of important volatile**

<table>
<thead>
<tr>
<th>Storage temperature, ºC</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table-ripe tomatoes stored for 6 days</td>
<td>6.0</td>
<td>9.8</td>
<td>9.3</td>
<td>9.9</td>
</tr>
</tbody>
</table>

Cantwell, UC Davis, unpublished

It is quite common that tomatoes are held at 45°F. Results in decay and poor color.
Consequences of Storing Tomatoes Below Recommended Temperatures

- Round Tomatoes, cv Bobcat, color stage 2-3
- Stored at 5, 7.5, 10 and 12.5°C for up to 3 weeks
- Transferred to 20°C to complete ripening maximum 7 days
- Evaluate respiration and ethylene production rates
- weight loss, decay, firmness, color composition (%SS, acidity, sugars, lycopene, Vitamin C)
- Several experiments on rounds & grape tomatoes

Cantwell, Ara and Hong, 2007
Ethylene Production Rates
during storage and after transfer to
20°C at 7, 14 and 21 days

Color Changes
during storage and after transfer
to 20°C at 7, 14 and 21 days

6 = full red
30% color
Fruit stored
At 4 temperatures
For up to 3 weeks.

After storage,
Complete ripening
For 6 days at 20°C.

Ara and Cantwell, 2007 Test#2
Cv Bobcat, initial color = 3

Round Tomato (cv Bobcat) stored 4 weeks + 2 days
Initial stage = 3

10°C (50°F)          7.5°C (45°F)          5°C  (41°F)
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%

Storage for grape tomatoes is somewhat different due to water loss

Visual quality of packaged grape tomatoes after 9 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.

<table>
<thead>
<tr>
<th>Ripeness stage</th>
<th>12.5°C 55°F</th>
<th>15°C 59°F</th>
<th>17.5°C 64°F</th>
<th>20°C 68°F</th>
<th>22.5°C 72°F</th>
<th>25°C 77°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature-green</td>
<td>18</td>
<td>15</td>
<td>12</td>
<td>10</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Breaker</td>
<td>16</td>
<td>13</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Turning</td>
<td>13</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Pink</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
Effect of temperature on Tomato fruit ripening

Good temperature range: 15-25°C (59-77°F)

Best temperature: 20°C (68°F)

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
Ripening Tomatoes: 1-MCP treatments decreases respiration and ethylene production rates

Test2, cv Bobcat
1ppm 1-MCP 12h 20°C

Ripening Tomatoes: 1-MCP treatments decreases respiration and ethylene production rates

cv Bobcat  14 days at 20°C
Treated 12h with 1-MCP
at Breaker stage

cv Bobcat  14 days from Breaker stage
100 ppb  300 ppb  600 ppb
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
CTC 2003
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>Shrivelled, 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

Postharvest Tomato Quality

- Variety
- Maturity at harvest
- Minimize physical injury
- Storage: temperature & duration
- Ripening conditions
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

Bell Pepper (cv. Domino)
Growth & Ripening

Color changes during ripening of peppers

Maturity stages for Anaheim Chiles
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.

![Graph showing color change of breaker stage fruit](image1)

**Air**

- 100 ppm Ethylene
- 3 days at 20°C (68°F)

**Maturity:** Dark Green

**Maturity:** Light Chocolate

**Maturity:** Dark Chocolate

From TV Suslow, UC Davis
For bell peppers, temperature has the greatest effect on color change or ripening.

Holding at 25-29°C maximizes rate of color Change—but need High RH to prevent Water loss

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
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 Operation

Field Harvest: defect sorting

Plastic totes into refrigerated trailer for transport to packing house
3 productions systems, Mexico
Photos Jose Aguiar, UCR
Peppers transferred to shallow trailer
Gentle dry dump
Singulation for weight sizer
Water spray to remove dust (chlorinated)
Sponge rollers to remove excess water

Weight sizer
Volume sizer
Hand packing
Effect of Midday Sun Exposure on Visual Quality of Bell Peppers

Storage defects observed on field-grown peppers and chillis
Damage and bacterial decay
Greenhouse Peppers

- Sun exposure not as serious a problem as it is for field grown peppers
- But delays from harvest to packing and cooling lead to water loss and more decay
Importance of water loss

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

Salable Weight
Fresh Appearance
Texture

Water loss is Cumulative

Delays to cool affect quality of peppers

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

Green Bell Peppers, Cantwell and Muy, 2004