Fruit ripening
Color change and Conditioning

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Fruit ripening
Color change and Conditioning

1. Fruit development
   - Definition of maturation and ripening

2. Importance of color

3. Conditioning for ripening
   - Some climacteric fruits as examples
Stages of fruit development

Maturation
The stage of development leading to the attainment of physiological or horticultural maturity

• **Physiological maturity:**
  – The stage of development when a plant or plant part will **continue ontogeny even if detached**

• **Horticultural maturity:**
  – The stage of development when a plant or plant part possesses the **prerequisites for utilization by consumers for a particular purpose**
**Ripening:**
The composite of the processes:
- Occurring from the **latter stages of growth and development** through the **early stages of senescence**
- Resulting in **characteristic aesthetic and/or food quality**, as evidenced by **changes in composition, color, texture, or other sensory attributes**
**Maturity and ripeness stages of cherry tomatoes**

**Optimal harvest stages**

1. Fruit development

- For us...
  - Cosmetic value
  - Indicator of ripening
  - Nutritional value = Antioxidant

- Green - light capture (photosynthesis)
- **Red/orange etc** - Attract seed dispersers
- Protect tissues from oxidative stress

**Importance of “Color”**
Anthocyanins
Antioxidants

Carotenoids
Antioxidants
Provitamin A

2. Importance of color

Anthocyanins
Carotenoids

*Phenylpropanoids*
*Isoprenoids (terpenoids*)

Cf. Dr. Zakharov’s lecture
2. Importance of color

- **chromoplast**
- **“crystaline structure”**
- **lycopene**
- **Electron microgram**
- **cis-β-carotene**
- **“globules”**
- **Esters of cis-violaxanthin**

2. Importance of color

- **“Photosynthetic” carotenoids**
- **chlorophylls**
- **chloroplast**
- **“Non-photosynthetic” carotenoids**
- **Color Break**

Images and diagrams illustrate the different types of pigments and their structural representations.
Group 1: Nonclimacteric fruits:
Fruits that are not capable of continuing their ripening process once removed from the plant

<table>
<thead>
<tr>
<th>Blackberry</th>
<th>Loquat</th>
<th>Pomegranate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherry</td>
<td>Lychee</td>
<td>Prickly pear</td>
</tr>
<tr>
<td>Grape</td>
<td>Mandarin</td>
<td>Rambutan</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>Muskmelon*</td>
<td>Raspberry</td>
</tr>
<tr>
<td>Lemon</td>
<td>Orange</td>
<td>Strawberry</td>
</tr>
<tr>
<td>Lime</td>
<td>Pepper (bell)</td>
<td>Tamarillo</td>
</tr>
<tr>
<td>Longan</td>
<td>Pineapple</td>
<td>Watermelon</td>
</tr>
</tbody>
</table>

*Some muskmelon varieties are climacteric, but are best when harvested partially- or fully-ripe.
Maturity and ripeness stages of **cherries**

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Maturity and ripeness stages of **strawberries**

Strawberries must be picked fully-ripe

b/c they do not continue to ripen (improve in flavor) after harvest
Group 2: Climacteric Fruits:
Fruits that can be harvested at physiological maturity and ripened off the plant

<table>
<thead>
<tr>
<th>Apple</th>
<th>Mango</th>
<th>Persimmon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apricot</td>
<td>Nectarine</td>
<td>Plum</td>
</tr>
<tr>
<td>Avocado</td>
<td>Papaya</td>
<td>Quince</td>
</tr>
<tr>
<td>Banana</td>
<td>Passion fruit</td>
<td>Sapodilla</td>
</tr>
<tr>
<td>Cherimoya</td>
<td>Peach</td>
<td>Sapote</td>
</tr>
<tr>
<td>Guava</td>
<td>Pear</td>
<td>Tomato</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>Pepper (chili)</td>
<td></td>
</tr>
</tbody>
</table>

Except avocado, banana, and pear, these fruits attain best flavor if ripened on the plant.

Maturity and ripeness stages of apricots
Optimal conditions for ripening of climacteric fruits

Ripening rooms
- Temperature: 15 to 25°C (59 to 77°F)
- Relative humidity: 85-95%
- Air circulation (more uniform temperature and ethylene concentration)
- Ventilation (introduction of fresh air to keep carbon dioxide below 1%)

Treatment with ethylene
- 100 ppm ethylene in air for 1-3 days, depending on maturity stage at harvest

Temperature and relative humidity management is the most important factor affecting ripening rate & uniformity
Ripening rooms

Forced-air (pressure) ripening room

Ethylene generator

3. Conditioning for ripening

Ripening conditions for some commonly-ripened fruit

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Exposure time (hours)(^1) to 100ppm ethylene</th>
<th>Range of ripening temperatures(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avocado</td>
<td>8-48</td>
<td>15-20°C / 59-68°F</td>
</tr>
<tr>
<td>Banana</td>
<td>24-48</td>
<td>14-18°C / 58-65°F</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>12-24</td>
<td>12-25°C / 54-77°F</td>
</tr>
<tr>
<td>Mango</td>
<td>24-48</td>
<td>20-25°C / 68-77°F</td>
</tr>
<tr>
<td>Pear</td>
<td>24-48</td>
<td>20-25°C / 68-77°F</td>
</tr>
<tr>
<td>Tomato</td>
<td>24-72</td>
<td>18-20°C / 65-68°F</td>
</tr>
</tbody>
</table>

\(^1\) Shorter duration for more mature fruit
\(^2\) Faster ripening rate at higher temperatures
Current recommendations for avocado ripening

Temperature: 15.5-20°C (60-68°F)
Relative humidity: 90-95%
Ethylene concentration: 10-100ppm
Duration: 8-48 hr, depending on maturity stage
Carbon dioxide level: Adequate air flow to keep CO₂ below 1%

Effect of harvest date (maturity) on the time to ripen for ‘Hass’ avocado

<table>
<thead>
<tr>
<th>Harvest date</th>
<th>Control</th>
<th>Treated*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 8</td>
<td>13.9</td>
<td>10.8</td>
</tr>
<tr>
<td>Feb. 6</td>
<td>12.8</td>
<td>8.8</td>
</tr>
<tr>
<td>April 10</td>
<td>10.1</td>
<td>7.1</td>
</tr>
<tr>
<td>June 5</td>
<td>8.2</td>
<td>5.1</td>
</tr>
</tbody>
</table>

* Fruit treated with 1000ppm propylene, an ethylene analogue
Ethylene ($\text{C}_2\text{H}_4$) is required to induce banana ripening

![CONTROL vs C$_2$H$_4$ TREATED](image)

After 7 days at 20°C

Ethylene ($\text{C}_2\text{H}_4$) induces ripening of various banana and plantain cultivars

- Plantain
- Burro
- Red
- Manzano
- Petite

100ppm $\text{C}_2\text{H}_4$ for 2 days
Air for 3 days at 20°C (68°F)

Air for 5 days at 20°C (68°F)
Ripening conditions for **banana**

- **Fruit temperature:** 14-18°C (58-65°F)
- **Relative humidity:** 90-95%
- **Ethylene concentration:** 100 ppm
- **Duration of exposure to ethylene:** 24-48 hours, depending on maturity stage
- **Carbon dioxide:** Adequate air exchange to prevent accumulation of CO₂ above 1%

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**Effect of temperature during ripening on banana quality attributes**

![Graph showing the effect of temperature on banana quality attributes](image)
Note the 5-fold increase in respiration rate (carbon dioxide production) as banana ripens from stage 2 to stage 4.
Carbon dioxide reduces efficacy of ethylene in inducing banana fruit ripening

Low relative humidity (RH) accelerates water loss and appearance of physical damage symptoms on banana
**Mango maturity indices**

- *Fruit shape (fullness of the shoulders)*
- *Skin ground color change from dark-green to light-green to yellow (depending on cultivar)*
- *Flesh color change from green to yellow to orange*
- *Increase in total solids (dry weight)*
- *Increase in soluble solids (mainly sugars) and decrease in acidity*

**Mango maturity and ripeness stages**

* Minimum stage for harvest
Ripening conditions for mango

Fruit temperature: 20 to 22°C (68-72°F)
Relative humidity: 90-95%
Ethylene concentration: 100 ppm
Duration of exposure to ethylene: 24-48 hours, depending on maturity stage (flesh firmness)
Carbon dioxide: <1%

Mango ripeness vs. flesh firmness

<table>
<thead>
<tr>
<th>Ripeness stage</th>
<th>Flesh firmness (lb-force with 8mm-tip penetrometer)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature-green</td>
<td>&gt;14</td>
<td>Treat with ethylene for 48 hours</td>
</tr>
<tr>
<td>Partially-ripe</td>
<td>10-14</td>
<td>Treat with ethylene for 24 hours</td>
</tr>
<tr>
<td>Firm-ripe</td>
<td>6-10</td>
<td>Best stage to send to retail stores</td>
</tr>
<tr>
<td>Soft-ripe</td>
<td>2-6</td>
<td>Best stage for eating</td>
</tr>
<tr>
<td>Over-ripe</td>
<td>&lt;2</td>
<td>Good for juice</td>
</tr>
</tbody>
</table>
Maturity and ripeness stages of Nectarine

1. Immature
2. Mature-green
3. Partially-ripe
4. Ripe

Ethylene effects on stone fruit ripening at 20°C (68°F) as indicated by flesh firmness (means + standard deviation)

<table>
<thead>
<tr>
<th>Days</th>
<th>Treatment</th>
<th>Flesh Firmness (pounds-force)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nectarine</td>
</tr>
<tr>
<td>0</td>
<td>At harvest</td>
<td>11.6±2.1</td>
</tr>
<tr>
<td>4</td>
<td>W/O added ethylene</td>
<td>2.3±1.0</td>
</tr>
<tr>
<td>4</td>
<td>With 20ppm ethylene</td>
<td>1.8±0.4</td>
</tr>
</tbody>
</table>
Delayed cooling = conditioning = ripening of peaches to reduce internal breakdown

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°C 20 Days</td>
<td>(43% Mealy)</td>
</tr>
<tr>
<td>20°C 48 Hours + 5°C 20 Days</td>
<td>(100% Mealy)</td>
</tr>
<tr>
<td>5°C 20 Days</td>
<td>(0% Mealy)</td>
</tr>
</tbody>
</table>

From: Carlos Crisosto

**Smartfresh™ Technology**

On July 17, 2002, USEPA approved registration of Smartfresh™ technology and established an exemption from tolerance for its active ingredient: 1-methylcyclopropene (1-MCP) for the following fruits: apple, apricot, avocado, kiwifruit, mango, melon, nectarine, papaya, peach, pear, persimmon, plum, tomato.

Approval in other countries and for more commodities has occurred since 2002.

Responses of 1-MCP-treated fruits to ethylene depends on 1-MCP concentration used (100 to 1000 ppb) and elapsed time since the treatment.