Maturation and Maturity Indices
Carlos H. Crisosto, UC Davis
chrisosto@ucdavis.edu

Outline
• Definitions
• Maturity Indices
• Why do we need a Maturity Index?
  Examples
• One or two maturity indices
• How to put it to work?

Stages of Fruit Development

DEVELOPMENT
GROWTH
MATURATION
PHYSIOLOGICAL MATURE
RIpening
SENESCENCE
**Stages of Fruit Development**

**Development**
- The series of processes from the initiation of growth to death of a plant or plant part.

**Growth**
- The irreversible increase in physical attributes (characteristics) of a developing plant or plant part.

![Diagram of CO₂, Calvin Cycle, Sugars, Glycolysis, Volatiles, Pigments, Proteins, More carb. Acids, and More carbs.](image)
Stages of Fruit Development

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

Physiological maturity
- The stage when a plant or plant part will continue developing 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.

Indian Kew Pineapples and Composition at Different Stages of Ripeness

<table>
<thead>
<tr>
<th>Days from Anthesis</th>
<th>Shell Color</th>
<th>Chl mg/g</th>
<th>Dry wt. %</th>
<th>Soluble solids %</th>
<th>Titratable acidity %</th>
<th>Total Sugar %</th>
<th>Vit C mg/100g</th>
<th>Sensory Score*</th>
</tr>
</thead>
<tbody>
<tr>
<td>115-120</td>
<td>Green</td>
<td>0.77</td>
<td>12.97</td>
<td>7.9</td>
<td>0.06</td>
<td>6.49</td>
<td>13.7</td>
<td>3.0</td>
</tr>
<tr>
<td>135-140</td>
<td>1/8</td>
<td>0.76</td>
<td>15.26</td>
<td>12.6</td>
<td>0.74</td>
<td>8.37</td>
<td>12.9</td>
<td>4.6</td>
</tr>
<tr>
<td>140-145</td>
<td>1/4</td>
<td>0.83</td>
<td>16.09</td>
<td>16.2</td>
<td>0.77</td>
<td>11.23</td>
<td>14.4</td>
<td>3.4</td>
</tr>
<tr>
<td>146-150</td>
<td>1/2</td>
<td>0.83</td>
<td>17.68</td>
<td>18.9</td>
<td>0.77</td>
<td>11.59</td>
<td>14.9</td>
<td>6.8</td>
</tr>
<tr>
<td>151-155</td>
<td>2/3</td>
<td>0.21</td>
<td>17.76</td>
<td>18.0</td>
<td>0.83</td>
<td>12.44</td>
<td>15.3</td>
<td>8.7</td>
</tr>
<tr>
<td>156-160</td>
<td>Full</td>
<td>0.14</td>
<td>19.89</td>
<td>16.3</td>
<td>0.96</td>
<td>12.74</td>
<td>14.5</td>
<td>6.4</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td></td>
<td>0.01</td>
<td>0.17</td>
<td>0.87</td>
<td>0.05</td>
<td>0.88</td>
<td>0.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>


Physical and Compositional Changes during Development

Crisosto - Maturity & Maturity Indices
Too often we err on the side of shelf-life at the expense of good eating quality

Maturity Indices
Requirements to establish

- Simple, easy to carry out
- Objective vs subjective indicators
- Related to quality
- Related to storage life
- Represents a progressive change with maturity
- Permits prediction of maturity from year to year
- Use of inexpensive tools

California strawberries and cherries
Distribution Center Singapore
May 16, 2008
Strawberries from Oxnard; Cherries from Lodi
Air-shipped
California Minimum Maturity Indices for Selected Fruits

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Minimum maturity indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pomegranate</td>
<td>Red juice color and below 1.85% acid in juice</td>
</tr>
<tr>
<td>Grape</td>
<td>14 to 17.5% SS (depending on cultivar and production area) or a SS/A ratio of 20 or higher</td>
</tr>
<tr>
<td>Strawberry</td>
<td>&gt;3/4 of fruit surface showing a pink or red color</td>
</tr>
</tbody>
</table>

SS = soluble solids, A = acidity

Maturity Stages of Strawberries

Strawberries must be picked fully-ripe because they do not continue to ripen after harvest.

California Minimum Maturity Indices for Pome Fruits

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Minimum maturity indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Starch pattern, above 10.5 to 12.5% SS and below 18 to 23 lb-force firmness (depending on cultivar)</td>
</tr>
<tr>
<td>Pear (Bartlett)</td>
<td>Yellowish-green color, and/or below 23 lb-force firmness, and/or above 13% SS</td>
</tr>
<tr>
<td>Persimmon</td>
<td>Yellowish-green to orange color (depending on cultivar)</td>
</tr>
</tbody>
</table>

SS = soluble solids
Nectarine and Peach Ground Color Guides of the California Tree Fruit Agreement (CTFA)

The Easy Ones

CA Well Mature

Hue Angle Color Criterion

Research has shown that Hue angle is the most effective instrumental method of determining fruit maturity.

CIE hue angle 80 degrees
Maturity and Ripeness Stages of Apricots

Cherry Color Categories

The Difficult Ones
Full Dark Plums and Full Red Nectarines and Peaches
'Blackamber' plum quality changes during ripening “on the tree” - 2002 season

Market life of ‘Blackamber’ plums harvested on four different dates then stored at 0 or 5°C

<table>
<thead>
<tr>
<th>Harvest date</th>
<th>Firmness</th>
<th>SSC</th>
<th>TA</th>
<th>Maximum market life (weeks at 0ºC)</th>
<th>Minimum market life (weeks at 5ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/20/02</td>
<td>7.0</td>
<td>10.3</td>
<td>0.78</td>
<td>2³,4</td>
<td>&lt;2,3,4</td>
</tr>
<tr>
<td>6/26/02</td>
<td>5.1</td>
<td>10.8</td>
<td>0.47</td>
<td>5³</td>
<td>2³,4</td>
</tr>
<tr>
<td>7/2/02</td>
<td>4.8</td>
<td>11.7</td>
<td>0.43</td>
<td>5³</td>
<td>3³,4</td>
</tr>
<tr>
<td>7/8/02</td>
<td>2.8</td>
<td>12.3</td>
<td>0.33</td>
<td>5³</td>
<td>2³,4</td>
</tr>
</tbody>
</table>

Market life based on chilling injury (CI) determined when >25% of the fruit became mealy or leathery, or had flesh bleeding/browning or gel breakdown/translucency.

Maximum Maturity

Critical Bruising Threshold

Bruising Potential

Quality

Firmness

Harvest
Hauling
Packingline
Transportation
Retail handling

G’s
Developing Tree Ripe Standards


Proposed harvest maturity/quality indices based on firmness and minimum SSC for different plum cultivars.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Firmness (lb)</th>
<th>Minimum SSC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackamber</td>
<td>7-9</td>
<td>10-12(^2)</td>
</tr>
<tr>
<td>Fortune</td>
<td>7-9</td>
<td>11</td>
</tr>
<tr>
<td>Friar</td>
<td>7-9</td>
<td>11</td>
</tr>
<tr>
<td>Royal D.</td>
<td>7-9</td>
<td>11</td>
</tr>
<tr>
<td>Angeleno</td>
<td>6-9</td>
<td>12</td>
</tr>
<tr>
<td>Betty Anne</td>
<td>7-9</td>
<td>12</td>
</tr>
</tbody>
</table>

*Blackamber plums with TA ≤0.60% after ripening have a high consumer acceptance. If plums have ≥12.0% SSC, TA does not play a role.

Mechanical Pitter Damage

The Good vs. The Bad and Ugly
Canopy Firmness

"Mean fruit shoulder flesh firmness (lbf.) of 50 'Andross' fruit per sector."
The Tedious Ones

• For many products, it is necessary to use several indices to accurately determine maturity.

How to Measure Maturity

• Minimum Maturity (6.5% SSC)
• Maximum Maturity (≤14 pounds)

Impact Bruising

Gatti, R. 1983

Crisosto - Maturity & Maturity Indices
Storage Potential

Ethylene free

Kiwifruit Internal Breakdown after 3 Months of Cold Storage

Consumer Acceptance (‘in-store’)
How to assure Consumer Quality

- Minimum Maturity (6.5% SSC)
- Maximum Maturity (≤14 pounds)
- Consumer Quality (≥12.5% RSSC)
- Fruit Handler Quality (≥15.1% DW)

California switched to Dry Matter in 80's from oil content
Relationship between dry wet and oil
Also "raised" minimum maturity based on sensory evaluation

Work of Lee et al. (UCR)

Current California
Minimum Maturity Standards

<table>
<thead>
<tr>
<th>Variety</th>
<th>Dry Matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacon</td>
<td>17.7</td>
</tr>
<tr>
<td>Zutano, Reed</td>
<td>18.7</td>
</tr>
<tr>
<td>Fuerte</td>
<td>19.0</td>
</tr>
<tr>
<td>Hass</td>
<td>20.8</td>
</tr>
<tr>
<td>Pinkerton</td>
<td>21.6</td>
</tr>
<tr>
<td>Lamb Hass</td>
<td>22.8</td>
</tr>
<tr>
<td>Owen</td>
<td>24.2</td>
</tr>
</tbody>
</table>

Data/Size Maturity Releases
- Industry interest in harvest dates by size and variety.
- Model developed to predict the dates when dry matter will reach minimum maturity (Ronney et al.).
- Date/Size maturity releases allow avocados to move in a uniform manner.
- Avocados can still be harvested before the release dates, but they will be tested for minimum maturity standard.
Composition of fig cultivars separated by stage of maturity.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Maturity stage</th>
<th>Weight, g</th>
<th>Firmness, N</th>
<th>Soluble solids, %</th>
<th>Titratable acidity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Mission</td>
<td>Under-ripe</td>
<td>29.9</td>
<td>12.1</td>
<td>14.3</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Commercial maturity</td>
<td>32.2</td>
<td>7.2</td>
<td>17.5</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>Tree ripe</td>
<td>34.5</td>
<td>4.0</td>
<td>21.0</td>
<td>0.22</td>
</tr>
<tr>
<td>Kadota</td>
<td>Under-ripe</td>
<td>45.1</td>
<td>11.0</td>
<td>15.2</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Commercial maturity</td>
<td>56.3</td>
<td>4.4</td>
<td>15.9</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Tree ripe</td>
<td>57.6</td>
<td>2.4</td>
<td>17.9</td>
<td>0.28</td>
</tr>
<tr>
<td>LSD.05</td>
<td>3.7</td>
<td>1.3</td>
<td>1.9</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

(Cantwell & Crisosto, 2010)
Indicators of Harvest Maturity

APPLES

- Days from full bloom
- Time/temp (heat units) from anthesis
- Days from harvest to onset of ethylene production
- Ground color
  - Soluble solids content (SSC)
  - Flesh firmness and SSC
  - Starch disappearance pattern
- Internal ethylene concentration
- Changes in firmness or starch content

Streif Index considers starch, sugar, firmness

Starch Content is an Indicator of Apple Harvest Maturity

Use of Maturity Indices

Limitations

- Soil conditions, nutrition, irrigation
- Season, climate
- Position on the plant
- Pruning, other cultural practices
- Varieties