Maturation and Maturity Indices

When to Harvest?

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IMPORTANCE

✓ Maturity Indices = Harvest Indices
✓ Sensory and Nutritional Quality
✓ Use—Fresh market or Processed
✓ Adequate shelf-life
✓ Facilitate marketing—standards
✓ Productivity—yield at harvest and use

Developmental Continuum

Watada et al., 1984

Terminology

PHYSIOLOGICAL MATURITY
The stage of development when a plant part will continue development even if detached; mature fruits

HORTICULTURAL MATURITY
The stage of development when a plant part possesses the necessary characteristics for use by consumers

Ch. 11 – Fruit growth, ripening and post-harvest physiology. Brummell, D.2. New Zealand

Watada et al., 1984

Asparagus
Cucumber
Beans
Sweet corn

Carrot
Onion
Potato

Melon
Pear
Pineapple
Tomato
**Physiological Maturity**

**FRUITS**
- Immature
- Mature
- Ripening
- Ripe
- Overripe

**Horticultural Maturity**

**VEGETABLES**
- Immature
- Mature
- Overmature

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**Maturity Indices**

- **Asparagus**
  - Size
  - Apex closed

- **Broccoli/Cauliflower**
  - Size
  - Florets closed

- **Carrot**
  - Size

- **Lettuce, head**
  - Size
  - Firmness, solidity
  - Flavor-sweetness, bitterness

- **Lettuce, Romaine**
  - Number of leaves

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**Maturity Stages of Iceberg Lettuce**

1. Immature  
2. Mature  
3. Overmature

**Weight**  
**Firmness**  
**% Green**  
**Sweetness**  
**Bitterness**  
**Phenolics**

1. Immature  
2. Mature  
3. Overmature

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**Composition of Potato Tubers**

<table>
<thead>
<tr>
<th></th>
<th>Weight g</th>
<th>dry wt. %</th>
<th>Starch %</th>
<th>Sugar %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowering</td>
<td>9</td>
<td>16</td>
<td>64</td>
<td>4.8</td>
</tr>
<tr>
<td>Flowering ends</td>
<td>11</td>
<td>17</td>
<td>66</td>
<td>5.2</td>
</tr>
<tr>
<td>Leaves decline</td>
<td>28</td>
<td>19</td>
<td>72</td>
<td>2.9</td>
</tr>
<tr>
<td>80% leaves dead</td>
<td>33</td>
<td>21</td>
<td>73</td>
<td>0.8</td>
</tr>
<tr>
<td>100% leaves dead</td>
<td>51</td>
<td>20</td>
<td>72</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*cv. Irish Cobbler; data from Burton, 1966*

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Maturity Indices

- **Onions/Garlic**
  - Size
  - Drying and collapse of the “neck”
  - Drying of leaf scales

- **Potatoes**
  - Death of the plant
  - Size of tubers
  - Starch content; specific gravity
  - Periderm development

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Maturity Indices

- **Beans**
  - Size

- **Cucumber**
  - Size
  - External color

- **Okra**
  - Size
  - External color

- **Summer Squash**
  - Size
  - External color

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Harvest Maturity

**Harvest & Maturity Indices**

- **Peppers**
  - Size
  - Color
  - Firmness
  - Seed and locule development

- **Tomato**
  - External and internal color
  - Development of locules (jelly)
  - Firmness
  - Size
  - Development of cuticle

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Tomato 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 tanish-yellow, pink or red or 10% or less of the tomato surface.

3. **TURNING**
   - Tanish-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.
Checker boarding
Due to poor separation of maturity stages of round tomatoes at packing

At Packhouse

TOV at harvest and after 4 days at distribution center. Likely these green fruit will not ripen.

At Distribution

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>38.3</td>
<td>13.6</td>
<td>6.7</td>
<td>30</td>
<td>0.68</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>32</td>
<td>0.67</td>
<td>99</td>
</tr>
<tr>
<td>LSD.05</td>
<td>0.6</td>
<td>ns</td>
<td>1.5</td>
<td>0.8</td>
<td>3</td>
<td>0.09</td>
<td>ns</td>
</tr>
</tbody>
</table>

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

Cantwell, UC Davis, 2003

Group 1* Non climacteric Fruits
Fruits that are not capable of continuing ripening process (physiological changes) once removed from the plant.
*No increase in sugar content; decrease in respiration after harvest. Changes in firmness, external color, and aroma may occur

<table>
<thead>
<tr>
<th>Blackberry</th>
<th>Loquat</th>
<th>Pomegranate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherry</td>
<td>Litchi</td>
<td>Prickly Pear</td>
</tr>
<tr>
<td>Grape</td>
<td>Mandarin</td>
<td>Rambutan</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>Muskmelons</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>

Composition of Ripe Strawberry
Harvested at different stages. Held at 70°F (21°C) to complete color change.

<table>
<thead>
<tr>
<th>Maturity</th>
<th>% SS</th>
<th>% Acid</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% color</td>
<td>4.28</td>
<td>0.80</td>
<td>5.35</td>
</tr>
<tr>
<td>50% color</td>
<td>4.56</td>
<td>0.79</td>
<td>5.77</td>
</tr>
<tr>
<td>75% color</td>
<td>4.98</td>
<td>0.68</td>
<td>7.32</td>
</tr>
<tr>
<td>100% color</td>
<td>5.48</td>
<td>0.59</td>
<td>9.28</td>
</tr>
</tbody>
</table>

Cantaloupe Maturity/Ripeness

- Fruit begins to separate from the stem
- Abscission zone; “slip”
- External color between net
- Net well developed with wax
- Subtending leaf dries up
- Internal color, firmness, soluble solids

Cantwell, UC Davis, 2003

Cantaloupe Maturity/Ripeness: Changes in Sugar Content

Cantaloupe, UC Davis, 2007

Physalis (Goldenberry; Cape Gooseberry) & Stage of Maturity/Ripeness

Cantwell, UC Davis, 2007
Harvest too early
Small size
Poor color
Poor flavor
Harvest too late
Soft fruit
Increased decay susceptibility
More shrivel, stem browning and pitting

Maturity and Ripeness Stages of Cherries

California strawberries and cherries
Distribution Center Singapore
May 16, 2008
Strawberries from Oxnard; Cherries from Lodi

Changes during development and ripening of Sunburst sweet cherries

Composition of fig cultivars separated by stage of maturity (ripeness).

All the fruit were in boxes of ‘Commercial Maturity’ (Cantwell & Croxton, 2010)

Composition of fig cultivars separated by stage of maturity (ripeness).


Indian Kew Pineapples and Composition at Different Stages of Ripeness

Relationship between sugar/acid ratio and sensory panelist’s Response to the question about Willingness to Buy navel oranges

Source: Ivens and Feree, 1987

*D from California A grade standard

Lack of sufficient uniformity of maturity/ripeness within a box leads to repacking or marketing losses

<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>0.66</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>8.87</td>
<td>13.9</td>
<td>4.6</td>
</tr>
<tr>
<td>140-145</td>
<td>1/4</td>
<td>0.83</td>
<td>16.69</td>
<td>18.2</td>
<td>0.77</td>
<td>11.23</td>
<td>14.4</td>
<td>5.4</td>
</tr>
<tr>
<td>146-150</td>
<td>1/2</td>
<td>0.53</td>
<td>17.65</td>
<td>19.9</td>
<td>0.77</td>
<td>11.99</td>
<td>14.9</td>
<td>6.8</td>
</tr>
<tr>
<td>151-155</td>
<td>2/5</td>
<td>0.21</td>
<td>17.76</td>
<td>18.0</td>
<td>0.80</td>
<td>12.44</td>
<td>15.3</td>
<td>6.7</td>
</tr>
<tr>
<td>156-160</td>
<td>Full</td>
<td>0.14</td>
<td>19.69</td>
<td>18.3</td>
<td>0.96</td>
<td>12.74</td>
<td>14.5</td>
<td>6.4</td>
</tr>
<tr>
<td>LSD*</td>
<td>0.05</td>
<td>0.17</td>
<td>0.47</td>
<td>0.07</td>
<td>0.05</td>
<td>2.38</td>
<td>1.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Sensory determined by panel of 10 untrained members based on nine point hedonic scale

California Navel Maturity Standards

The California Standard is easily converted to a table format, similar to the SSC/TA tables currently in use. It is a slight modification of the BrimA calculation proposed by Jordan et al.

Steps involved in determining the California Standard:
- Juice sample using Boswell Press
- Determine Brix using standard protocols
- Determine Titratable Acidity using standard protocols
- Use Table or formula to determine California Standard

Formula for California Standard:
California Standard = (Brix – (TA * 4)) * 16.5

M.L. Arpaia, UC
D. Obenland, USDA

http://www.cdfa.ca.gov/is/i_%26_c/citrus.html

Group 2* Climacteric Fruits
Fruits that can be harvested and ripened off the plant. Fruits undergo significant physiological changes. Fruits have large increases in sugar during ripening because they have starch.

Apple‡ Mango ‡ Pepper (chili)
Apricot Mangosteen Persimmon ‡
Avocado Nectarine Plum
Banana ‡ Papaya Quince ‡
Cherimoya ‡ Passion fruit Sapodilla ‡ (chico)
Guava ‡ Peach Sapotes ‡
Kiwifruit ‡ Pear ‡ Tomato

*Except for avocado, banana, mango and pear, best flavor if ripened on the plant

What should be done? When should harvest?

Papaya (Exotica2), slow ripening cultivar (Malaysia)
Harvest at first color
PH treatment with Ethrel
2 days after treatment, Differences in maturity
Accentuated; some fruit overripe

Mangosteen and eating
Quality—maturity issues

Color Index | Color of Fruit
---|---
1 | Pale yellow green
2 | Blotchy pink
3 | Pinkish red
4 | Maroon Red
5 | Dark maroon violet
6 | Violet black

Mango maturity indices
Fullness of shoulders
Internal and external color
Lenticels and hairs on pit
Starch content
Specific gravity

Golden Delicious at Retail Market: How is the maturity in this box?
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

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

% Dry Weight and Maturity

- Vegetables
  - Potato
  - Onion
  - Garlic
- Fruits
  - Avocado
  - Apples
  - Mango
  - Kiwi

Oil content avocado linearly correlated with % dry weight

Maturity Indices

Requirements for establishing

- 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
- Inexpensive

Use of Maturity Indices

Limitations

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

Predicting Maturity

- Days from planting to harvest
- Progressive changes in size, composition
- Difficult to predict; need new tools and methods
  - Nondestructive firmness measurement, fruits
  - Chlorophyll fluorescence, broccoli; green tissues
  - NIR spectroscopy, sugar concentration in melon
  - MR imaging constituents, internal defects
  - Gene expression rapid assessment


Harvest Prediction For Peaches, Plums & Nectarines: Using Growing Degree Hours
http://fruitsandnuts.ucdavis.edu/Weather_Services/Harvest_Prediction__About_Growing_Degree_Hours/

Maturity and Shelf-life

...Quality is maximized when the product is harvested more mature or ripe, whereas shelf- and storage life are extended if the product is harvested less mature or unripe....


Upper maturity
- Never ripens
- Never shrivels
- Poor flavor
- No repeat buys
- Long shelf-life

Lower maturity
- More decay
- Better flavor
- Too soft
- Bruises easily
- Poor shelf-life
I prefer the Spanish mandarins because they are sweeter than California fruit. This honeydew melon has no sweetness. I love blueberries but these are too tart. These Chilean avocados have no flavor. Discerning consumers say..... This fruit looks great, but .................

Maturity and Product Quality

- Know the consequences of harvesting at different stages of maturity/ripeness on final eating quality.
- Make sure workers involved in harvest and selection are well trained to critically identify maturity/ripeness stages.
- Most indices are a compromise between eating quality and shelf-life.
- As consumers, take back fruit with poor eating quality.

References Maturity Indices