Fruit Ripening and Quality Relationships

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.

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

Ripening
- The set of processes that occur from the later stages of growth and development through the early stages of senescence and that results in characteristic aesthetic and/or eating quality, as evidenced by changes in composition, color, texture, or other sensory attributes.
Stages of Fruit Development

Senescence
- The last stage of development during which degradation of biological components occur.

Physiological Changes Accompanying Senescence of Horticultural Crops
Cellular:
- Loss of chlorophyll, disassembly of chloroplast structure
- Degradation of cell walls
- Altered membrane composition, loss of fluidity
- Loss of cellular compartmentation, release of vacuolar contents

Composition:
- Altered sugar content, and switch to alternative substrates for respiration
- Net loss of RNA
- Increased protease activity, net loss of protein
- Altered amino acid content

Physical Changes Accompanying Senescence of Horticultural Crops
Color:
- Loss of green color
- Synthesis of new pigments (carotenoids, flavanoids)

Texture:
- Softening
- Wilting
- Drying

Loss of resistance to pathogens:
- Development of infections
- Lesions

Respiration and ethylene production rates of climacteric and non-climacteric fruits

Compositional Changes During Pineapple Development
Maturity and Ripening

**Group 1:** Fruits that are *not* capable of continuing their ripening process once removed from the plant.

- Blackberry
- Loquat
- Pomegranate
- Cherry
- Lychee
- Prickly pear
- Grape
- Mandarin
- Rambutan
- Grapefruit
- Muskmelons
- Raspberry
- Lemon
- Orange
- Strawberry
- Lime
- Pepper (bell)
- Tamarillo
- Longan
- Pineapple
- Watermelon

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

**California Minimum Maturity Indices for Selected Non-Climacteric 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

**Group 2:** Fruits that *can be* harvested and ripened off the plant

- Apple
- Mango
- Persimmon
- Apricot
- Nectarine
- Plum
- Avocado
- Papaya
- Quince
- Banana
- Passion fruit
- Sapodilla
- Cherimoya
- Peach
- Sapote
- Guava
- Pear
- Tomato
- Kiwifruit
- Pepper (chili)

**Maturity and Ripening Stages of Apricots**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Maturity and Ripeness Stages of Apricots</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100% green, firm, immature fruit</td>
</tr>
<tr>
<td>2</td>
<td>90% green with some yellow</td>
</tr>
<tr>
<td>3</td>
<td>80% green with dark yellow</td>
</tr>
<tr>
<td>4</td>
<td>70% green with dark yellow</td>
</tr>
</tbody>
</table>

**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 (depending on cultivar)</td>
</tr>
<tr>
<td>Persimmon</td>
<td>Yellowish-green to orange color</td>
</tr>
</tbody>
</table>

SS=soluble solids
Quality Attributes of Fruits

- Vary depending on protagonist in PH chain
- Consumer-centric “quality” ultimately drives marketability and sales
- Overall consumer acceptance strongly correlated with “Flavor acceptance”

Perception of Quality

- Our sensory systems are responsible for generating an internal representation of the outside world, including its chemical (taste and olfaction) and physical (mechanical, sound, vision, and temperature) features.
- When evaluating the quality of the foods we eat, we use the complete array of our sensory system (chemical and physical senses) and integrate this information to formulate a judgment.
- From an evolution standpoint, chemical senses are the most primal of the senses.

Sensory Attributes of Foods

- Appearance
- Taste
- Odor/smell/aroma
- Irritation/pain
- Texture/mouthfeel
- Temperature

Sensory Attributes of Foods

- Our sense of taste is in charge of evaluating the nutritious content of food and preventing the ingestion of toxic substances.
- Taste is a sensation perceived in the mouth, more specifically on the tongue. We have innate likes and dislikes for it.

- Sweet
- Salty
- Bitter
- Sour (acidic)
- Umami (protein – savory)

Sensory Attributes of Foods

<table>
<thead>
<tr>
<th>Maturity stage at harvested</th>
<th>Total phenolics (mg/100g)</th>
<th>Total protein (mg/100g)</th>
<th>Total carbohydrates (mg/100g)</th>
<th>Soluble solids (%)</th>
<th>Total sugar (%)</th>
<th>Total acidity (%)</th>
<th>pH</th>
<th>TRA/TAA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactive</td>
<td>27.7a</td>
<td>9.8a</td>
<td>1.7a</td>
<td>10.8a</td>
<td>9.4a</td>
<td>0.6a</td>
<td>17.7a</td>
<td></td>
</tr>
<tr>
<td>Optimum maturity</td>
<td>51.1a</td>
<td>11.7a</td>
<td>2.9a</td>
<td>13.2a</td>
<td>10.1a</td>
<td>0.9a</td>
<td>21.4a</td>
<td></td>
</tr>
<tr>
<td>Chilling</td>
<td>32.2a</td>
<td>13.7a</td>
<td>2.4a</td>
<td>12.5a</td>
<td>10.3a</td>
<td>0.9a</td>
<td>24.8a</td>
<td></td>
</tr>
</tbody>
</table>
**Sensory Attributes of Foods**

**Aroma**
Aroma (or smell or odor) is the sensation perceived when volatile compounds are drawn into the nose.

We have learned likes and dislikes for it.

**The Aroma of a Strawberry**
Over 200 volatile compounds!!

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**Sensory Attributes of Foods**

**Chemical irritation**
- Common chemical sense
- Stimulated by chemical irritants
  - Ex: capsaicin, piperin, alllicin, glucosinolates, etc...

Innate dislikes (protection)

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**Sensory Attributes of Foods**

**Texture and Mouthfeel**
- Astringency (tannins, calcium oxalate)
- Sense of touch (mechanoreceptors)

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**Fruit Composition and Taste**

<table>
<thead>
<tr>
<th>Quality</th>
<th>Class of compound</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>Sugars</td>
<td>Sucrose, fructose, glucose</td>
</tr>
<tr>
<td></td>
<td>Some proteins</td>
<td>Monellin, thaumatin</td>
</tr>
<tr>
<td>Sour</td>
<td>Acids</td>
<td>Citric acid, malic acid, tartaric acid</td>
</tr>
<tr>
<td>Bitter</td>
<td>Alkaloids, Phenolics, Terpenoids, some proteins</td>
<td>Naringin, cucurbitacins, limonoids</td>
</tr>
<tr>
<td>Salty</td>
<td>Ions</td>
<td>Sodium, calcium</td>
</tr>
<tr>
<td>Umami</td>
<td>Amino acids</td>
<td>Glutamate, aspartate</td>
</tr>
</tbody>
</table>

**A rapid method for measuring sugar content in a liquid**

- A refractometer measures the refraction of light as it passes through a drop of liquid.
- The refractive index is directly proportional to the concentration of diluted solutes in the liquid.
- The “Brix” scale is based solely on a dilution series of sucrose in water.
- The correct term for fruit juice is:
  TOTAL Soluble Solids (TSS or SSC) = sugars, organic acids, soluble pectins, anthocyanins, phenolic compounds...
**Flavor vs. Sugar/Acid Ratio**

<table>
<thead>
<tr>
<th>Acids</th>
<th>Sugars</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Insipid,</td>
<td>Sweet</td>
<td></td>
</tr>
<tr>
<td>Moderate to High</td>
<td>Sour, tart</td>
<td>Best flavor combination</td>
<td></td>
</tr>
</tbody>
</table>

Sensory Attributes and Fruit Composition

- All fruit components (sugars, acids, volatiles, etc...) **combine** to generate a **unique sensory experience** for the consumer.

- Physical methods can give accurate measurements of **fruit composition** but it is difficult to relate these measurements to **fruit quality** without information about **sensory perception**.

Sensory Methodology

- **Analytical tests**
  - Difference? What is it? How strong is it?
  - Descriptive analysis
  - Trained judges

- **Consumer tests**
  - Preference, liking, purchase intent
  - Attitudes, beliefs
  - Ethnography
  - Untrained consumers

Objective measurements and Quality prediction

- Developmental program
- Physiological processes (metabolism)
- Changes in composition
- Genetic/environmental/cultivation factors

- Harvesting at maximum potential

- Altered physiological processes (metabolism)
- Changes in composition
- Genetic/environmental/handling factors

- Attaining and retaining maximum quality
Sensors for Nondestructive Testing of Produce Quality

- Acoustic impulse transmission
- Aroma sensing technology ("electronic noses")
- Chlorophyll fluorescence
- Electrical and mechanical impedance
- Fruit bounce firmness measurement
- Near infrared (NIR) transmittance
- Nuclear magnetic resonance (NMR) imaging
- X-ray imaging

Volatiles as Sensory Markers for Quality

- Testing a rapid method for volatile analysis for use in commercial setting to monitor flavor quality (pre- and post-harvest)
  - zNose
  - HS-SBSE GC-MS

Nondestructive Quality Sensing Needs

- Degree of freshness (time since harvest)
- Prior exposure to ethylene
  (Concentration x duration x temperature)
- Prior exposure of chilling-sensitive commodities to chilling conditions (temperature x duration)
- Internal translucency
- Internal browning
- Mealiness (lack of juiciness)

Questions?