Postharvest Biology: An Overview

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POSTHARVEST SPECIALISTS

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Food Safety

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Fruit & Nut Quality 1941-2012

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Cut Flowers & Potted Plants

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Vegetables & Microbial Safety

Jim Thompson
Cooling, Transport, Fumigation
### Examples Contributions Fruits and Vegetables to Human Health

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Sources</th>
<th>Impacted Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Antioxidants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Broccoli, cantaloupe, citrus, guava, leafy greens, pepper, strawberry tomato, pineapple</td>
<td>Cancer, cataracts, heart disease, stroke</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>Dark-green leafy vegetables, orange vegetables (sweetpotato), orange-flesh fruits (papaya, tomato)</td>
<td></td>
</tr>
<tr>
<td>Vitamin E</td>
<td>Nuts</td>
<td></td>
</tr>
<tr>
<td>Flavonoids</td>
<td>Red, blue and purple fruits (berries, grapes, plum, pomegranate)</td>
<td></td>
</tr>
<tr>
<td><strong>Fiber</strong></td>
<td>Most fruits and vegetables, nuts</td>
<td>Diabetes, heart disease</td>
</tr>
<tr>
<td><strong>Folate</strong></td>
<td>Dark-green leafy veggies; oranges, peas</td>
<td>Birth defects, cancer, heart disease</td>
</tr>
<tr>
<td><strong>Potassium</strong></td>
<td>Potato, sweetpotato, banana, greens</td>
<td>Hypertension, stroke</td>
</tr>
</tbody>
</table>


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### Postharvest Losses and Waste are Costly

Represent loss of inputs and profits
Reduce postharvest losses and increase sustainability
--reduce land, chemical, energy other inputs
--conserve land, water, energy

#### Estimated Postharvest Losses (%) of Fresh Produce

<table>
<thead>
<tr>
<th>Locations</th>
<th>Developed countries</th>
<th>Developing countries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>From production to retail sites</td>
<td>2-23</td>
<td>12</td>
</tr>
<tr>
<td>At retail, foodservice, and consumer sites</td>
<td>5-30</td>
<td>20</td>
</tr>
<tr>
<td>Cumulative total</td>
<td><strong>32</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>

Slide from Adel Kader, Nov 2009, BMG project
Characteristics of Horticultural Crops

- High water content
- Easily damaged
- Diverse
  - genome
  - tissue type
  - physiological state
- Alive – a biological system
- Deterioration begins at harvest

Causes of Quality & postharvest Losses

Leafy Vegetables

- Lettuces
- Spinach
- Cabbage
- Chard
- Broccoli
- Celery
- Herbs
- Endives
- Asparagus

- Water loss
- Mechanical damage
- Loss of chlorophyll and other nutrients
- Respiration rates
- Microbial growth
- Sensitivity to ethylene
Causes of Quality & Postharvest Losses

**Fruits**

- Banana: Mechanical damage
- Apple: Maturity, immature, overmature
- Avocado: Poor ripening, conditioning
- Melons: Softening, texture loss
- Citrus: Changes in composition
- Mango: Water loss
- Tomato: Chilling injury
- Chiles: Microbial growth

From Gordon Mitchell, UC Davis
Fresh Produce Deterioration

- Metabolic changes:
  - respiration, ethylene,
  - texture, aroma, etc.
- Growth and development
- Transpiration
- Mechanical injury
- Physiological disorders
- Decay; microbial growth

Temperature Affects All Causes of Deterioration

Temperature - why is it important?

- Rate of deterioration $\alpha$ rate of respiration
- Respiration:
  
  \[ \text{Sugar} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{Energy (Heat)} \]
- Respiration increases exponentially with T
Cauliflower heads and florets have very similar respiration rates & quality changes during storage

Hevajulige & Cantwell, 2004
Broccoli Shelf-life & Temperature

Storage temperature

Days (to initiate yellowing)

<table>
<thead>
<tr>
<th>Storage temperature</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°C 32°F</td>
<td>7</td>
</tr>
<tr>
<td>5°C 41°F</td>
<td></td>
</tr>
<tr>
<td>10°C 50°F</td>
<td></td>
</tr>
<tr>
<td>15°C 59°F</td>
<td></td>
</tr>
<tr>
<td>20°C 68°F</td>
<td></td>
</tr>
</tbody>
</table>

cv. Legacy

7 days
Broccoli Compositional Quality and Storage Temperature

Chlorophyll

Carotenoids

Ascorbic Acid

Sugars

Limit of Salability

0°C (32°F)
10°C (50°F)
20°C (68°F)

Importance of Temperature to Maintain Quality

A
0°C  32°F

B
5°C  41°F

C
10°C  50°F

7 days
Commercial Cooling Methods

- Room Cooling
- Forced Air Cooling
- Vacuum Cooling
- Hydrocooling
- Icing
- Cooling in refrigerated transport

Product requirements
- Scale appropriate technology
- Conventional, Organic products
- Microbial food safety issues

Maintaining temperature is a major challenge during distribution

Cold Chain Monitoring

6/16/2013
### Effect of Temperature on Deterioration

<table>
<thead>
<tr>
<th>Temp. °F</th>
<th>Temp. °C</th>
<th>$Q_{10}$</th>
<th>Relative Velocity of Deterioration</th>
<th>Relative Shelf-life</th>
<th>Daily Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>0</td>
<td>--</td>
<td>1.0</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>3.0</td>
<td>3.0</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>68</td>
<td>20</td>
<td>2.5</td>
<td>7.5</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>86</td>
<td>30</td>
<td>2.0</td>
<td>15.0</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>104</td>
<td>40</td>
<td>1.5</td>
<td>22.5</td>
<td>4</td>
<td>25</td>
</tr>
</tbody>
</table>

$Q_{10} =$ rate of deterioration at $T+10^\circ$  
rate of deterioration at $T$

No fresh product freezes at 0°C (32°F)  
Lettuce freezes at -0.2°C (31.7°F)
Two Groups of Products
Temperature Compatibility

- **Non-chilling sensitive** products --store near 0°C
- **Chilling sensitive** products --store around 10°C (varies)
  -- Occurs above freezing point
  -- Sensitivity, exposure time, temperature

![Graph showing storage life of broccoli and black bell eggplants](image)

**Symptoms of chilling injury**

- Surface pitting
- Water soaking
- Browning
- Necrosis
- Rots
- Poor flavor
- Poor ripening

Commonly chilling symptoms do not appear until product is transferred from the cold room to a warmer temperature
Temperature and other Postharvest Recommendations

- [http://postharvest.ucdavis.edu](http://postharvest.ucdavis.edu)
  
  **Produce Facts**

  USDA Agriculture Handbook Number 66
  *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks*

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**Modified or Controlled Atmospheres**

- Reducing oxygen
- Increasing carbon dioxide
- Removing carbon dioxide
- Removing ethylene and other volatiles
- Degree of precision differentiates MA and CA

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**Composition of Normal Air**

- 78.08% Nitrogen (N₂)
- 20.95% Oxygen (O₂)
- 0.93% Argon (Ar)
- 0.03% Carbon dioxide (CO₂)
- 0.0001% Ethylene (C₂H₄) (1 ppm)
Some uses of MA for fruits and vegetables
MA is a Supplement to Good Temperature Management

Factors contributing to postharvest losses

• Temperature
  • Water loss
  • Damage
  • Diseases
  • Ethylene
  • Continued growth
  • Physiological disorders

TIME
Transpiration (water loss)

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

Loss of Salable Weight
Loss Fresh Appearance
Loss of Texture

Water loss is Cumulative

\[
\text{Wt loss (\%/day)} = \text{product } K \times \text{VPD}
\]

WATER LOSS

- Products are covered with holes - needed for gas exchange
- Loss of water depends on the vapor pressure deficit (VPD)
- VPD increases exponentially with rising temperature
- Increases linearly with falling humidity

Stomates in leaves; lenticels in fruits
**Water loss and temperature**

\[ \text{Wt loss (\%/day)} = \text{product } K \times \text{VPD} \]

**Psychrometric Chart**

Thermodynamic properties of air

Temperature and Water Content

VPD increases exponentially with rising temperature

VPD increases linearly with falling humidity

Typical field and storage conditions

**% Water Loss**

Table Grapes

Ideal vs Poor Postharvest Handling

<table>
<thead>
<tr>
<th>Delay Before Cooling</th>
<th>6 hours Cooling</th>
<th>7 day Storage</th>
<th>7 day Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load at 40°F, Transport at 40°F</td>
<td>Load at 32°F, 95% RH, air at 0.5 mph</td>
<td>32°F 95% RH, air at 2 mph</td>
<td>32°F 95% RH, air at 2 mph</td>
</tr>
<tr>
<td>6 hrs 80°F 20% RH</td>
<td>1 hr</td>
<td>32°F, 95% RH</td>
<td>32°F, 95% RH</td>
</tr>
</tbody>
</table>

From G. Mitchell, UC Davis
Packaging to reduce water loss. Contain, Protect, Inform. 
RPCs, Paper, Carton, Plastic.

Factors contributing to postharvest losses

- Temperature
- Water loss
- Damage
- Diseases
- Ethylene
- Continued growth
- Physiological disorders
Overcome Damage

• CARE!
• Careful harvesting
• Into lined baskets/bins
• Don’t throw, dump, or drop
• Avoid rough surfaces
• Minimize touch points
• Pack gently but securely

What’s wrong with these pictures?
‘Ranch Pack’ Peach Handling: Simple, Clean and Careful Handling for High Quality Product

Now packers wear hairnets, sometimes gloves

3rd party Inspectors Forced Air Cooling

Diseases
• Major cause of loss
• Relatively few important genera
  – Most are weak pathogens and need injury
• Many products are not infected
Typically the more the product is handled, the greater the physical damage to the product and the greater the risk of postharvest disease.

Changes in Spinach quality:
washed and bagged product stored at 4 Temperatures

DAMAGE AND DECAY
Microbes present an "invisible challenge"

- They don't usually change the appearance, taste or odor of food.
- Fresh produce with no kill step
- Prevention of Contamination is key

**Raw Foods Contain Microorganisms**
**Some are Pathogenic to Humans**

**Good Practices: Key Areas for All Scales of Farming and Shipping**

- Water
- Workers
- Waste
- Wildlife
- Record-keeping
- Traceability

*Water Quality Concerns Rank High on the FDA Priority Risk List*
Factors contributing to postharvest losses

• **Temperature**
  - Water loss
  - Damage
  - Diseases
• **Ethylene**
  - Continued growth
  - Physiological disorders

**Ethylene - an important factor**

*Plant hormone with positive and negative effects on fresh produce*

**Useful:**
- Accelerates ripening
- Causes abscission
- Chlorophyll destruction

**Problematic:**
- Accelerates ripening
- Causes abscission
- Chlorophyll destruction
- Accelerates senescence
Respiration rates of Ripening Fruits

Ethylene induces Ripening

Ethylene not involved in Ripening

Ethylene Production Rates at 20°C (68°F)

<table>
<thead>
<tr>
<th>Range (µL/kg-h)</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01-0.1</td>
<td>Citrus, grape, cherry strawberry</td>
</tr>
<tr>
<td>0.1-1.0</td>
<td>Pineapple, blueberry, cucumber</td>
</tr>
<tr>
<td>1.0-10.0</td>
<td>Banana, mango, tomato, honeydew melon, fig</td>
</tr>
<tr>
<td>10-100</td>
<td>Apple, avocado, cantaloupe, nectarine, papaya, pear</td>
</tr>
<tr>
<td>&gt;100</td>
<td>Cherimoya, passion fruit, sapotes</td>
</tr>
</tbody>
</table>
Postharvest Compatibility Issues

- Temperature
- Relative Humidity
- Ethylene
- Odor

Transportation and Loading

Distribution warehouses and Storage rooms

Retail & Food Service outlets

Manage Ethylene Effects

1. Avoidance
   Products, combustion engines, smoke

2. Removal
   Ventilation (1 air exchange per hour), oxidation, absorption

3. Inhibition of production
   Low temperature, chemical inhibitors of enzymes, antisense technology

4. Inhibition of action
   Low temperature, high CO2, low O2, STS, 1-MCP (Smartfresh™)

5. Germplasm
   Selection of mutants and molecular modification

Control 300 600ppb 1-MCP
Factors contributing to postharvest losses

- Temperature
- Water loss
- Damage
- Diseases
- Ethylene
- Continued growth
- Physiological disorders

Continued growth--temperature

- Sprouting (potato, onion, garlic)
- Rooting (onion, potato)
- Growth away from gravity (asparagus, flowers)
- Internal seed growth (cucumber, beans)
- Opening of immature buds (broccoli)
PHYSIOLOGICAL DISORDERS

- Disorders resulting from abnormal conditions during production and handling
- Abnormal temperatures
- Extended storage
- Abnormal gases
- Nutritional imbalance

Factors that influence U.S. Consumers’ Produce Purchases

Food Safety is Assumed

- Appearance
- Freshness, ripeness
- Taste/Flavor
- Price
- Nutritional value
- In-season
- Size
- Conventional, prepared
- Certified safe, testing
- Storage life
- Type
- Calorie
- Growing region/country
- Organic
- Prepackaged
- Brand name

% of Consumers

Postharvest Problem

...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....


<table>
<thead>
<tr>
<th>ACIDS</th>
<th>SUGARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Insipid,</td>
<td>Sweet</td>
</tr>
<tr>
<td>tasteless</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Sour, tart</td>
</tr>
<tr>
<td>to High</td>
<td></td>
</tr>
</tbody>
</table>

Soluble solids measured by a refractometer = sugars, but also organic acids, soluble pectins, anthocyanins, phenolics, ascorbic acid, others
Based on Appearance (Visual Quality)  
Based on Flavor & Nutritional Quality  
Based on Firmness & Texture

Postharvest Life Under Optimum Conditions


General Principles

• Fresher the product (time), better the quality and flavor
  – True for vegetables
  – More complicated for fruits that require ripening

• Adhering to storage and handling guidelines results in better flavor

• Postharvest treatments may extend the storage -life but not necessary preserve flavor

✓ Need more critical postharvest studies that determine flavor life as well as appearance life.
✓ Reassess current recommendations for whole and fresh-cut products.
How do we successfully move so many products through diverse transportation/distribution channels? How long to market? What storage life is needed? What quality is needed?

1-2 days to harvest, cool, store
1-2 days local transport
7-21 days truck or marine transport
1-3 days to distribution center
1-3 days at retail
1-3 days at consumer

Total = 12 - 34 days

Product under ideal conditions? UNLIKELY!

Factors contributing to postharvest losses

• Respiration
• Water loss
• Damage
• Diseases
• Ethylene
• Continued growth
• Physiological disorders
• Light

TIME and TEMPERATURE

FRESH PRODUCE
Profitable Horticulture Depends on Good Postharvest Handling

- Reduce losses!
- Increase sales and consumption
- Improve quality
  - Taste
  - Nutritional
- New products
- Niche markets
- Lightly processed
- Food safety