Postharvest Biology Overview of Horticultural Crops

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

<table>
<thead>
<tr>
<th>Locations</th>
<th>Developed countries</th>
<th>Mean</th>
<th>Developing countries</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>From production to retail sites</td>
<td>2-20</td>
<td>12</td>
<td>5-95</td>
<td>22</td>
</tr>
<tr>
<td>At retail, foodservice, and consumer sites</td>
<td>5-30</td>
<td>20</td>
<td>2-20</td>
<td>10</td>
</tr>
<tr>
<td>Cumulative total</td>
<td>32</td>
<td>32</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From Adel Kader, Nov 2009, BMG project

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

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

**Fruits**

- Banana
- Apple
- Avocado
- Melons
- Citrus
- Mango
- Tomato
- Chiles
- Berries

- Mechanical damage
- Maturity, immature, overmature
- Poor ripening, conditioning
- Softening, texture loss
- Changes in composition
- Water loss
- Chilling injury
- Microbial growth
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 $\propto$ rate of respiration
- Respiration:
  - Sugar + O$_2$ $\rightarrow$ CO$_2$ + H$_2$O + Energy (Heat)
- Respiration increases exponentially with T

Cauliflower heads and florets have very similar respiration rates & quality changes during storage

Relative Perishability

Asparagus
Artichoke
Broccoli
Peach
Strawberry
Banana
Tomato
Carrot
Nuts
Dates

Relative Respiration Rate

Broccoli Shelf-life & Temperature
Importance of Temperature to Maintain Quality

<table>
<thead>
<tr>
<th></th>
<th>A (0°C)</th>
<th>B (5°C)</th>
<th>C (10°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp.</td>
<td>32°F</td>
<td>41°F</td>
<td>50°F</td>
</tr>
</tbody>
</table>

Maintaining temperature is a major challenge during distribution.

Broccoli Compositional Quality and Storage Temperature

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

Effect of Temperature on Deterioration

<table>
<thead>
<tr>
<th>Temp. °F</th>
<th>Temp. °C</th>
<th>Q₁₀</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>

\[ Q_{10} = \text{rate of deterioration at } T+10°C \]
\[ = \text{rate of deterioration at } T \]
No fresh product freezes at 0°C (32°F)
Lettuce freezes at -0.2°C (31.7°F)

- Non-chilling sensitive products
- Chilling sensitive products
- Chilling sensitivity occurs at temperatures above the freezing point

Eggplants are Chilling Sensitive

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
- Produce Facts
- http://www.ba.ars.usda.gov/hb66/
  USDA Agriculture Handbook Number 66
  The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks

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

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

- MAP Salad Products
- MA for strawberry pallets to control Botrytis
- Bag-in-box MA for melons

Factors contributing to postharvest losses

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

Transpiration (water loss)

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

Water loss is Cumulative

Water loss = product K x VPD

Water loss and temperature

Psychrometric Chart

Temperature and Water Content

Stomates in leaves, lenticels in fruits

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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

Water loss in relation to VPD in 4 products

- Strawberry: $y = 0.506x + 0.35$, $R^2 = 0.91$
- Broccoli: $y = 1.01x + 0.34$, $R^2 = 0.97$
- Romaine: $y = 0.84x + 0.43$, $R^2 = 0.94$
- Mushroom: $y = 1.48x + 0.21$, $R^2 = 0.98$

Psychrometric Chart

Thermodynamic properties of air

Temperature and Water Content

Cantwell, UC Davis
Preventing water loss - reduce VPD

- Harvest when cool
- Reduce temperature
- Increase external VP
  - polyethylene bags
  - increase humidity
- Beware of condensation
  - disease!

Factors contributing to postharvest losses

- Temperature
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  - Physiological disorders

Overcoming 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 this picture?

Packaging to reduce water loss. Contain, Protect, Inform
RPCs, Paper, Carton, Plastic

Hammock Pack for Ripe Fruit
Thompson & Slaughter, UC Davis
‘Ranch Pack’ Peach Handling: Simple, Clean and Careful Handling for High Quality Product

Now packers wear hairnets, sometimes gloves

Hairnets; 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

Temperature and Postharvest Decay

SPINACH: DAMAGE, DECAY, TEMPERATURE

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

DAMAGE AND DECAY

Raw foods contain microorganisms
Some are pathogenic to humans

Microbes present an "invisible challenge"

בוטים הם "אתגר בלתי נראה"

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

From Trevor Suslow, UC Davis

Food Safety Issues
Sources of Contamination: Prevention
Good Production & Handling Practices

Insects, harvesting, handling, processing environments
ANIMALS, BIRDS
SAUSAGE
MEAT
PLANTS
SILAGE
MEAT, MILK, EGGS

From Trevor Suslow, UC Davis
Factors contributing to postharvest losses

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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 Production Rates by Fruits 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>

Manipulating Ethylene Effects

1. Avoidance
   - Products, combustion engines, smoke
2. Removal
   - Ventilation, oxidation, absorption
3. Inhibition of production
   - Low temperature, chemical inhibitors enzymes, antisense technology
4. Inhibition of action
   - Low temperature, high CO2, low O2, STS, 1-MCP (Smartfresh)
5. Germplasm selection/engineering

Compatibility

- Temperature
- Relative Humidity
- Ethylene
- Odor

7 day storage compatibility chart

http://postharvest.ucdavis.edu/produce_information/
Factors contributing to postharvest losses

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- Damage
- Diseases
- Ethylene
- Continued growth
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Factors that influence U.S. Consumers’ Produce Purchases

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

Taste and the Sugar:Acid Ratio

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

Soluble solids measured by a refractometer = sugars, but also organic acids, soluble pectins, anthocyanins, phenolic compounds, ascorbic acid
Characteristics of horticultural crops

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

Factors contributing to postharvest losses

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

10 Basic Postharvest Principles

1) Harvest at correct maturity
2) Reduce physical handling
3) Protect product from sun
4) Keep packingline simple and clean; ensure good worker hygiene
5) Select, classify, and pack carefully
6) Align cartons, strap pallet
7) Cool as soon as possible
8) Know market and product requirements
9) Coordinate efficient & rapid handling
10) Train and compensate workers adequately