Supplemental Treatments

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Preparation for Market Postharvest Treatments

• **Wash** (sprays, brushes, etc.) to remove dirt, residues, etc. Water sanitation is critical – *Covered in previous lecture*

• **Drying** (air, sponge-roller) – *Covered in previous lecture*

• **Wax application** – reduce water loss, enhance appearance, reduce decay (carry fungicide)

• **Fungicide** application – *Covered in previous lecture*

• **Curing** (e.g. potato, dry onions) – wound healing & reduced decay. In field or in rooms

• **Ripening/degreening** treatments

• **Trimming & Fresh-cut** (e.g. lettuce, celery, cauliflower, etc.)

• **Quarantine (insect)** treatments (e.g. fumigation, hot water or air, cold treatments, controlled atmospheres, etc.)
Water Loss

• Typically, 90 to 95% of a commodity is water
• Besides resulting in direct loss of salable weight, it is also an **important source of quality loss**
  – **Appearance quality** - wilting, shriveling, accelerated development of injuries
  – **Textural quality** – loss of crispness, juiciness, etc.
  – **Nutritional quality** – e.g. vitamins A & C
• Thus, managing water content of commodities is critically important
Why do fruits and vegetables lose moisture?

• 100% saturated air in interstitial spaces
• Creates a pressure gradient with surrounding air
• Water vapor moves from high to lower pressure
• Amount of water vapor in air changes with temperature

Figure 4. Primary routes of water loss in fresh produce.
Factors Affecting Water Loss

• Commodity factors
  – Surface to volume ratio
  – Routes of water loss
    • Epidermal cells vs. periderm & other cells
    • Structure of the surface
      • Stomates
      • Lenticels
      • Surface imperfections
      - Cuticular waxes
      - Trichomes
      - Architecture
Radish Weight Loss

Weight (g)

Day 1   Day 2   Day 3   Day 4   Day 5   Day 6   Day 7

w/ tops

w/out tops

Radish Weight Loss

Weight (g)

Day 1   Day 2   Day 3   Day 4   Day 5   Day 6   Day 7

w/ tops

w/out tops
Factors Affecting Water Loss

- **Environmental factors**
  - **Humidity**
    - Lower humidity $\Rightarrow$ greater VPD $\Rightarrow$ greater water loss
  - **Diffusion shells and air velocity**
    - Outside the epidermis, there is a thin layer of air that maintains high humidity (“diffusion shell”). Surface features (e.g. hairs) strongly influence the thickness of this shell
    - Faster air flow $\Rightarrow$ decreases thickness of the diffusion shell $\Rightarrow$ increases water loss
Factors Affecting Water Loss

- **Environmental factors (continued)**

  - **Temperature**
    - Higher temperatures => generally greater VPD => greater water loss
  
  - **Atmospheric pressure**
    - Lower pressures (high altitudes) increases water loss
Reducing Water Loss

Commodity Treatment

- Addition of water to some commodities (incl. cut flowers, potted plants)
Reducing Water Loss
Commodity Treatment

• Careful handling
  – Injury and punctured surfaces greatly increase water loss
  – Proper temperature, R.H., packaging, etc.
Reducing Water Loss
Commodity Treatment

- Rapid cooling & keeping cold
Reducing Water Loss
Commodity Treatment

- Curing of certain root, bulb, and tuber vegetables

Reducing Water Loss
Commodity Treatment

• Waxing and other surface coatings
Reducing Water Loss

Commodity Treatment

- Use of plastic films (wraps) or containers that act as moisture barriers
Reducing Water Loss
Commodity Treatment

- **Packaging**
  - Polyethylene or plastic liners
  - Wood or plain fibreboard boxes can absorb water
Reducing Water Loss
Manipulating the Environment

• Maintaining temperature of refrigeration coils within 1°C of the air temperature
  – Larger evaporator coils
• Minimizing air movement around the commodity & reducing room air exchanges
• Addition of moisture to the air (humidifiers)
Reducing Water Loss
Manipulating the Environment

• **Moisture barriers**, e.g.
  – In the walls of storage rooms and transport vehicles
  – Polyethylene liners or curtains within shipping containers

• **Wet the floor** in storage rooms
Reducing Water Loss
Manipulating the Environment

- **Use crushed ice** in shipping containers and in retail display of commodities that tolerate direct contact with ice.
Reducing Water Loss
Manipulating the Environment

• Sprinkle produce with water during retail marketing
  – Can be used on leafy vegetables, cool-season root vegetables, and immature fruit vegetables (e.g., snap beans, peas, sweet corn, and summer squash)

Ripening & Degreening
The use and control of Ethylene
Climacteric Commodities

- Have increased respiration & ethylene production during ripening
<table>
<thead>
<tr>
<th>Climacteric</th>
<th>Non-Climacteric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Muskmelon</td>
</tr>
<tr>
<td>Apricot</td>
<td>Cacao</td>
</tr>
<tr>
<td>Avocado</td>
<td>Carambola</td>
</tr>
<tr>
<td>Banana</td>
<td>Cherry</td>
</tr>
<tr>
<td>Blueberry</td>
<td>Fig</td>
</tr>
<tr>
<td>Breadfruit</td>
<td>Passion Fruit</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Cucumber</td>
</tr>
<tr>
<td>Carnation</td>
<td>Grape</td>
</tr>
<tr>
<td>Cherimoya</td>
<td>Grapefruit</td>
</tr>
<tr>
<td>Feijoa</td>
<td>Lemon</td>
</tr>
<tr>
<td>Fig</td>
<td>Lime</td>
</tr>
<tr>
<td>Guava</td>
<td>Longan</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>Loquat</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>Lychee</td>
</tr>
<tr>
<td>Mango</td>
<td>Olive</td>
</tr>
<tr>
<td></td>
<td>Orange</td>
</tr>
<tr>
<td></td>
<td>Pepper</td>
</tr>
<tr>
<td></td>
<td>Pineapple</td>
</tr>
<tr>
<td></td>
<td>Pomegranate</td>
</tr>
<tr>
<td></td>
<td>Strawberry</td>
</tr>
<tr>
<td></td>
<td>Tamarillo</td>
</tr>
<tr>
<td></td>
<td>Watermelon</td>
</tr>
<tr>
<td></td>
<td>Soursop</td>
</tr>
<tr>
<td></td>
<td>Tomato</td>
</tr>
</tbody>
</table>
Ripening Fruit

- **Exogenous ethylene application**
  - Initiate or accelerate fruit ripening
  - <1 ppm in lab
  - 10-100 ppm in field; 65F-77F; 90-95% RH
Atmospheric Concentration of Ethylene

- Climacteric & Non-Climacteric plant organs differ in their response to ethylene in the environment.

- Climacteric fruit:
  - Ethylene reduces the time to onset of the climacteric rise (including autocatalytic ethylene production).
  - Concentration of added ethylene has little effect on respiration rate before or during the climacteric.

Kays & Paull, 2004, redrawn from Biale.
Banana Pressure Ripening Room
Tomato Ripening Room
Atmospheric Concentration of Ethylene

- **Non-Climacteric fruit:**
  - Added ethylene induces a rise in respiration
  - Exposure to greater ethylene concentrations do not change how fast maximum respiration rates are obtained
  - Exposure to greater ethylene concentrations elicit greater rates of respiration
  - Does not induce autocatalytic ethylene production
  - Respiration rates return to normal after ethylene is removed
Degreening Citrus

<table>
<thead>
<tr>
<th>Florida</th>
<th>California</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>28 to 29°C (82 to 85°F)</td>
</tr>
<tr>
<td>Ethylene</td>
<td>5 ppm</td>
</tr>
<tr>
<td>Humidity</td>
<td>90 to 96%</td>
</tr>
<tr>
<td>Ventilation (keep below 0.1% CO₂)</td>
<td>1 air change per hour</td>
</tr>
<tr>
<td>Air Circulation</td>
<td>100 CFM per 900 lb. bin</td>
</tr>
<tr>
<td>(CFM = cubic feet per minute)</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>20 to 25°C (68 to 77°F)</td>
</tr>
<tr>
<td>Ethylene</td>
<td>5 to 10 ppm</td>
</tr>
<tr>
<td>Humidity</td>
<td>90%</td>
</tr>
<tr>
<td>Ventilation (keep below 0.1% CO₂)</td>
<td>1 to 2 air changes per hour</td>
</tr>
<tr>
<td>Air Circulation</td>
<td>1 room volume per minute</td>
</tr>
</tbody>
</table>
Fig. 3.—Effect of temperature on rate of degreening of Hamlin oranges. Adapted from Grierson and Newhall (29).

Fig. 3. Effect of Temperature on Rate of Degreening of Marsh Grapefruit.
Barrier prevents air from flowing over the top of the bin stack.

Air flows from behind the barrier.
Air should flow in-between pallet bins.

Air should not short circuit through spaces between pallet bin stacks.
Potential Problems

- Ethylene can potentially be explosive (between 3% and 34%).

Packer
July 12, 1999
Avoiding Exposure to Ethylene

- Keeping ethylene away
  - Exclude other pollution sources (e.g., decaying produce & plant tissue, certain lighting, internal combustion engines, etc.)
  - Use electric forklifts
  - Don’t mix ethylene-producing and ethylene-sensitive crops
**Postharvest Sources and Levels of Ethylene in Lettuce Handling**

<table>
<thead>
<tr>
<th>Sample locations</th>
<th>Ethylene concentration (ppm)</th>
<th>No. of samples analyzed</th>
<th>Potential sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td></td>
<td>21</td>
<td>Air pollution.</td>
</tr>
<tr>
<td>Field to cooler</td>
<td>B* 0.03—0.11 0.07</td>
<td>3</td>
<td>Mechanically injured lettuce. Exhaust from truck, other pollution</td>
</tr>
<tr>
<td>Holding areas prior to vacuum cooling</td>
<td>A 0.01—0.61 0.05</td>
<td>47</td>
<td>Exhaust from trucks and forklifts</td>
</tr>
<tr>
<td>Holding areas prior to vacuum cooling</td>
<td>B 0.01—0.80 0.16</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Immediately following cooling</td>
<td>B 0.01—0.29 0.12</td>
<td>11</td>
<td>(Vacuum cooling removes much of the C₂H₄ inside cartons)</td>
</tr>
<tr>
<td>Cold storage rooms at vacuum coolers</td>
<td>A 0.01—2.78 0.33</td>
<td>144</td>
<td>Exhaust from forklifts, other commodities</td>
</tr>
<tr>
<td>Inside rail cars at destination</td>
<td>A 0.01—0.19 0.06</td>
<td>73</td>
<td>Decay, other pollution sources</td>
</tr>
<tr>
<td>Inside truck units at destination</td>
<td>B 0.01—0.02 0.01</td>
<td>9</td>
<td>Decay, other pollution sources</td>
</tr>
<tr>
<td>Inside truck units at destination</td>
<td>B 0.08—0.11 0.09</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Distribution centers and warehouses</td>
<td>A 0.03—2.49 0.25</td>
<td>22</td>
<td>Exhaust, other commodities</td>
</tr>
<tr>
<td>Retail storage areas</td>
<td>B 0.01—0.78 0.08</td>
<td>43</td>
<td>Other commodities</td>
</tr>
<tr>
<td>Home refrigerator</td>
<td>A 0.02—1.58 0.25</td>
<td>33</td>
<td>Other commodities</td>
</tr>
</tbody>
</table>

*A = atmosphere external to carton; B = inside carton
†Trace = less than 0.10 ppm
Avoiding Exposure to Ethylene

• Remove ethylene from storage rooms
  – Adequate ventilation (air exchange)
  – Use of ethylene absorbers
    • Potassium permanganate, activated and brominated charcoal, palladium-impregnated zeolite
  – Use ozone or UV radiation to oxidize ethylene
Avoiding Exposure to Ethylene

- **Inhibiting Ethylene Biosynthesis & Action**
  - Biosynthesis inhibition
    - AVG (aminoethoxyvinylglycine) - commercial product is “ReTain”
  - Action inhibition
    - 1-MCP (1-methylcyclopropene)
      - Irreversibly binds to ethylene receptors
      - “EthylBloc” for ornamentals and “SmartFresh” for fruits (“Harvista” for preharvest)

https://www.jaguaranalytics.com/home-post/agrofresh-solutions-agfs-how-do-you-like-them-apples/
Modified and Controlled Atmospheres
Relationship Between O2 and CO2 Concentrations and Respiratory Metabolism

Source: A.A. Kader, UC Davis
Modified and Controlled Atmosphere Storage

\[ \text{Sugars} + O_2 \xrightarrow{k} CO_2 + H_2O + \text{Chemical Energy} + \text{Heat} \]

• **Modified atmosphere** (MA) = commodity-generated atmosphere maintained by restricted diffusion
  – Storage rooms, transport vehicles, and packages ("MAP")

• **Controlled atmosphere** (CA) = feedback control and active adjustment of atmosphere
  – Storage rooms and transport vehicles
Relationship Between Biological Gas Concentrations Within a Fruit and Diffusion Through the Various Barriers

H₂O (Variable)  N₂ (78.1%)  O₂ (20.8%)  CO₂ (0.03%)  C₂H₄ (Trace)

BARRIER 1: Commodity

BARRIER 2: Packaging

BARRIER 3: Storage / Transit vehicle

ENVIRONMENT
Banavac Carton MAP System
Pallet MA - Strawberries
Marine Container
CA/MA
Systems

Source: Carrier

Source: Transfresh
Modified Atmosphere Packaging

Semipermeable Film

Microperforated Film

Carton Liner
Fresh-cut Products

Semipermeable Film (MAP) Packages
Quarantine Treatments

Postharvest Control of Insects & Other Pests
Quarantine Pests

“A quarantine pest is a plant pest of potential economic importance to an area that is not yet present there or that is present but not widely distributed and officially controlled.”

Follett & Neven, 2006
Overview

• World trade in agricultural commodities continues to increase

• Phytosanitary restrictions protect the agriculture in a region – Keeps bad bugs out
  – Should be based on a risk assessment, and not a zero risk
  – Should be based on scientific data, and not politics

• At times, phytosanitary regulations, without sound scientific support, are used as trade barriers
Overview

• If accepted disinfestation measures are not available, quarantine pests will prohibit marketing of fresh agricultural products
  – Between countries
  – Between geographical areas within countries (e.g., between Florida and other states)
Overview

- Quarantine or phytosanitary treatments eliminate, sterilize, or kill regulatory pests in exported commodities to prevent their introduction and establishment to new areas.
Treatments

• Treatment protocols are under the authority of the USDA Animal and Plant Health Inspection Service (APHIS)

• This includes overseeing treatment application
Treatments

• Phytosanitary restrictions
  – Often a very high degree of insect control is required before commodities are allowed in
  – “Probit 9 mortality” = the treatment kills or sterilizes 99.9968% of the insect pests
    • ~ 3 survivor in 100,000 insects, or no survivors in 93,613 insects

• See http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf for a list of approved treatments
Treatments Protocol Strategy

1. Kill the most resistant life stage of the pest (insect, etc.)
2. Cause NO physiological injury to the host commodity

• That’s a TALL order! And it doesn’t always work...
Unfortunately for Fresh Produce

• The most important aspect of any treatment(s) is
  – **Preventing pest introductions**
  – **NOT** on the impacts of those treatments on product quality!

https://www.researchgate.net/publication/330945775_Citrus/figures?lo=1
Treatments

• Chemical
  – Fumigation
  – Detergent washes
  – Insecticides

• Physical
  • Temperature
    – Cold treatments
    – Heat treatments
  • Irradiation
  • Controlled Atmospheres
Fumigation

- Most common type of postharvest insect control
  - both for disinfestation & storage
- Often easy to use and relatively inexpensive
- Future availability of some fumigants is questionable
  - Human health issues
  - Environmental impacts
Methyl Bromide (MeBr)

• Methyl Bromide (MeBr)
  – Most commonly used (general biocide)
• Hydrogen Cyanide (HCN)
  – Many commodities are injured by HCN exposure
  – HCN is also very hazardous to people
• Phosphine
  – Limited to dried fruit and nuts
Physical Treatments

Temperature

• Advantages:
  – No residue left on the commodity
  – Relatively safe for workers

• Disadvantages:
  – Possible product injury
  – Higher energy costs
  – Treatment times potentially longer
Cold Treatments

- Approved for a variety of insects on many commodities
- Most effective on insects from subtropical and tropical environments
  - However, crops from these areas are chilling sensitive
  - Potential used of other conditioning treatments to help protect the crops from CI
Heat Treatments

• Hot water dips, vapor heat, and high-temperature forced air treatments
  – e.g., mango, lychee, papaya, citrus
• Vapor heat was one of the first postharvest insect control methods (1920’s)
Irradiation Treatments

• **Gamma rays**
  – Isotopic sources: cobalt-60 or cesium-137

• **X-rays**
  – Electrically driven machine source

• **Electrons** from E-beam
Irradiation Treatments

• Insect sterilization often requires doses < 300 Gy
• Decay control (esp. fungi) often requires doses > 1,000 Gy
• For required levels of irradiation to the center of pallets, outside product must receive 2-3X the minimum C60 or Cs137 dose
• E-beam requires treatment of individual cartons
Controlled Atmospheres

- CA quarantine treatments involve raising the level of CO₂ and/or lowering the level of O₂ in combination with heat or cold to reduce the duration of the lethal treatment and help maintain commodity quality.
Alternative Methods

• **Systems Approach**
  – Integration of numerous biological & physical factors with operational procedures to provide overall quarantine security
    • Can be time-consuming & costly to develop
  – Developed so that if one of the mitigating measures fail, built in safeguards keep the overall risk to negligible levels

• **Eradication**
  – Removal of all target pests from a geographical area, with little chance of normal re-infestation