Importance of Temperature Management

Credits: Michael S. Reid, Marita Cantwell

Outline

- Low temperature storage – benefits
- Factors affected by low temperatures
- Temperature disorders
- Cold Chain and monitoring
- Considerations for Successful Cooling/Storage

Low temperature storage

- Prolongs Shelf Life (=maintains initial quality)
- Slows down ripening (enzymatic degradation and respiratory activity)
- Prevents wilting by slowing or inhibiting water loss
- Slows the rate of produce decay (slows or inhibits microbial growth) – Microbial Food Safety
- Reduces rate of ethylene production
- Minimizes the impact of ethylene
  ✓ Quickly reach the optimum temperature
    • Fast and efficient cooling after harvest
    ✓ Maintain the cold chain
      • Avoid re-warming

Low temperature storage

- First step: removing field heat
- Second step: maintaining a suitable storage temperature
- Field heat is removed slowly in large, poorly ventilated room with a lot of air space (most walk-in coolers-inefficient at removing field heat)
- Faster cooling techniques: hydro-cooling, vacuum cooling and ice to remove field heat
- Refrigerated trucks are designed to maintain product temperature, not reduce it!
Cooling principles

- Harvested produce alive-respires even after it is detached from plant
- Respiration cannot be halted completely
  - objective of postharvest cooling to slow the processes and thus increase storage life
- The higher the holding temperature -> the greater the respiration rate -> the sooner the quality becomes unacceptable

Benefits of Cold Storage

- Minimizes production losses
  - Weather variability cause produce to mature earlier or later than planned
  - Allows produce to be harvested on time and sold when markets become available
- Improves economics of harvest operations
  - Daily harvest may be increased since quality can be preserved -> harvesting over a longer period, spreading out workloads
  - Harvest hours could be extended (effect of ambient temperatures on the produce is lessened)
  - Better use of equipment and personnel
- Minimizes losses during marketing
  - Allows for postharvest storage of very perishable crops to be of acceptable quality (strawberries, leafy vegetables)
- Improves utilization by consumer
  - Supply of top quality produce with longer shelf life -> no urgency to consume or process produce quickly after purchase
  - Consumers more likely to make larger purchases, enjoy lower handling costs and have more timely product utilization
- Expands market opportunities
  - Allows produce to maintain high quality and long/practical shelf life
  - Products compete with quality imports and/or gives export opportunities

Temperature affects other factors important to product life

- Ethylene
  - Production
  - Response
- Water loss
- Wound response
- Decays
- Food safety
- Unintended growth
First Red Roses

Cherry shelf life

Credit: M. Reid, UC Davis

Postharvest Decay

Credit: M. Cantwell, UC Davis

Damage and Decay Impact of Temperature on Quality

Spinach:
- Commercial washed and bagged product
- Leaf damage is very common defect
- Leads to increased decay

Credit: M. Cantwell, UC Davis

But....
Target temp. 0°C (32°F)
Temperature management and microbial food safety

- Generally the product is coldest when loaded for transport to destination markets
- Temperature management supplements good sanitation practices
  - Low temp slows pathogen growth but prolongs pathogen survival (food source required)
  - High temperature shortens pathogen survival time if humidity is low (i.e. no consumer packaging)
  - High temperature + high humidity + food source = proliferation

Time and Temperature are Amplifiers of Risk

Asparagus stored at high temperatures

What is the correct temperature?

- Species from cool climates
  - 0 – 3°C
- Species from tropical climates
  - 10 – 15°C
- Species from sub-tropical climates
  - Varies
    - Avocados – 10°C
    - Kiwi - 0°C

Chilling Injury

- Physiological disorder of plants of subtropical and tropical origin that results in:
  - Reduced quality
  - Loss of product utilization
  - Temperatures between 0 and 15°C (32-59°F)
- CI symptoms become apparent after transfer to ambient conditions

Effect of chilling injury | Symptom
--- | ---
Discoloration | Internal or external or both, usually brown or black
Skin pitting | Sunken spots, especially under dry conditions
Abnormal ripening | Ripening is uneven or fails; compositional changes, off flavors
Increase in decay | Activity of microorganisms

Credit: T.V. Suslow, UC Davis
Credit: M. Cantwell, UC Davis

Photo Credit: Leonard Morris, UC Davis
Photo Credit: CDFA
Products Temperature Compatibility Groups

- **Non-chilling sensitive** products - store near 0°C (32°F)
  - Occurs at low temperatures above freezing point
  - Sensitivity, exposure time, temperature

- **Chilling sensitive** products - store around 10°C (50°F) - varies
  - Persistence, exposure time, temperature

### Symptoms of chilling injury

- **Internal Breakdown**
  - Mealiness (soft but not juicy)
  - Flesh Browning
  - Lack of Flavor
  - Failure to Ripen

### Chilling Sensitivity

<table>
<thead>
<tr>
<th>Lowest safe temperature</th>
<th>Commodity</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>°F</td>
</tr>
<tr>
<td>0-2</td>
<td>32-36</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
</tr>
<tr>
<td>4-40</td>
<td>40</td>
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<tr>
<td>5</td>
<td>41</td>
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<td>7</td>
<td>45</td>
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<td>10</td>
<td>50</td>
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<tr>
<td>13</td>
<td>55</td>
</tr>
</tbody>
</table>

- Apples, beetroot, cabbage, carrots, cauliflower, lettuce, leeks, pears, spinach
- Asparagus, strawberry, zucchini
- Cantaloupe, certain apple cultivars (McIntosh and Yellow Newton), certain avocado cultivars (Booth and Lula), lychee, potato
- Cactus pear, rose apple, durian, feijoa, guava, bumble, limes, bananas, mangosteen, orange, papaya
- Carambola, cucumber, eggplant, grapefruit, lime, mango (ripe), melons (cantaloupe, honeydew, pomelo), passion fruit, pineapple, squash (buff), squash (green), tomato (ripe), watermelon
- Banana, breadfruit, cherimoya, grape, jackfruit, jujube, lemon, mango (mature-green), mangosteen, pumpkin and hard-skinned squash, sapotes, sweet potato, tomato (mature-green), yam

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**Symptoms of chilling injury**

- Surface pitting
- Water soaking
- Browning
- Necrosis
- Rots
- Poor flavor
- Poor ripening
Cucumber chilling injury

Photo credit: Yilmaz Ilker, UC Davis

Chilling injury symptoms

Photo credit: Yilmaz Ilker, UC Davis

Photo credit: Bill Grierson, University of Florida

Ethylene production affected by storage temperatures

• Low temps can:
  • Prevent perception of ethylene
  • Prevent ethylene response

Photo Credit: Don Edwards, UC Davis

Freezing Injury

• Storage recommendations for chilling tolerant commodities slightly above the freezing point
• Occurs when ice crystals form in the tissues
• Cultivars, locations, and growing conditions may affect the freezing point
• Highest safe temperature should be used
• Severity of freezing injury influenced by a combination of time and temperature
**Heat Injury**

- High temperature conditions are injurious to perishable crops
- Organs removed from the plant lack the protective effects of transpiration
- Direct sources of heat (sunlight) can elevate the tissue temperatures to above the thermal death point of their cells, leading to:
  - localized bleaching
  - necrosis (sunburn or sunscald)
  - general collapse

**Direct sun exposure reduces marketable quality**

(product temperature reached 50°C / 122°F after 1 hour)

Photo credit: M. Cantwell, UC Davis
High temperature effects on tomatoes

20°C  25°C  30°C  35°C

Photo Credit: Adel Kader, UC Davis

2 week tomato storage

0°C  15°C  5°C  20°C  10°C  30°C

Photo Credit: Don Edwards, UC Davis

Cantaloupe Melon cooling delays

A. Edible Quality
B. % Soluble solids
C. % Weight loss
D. Pulp Firmness

Quality evaluated after storage for 14 d at 5°C
Generally for netted melons recommend <4 hours delay to cool

DELAYS TO COOL
- Allow for microbial growth
- Allow critical weight loss
- Allow metabolic changes
- Incurring costs without full benefit of cooling operation

Credit: M. Cantwell, UC Davis

Manage the Need to Cool
- Cooling begins in the field
- Harvest early
- Keep product shaded
- Transport frequently to cooler
- Reduce delays to cool
- 1 hour delay to cool = 1 less day shelf-life
- Coordinate harvest and cooling

Credit: M. Cantwell, UC Davis
Cooling Delays

- It is more important to reduce delays to cool than to use the most rapid method of cooling

- Delays permitted (minimal postharvest impact):
  - Berries < 2 hrs (decay)
  - Lettuces < 4 hrs (pinking decay)
  - Broccoli < 3 hrs (firmness)
  - Pepper < 3 hrs (firmness)
  - Eggplant < 3 hrs [gloss]
  - Melon < 4 hrs (future browning)

Relative Humidity (RH)

- RH influences:
  - Water loss
  - Decay development
  - Incidence of some physiological disorders
  - Uniformity of fruit ripening
- Appropriate RH range for storage of fruits is 85 to 95% while that for most vegetables varies between 90 and 98%.
- Optimal RH range for dry onions and pumpkins is 70 to 75%. Some root vegetables, such as carrot, parsnip, and radish, can best be held at 95 to 100% RH.

Relative Humidity (RH) considerations

- Fresh produce continues to transpire and lose water after harvest
- High RH in the storage atmosphere reduces water loss
  - Can be difficult to achieve depending on air exchange rates
- Most refrigeration systems operate at low RH (a rapid drying effect)
- Fresh produce cooling facilities need to be especially designed to provide water vapor management at a high RH

Considerations for Successful Cooling:

- Time between harvest and pre-cooling
- Type of carton, pallet; ventilation
- Cooling method and time allowed
- Initial product temperature
- Final product temperature
- Sanitation of cooling method
- Maintain product temperature

Cold storage:

- Expected storage life or degree of perishability
- Temperature
- Relative humidity
- Sensitivity to chilling injury
- Sensitivity to ethylene
Cold Chain

• All the critical steps and processes that perishable products must undergo in order to maintain their quality
• It is only as strong as its weakest link
• Issues experienced by the cold-chain: poor temperature management due to either the lack of, or limitations in, refrigeration, handling, storage, and humidity control

Maintaining The Cold Chain For Perishables

<table>
<thead>
<tr>
<th>Stage</th>
<th>Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>Minimize delays before cooling, Cool the product thoroughly as soon as possible</td>
</tr>
<tr>
<td>Cooling</td>
<td>Store the product at optimum temperature</td>
</tr>
<tr>
<td>Temporary Storage</td>
<td>Practice first in first out rotation</td>
</tr>
<tr>
<td></td>
<td>Ship to market as soon as possible</td>
</tr>
<tr>
<td>Transport to Market</td>
<td>Use refrigerated loading area, Cool truck before loading, Avoid delays during transport, Load pallets towards the center of the truck, Put insulating plastic strips inside door of reefer if truck makes multiple stops, Monitor product temperature during transport</td>
</tr>
<tr>
<td>Handling at destination</td>
<td>Use a refrigerated unloading area, Measure product temperature, Move product quickly to the proper storage area, Transport to retail markets or foodservice outlet, Operations in refrigerated trucks, Display at proper temperature range</td>
</tr>
<tr>
<td>Handling at home or foodservice outlet</td>
<td>Store product at proper temperature, Use the product as soon as possible</td>
</tr>
</tbody>
</table>

Temperature monitoring tools

• Dataloggers
• Time/temperature labels
• Active RFID

Innovation is here!

• Wireless temperature sensors for easy installation and relocation
• 7 – 10 year battery life
• Washable, NSF-certified sensors for use in food handling
• Intuitive software for easy system management
• Automated email and SMS alerts for quick notification and response
• Intelligent management of expected behaviors such as defrost cycles
Temperature and other Postharvest Recommendations

• http://postharvest.ucdavis.edu (various dates)
  Produce Facts. Recommendations for Maintaining Postharvest Quality

• http://www.ars.usda.gov/is/np/CommercialStorage/CommercialStorage.pdf
  USDA Agriculture Handbook Number 66; The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks
  Printed version 2016

Thanks for your attention