Postharvest Storage

Webinar

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Outline

• Postharvest Basics
• 4 Crop Case Studies
• Systems & Monitoring
If you needed to store these vegetables for 6 months…

…What would you worry about? What specific things should you pay attention to?
What is common about these vegetables and what is different?
You Grew It... Now what?

- By the time you harvest, most costs are sunk.
- Lasting quality depends on good storage.
- Profitability is directly related to waste.
- Market and season expansion
<table>
<thead>
<tr>
<th>Harvest</th>
<th>Postharvest Processing</th>
<th>Storage</th>
<th>Poststorage Processing</th>
<th>Distribution</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety selection</td>
<td>Transport</td>
<td>Temperature control</td>
<td>Rinsing / washing</td>
<td>Transport</td>
<td>Appearance</td>
</tr>
<tr>
<td>Preharvest pathology</td>
<td>Receiving Quality Assurance</td>
<td>Humidity control</td>
<td>Packing</td>
<td>Handling</td>
<td>Flavor</td>
</tr>
<tr>
<td>Cultivation for harvest and storage</td>
<td>Precooling</td>
<td>PACKAGING</td>
<td>Trimming</td>
<td>Crop separation / combination</td>
<td>Form</td>
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<tr>
<td>Field food safety</td>
<td>Washing / rinsing</td>
<td>Trimming</td>
<td>Sorting / culling</td>
<td>Ripening</td>
<td>Texture</td>
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<tr>
<td>Harvest practices</td>
<td>Trimming</td>
<td>Value addition / conversion</td>
<td>Handling</td>
<td>Decay in distribution</td>
<td>Color</td>
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<tr>
<td>Field food safety</td>
<td>Sorting and culling</td>
<td>Controlled and modified atmosphere</td>
<td>Value addition / conversion</td>
<td>Processing Food Safety</td>
<td>Nutrition</td>
</tr>
<tr>
<td>Field packing</td>
<td>Value addition / conversion</td>
<td>Ethylene controls</td>
<td>Crop and variety storage performance (decay &amp; pathology)</td>
<td>Tracking / Tracing</td>
<td>Value</td>
</tr>
<tr>
<td>Field quality assurance</td>
<td>Handling</td>
<td>Handling</td>
<td>Crop separation / combination</td>
<td>Tracking / Tracing</td>
<td>Net energy per calorie</td>
</tr>
<tr>
<td>Field dwell</td>
<td>Packing</td>
<td>Processing Food Safety</td>
<td>Worker safety and ergonomics</td>
<td>Tracking / Tracing</td>
<td>Food Safety</td>
</tr>
<tr>
<td>Maturity at harvest</td>
<td>Ripening</td>
<td>Storage Food Safety</td>
<td>Worker safety and ergonomics</td>
<td>Tracing / tracking &amp; Monitoring</td>
<td>Food Security</td>
</tr>
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<td>Processing food safety</td>
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C. Callahan, UVM Extension. [http://blog.uvm.edu/cwcallah](http://blog.uvm.edu/cwcallah)
Storage Characteristics of Food

- Respiration & Metabolism
- Temperature
- Humidity
- Ethylene
- Food Safety
- Pathology
Postharvest Basics

- Stored crops are still alive.
- Metabolism continues after harvest (respiration).
- ...and it is highly dependent on temperature.
What happens in storage?

• Chilling / Freeze Injury
  – Tissue damage
  – Variable over body of plant
  – Min temp not same as freezing temp

• Desiccation / Drying Damage
  – Cool or cold air
  – Heat from respiration
  – Moisture (H2O) available at surface of produce
  – Need humidity (H2O) in air, “RH” or relative humidity
What happens in storage?

- Ethylene
  - C2H4
  - Produced in stored produce (at various rates)
    - plant hormone
    - physiologically active at very low concentrations
      - (0.1 to 10 ppm)
  - Stored produce is variably sensitive to Ethylene
    - Bittering effect
    - Premature decay
Storage is a hotel.
Not a hospital.
And each crop is different

- Recommended storage conditions
  - Temperature
  - Relative humidity
- Ethylene production rate
- Ethylene sensitivity
- Chilling/Freezing Injury
- Variety differences


[http://www.ba.ars.usda.gov/hb66](http://www.ba.ars.usda.gov/hb66)
# Storage Crops – Case Studies

<table>
<thead>
<tr>
<th>Crop</th>
<th>Units</th>
<th>Carrot</th>
<th>Onion</th>
<th>Potato</th>
<th>Cabbage</th>
<th>Squash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Density</td>
<td>lb/ft³</td>
<td>22</td>
<td>20</td>
<td>42</td>
<td>17</td>
<td>35</td>
</tr>
<tr>
<td>Temp</td>
<td>ºF</td>
<td>32–34</td>
<td>32</td>
<td>36-40</td>
<td>32</td>
<td>50</td>
</tr>
<tr>
<td>RH</td>
<td>%</td>
<td>98 – 100</td>
<td>65 – 70</td>
<td>99 – 100</td>
<td>98 – 100</td>
<td>50-70</td>
</tr>
<tr>
<td>Duration</td>
<td>Months</td>
<td>7 – 9</td>
<td>6 – 9</td>
<td>Up to 12</td>
<td>3 – 6</td>
<td>1-3</td>
</tr>
<tr>
<td>Resp. rate at temp</td>
<td>mg CO₂ kg · hr</td>
<td>10-20</td>
<td>3 (cured)</td>
<td>6 – 18 (cured)</td>
<td>4 – 6</td>
<td>100</td>
</tr>
<tr>
<td>BTU ton-hr</td>
<td></td>
<td>138</td>
<td>28</td>
<td>110</td>
<td>46</td>
<td>917</td>
</tr>
<tr>
<td>Ethylene Prod. Rate</td>
<td>uL kg-hr</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>Trace</td>
</tr>
<tr>
<td>Ethylene Sensitivity</td>
<td>uL L</td>
<td>High ~ 0.2</td>
<td>Low &gt; 1500-2000</td>
<td>Low</td>
<td>High ~ 1.0</td>
<td>Low</td>
</tr>
</tbody>
</table>
Zoned Storage

- Zoned by temperature and relative humidity
- Also consider ethylene production and sensitivity
- Low cost – perforated bags, vapor barrier walls, greenhouse poly, moist burlap
- Higher cost – dedicated structures
- Could also be useful to have a zone dedicated to precooling / removal of field heat.
Removing Heat

- Root Cellar
  - Essentially a cool sink with high humidity
- Air Exchange
  - Exchanging cool outside air with warm inside air using fans and thermostat controls
- Cooler
  - Mechanical refrigeration to “pump” heat out

Adding Heat

- For higher temperature crops
  - Electric, propane, biomass/pellet heaters
“Cold” Storage or “Warm” Storage?
Elliston Root Cellar, Newfoundland - 1610
Structure and Materials

- Sound
- Durable
- Moisture tolerance
- Reusable?
- Portable?
Finish/Inside Materials

“Smooth and cleanable”

- Galvalum roofing
- Lauan (1/8” underlayment, top coat with paint)
- Fiber reinforced plastic (FRP, “dairy board”)
## Cost Summary of Finish Materials

<table>
<thead>
<tr>
<th>Finish Material Options</th>
<th>$/sqft</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRP (Smooth) on 3/8 CDX Plywood</td>
<td>2.48</td>
</tr>
<tr>
<td>FRP (Textured) on 3/8 CDX Plywood</td>
<td>2.62</td>
</tr>
<tr>
<td>1/4&quot; Lauan on 3/8 CDX Ply, Painted</td>
<td>1.60</td>
</tr>
<tr>
<td>Araucoply/Selex 3/8&quot;, Painted</td>
<td>1.35</td>
</tr>
</tbody>
</table>
Structure and Materials

Practices to avoid

Direct soil contact

Uncoated plywood / chipboard / sheetrock

Uncoated sprayfoam
Doors and Sealing

• Check door seals and latches - adjustable
Structure and Materials

• Sealing –
  – daylight test
  – (or dog/cat test).
Rodent & Pest Control

• New construction vs. Retrofit
• Bait & traps
  – OMRI approved D3 rodenticide
  – Must have strict schedule for checking traps!
• Tight envelope excludes pests
  – Wire mesh / hardware cloth
• Some storage bins help exclude rodents
• Cement curb
Refrigeration

Outside the Cooler

Inside the Cooler
Refrigeration

Evaporator Unit

Compressor / Condenser Unit
Evaporator Options

- Standard
- Low Velocity (High Humidity)
- Plates
Humidification

• Generally required for root veg storage
Humidification

Dayton – Humidifier Control 20-90%, $60

Standard room humidifier, refills are manual. $30
Humidification

Trion Duct Humidifier
$285

Atomizing type
Auto-fill

6 gal per day

www.qasupplies.com
DIY Autofill Bucket Humidifier
5 gal per day at 33 F room temp
Evaporative type
Open source design
Parts ~$155

www.FarmHack.net

http://farmhack.net/tools/auto-fill-high-output-temperature-controlled-humidifier#wiki
CoolBots™

- Adapt an air conditioner for use as a refrigeration system.
- Air conditioners are basically “packaged” refrigeration systems run at higher temperature.
- Build a “good box” first.
CoolBots™

• Pro’s
  – Low initial cost
  – Easy to retrofit into existing spaces with basic construction
  – Potential efficiency benefit

• Con’s
  – Slow to “pull down” temperature
  – Slow to recover from rises in temp
  – Can not freeze, only cools down to 35 ºF

www.storeitcold.com – Has loads of info and is very clear.
CoolBot vs. Conventional

- 2009 NYSERDA Study
- 8’x10’ storage room - Albany, NY conditions
- Cooled to 35 F
  - with evap fan controls
    - Conventional is 74 kWhr/yr more efficient ($10/yr)
  - without evap fan controls
    - CoolBot is 230 kWhr/yr more efficient ($30/yr)
- Coolbot cost $750 (net of cold room)
- Conventional cost $4,400 (net of cold room)
Controls - Thermostats

• Control a load based on temperature

“remote bulb” allows measurement inside, adjustment outside of room.
Adding Humidity
• Crops will add some humidity as they respire
• Moist slabs
• Moist burlap / cloth blankets
• Should be cleaned regularly
• Foggers / Nozzles

Removing Humidity
• Outside air exchange can be very effective
  – Small fan with ducting
Humidity Sensors

- Humidity: 10 to 99% RH
- Temperature: 14 to 140°F (-10 to 60°C)
- Accuracy: ±5%RH; ±1.8°F, ±1°C
Sling Psychrometers

QA Supplies
Bacharach Heavy Duty Sling Psychrometer - $155
www.qasupplies.com

Ben Meadows
Weksler Sling Psychrometer - $68
www.benmeadows.com
Containers

• Storage bins/pallet sizing
• Consider: Wood vs. Plastic, Maneuverability, Stackability, Airflow & circulation
Measure and Monitor

• “The measured variable improves.”

• Temperature **AND** Relative Humidity

• Don’t assume you have the conditions you want. **Measure**.

• **Low tech** – wall sensors, daily checks, log book

• **High tech** – remote monitoring, email alerts

• Calibration and certification
USB Data Loggers

DATA-Q  www.dataq.com

EL-USB-2+ USB Data Logger
Measures ambient temperature and humidity
Higher accuracy than EL-USB-2
Automatically calculates dew point
-35 to +80 °C (-31 to +176 °F) temp measurement range
±0.3 °C (±0.6 °F) overall temp accuracy
0-100% RH measurement range
±2.0% overall RH accuracy (20-80%RH)
2 User-programmable temp alarm thresholds
2 User-programmable RH alarm thresholds

5 minute readings = 56 days storage
1 minute readings = 11 days storage
Download data to computer

$125 (RH +/-2%)
$99 (RH +/-3%)
$82 (RH +/-3%)
Apitronics

Base (Hive): $111
Sensors (Bees): $205-240

All wireless

www.apitronics.com
Scouting

- Daily checks for spoilage, sprouting
- Have different people perform the task
- When pulling stored crops, check other bins
- Check for spoilage, sprouting
- Use all five senses
- “Scout” the mechanicals also

Rhizopus Soft Rot on Sweet Potatoes

Potato Affected by Fusarium Dry Rot

Potato Affected by Soft Rot
Cooler Audit

• Envelope (“The Box”)
  – All doors close tightly
  – All seals are sealing
  – Signs of degradation
  – Signs of mold
  – Air circulation inside

• Mechanicals (“The Chiller”)
  – Noise is energy
  – Condenser coil is clean and clear
  – Annual refrigeration tuning
Technical References

- UVM Extension Ag Engineering Blog
  - [http://blog.uvm.edu/cwcallah/](http://blog.uvm.edu/cwcallah/)
- USDA HB 66
- NE Vegetable Management Guide
  - [http://nevegetable.org/](http://nevegetable.org/)
- UC Davis Post Harvest Website
  - [http://postharvest.ucdavis.edu](http://postharvest.ucdavis.edu)
- Psychrometric Charts and Calculators
Remote Data Monitoring – 1st Install at Pete’s Greens

Pete: December 22nd, 2012 by Chris Callahan

As an engineer, I love data. I turn out farmers do also. At least, Pete Johnson and Isaac Jacobs at Pete’s Greens in Craftsbury, VT do. “Is it working yet?” Isaac asks as I put the finishing touches on the remote data monitoring system we have been installing in the four zone drive-in cooler. Just about ... I think. I say with trepidation. Isaac has been up and down in a aircraft 4 times since installing and removing a sensor that was being difficult. And he’s been wrestling with a data station to make it communicate over the wireless network, so that we can actually see the data being collected by the new remote monitoring system.

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