Postharvest Handling
Roots, Tubers, Bulbs

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Postharvest Technology Short Course
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Root, Tubers & Bulbs
General Characteristics
- Storage organs (carbohydrates)
- Relatively low respiration rates
- Low surface to volume ratios
- Bulky and weighty
- Relatively long shelf-life (months)
- Postharvest sprouting, rooting

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General Characteristics
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Root, Tubers & Bulbs
A
- Rutabaga
- Carrots
- Radish
- Beet
- Onion
- Garlic
B
- Sunchoke
- Horseradish
- Celeriac
- Salsify
- Parsnip
- Turnip
C
- Cassava
- Sweetpotato
- Yam
- Taro
- Jicama
- Potato

Storage Temperatures
Roots and Tubers
- Chilling insensitive roots: 0-5°C (32-41°F)
- Most chilling sensitive roots: 10-15°C (50-59°F)
- Potatoes, Mature: 7.5°C (45°F)
- Potatoes, Immature: 4-7°C (40-45°F)

Many root crops are chilling sensitive: Jicama as example

Potatoes can show similar internal breakdown
cv Yellow Finn stored 5 mo. at 2°C
Curing or wound healing is essential for many root and tubers. High humidity is essential to maintain live cells that are capable of healing.

### Curing Conditions

<table>
<thead>
<tr>
<th></th>
<th>Potato</th>
<th>Tropicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>15-20°C (59-68°F)</td>
<td>25-35°C (77-85°F)</td>
</tr>
<tr>
<td>% RH</td>
<td>95 or higher</td>
<td>95 or higher</td>
</tr>
<tr>
<td>Time, days</td>
<td>5-10</td>
<td>1-7</td>
</tr>
</tbody>
</table>

### Sweet potatoes

- Beuregard variety
- 6 kg cartons for Europe
- IMAPESA, Palos Blancos, Sula Santa Barbara Honduras

Sweetpotato storages:
- Evaporative cooling
- Mechanical refrigeration
- 59-66°F (15-18°C)
- High humidity
Harvest and storage of jicama in Mexico

Composition of Potato Tubers

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Weight (g)</th>
<th>dry weight %</th>
<th>Starch %</th>
<th>Sugar %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowering</td>
<td>9</td>
<td>16</td>
<td>64</td>
<td>4.8</td>
</tr>
<tr>
<td>Flowering ends</td>
<td>11</td>
<td>17</td>
<td>66</td>
<td>5.2</td>
</tr>
<tr>
<td>Leaves decline</td>
<td>28</td>
<td>19</td>
<td>72</td>
<td>2.9</td>
</tr>
<tr>
<td>80% leaves dead</td>
<td>33</td>
<td>21</td>
<td>73</td>
<td>0.8</td>
</tr>
<tr>
<td>100% leaves dead</td>
<td>51</td>
<td>20</td>
<td>72</td>
<td>0.7</td>
</tr>
</tbody>
</table>

cv. Irish Cobbler; data from Burton, 1966

What are “new potatoes”
- New potatoes are those which are harvested and sold in an immature condition
- Many new potatoes are produced from early varieties.
- May be small in size, but not necessarily
- Are easily damaged, i.e., skins come off easily
- Are not cured or stored, but harvested immediately

“New or Salad Potatoes”
Quality characteristics of ‘Morning Gold’ potatoes harvested at different times and at different plant kill dates.

<table>
<thead>
<tr>
<th>Kill Date</th>
<th>Harvest Date</th>
<th>Avg. wt. potato</th>
<th>% Dry wt</th>
<th>Sugar, mg/g DW</th>
<th>% wt loss (54.7°F)</th>
<th>Skin Score</th>
<th>Torque Score</th>
<th>Respiration µL CO2/g-h</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 Jul</td>
<td>17 Jul</td>
<td>21.7</td>
<td>16.0</td>
<td>152.6</td>
<td>4.1</td>
<td>2.1</td>
<td>1.2</td>
<td>6.25</td>
</tr>
<tr>
<td>17 Jul</td>
<td>22 Jul</td>
<td>22.5</td>
<td>15.2</td>
<td>87.5</td>
<td>3.3</td>
<td>2.0</td>
<td>1.1</td>
<td>6.75</td>
</tr>
<tr>
<td>17 Jul</td>
<td>27 Jul</td>
<td>21.5</td>
<td>14.6</td>
<td>69.9</td>
<td>1.2</td>
<td>2.2</td>
<td>2.6</td>
<td>7.35</td>
</tr>
<tr>
<td>17 Jul</td>
<td>1 Aug</td>
<td>22.4</td>
<td>15.1</td>
<td>56.1</td>
<td>1.8</td>
<td>3.5</td>
<td>4.4</td>
<td>6.30</td>
</tr>
<tr>
<td>17 Jul</td>
<td>6 Aug</td>
<td>31.4</td>
<td>14.3</td>
<td>40.2</td>
<td>0.5</td>
<td>4.7</td>
<td>0.2</td>
<td>4.90</td>
</tr>
<tr>
<td>22 Jul</td>
<td>22 Jul</td>
<td>36.8</td>
<td>18.2</td>
<td>102.4</td>
<td>4.1</td>
<td>2.8</td>
<td>1.5</td>
<td>6.60</td>
</tr>
<tr>
<td>22 Jul</td>
<td>27 Jul</td>
<td>34.6</td>
<td>18.5</td>
<td>68.1</td>
<td>2.3</td>
<td>2.1</td>
<td>2.7</td>
<td>6.35</td>
</tr>
<tr>
<td>22 Jul</td>
<td>1 Aug</td>
<td>43.5</td>
<td>15.8</td>
<td>89.2</td>
<td>2.1</td>
<td>3.2</td>
<td>3.0</td>
<td>5.60</td>
</tr>
<tr>
<td>22 Jul</td>
<td>6 Aug</td>
<td>36.8</td>
<td>17.7</td>
<td>25.9</td>
<td>0.6</td>
<td>3.3</td>
<td>4.3</td>
<td>4.70</td>
</tr>
<tr>
<td>22 Jul</td>
<td>11 Aug</td>
<td>29.8</td>
<td>15.7</td>
<td>43.5</td>
<td>0.5</td>
<td>5.8</td>
<td>-</td>
<td>5.30</td>
</tr>
</tbody>
</table>

LSD.05: 9.3 2.2 6.0 0.8 0.3 0.5 1.21

Cantwell and Carlson, Tule Lake, CA, 2002

Starch-Sugar Conversions
- Higher storage temperature favors starch accumulation
- Lower temperatures favor sugar increase
- Maturity at harvest
- Cultivar
- Length of storage
  - Senescent sweetening
  - Sugar increase with sprouting

Specific gravity = Weight in air/(Weight in air - Weight in water)

http://www.kimberly.uidaho.edu/potatoes/sp-grvty.htm

Sugars react to form a dark color when potato is fried. Sugars at 2% fresh weight may result in rejection for processing.
Potato Storage

- **Early crop or Short-term storage**
  - Usually not store; ship immediately
  - Cure, store 4-7°C (40-45°F) 2-4 months

- **Late crop or Long-term storage**
  - Sprout inhibitor
  - 5-8°C (41-47°F) >90% RH
  - Store 7 to 12 months

- **Seed potato storage**
  - Low temperature (2-5°C) in the dark
  - Diffuse light storage at 10-20°C

Idaho facility to store 250,000 cwt potatoes. The storage had a center plenum for delivery of air into 2 separate bays.

Potatoes are not washed until ready to market.

Idaho potato Center: [http://www.kimberly.uidaho.edu/potatoes/](http://www.kimberly.uidaho.edu/potatoes/)


Oregon State University- cleaning equipment and storage rooms: [http://oregonstate.edu/potatoes/storproc.htm](http://oregonstate.edu/potatoes/storproc.htm)

Manitoba Canada potato storage structures and management: [http://www.gov.mb.ca/agriculture/crops/potatoes/bda04s06.html](http://www.gov.mb.ca/agriculture/crops/potatoes/bda04s06.html)


Potato links: [http://oregonstate.edu/potatoes/potliv.html](http://oregonstate.edu/potatoes/potliv.html)

Potato Dormancy

Sprouting is undesirable:
- Higher weight loss
- Texture changes
- Compositional changes

- Natural dormancy prevents sprouting for about 2-3 months after harvest.
- For longer periods, need to inhibit sprout growth
  - Temperature
  - Preharvest control
  - Postharvest fumigation after curing

Preharvest Control
- Maleic hydrazide 2-3 wks before harvest, 2500ppm foliar spray

Postharvest Control
- CIPC as dust or aerosol, 10-20 ppm, after curing
- Irradiation at 0.03-0.15 kGy
- Temperature: no sprouting if store below 4°C
- Natural sprout inhibitors (suppressants), carvone, aldehydes (WSU), essential oils from mints

Undesirable greening and increases in glycoalkaloids may occur readily during marketing of specialty potatoes with exposure to LIGHT

Glycoalkaloids affect the nervous system by interfering with the body’s ability to regulate acetylcholine, a chemical responsible for conducting nerve impulses.

<table>
<thead>
<tr>
<th>0</th>
<th>3</th>
<th>6 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed to cool-fluorescent light 20°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposed to cool-fluorescent light 20°C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Major glycoalkaloids in Potatoes: α-Solanine, α-Chaconine
Glycoalkaloids in Potatoes
α-Solanine, α-Chaconine
- Highest content in peel and sprouts
- Cultivars vary considerably
  - 5 mg/100 g fresh wt. is typical
  - >20 mg/100 g is a health hazard
  - >30 mg/100g causes bitterness
- Increase with bruising, wounding
- Increase greatly with light and warmer storage temperatures

Toxic glycoalkaloid formation is closely associated with greening
Control greening & glycoalkaloids:
• No Light (opaque packaging)
• Low Temperature
• Short Duration

http://www.huntsingerfarms.net/
http://potatoes.wsu.edu/research/equipment.htm

Harvest of early-mature potatoes in California
Flume handling Chlorination
Mechanical and Physiological Disorders of Potato (other than Sprouting)

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Symptoms</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greening</td>
<td>Surface turns green with light treatment</td>
<td>Minimize exposure to light</td>
</tr>
<tr>
<td>Black heart</td>
<td>Sharply defined, purplish-grey to black area in center or carries due to O₂ starvation</td>
<td>Provide good air circulation to prevent heating and oxygen deprivation; avoid chilling injury</td>
</tr>
<tr>
<td>Chilling injury</td>
<td>Gray to red-brown areas or black heart</td>
<td>Store tubers above 4°C</td>
</tr>
<tr>
<td>Freezing injury</td>
<td>Vascular tissue turns black and tubers leak when thawed</td>
<td>Store tubers above -1°C</td>
</tr>
<tr>
<td>Blackspot</td>
<td>Internal black spots due to bruising; can cause shatter in some potatoes</td>
<td>Minimize bruising; warm to 15°C before grading</td>
</tr>
</tbody>
</table>

Modified from [http://www.extension.umn.edu/distribution/horticulture/DG6239.html](http://www.extension.umn.edu/distribution/horticulture/DG6239.html)

Potato Diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>Causal Agent</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry rot</td>
<td>Fusarium spp.</td>
<td>Brown, firm, sunken flesh; sunken and wrinkled surfaces with blue or white protuberances</td>
</tr>
<tr>
<td>Soft rot</td>
<td>Erwinia carotovora</td>
<td>Soft, water cavities in flesh, foul smell; in non-russeted varieties, shallow, round lesions around lenticels</td>
</tr>
<tr>
<td>Leak</td>
<td>Pythium</td>
<td>Cooling tubers, well defined areas between healthy and diseased flesh; pink then black flesh with granular, mushy rot</td>
</tr>
<tr>
<td>Late blight</td>
<td>Phytophthora infestans</td>
<td>Small, shrunk, dark spots in flesh; foul smell</td>
</tr>
<tr>
<td>Ring rot</td>
<td>Corynebacterium sepedonicum</td>
<td>Vascular ring yellow</td>
</tr>
</tbody>
</table>

Modified from [http://www.extension.umn.edu/distribution/horticulture/DG6239.html](http://www.extension.umn.edu/distribution/horticulture/DG6239.html)

Water sanitation problem.
Decay due to *Erwinia* bacteria

Severe bacterial soft rot in stored potatoes.

From Trevor Suslow, UC Davis


![Early Stages of Infection](http://info.ag.uidaho.edu/pdf/CIS/CIS1131.pdf)

Pink rot

*Phytophthora erythroseptica*

![Pink rot](http://info.ag.uidaho.edu/pdf/CIS/CIS1131.pdf)
Phytophthora infestans, Late blight

Figure 3. Potato tubers with late blight infection. The tuber in the center shows symptoms of infection through an eye. The blight occurs on either side of the green ear. Brown discoloration associated with late blight.

http://info.ag.uidaho.edu/pdf/CIS/CIS1131.pdf

Important Constituents—Health Benefits, Phytonutrients

- **Quercetin** (flavonoid)
  - Antioxidant activity—delay or slow the oxidative damage to cells
  - Reduce/eliminate free radicals in the body
  - Inhibit low-density lipoprotein (LDL) oxidation (heart disease)
  - Protect and regenerate vitamin E (a powerful antioxidant)

- **Sulfur-containing compounds**
  - Allyl and diallyl sulfides and others—Flavor
  - Reduce blood cholesterol levels
  - Improve immune function
  - Lower blood sugar levels
  - Increase production of enzymes that protect cells against cancer-causing substances (carcinogens)

http://www.onions-usa.org/

Sun scald

Field packing of sweet white onions
Onion Curing Conditions

- Windrow in the field
- Sacks in the field
- Sacks, bins in a protected shed/shade house
- Storage room with slatted floor, heated air

- 1-4 weeks depending on conditions
- Best skin color at 24-32°C (75-90°F)
- Used heated air at same temperature
- Modify air flow rate, dry surface rapidly
- Use lower humidity air if onions are wet (25-35%)
Scale Greening—sun exposure

Blue mold decay
Penicillium

Senescence- translucency

Ammonia Injury

ONION PUNGENCY ASSAY

\[
\text{RSH}_2\text{CCHNH}_2\text{COOH} + \text{H}_2\text{O} \rightarrow \text{methyalliin}
\]

\[
\text{Alliinase} \]

Disrupt Tissue

\[
[R\text{SOH}] + \text{NH}_3 + \text{CH}_3\text{COOCOH} \rightarrow \text{pyruvic acid}
\]

Sweet onions: 5 µmol pyruvate/g FW
Supersweet: 3 or less
Storage onions: 8

Garlic Composition

- **Allin** is the main precursor to important flavor and potentially biological active sulfur-compounds in garlic.
- **Allicin** is the main thiosulfinate produced: provides flavor and pungency and is bioactive.

**Allin and allicin concentrations vary by:**
- Garlic variety (8-29 mg allin/g DW in 190 accessions)
- Irrigation and fertilization practices (higher with inc water)
- Storage conditions and duration
Garlic Bulb Storage

- Well cured
- Relative humidity 60-70% (reduce molds, rooting)
- -2°C to 0°C (28.5°-32°F) long-term
- CA beneficial (1-3%O₂ + 10-15%CO₂)
- 20°C-30°C (68-86°F) 1-2 months
- 5°C-18°C (41°-65°F) favor sprout growth
- Odor easily transferred to other products

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

CA Storage of Garlic

Volk et al. 2004 HortScience 39: 571

Handling Carrots and related roots

- 0°C for storage
- Very high humidity
- Packaging
- Topped to reduce water loss

Carrot varieties

- Carotene-uniformity of color
- Sugar
- Fiber-texture
- Cracking susceptibility
Mechanical harvest of carrots

Longitudinal cracking is highly dependent on variety

Carrots require Diameter & Length Sizing

After sizing, Carrots are hydrocooled (left), Defects removed (below), and then packaged

Carrot Flavor Defects

- **Harshness**: Terpenes  
  - Variety  
  - Growing conditions
- **Bitterness**: Isocoumarin  
  - Postharvest defect  
  - Ethylene exposure

Parsnips also become bitter with ethylene exposure

Bitterness in Carrots

- Induced by ethylene
- Threshold ~0.15 ppm C₂H₄ at 0-5°C
- 70% of isocoumarin in the peel
- Sliced carrots form 4X more isocoumarin
- Physical damage increases isocoumarin
- Other factors: temperature, age, variety