Postharvest Handling
Roots, Tubers, Bulbs

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
### Root, Tubers & Bulbs

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rutabaga</td>
<td>Sunchoke</td>
<td>Cassava</td>
</tr>
<tr>
<td>Carrots</td>
<td>Horseradish</td>
<td>Sweetpotato</td>
</tr>
<tr>
<td>Radish</td>
<td>Celeriac</td>
<td>Yam</td>
</tr>
<tr>
<td>Beet</td>
<td>Salsify</td>
<td>Taro</td>
</tr>
<tr>
<td>Onion</td>
<td>Parsnip</td>
<td>Jicama</td>
</tr>
<tr>
<td>Garlic</td>
<td>Turnip</td>
<td>Potato</td>
</tr>
</tbody>
</table>

- Chilling insensitive roots: 0-5°C
- Most chilling sensitive roots: 10-15°C
- Potatoes 4-8°C
- Low humidity for onion, garlic

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Many root crops are chilling sensitive: Jicama as example

Potatoes can show similar internal breakdown

cv Yellow Finn stored 5 mo. at 2C
Curing or wound healing is essential for many root and tubers.

High humidity is essential to maintain live cells that are capable of healing.

Roots cured in the lab or in commercial storage.
## 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

[Image of sweet potatoes in the field and being harvested]

[Image of sweet potatoes being loaded onto a trailer]

[Image of workers handling sweet potatoes]

[Image of sweet potatoes in a bin]

[Image of sweet potatoes being extracted from the ground]

[Image of sweet potatoes being washed and processed]

[Image of sweet potatoes being dried and stored]

[Image of sweet potatoes being sold or shipped]

6/16/2013
**Sweetpotato storages**
- Evaporative cooling
- Mechanical refrigeration
- 59-60°F (15-16°C)
- High humidity

**Sweetpotato Handling**
For market

Beuregard variety
6 kg cartons for Europe

IMAPESA, Palos Blancos, Sula Santa Barbara Honduras
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
Potatoes are nutritious
- 20% dry matter
- 18% carbohydrate
- 2% protein

Vitamins
- Ascorbic Acid (Vit C; ~20mg/100gFW)
- Folate (Vit B9; ~20µg/100gFW)
- Pyroxidine (Vit B6; 0.25mg/100g FW)

Minerals
- Potassium, Iron, Magnesium, Calcium, Zinc, Phosphorus

Phytonutrients
- Phenolics, Anthocyanins, Flavonols
- Carotenoids, Glycoalkaloids

Controversy regarding potato as large part of a healthful diet—depends on how it is prepared

Quality characterization of potatoes harvested at different times after different plant kill dates.

- 2 cultivars: Morning gold and Carlingford
- 4 kill dates each with 5 harvest dates
- Size, dry weight, sugar content, skin integrity (weight loss, skin score, torque measurement), respiration rates

Skin integrity (Subjective assessment) scale of 5 to 1, where 5 = skin resistant to removal by finger pressure; 1 = very poor skin, skin slips easily with slight finger pressure.

Skin integrity (resistance to skimming). Standard torque test using a modified Halderson periderm tester fitted to a Snap-on® “Torqometer”. Rubber tip with #400 water resistant grit paper. Tip is applied to a flat area of the root with 17 pounds pressure and then rotated clockwise quickly until the skin breaks.
Quality characteristics of ‘Morning Gold’ salad potatoes harvested at different times and plant kill dates.

<table>
<thead>
<tr>
<th>Kill Date</th>
<th>Harvest Date</th>
<th>Ave. wt. g/potato</th>
<th>% dry wt.</th>
<th>Sugar, mg/g DW</th>
<th>% wt loss (5d 7.5°C)</th>
<th>Skin Score</th>
<th>Torque (lb-inch)</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>13.8</td>
<td>132.6</td>
<td>4.1</td>
<td>2.1</td>
<td>1.2</td>
<td>6.75</td>
</tr>
<tr>
<td>17 Jul</td>
<td>22 Jul</td>
<td>22.5</td>
<td>13.2</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>65.9</td>
<td>1.2</td>
<td>2.2</td>
<td>2.8</td>
<td>7.25</td>
</tr>
<tr>
<td>17 Jul</td>
<td>1 Aug</td>
<td>23.4</td>
<td>14.1</td>
<td>59.1</td>
<td>1.8</td>
<td>3.9</td>
<td>4.4</td>
<td>6.30</td>
</tr>
<tr>
<td>17 Jul</td>
<td>6 Aug</td>
<td>21.4</td>
<td>14.3</td>
<td>46.2</td>
<td>0.5</td>
<td>4.7</td>
<td>6.2</td>
<td>4.90</td>
</tr>
<tr>
<td>22 Jul</td>
<td>22 Jul</td>
<td>30.0</td>
<td>15.2</td>
<td>102.6</td>
<td>4.1</td>
<td>2.0</td>
<td>1.5</td>
<td>6.00</td>
</tr>
<tr>
<td>22 Jul</td>
<td>27 Jul</td>
<td>34.6</td>
<td>15.5</td>
<td>66.1</td>
<td>2.5</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>15.2</td>
<td>60.2</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>38.8</td>
<td>17.7</td>
<td>39.9</td>
<td>0.6</td>
<td>3.9</td>
<td>4.3</td>
<td>4.70</td>
</tr>
<tr>
<td>22 Jul</td>
<td>11 Aug</td>
<td>39.0</td>
<td>15.7</td>
<td>43.5</td>
<td>0.5</td>
<td>5.0</td>
<td>--</td>
<td>5.30</td>
</tr>
<tr>
<td>LSD.05</td>
<td></td>
<td>9.3</td>
<td>2.2</td>
<td>6.0</td>
<td>0.8</td>
<td>0.3</td>
<td>0.5</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Specific gravity = Weight in air/(Weight in air - Weight in water)
Specific gravity is directly correlated to % dry matter

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

Sugars react with amino acids to form a dark color when potato is fried. Sugars at 2% fresh weight may result in rejection at processing plant.

During storage, aim to minimize respiration rates

Fig. 12.8 Respiration of samples of potato tubers after about one month at various storage temperatures.
Re-drawn from Burton et al. (1955) with additional points
## Potato Storage

<table>
<thead>
<tr>
<th><strong>Type</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
</table>
| **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                                             |

### Storage Information

- Idaho potato Center: [http://www.kimberly.uidaho.edu/potatoes/](http://www.kimberly.uidaho.edu/potatoes/)
- Oregon State University: [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)
- Washington State University Potato Information and Exchange: [http://potatoes.wsu.edu/research](http://potatoes.wsu.edu/research)
- Exeter-Engineering, Exeter CA: [www.exeter-engineering](http://www.exeter-engineering)
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 (Chlorpropham) dust, aerosol, 10-20 ppm, after curing
- Other chemicals: 1,4-dimethylnaphthalene (1,4 Sight)
- Irradiation at 0.03-0.15 kGy
- Temperature: no sprouting if store below 4°C
- Ethylene
- Natural sprout inhibitors (suppressants), carvone, aldehydes (WSU), essential oils from mints
3. New packaging

Packaging specialty potatoes

- Netted bags-burlap, polyethylene
- Plastic wrapped tray
- Opaque plastic or paper bag
- Microwaveable pouches

Glycoalkaloids in Potatoes

$\alpha$-Solanine, $\alpha$-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 and glycoalkaloids:
- No Light
- Low Temperature
- Short Duration
- Opaque or other packaging
- Other treatments

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 cavities due to O$_2$ 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)

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**Common Defects**
- Growth cracks
- Poor shape, irrigation irregular
- Greening, not covered with soil
- Weed roots penetrate tubers
- Physical damage at harvest
- Decay

**Drops and other mechanical damage cause internal bruising and discoloration**
# Potato Diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>Causal Agent</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry rot</td>
<td><em>Fusarium</em> spp.</td>
<td>brown, firm, sunken flesh; sunken and wrinkled surfaces with blue or white protuberances</td>
</tr>
<tr>
<td>Soft rot</td>
<td><em>Erwinia carotovora</em></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><em>Pythium</em></td>
<td>oozing 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><em>Phytophthora infestans</em></td>
<td>small, shrunken, dark spots in flesh; foul smell</td>
</tr>
<tr>
<td>Ring rot</td>
<td><em>Commbacterium sepedonicum</em></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)

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## Water sanitation problem.
Decay due to *Erwinia* bacteria

Severe bacterial soft rot in Stored potatoes.

From Trevor Suslow, UC Davis

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

![Early Stages of Infection](image1)

![Severe bacterial soft rot in Stored potatoes.](image2)

*Figure 6.* Advanced stages of bacterial soft rot occurring prior to tuber harvest. Rot begins at the point of stolon attachment and continues through the central pith tissue of the tuber. These two tubers additionally show rot caused by secondary tuber rot organisms.
Figure 1. Tuber symptoms of pink rot. Infected tubers first appear cream colored when sliced open. The salmon-pink coloration appears after 15 to 20 minutes at room temperature. 
http://info.ag.uidaho.edu/pdf/CIS/CIS1131.pdf

Phytophthora erythroseptica

Figure 3. Potato tubers with late blight infection. The tuber in the center shows symptoms of infection through an eye. The tuber slices on either side depict the granular, brown dry decay associated with late blight. 
http://info.ag.uidaho.edu/pdf/CIS/CIS1131.pdf

Phytophthora infestans, Late blight
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 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/
Field packing of sweet white onions
Sun scald

Forced air curing of onion skins

Curing with natural ventilation under shade cloth
Packaging must allow for air flow to prevent moisture accumulation.

**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%)
Onion Bulb Storage

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

Botrytis Neck Rot
*Botrytis allii, B. squamosa, B. cinerea*

Symptoms usually appear after harvest
Infections originate in the field.
Develops best under cool & humid conditions (15-20°C)

Control
Grow varieties known to store well
Follow production practices that promote crop storability.
Avoid excessive and late applications of nitrogen.
Do not irrigate within 10 to 14 days of lifting onions.
Allow tops to dry approximately 1 week before topping.
Harvest only when the crop is mature, and during dry weather.
Good storage onions
  - at least three wrapper scales
  - tight neck when dried
Provide good ventilation for curing onions before storage.

http://cru.cahe.wsu.edu/CEPublications/eb1359/eb1359.html
Black Mold
*Aspergillus*

- High temperatures (85-95°F) and moisture favor disease development.
- Bulbs should be protected from moisture during harvesting and shipping.

Scale Greening—sun exposure

Blue mold decay
*Penicillium*

Senescence- translucency

Ammonia Injury
Sour Skin
*Pseudomonas (Burkholderia) cepacia*

Bacterial soft rot
*Erwinia carotovora* & other species

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### Onion Handling and Storage Attributes

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Spring/summer Fresh Onions</th>
<th>Fall/winter Storage Onions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storing Ability</td>
<td>Typically not stored, unless under controlled atmosphere or refrigeration</td>
<td>Designed specifically to withstand long periods of storage</td>
</tr>
<tr>
<td>Storage/Shelf-life</td>
<td>30 – 60 days</td>
<td>30 – 180 days</td>
</tr>
<tr>
<td>Retail Shelf-life</td>
<td>30 days or less</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>Room temperature – Dry storage</td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td>Keep in a dry, well ventilated place</td>
<td></td>
</tr>
<tr>
<td>Freezing Injury</td>
<td>Moderately sensitive. Highest freezing point = 30.6°F or -0.8°C</td>
<td>Hardier than other types. Highest freezing point = 30.6°F or -0.8°C</td>
</tr>
<tr>
<td>Odor Sensitivity</td>
<td>Odors will be absorbed by apples, celery and pears. Will absorb odors produced by apples and pears.</td>
<td></td>
</tr>
<tr>
<td>Sweetness</td>
<td>Sweet/mild to slightly pungent flavors</td>
<td>Varies from mild to very pungent</td>
</tr>
<tr>
<td>Aroma</td>
<td>Mild to slightly pungent</td>
<td>Mildly pungent to strong</td>
</tr>
<tr>
<td>Interior Texture</td>
<td>Soft to medium</td>
<td>Medium to firm</td>
</tr>
<tr>
<td>Exterior</td>
<td>Thin, light colored skin</td>
<td>Multiple layers of thick, dark skin</td>
</tr>
</tbody>
</table>

http://www.onions-usa.org
Garlic harvest and curing

Large variation among Varieties
In % dry wt. In 190 accessions, it varied from 30 to 45%.

Garlic Composition

- **Alliin** 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.

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

Intermediate temperatures (8-18°C) favor sprouting

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°-30°C (68-86°F) 1-2 months
- 5°-18°C (41°-65°F) favor sprout growth
- Odor easily transferred to other products

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
Carrot Flavor Defects

• Harshness: Terpenes
  – Variety
  – Growing conditions

• Bitterness: Isocoumarin (other cpds)
  – Postharvest defect induced by ethylene
  – Most of bitterness in peel
  – Threshold 0.15ppm C2H4 at 0-5°C

Parsnips also become bitter with ethylene exposure