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

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

Harvest and storage of jicama in Mexico
Sweet potatoes
Sweetpotato storages
- Evaporative cooling
- Mechanical refrigeration

Beuregard variety
6 kg cartons for Europe

IMAPESA, Palos Blancos, Sula Santa Barbara Honduras
Composition of Potato Tubers

<table>
<thead>
<tr>
<th>Stage</th>
<th>Weight, g</th>
<th>dry wt, %</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 damage, i.e., skins come off easily
- Are not cured or stored, but harvested and marketed immediately
Specific gravity = \frac{\text{Weight in air}}{\text{Weight in air} - \text{Weight in water}}

\[
\% \text{ DW} = 219.488 \text{ sp. grav} - 216.325 \\
R^2 = 0.9998
\]

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 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 has a center plenum for delivery of air into 2 separate bays.
Potato Storage Information

- 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)
- Washington State University Potato Information and Exchange [http://potatoes.wsu.edu/research/](http://potatoes.wsu.edu/research/)

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, .03-.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

Major glycoalkaloids in Potatoes: \( \alpha \)-Solanine, \( \alpha \)-Chaconine
Glycoalkaloids in Potatoes

$\alpha$-Solaneine, $\alpha$-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/100 g 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

[Solanine Formation in Potato Slices](#)

R. Burbank stored 48 hrs; from Salunkhe, 1972
### Average TGA Concentrations (mg/100g FW)

<table>
<thead>
<tr>
<th>Cultivar (color)</th>
<th>0 time</th>
<th>9d dark</th>
<th>9d light</th>
</tr>
</thead>
<tbody>
<tr>
<td>A94381 (r/y)</td>
<td>2.1</td>
<td>3.0</td>
<td>6.6</td>
</tr>
<tr>
<td>CalRed (r/w)</td>
<td>8.0</td>
<td>21.6</td>
<td>29.4</td>
</tr>
<tr>
<td>Durango (r/w)</td>
<td>4.8</td>
<td>6.6</td>
<td>9.9</td>
</tr>
<tr>
<td>VC1015 (r/y)</td>
<td>4.3</td>
<td>5.6</td>
<td>7.0</td>
</tr>
<tr>
<td>CalWhite (w/w)</td>
<td>4.7</td>
<td>9.9</td>
<td>26.7</td>
</tr>
<tr>
<td>Latona (w/y)</td>
<td>3.8</td>
<td>5.9</td>
<td>12.1</td>
</tr>
<tr>
<td>Satina (w/y)</td>
<td>2.4</td>
<td>4.4</td>
<td>10.0</td>
</tr>
<tr>
<td>Yukon Gold (w/w)</td>
<td>3.5</td>
<td>4.5</td>
<td>5.4</td>
</tr>
</tbody>
</table>

**Notes:**
- 6 days
- 20°C
- Dark L
- Light R
Harvest of early mature potatoes in California
## Mechanical and Physiological Disorders of Potato (other than Sprouting)

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Symptoms</th>
<th>Control</th>
</tr>
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<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 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)

**Drops and other mechanical damage cause internal bruising and discoloration**
Common Defects
- Growth cracks
- Poor shape, irrigation irregular
- Greening, not covered with soil
- Weed roots penetrate tubers
- Physical damage at harvest
- Decay

Potato Diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>Causal Agent</th>
<th>Symptoms</th>
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<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>
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Modified from http://www.extension.umn.edu/distribution/horticulture/DG6239.html
Water sanitation problem.
Decay due to *Erwinia* bacteria

Severe bacterial soft rot in Stored potatoes.

**Early Stages of Infection**

From Trevor Suslow, UC Davis

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

**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.

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**Pink rot**

**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

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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/

Onions and Garlic
Field packing of sweet white onions
Sun scald

Forced air curing of onion skins

Curing with natural ventilation under shade cloth
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 heat air at same temperature
- Modify air flow rate, dry surface rapidly
- Use lower humidity air is onions are wet (25-35%)
Onion Bulb Storage

- Well cured
- Relative humidity 60-70% (reduce molds, rooting)
- 0°C (32°F) long-term
- 20°-30°C (68-86°F) 1-2 months
- 5°-18°C (41°-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
## Onion Handling and Storage Attributes

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Spring/summer Fresh Onions</th>
<th>Fall/winter Storage Onions</th>
</tr>
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<tr>
<td><strong>Storing Ability</strong></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><strong>Storage/Shelf-life</strong></td>
<td>30 – 60 days</td>
<td>30 – 180 days</td>
</tr>
<tr>
<td><strong>Retail Shelf-life</strong></td>
<td>30 days or less</td>
<td>Hold for up to 180 days</td>
</tr>
<tr>
<td><strong>Humidity</strong></td>
<td>Keep in a dry, well ventilated place</td>
<td>Hold at room temperature – Dry storage</td>
</tr>
<tr>
<td><strong>Freezing Injury</strong></td>
<td>Moderately sensitive. Highest freezing point = 30.6°F or -0.8°C</td>
<td>Harsher than other types. Highest freezing point = 30.6°F or -0.8°C</td>
</tr>
<tr>
<td><strong>Odor Sensitivity</strong></td>
<td>Odors will be absorbed by apples, celery and pears. Will absorb odors produced by apples and pears.</td>
<td>Odors will be absorbed by apples, celery and pears.</td>
</tr>
<tr>
<td><strong>Sweetness</strong></td>
<td>Sweet/mild to slightly pungent flavors</td>
<td>Varies from mild to very pungent flavors</td>
</tr>
<tr>
<td><strong>Aroma</strong></td>
<td>Mild to slightly pungent</td>
<td>Mildly pungent to strong</td>
</tr>
<tr>
<td><strong>Interior Texture</strong></td>
<td>Soft to medium</td>
<td>Medium to firm</td>
</tr>
<tr>
<td><strong>Exterior</strong></td>
<td>Thin, light colored skin</td>
<td>Multiple layers of thick, dark skin</td>
</tr>
</tbody>
</table>

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### ONION PUNGENCY ASSAY

\[
O
RSCH_2\text{CHNH}_2\text{COOH} + H_2O \xrightarrow{\text{Alliinase}} \text{methyalliin} \xrightarrow{\text{Disrupt Tissue}} \text{Sulfenic acids, thiosulfinates, pyruvic acid}
\]

- **Sweet onions**: 5 µmol pyruvate/g FW
- **Supersweet**: <3
- **Storage onions**: 8
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/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
- 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

http://postharvest.ucdavis.edu; Produce Facts:

Mechanical damage
Decay
Sprouting
CA Storage of Garlic

Sprout Development

Root Development

Storage Temperature, °C

Sprout growth, % per week

Garlic Sprouting

Intermediate temperatures (8-18C) favor sprouting
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
Mechanical Harvest
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

Bitterness in Carrots

- Induced by ethylene
- Threshold $\sim 0.15$ ppm $\text{C}_2\text{H}_4$ at $0-5^\circ\text{C}$
- 70% of isocoumarin in the peel
- Sliced carrots form 4X more isocoumarin
- Physical damage increases isocoumarin
- Other factors: temperature, age, variety