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

Many root crops are chilling sensitive:
Jicama as example

Potatoes can show similar internal breakdown
cv Yellow Finn stored 5 mo. at 2C

Roots cured in the lab or in commercial storage

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

Sweet potato storages
- Evaporative cooling
- Mechanical refrigeration
- 59-60°F (15-16°C)
- High humidity

Beurregard 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/100g FW)
Folate (Vit B9; ~20µg/100g FW)
Pyridoxine (Vit B6; 0.25mg/100g FW)

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

Phytonutrients
Phenolics, Anthocyanins, Flavonols
Carotenoids, Glycoalkaloids

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

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

During storage, aim to minimize respiration rates

Cantwell and Carlson, UC Davis, 2002

Specific Gravity

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.

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

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
imized by finger pressure; 1=very poor skin, skin slips easily with slight finger pressure.

Skin integrity (resistance to skinning). 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.

During storage, aim to minimize respiration rates

http://www.healthypotato.com/

http://www.mypyramid.gov

http://www.ars.usda.gov/ba/bhnrc/ndl

specific gravity = 219.488 sp. grav - 216.325
R2=0.9998

Specific Gravity

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

Specific Gravity

Dry Weight %

During storage, aim to minimize respiration rates

Starch-Sugar Conversions
• Higher storage temperature favors starch accumulation
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http://www.mypyramid.gov

quality characteristics of 'Morning Gold' salad potatoes harvested at different times and plant kill dates.

LSD.05 9.3 2.2 6.0 0.8 0.3 0.5 1.21

Cantwell and Carlson, UC Davis, 2002
**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

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**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

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**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

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**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/trops/potatoes/bda04s06.html](http://www.gov.mb.ca/agriculture/trops/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.com](http://www.exeter-engineering.com)

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**Packaging specialty potatoes**

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

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**Sprouting**

- Natural dormancy prevents sprouting for about 2-3 months after harvest.
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  - Preharvest control
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**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 Insight)
- 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

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Potatoes are not washed until ready to market.
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

Flume handling
Chlorination

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>
</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 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/DG8239.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>oozing tubers; well defined areas between healthy and diseased flesh; pink then black flesh with granular, miliary 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/DG8239.html

Water sanitation problem. Decay due to Erwinia bacteria

Severe bacterial soft rot in Stored potatoes.

Figure 6. Advanced stages of bacterial soft rot occurring prior to tuber harvest. The infection at the point of stem attachment and continues through the vascular phloem tissues of the foliage. The flesh at the distal end is typically dryer and has not been caused by secondary tuber or organellar disease.

From Trevor Suaying, UC Davis

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

Pink rot

Phytophthora erythroseptica

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

Figure 1. Tuber symptoms of pink rot. Infected tubers first appear cream colored when sliced open. The salmon-pink coloration appears around 15 to 20 minutes at room temperature.

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 tuber slices on either side depict the granular, brown dry decay associated with late blight.

http://info.ag.uidaho.edu/pdf/CIS/CIS1131.pdf
**Postharvest Handling of Onions and Garlic**

**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**

**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°-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.

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
Ammonia Injury
Senescence—translucency

http://cru.cahe.wsu.edu/CEPublications/eb1359/eb1359.html
**Sour Skin**  
*Pseudomonas (Burkholderia) cepacia*

**Bacterial soft rot**  
*Erwinia carotovora* & other species

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**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.
- **Alliin** is the main thiosulfinate produced: provides flavor and pungency and is bioactive.

Alliin and alliin 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 Bulb Storage**

- Well cured
- Relative humidity 60-70% (reduce molds, rotting)
- -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

**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

Carrots require Diameter & Length Sizing

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

Mechanical harvest of carrots
Longitudinal cracking is highly dependent on variety

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