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><strong>Onion</strong></td>
<td><strong>Parsnip</strong></td>
<td>Jicama</td>
</tr>
<tr>
<td><strong>Garlic</strong></td>
<td><strong>Turnip</strong></td>
<td><strong>Potato</strong></td>
</tr>
</tbody>
</table>

Storage Temperatures
Roots, Tubers and Bulbs

- Chilling insensitive roots: 0-5°C (32-41°F)
- Chilling sensitive roots: 10-15°C (50-59°F)
Processing Baby Peeled Carrots

- Washing
- Disinfecting
- Rapid cooling
- Cut to 2 inch sections
- Mechanical Peeling
- Mechanical shaping
- Disinfection
- Cooling
- Computerized quality and color sorting
- VFS packaging

There’s Always Something New at Grimmway Farms!

CARROT DIPPERS™
CARROT SNACKS™ for Horses!
CARROT CHIPS™
CRINKLE-CUT COINS
CARROT STICKS
SHREDDED CARROTS

http://www.grimmway.com
Baby carrots

“Baby” carrots

Carrot varieties

Carotene-uniformity of color
Sugar
Fiber-texture

Longitudinal cracking is highly dependent on variety
Abrasion peeling of carrots leads to fragmented cell walls that dry out and result in “white blush”; can rehydrate carrots.

New equipment automatically peels and then cuts the carrots; have less problem with “white blush”

Carrots do not respond well to Modified atmospheres

White blush or chalking is Minimized at low temperature or with hygroscopic coatings

Free moisture in the bag favors Decay (5°C 1 month)
Carrot Flavor Defects

- Harshness: Terpenes
  - Variety
  - Growing conditions

- Bitterness: Isocoumarin
  - Postharvest defect
  - Ethylene exposure

Bitterness in Carrots

- Induced by ethylene
- Threshold ~0.15 ppm C$_2$H$_4$ 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
Wounding increases sensitivity to ethylene

Pulp of unpeeled 5 cm pieces is very sensitive to ethylene
## 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>Harder 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
Botrytis - gray mold
Aspergillus - black mold
Sunburn
Senescence - translucency

Storage Temperature:
0°C (32°F)
20°C (68°F)
Low RH (~65-70%)

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

ONION PUNGENCY

alliinase

[RSH] + NH₃ + CH₃COCOOH
pyruvic acid

S-containing odoriferous cpds
Low temperature minimizes wound response

Diced onions yellow, decay, soften and leak more than whole peeled onions

Impact of temperature and controlled atmospheres on quality of fresh-cut diced onions

RO=rolled (damaged)
Fresh-cut Onions (dices)
Low temperature is essential for shelf-life and quality

Respiration of Onion Dices

Visual Quality

Limit of Salability

Discoloration

Decay

Pungency
Respiration increases exponentially with increased temperature.

At 10°C, chopping doubles respiration rate.

At 0°C, wound response is minimized.
Visual quality and CA storage

Days at 5°C

Intact

Cut

Heat treated + Cut

Visual quality and CA storage

0 7 14 21
Garlic Bulb Storage

- Well cured
- Relative humidity 60-70% (reduce molds, rooting)
- -1°C to 0°C (30°-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

Considerations for Maintaining the Quality of Fresh Peeled Garlic

- Respiration rates; mechanical injury
- Storage temperatures
- Controlled atmospheres
- Control of sprout/root growth
Careful peeling causes a substantial increase in respiration rates.

Mechanical compressed air peeling **doubles** respiration rates.

Average Respiration Rates ($\mu$L CO$_2$/g-h)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Unpeeled Cloves</th>
<th>Manually Peeled</th>
<th>Compressed Air Peeled</th>
</tr>
</thead>
<tbody>
<tr>
<td>5°C (41°F)</td>
<td>10.6</td>
<td>17.4</td>
<td>21.2</td>
</tr>
<tr>
<td>10°C (50°F)</td>
<td>18.1</td>
<td>29.3</td>
<td>40.6</td>
</tr>
</tbody>
</table>

Commercially Peeled Garlic Stored 9 Days

- 0°C (32°F)
- 5°C (41°F)
- 10°C (50°F)
- 15°C (59°F)
Controlled atmospheres with 10% CO2 helped maintain visual quality of peeled garlic at 5°C (41°F) and 10°C (50°F).

High CO2 atmospheres retarded discoloration and decay.

1% O₂ + 10% CO₂
Remainder N₂
Heat treatments control sprout growth and root growth

Cantwell, Kang, Hong, 2000; stored at 10°C

Sprout Ratio (>1.0 = emerging)

Weeks at 10°C (50°F)

1=none, 3=3-5, 5=11-15, and 7=>20mm

A. Sprout growth

B. Root growth

- 20°C (68°F) 60 min
- 50°C (122°F) 10 min
- 50°C (122°F) 20 min
- 55°C (131°F) 10 min
- 60°C (140°F) 2.5 min
- 45°C (113°F) 60 min

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
- Irrigation and fertilization practices
- Storage conditions and duration
Maintaining Quality of Peeled Garlic

• Reduce mechanical injury at peeling
• Store at low temperature, ~0°C (32°F)
• Use modified atmospheres with 5-10% CO₂
• Heat shock treatments retard sprout/root growth

• Selection of varieties with specific qualities, high or low pungency, long dormancy, resistance to bruising and mechanical injury
• Treatments to remove “crowns” during peeling

Many root crops are chilling sensitive: Jicama as example

Potato stored 4-5 mo. 2°C
Jicama:
- Discoloration is problematic only at high temperatures
- Raw material quality, starch-sugar
- Surface drying

Potato Internal Color
### Defects
1. Skinning
2. Internal deterioration
3. Cut edge discoloration

---

#### “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>Ave. wt.</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>29.9</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>

Cantwell and Carlson, Tule Lake, CA, 2002
Storage of “new potatoes” at 5°C (41°F) in air results in significant increases in sugar concentrations, while sugar levels do not increase much at 10°C (50°F).

![Graph](image)

Tule Lake potatoes, 2001

The 2 bags tested created very different atmospheres.

Storage temperatures from 2.5-7.5°C (36-45°F) did not greatly affect gas concentrations

MA Test #1, Tule Lake, “new potato” cv. Penta
Sugars increased more in potatoes stored in the bag that provided higher O2 and lower CO2 concentrations.

MA Test #1, Tule Lake, “new potato” cv. Penta

---

**Fresh-peeled and cut Potatoes**

**Raw material quality**

**Washing and peeling, slicing** (sharp)
- abrasion, steam, caustic

**Focus on control of browning**
- Cultivars vary widely
- Citric, ascorbic acid
- Bisulfites not allowed
  - http://hort.cabweb.org/Postharv/Laurila.htm

**Temperatures and atmospheres**
- Cold
- MA: high CO2 + N2
Toxic glycoalkaloid formation is closely associated with greening.

Control greening & glycoalkaloids:
- No Light - opaque packaging
- Low Temperature
- Short Duration

Potato variety
1 Sabra
2 Crispin
3 Moly
4 Yukon Gold
5 Red La Soda
6 Cal Red
7 Ruby Red
8 Alaska
9 White Rose
10 Durango
11 Morning Gold
12 Satina
13 Crispin

mg/100g fresh weight

Solanine Formation in Potato Slices
R. Burbank stored 48 hrs; from Salunkhe, 1972
Glycoalkaloids vs Chlorophyll Content

![Graph showing TGA vs Chlorophyll content with regression equations and data points for different cultivars.]

**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>4.8</td>
<td>6.6</td>
<td>9.9</td>
</tr>
<tr>
<td>Durango (r/w)</td>
<td>4.3</td>
<td>5.6</td>
<td>7.0</td>
</tr>
<tr>
<td>VC1015 (r/y)</td>
<td>4.7</td>
<td>9.9</td>
<td>26.7</td>
</tr>
<tr>
<td>CalWhite (w/w)</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>