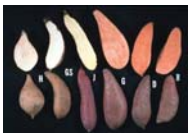
Postharvest Technology Short Course
June 2009

Postharvest Handling Roots, Tubers, Bulbs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http://postharvest.ucdavis.edu

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

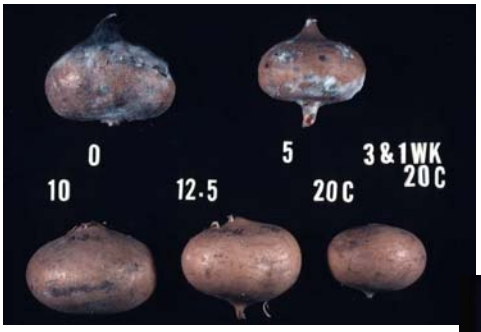
Root, Tubers & Bulbs

A	B	C
Rutabaga	**Sunchoke**	**Cassava**
Carrots	**Horseradish**	**Sweetpotato**
Radish	**Celeriac**	**Yam**
Beet	**Salsify**	**Taro**
Onion	**Parsnip**	**Jicama**
Garlic	**Turnip**	**Potato**

Storage Temperatures Roots and Tubers

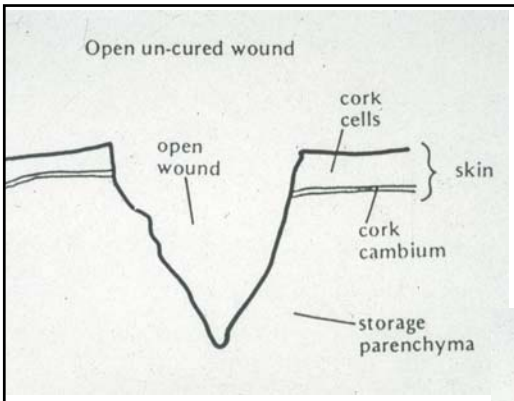
- Chilling insensitive roots: **0-5°C (32-41°F)**
- Most chilling sensitive roots: **10-15°C (50-59°F)**
- Potatoes, Mature: **7.5°C (45°F)**
- Potatoes, Immature: **4-7°C (40-45°F)**

Many root crops are chilling sensitive: Jicama as example

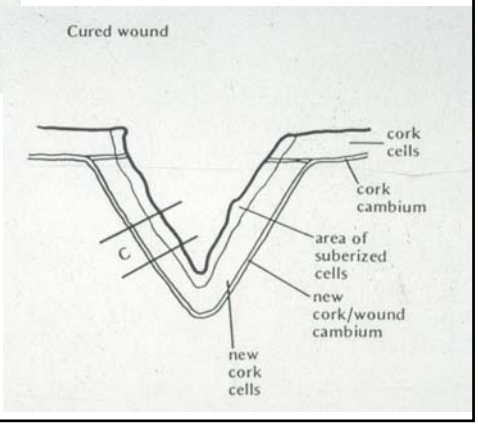


Potatoes can show similar internal breakdown

cv Yellow Finn stored 5 mo. at 2C

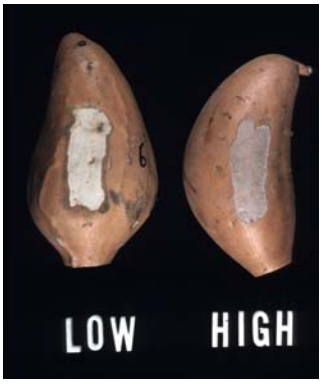


Curing or wound healing is essential for many root and tubers



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

Roots cured in the lab or in commercial storage



Curing Conditions

	Potato	**Tropicals**
Temperature	15-20°C (59-68°F)	25-35°C (77-85°F)
% RH	95 or higher	95 or higher
Time, days	5-10	1-7

Harvest and storage of jicama in Mexico

Sweet potatoes

Sweetpotato storages

- **Evaporative cooling**
- **Mechanical refrigeration**

Sweetpotato Handling

Beuregard variety
6 kg cartons for Europe

IMAPESA, Palos Blancos, Sula Santa Barbara Honduras

Composition of Potato Tubers

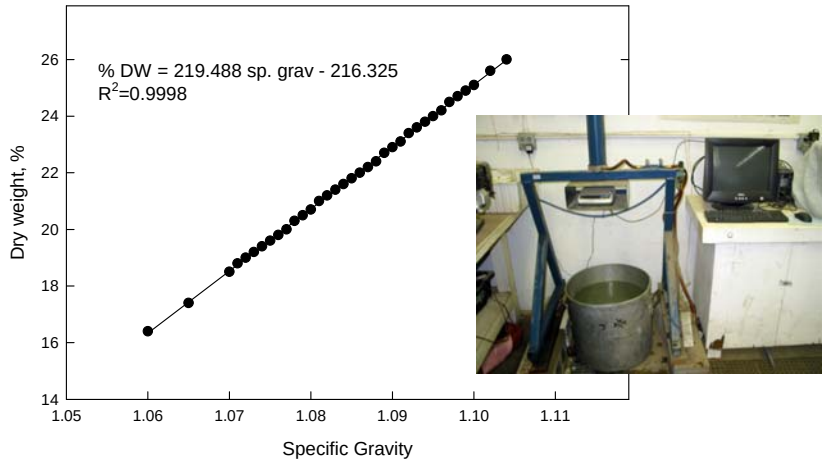
	Weight ,g	dry wt, %	Starch, %	Sugar, %
Flowering	9	16	64	4.8
Flowering ends	11	17	66	5.2
Leaves decline	28	19	72	2.9
80% leaves dead	33	21	73	0.8
100% leaves dead	51	20	72	0.7

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 harvest marketed immediately

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



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

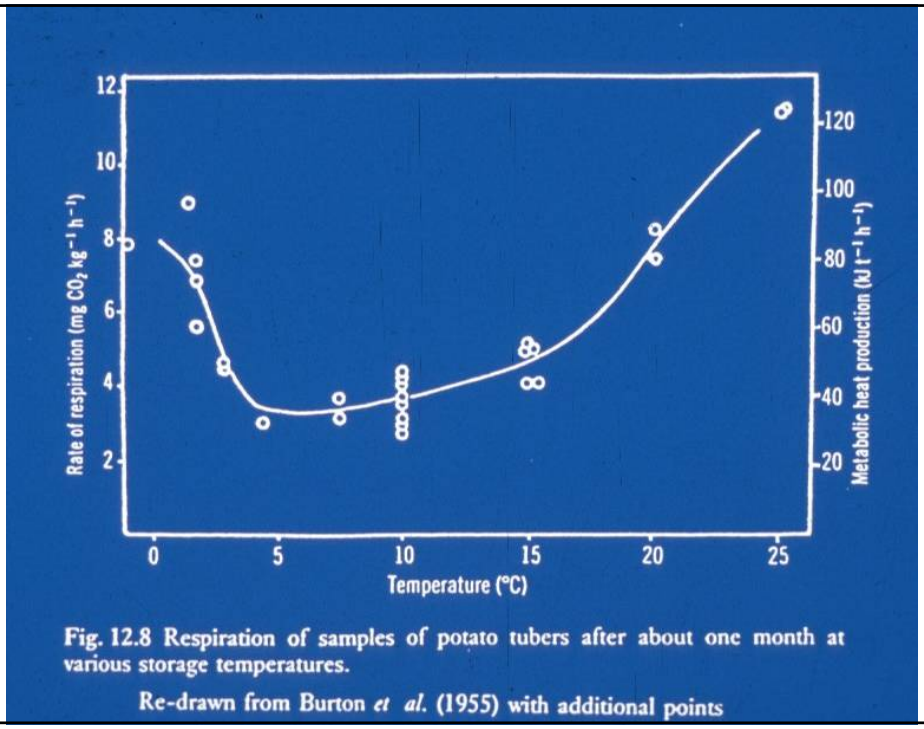


Fig. 12.8 Respiration of samples of potato tubers after about one month at various storage temperatures.

Re-drawn from Burton *et al.* (1955) with additional points

Potato Storage

Idaho facility to store 250,00 cwt potatoes. The storage has a center plenum for delivery of air into 2 separate bays.

- **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

Potato Storage information

- Idaho potato Center http://www.kimberly.uidaho.edu/potatoes/
- Potato storage diseases, Univ. Idaho http://info.ag.uidaho.edu/pdf/CIS/CIS1131.pdf
- Oregon State University- cleaning equipment and storage rooms http://oregonstate.edu/potatoes/storproc.htm
- Manitoba Canada potato storage structures and management http://www.gov.mb.ca/agriculture/crops/potatoes/bda04s06.html
- Global potato news http://www.potatonews.com/news/news.asp
- Potato links. http://oregonstate.edu/potatoes/potliv.html
- Washington State University Potato Information and Exchange 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

CIPC fumigation of potato storage

Postharvest Control

- CIPC as dust or aersol, 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

0 3 6days
Exposed to cool-fluorescent light 20°C

0 3 6days
Exposed to cool-fluorescent light 20°C

Major glycoalkaloids in Potatoes: α-Solanine, α-Chaconine

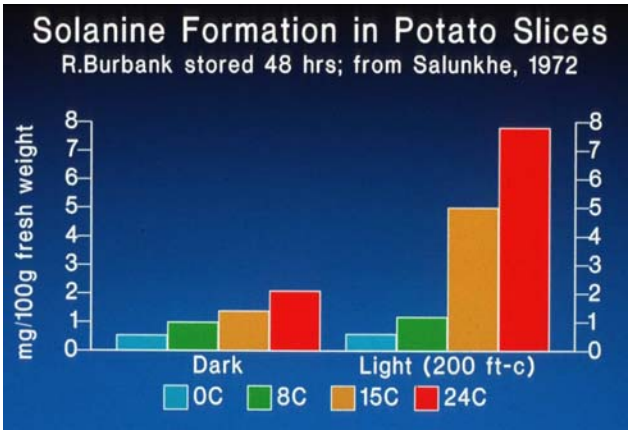
Glycoalkaloids in Potatoes

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

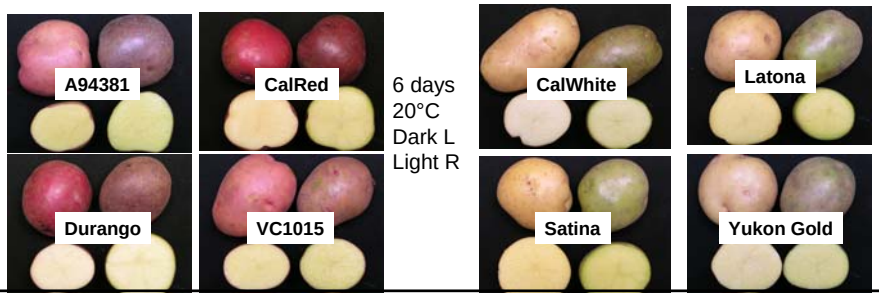
Toxic glycoalkaloid formation is closely associated with greening

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



Average TGA Concentrations (mg/100g FW)

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



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)

Disorder	Symptoms	Control
Greening	surface turns green with light treatment	minimize exposure to light
Black heart	sharply defined, purplish-grey to black area in center or cavities due to O_2 starvation	provide good air circulation to prevent heating and oxygen deprivation; avoid chilling injury
Chilling injury	gray to red-brown areas or black heart	store tubers above 4°C
Freezing injury	vascular tissue turns black and tubers leak when thawed	store tubers above -1°C
Blackspot	internal black spots due to bruising; can cause shatter in some potatoes	minimize bruising; warm to 15°C before grading

Modified from 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

Disease	Causal Agent	Symptoms
Dry rot	*Fusarium* spp.	brown, firm, sunken flesh; sunken and wrinkled surfaces with blue or white protuberances
Soft rot	*Erwinia carotovora*	soft, water cavities in flesh, foul smell; in non-russeted varieties, shallow, round lesions around lenticels
Leak	*Pythium*	oozing tubers; well defined areas between healthy and diseased flesh; pink then black flesh with granular, mushy rot
Late blight	*Phytophthora infestans*	small, shrunken, dark spots in flesh; foul smell
Ring rot	*Cornybacterium sepedonicum*	vascular ring yellow

Modified from http://www.extension.umn.edu/distribution/horticulture/DG6239.html

Water sanitation problem.
Decay due to *Erwinia* bacteria

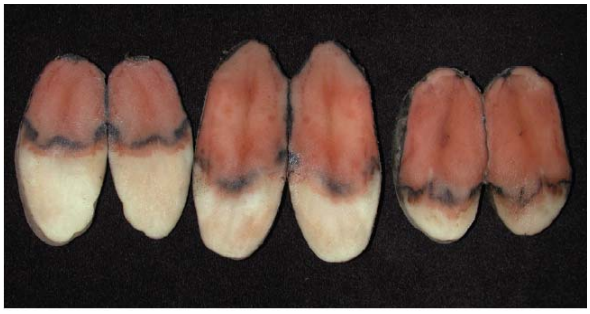
Early Stages of Infection

From Trevor Suslow, UC Davis

Severe bacterial soft rot in
Stored potatoes.

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.

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



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

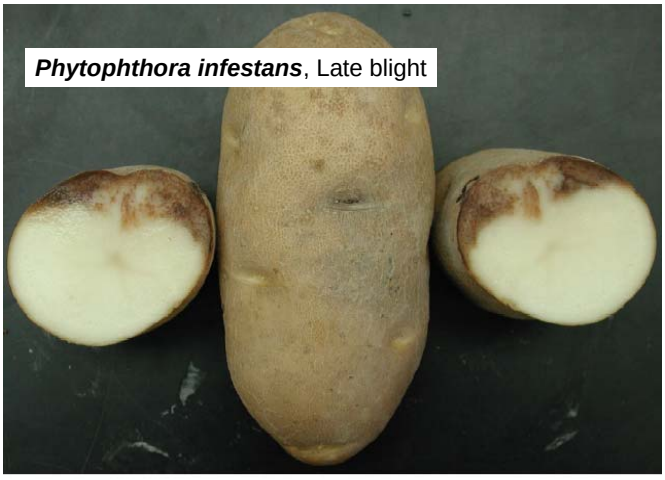


Figure 3. Potato tubers with late blight infection. The tuber in the center shows symptoms of infection through an eye. The tuber slices on either side depict the granular, brown dry decay associated with late blight.

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

Root, Tubers & Bulbs

A	B	C
Rutabaga	Sunchoke	Cassava
Carrots	Horseradish	Sweetpotato
Radish	Celeriac	Yam
Beet	Salsify	Taro
Onion	Parsnip	Jicama
Garlic	Turnip	Potato

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

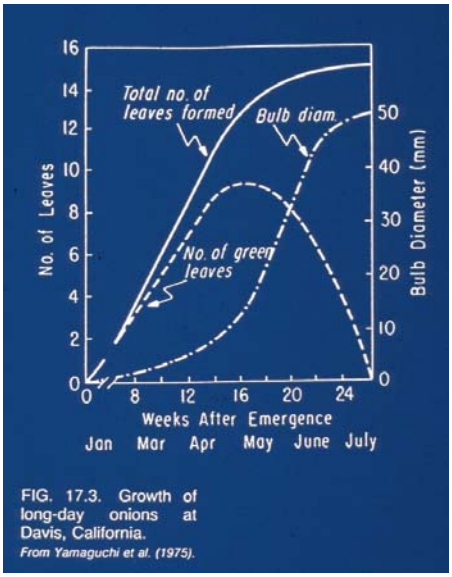
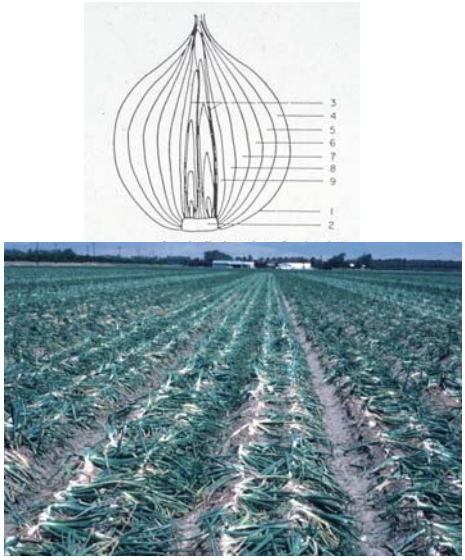


FIG. 17.3. Growth of long-day onions at Davis, California.
From Yamaguchi et al. (1975).



Field packing of sweet white onions

Sun scald

Forced air curing of onion skins

Curing with natural ventilation under shade cloth

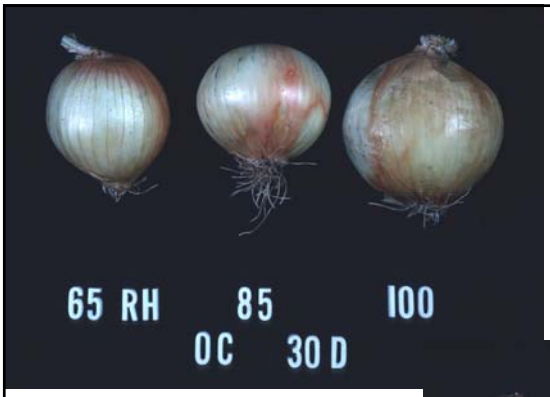
Onion Curing Conditions

- 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



Storage Conditions:
0°C (32°F)
20°C (68°F)

Low RH (~65-70%)

0°C = 32°F
25°C = 77°F

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 (15-20C)

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

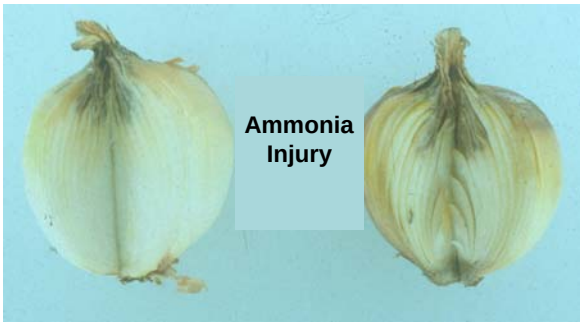
Black Mold
Aspergillus

- 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



Sour Skin
Pseudomonas (Burkholderia) cepacia

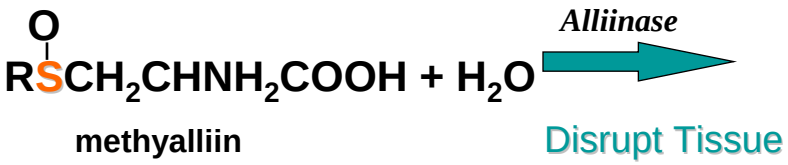
Bacterial soft rot
Erwinia carotovora & other species

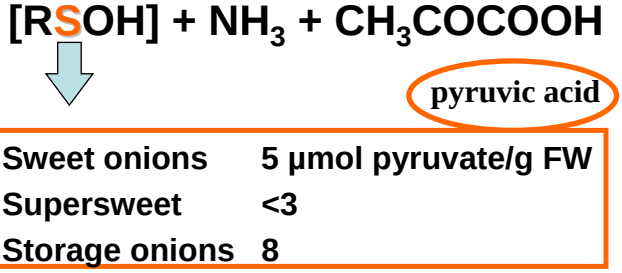
Onion Handling and Storage Attributes

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

http://www.onions-usa.org

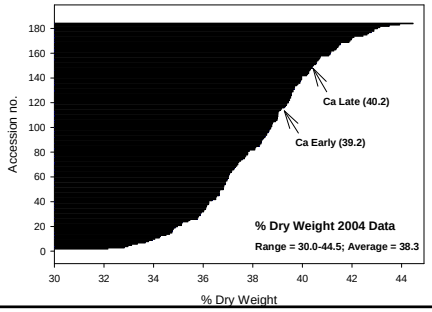
ONION PUNGENCY ASSAY





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

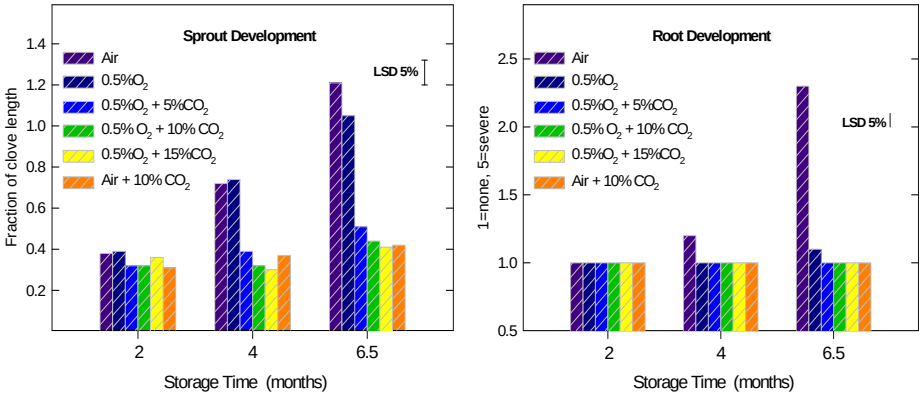
Garlic Bulb Storage

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

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

Mechanical damage
Decay
Sprouting

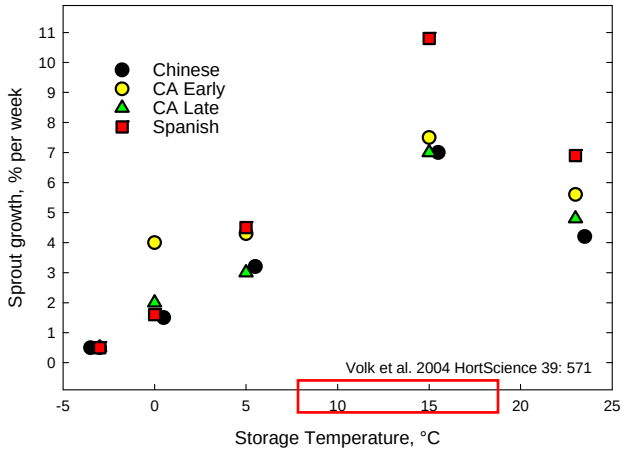
CA Storage of Garlic



Cantwell, UC Davis, CA Late, 1996

Garlic Sprouting

Intermediate temperatures (8-18C) favor sprouting



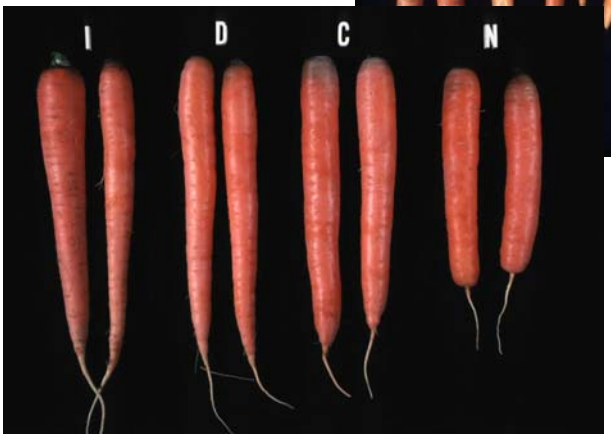
Carrots and related roots

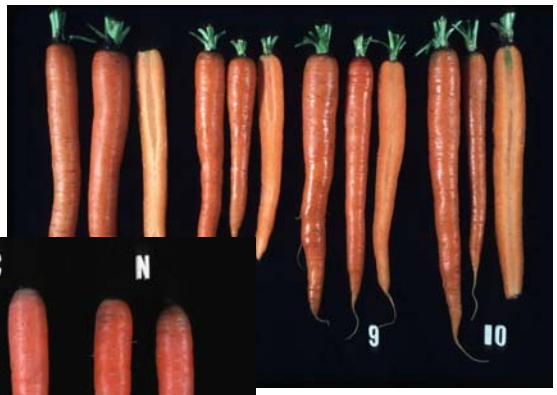
- 0°C for storage
- Very high humidity
- Packaging

- 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

Parsnips also become bitter with ethylene exposure

Bitterness in Carrots

- **Induced by ethylene**
- **Threshold ~0.15 ppm C_2H_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**