UCDAVIS POSTHARVEST TECHNOLOGY

Postharvest Biology: An Overview

Profitable Horticulture *Depends* on Good Postharvest Handling

Biology meets Technology meets Marketing

Marita Cantwell, UC Davis
micantwell@ucdavis.edu
http://postharvest.ucdavis.edu

Causes of Quality & postharvest Losses

Leafy Vegetables

Lettuces
Spinach
Cabbage
Chard
Broccoli
Celery
Herbs
Endives
Asparagus

- Water loss
- Mechanical damage
- Loss of chlorophyll and other nutrients
- Respiration rates
- Microbial growth
- Sensitivity to ethylene

Postharvest Losses and Waste are Costly

Represent loss of inputs and profits
Reduce postharvest losses and increase sustainability
--reduce land, chemical, energy other inputs
--conserve land, water, energy

Estimated Postharvest Losses (%) of Fresh Produce

	Developed Countries		Developing Countries	
Locations	Range	Mean	Range	Mean
From production to retail sites	2-23	12	5-50	22
At retail, foodservice and consumer sites	5-30	20	2-20	10
Cumulative total		32		32

from Adel Kader, 2009, BM Gates project

Causes of Quality & Postharvest Losses

Fruits

Banana
Apple
Avocado
Melons
Citrus
Mango
Tomato
Chiles
Berries

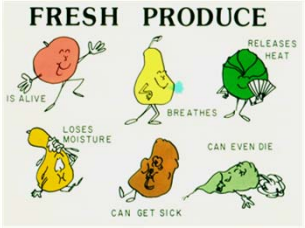
- Mechanical damage
- Maturity, immature, overmature
- Poor ripening, conditioning
- Softening, texture loss
- Changes in composition
- Water loss
- Chilling injury
- Microbial growth

Characteristics of Horticultural Crops

- High water content
- Easily damaged
- Diverse
  - genome
  - tissue type
  - physiological state
- Alive – a biological system
- Deterioration begins at harvest

Factors contributing to postharvest losses

- **TIME & TEMPERATURE**
- Respiration
- Ethylene
- Water loss
- Damage
- Diseases
- Continued growth
- Physiological disorders
- Light

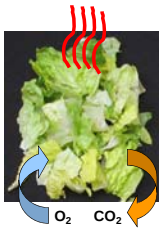


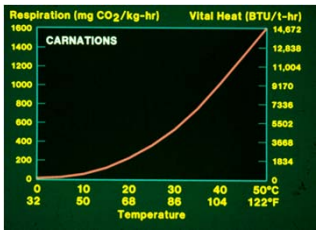
From Gordon Mitchell, UC Davis

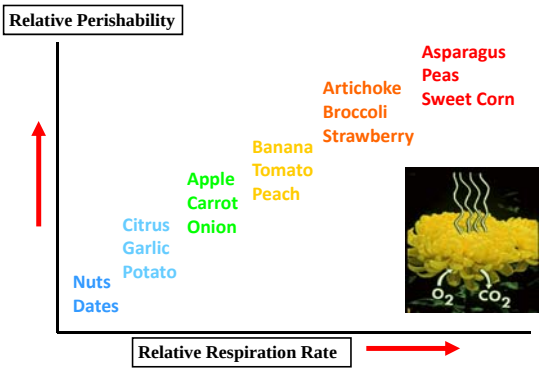
Temperature - why is it important?

- Rate of deterioration α rate of respiration
- Respiration:

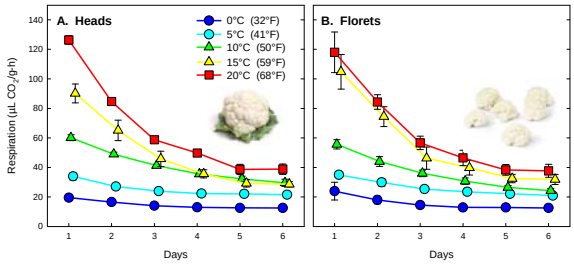
  Sugar + O_2 ➡➡➡ CO_2 + H_20 + Energy (Heat)
- Respiration increases exponentially with T



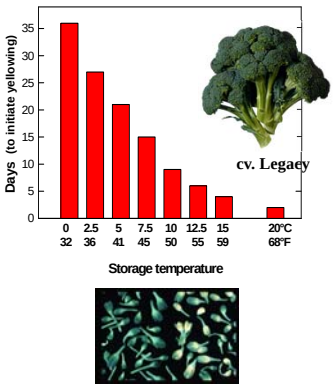




Cauliflower heads and florets have very similar respiration rates & quality changes during storage



Hevajulige & Cantwell, UC Davis



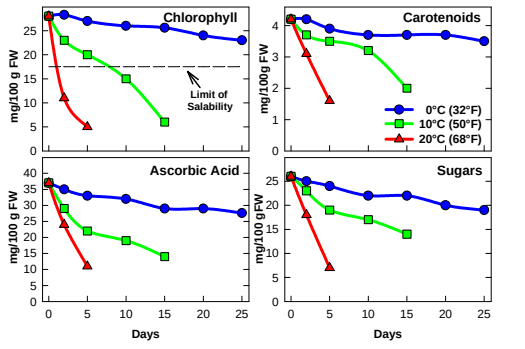
Broccoli Shelf-life & Temperature

Respiration Rates of Some Perishable Products

Category	Range at 5°C mg CO2/kg-h	Products
Very low	<5	Nuts, dates
Low	5-10	Apple, citrus, grape, kiwifruit, onion, potato (mature)
Moderate	10-20	Apricot, banana, cherry, peach, pear, plum; carrot, lettuce, pepper, tomato, cucumber, carrot (no tops); potato (immature)
High	20-40	Strawberry, other berries, cauliflower Leeks, carrots (with tops), avocado
Very high	40-60	Artichoke, snap beans, Brussels sprouts, cut flowers, okra, watercress
Extremely high	>60	Asparagus, broccoli, mushroom, peas, spinach, sweet corn

Respiration rate information for specific products:
Produce Facts: http://postharvest.ucdavis.edu/PF/
USDA Handbook 66: http://www.ba.ars.usda.gov/hb66/

Broccoli Compositional Quality and Storage Temperature



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Importance of Temperature to Maintain Quality

7 days

A	B	C
0°C	5°C	10°C
32°F	41°F	50°F

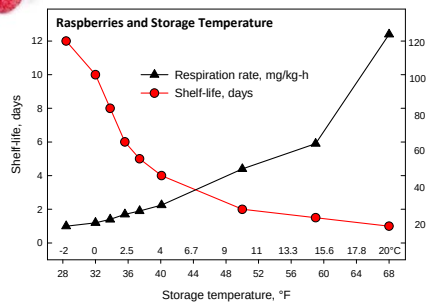
Effect of Temperature on Deterioration

Temp. °F	Temp. °C	Q_{10}	Relative Velocity of Deterioration	Relative Shelf-life	Daily Loss (%)
32	0	--	1.0	100	1
50	10	3.0	3.0	33	3
68	20	2.5	7.5	13	8
86	30	2.0	15.0	7	14
104	40	1.5	22.5	4	25

$Q_{10} = \frac{\text{rate of deterioration at T+10°}}{\text{rate of deterioration at T}}$

frambuesas

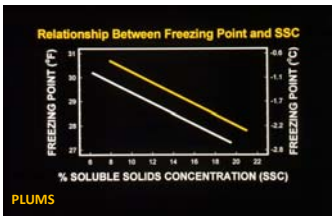
Temperature affects shelf-life by controlling metabolism and decay



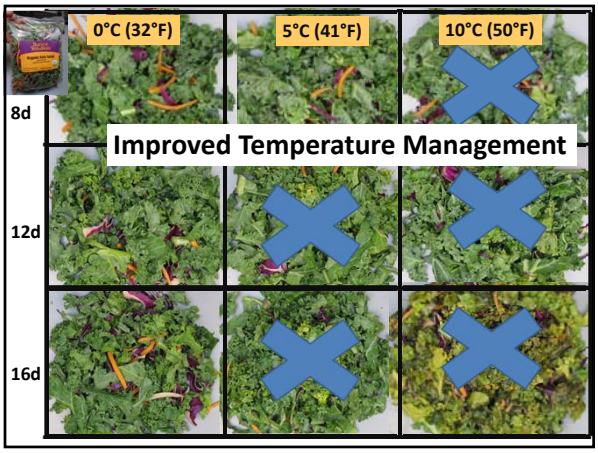
Mostly from data of Perkins-Veazie, Raspberries, USDA Agric Hdbk66

No fresh product freezes at 0°C (32°F)

Lettuce freezes at -0.2°C (31.7°F)



http://ucanr.edu/datastoreFiles/234-1931.pdf



1. Commercial Cooling Methods

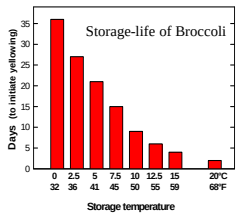
- **Room Cooling**
- **Forced Air Cooling**
- **Vacuum Cooling**
- **Hydrocooling**
- **Icing**
- **Cooling in refrigerated transport**

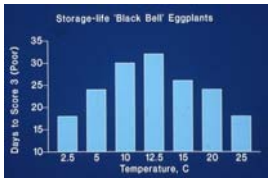
Product requirements
Scale appropriate technology
Conventional, Organic products
Microbial food safety issues

2. Temperature Control during Transport and Distribution is a Major Challenge

Two Groups of Products Temperature Compatibility

- **Non-chilling sensitive** products --store near 0°C
- **Chilling sensitive** products --store around 10°C (varies)
  - -- Occurs at low temperatures above freezing point
  - -- Sensitivity, exposure time, temperature





Some uses of Modified Atmospheres for fruits & vegetables
MA is a Supplement to Good Temperature Management

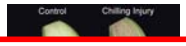
MA for strawberry pallets to control Botrytis

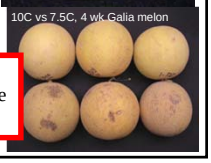
MAP Salad Products

Bag-in-box MA for melons

Symptoms of chilling injury

- Surface pitting
- Water soaking
- Browning
- Necrosis
- Rots
- Poor flavor
- Poor ripening





Commonly chilling symptoms do not appear until product is transferred from the cold room to a warmer temperature

Modified or Controlled Atmospheres

- Reducing oxygen
- Increasing carbon dioxide
- Removing carbon dioxide
- Removing ethylene and other volatiles
- Degree of precision differentiates MA and CA

Composition of Normal Air

78.08%	Nitrogen (N_2)
20.95%	Oxygen (O_2)
0.93%	Argon (Ar)
0.03%	Carbon dioxide (CO_2)
0.0001%	Ethylene (C_2H_4) (1 ppm)

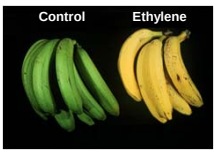
Temperature and other Postharvest Recommendations

- http://postharvest.ucdavis.edu
  Produce Facts
- http://www.ba.ars.usda.gov/hb66/
  USDA Agriculture Handbook Number 66
  The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks

Ethylene - an important factor

Plant hormone with positive and negative effects on fresh produce

- **Useful:**
  - **Accelerates ripening**
  - **Causes abscission**
  - **Chlorophyll destruction**
- **Problematic:**
  - **Accelerates ripening**
  - **Causes abscission**
  - **Chlorophyll destruction**
  - **Accelerates senescence**



Ethylene Production Rates at 20°C (68°F)

Range (µL/kg-h)	Product
0.01-0.1	Citrus, grape, cherry strawberry **MOST VEGETABLES**
0.1-1.0	Pineapple, blueberry, cucumber
1.0-10.0	Banana, mango, tomato, honeydew melon, fig
10-100	Apple, avocado, cantaloupe, nectarine, papaya, pear
>100	Cherimoya, passion fruit, sapotes

Water Loss (Transpiration)

<3% no visual effect, texture
3-5% visual quality affected
>5% shrivel, lose salability

Loss of Salable Weight
Loss Fresh Appearance
Loss of Texture

Water loss is Cumulative
Temperature Control Important
Appropriate Packaging

Postharvest Compatibility Issues

- **Temperature**
- **Relative Humidity**
- **Ethylene**
- **Odor**

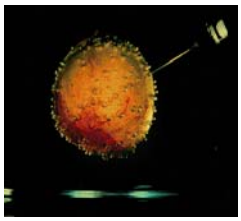
Transportation and Loading

Distribution warehouses and Storage rooms

Retail & Food Service outlets

WATER LOSS

- Products are covered with holes - needed for gas exchange
- Damage increases water loss
- Loss of water depends on the vapor pressure deficit (VPD)
- VPD increases exponentially with rising temperature



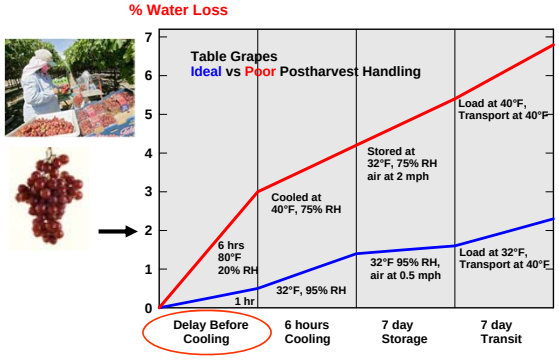
Stomates in leaves; lenticels in fruits

Manage Ethylene Effects

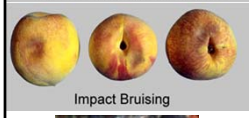
1. **Avoidance**
   Products, combustion engines, smoke
2. **Removal**
   Ventilation (1 air exchange per hour), oxidation, absorption
3. **Inhibition of production**
   Low temperature, chemical inhibitors of enzymes, antisense technology
4. **Inhibition of action**
   Low temperature, high CO2, low O2, STS, 1-MCP (Smartfresh™)
5. **Germplasm**
   Selection of mutants and molecular modification

Gordon Mitchell
UC Davis

Importance of Delays to Cool




Wounding During Harvest and Handling


Impact Bruising

Damage is a Major Problem

- TAKE CARE!
- Careful harvesting
- Into lined baskets/bins
- Don't throw, dump, or drop
- Avoid rough surfaces
- Minimize touch points
- Pack gently but securely

'Ranch Pack' Peach Handling: Simple, Clean and **Careful** Handling for High Quality Product






3rd party Inspectors
Forced Air Cooling

Now packers wear hairnets, sometimes gloves

Do you see anything wrong in these photos?




Consequences of poor handling are seen later. Repacking at Destination is VERY costly





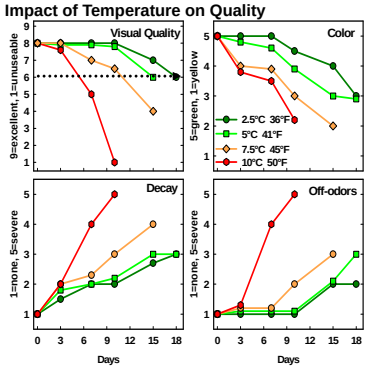
Repacking Peppers
Distribution Center, 2010

Do Basic Handling Steps Well

- **Harvest**
- **Sort for defec**
- **Preparation (**
- **Classify (by color, size)**
- **Pack**
- **Palletize**
- **Cool and temporary storage**

✓**The more the product is directly touched, the more damage occurs to the product.**
✓**Therefore get the product into the final shipping container as soon as possible.**

Damage and Decay
Impact of Temperature on Quality



Spinach:

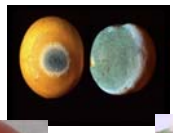
- **Commercial washed and bagged product**
- **Leaf damage is very common defect**
- **Leads to increased decay**

BUT….
Target Temp.
0°C (32°F)

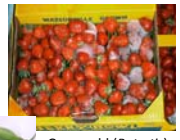
Cantwell, UC Davis

Postharvest Diseases

- Important cause of postharvest loss
- Relatively few important genera
- Most are weak pathogens and need injury



Penicillium sp.



Gray mold (*Botrytis*)

Sour rot (*Geotrichum*)

Sclerotinia rot

Good Agricultural Practices: Key Areas for All Scales of Farming and Shipping

- Water
- Workers
- Waste
- Wildlife
- Record-keeping
- Traceability

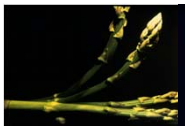
- Prevention of Contamination
- Water Quality Concerns High on FDA Priority Risk List
- Temperature control can reduce risk

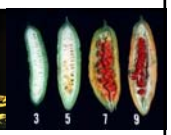
Reduce Physical Damage

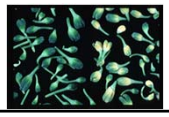
Typically the more the product is handled, the greater the physical damage to the product and the greater the risk of postharvest disease

Continued growth is affected by temperature

- **Sprouting** (potato, onion, garlic)
- **Rooting** (onion, potato)
- **Growth away from gravity** (asparagus, flowers)
- **Internal seed growth** (cucumber, beans)
- **Opening of immature buds** (broccoli)







Raw Foods Contain Microorganisms Some are Pathogenic to Humans

Microbes present an "invisible challenge"

- ⇨ **They don't usually change the appearance, taste or odor of food.**
- ⇨ **Fresh produce has no kill step**
- ⇨ **Prevention of Contamination is key**
- ⇨ **Temperature abuse sometimes contributes**

Bacterial pathogens can multiply on fresh produce

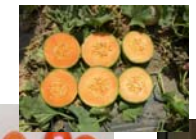
PHYSIOLOGICAL DISORDERS

- Disorders resulting from abnormal conditions during production and handling
- Abnormal temperatures
- Extended storage
- Abnormal gases
- Nutritional imbalance

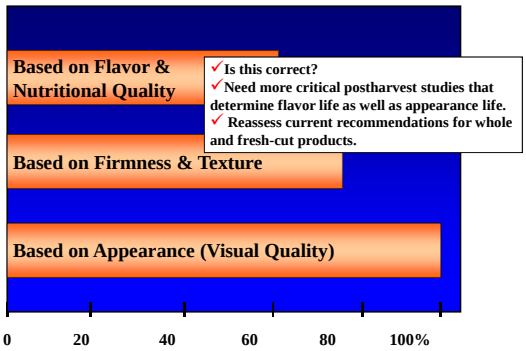
Maturity at Harvest

...Quality is maximized when the product is harvested more mature or ripe, whereas shelf- and storage life are extended if the product is harvested less mature or unripe....






Toivonen, P. 2007. Fruit maturation and ripening and their relationship to quality. Stewart Postharvest Review 2:7.



✓Is this correct?
✓Need more critical postharvest studies that determine flavor life as well as appearance life.
✓ Reassess current recommendations for whole and fresh-cut products.

Postharvest Life Under Optimum Conditions

Kader, A.A. 2003. A Perspective on Postharvest Horticulture. HortScience 38: 1004

Taste and the Sugar:Acid Ratio

ACIDS	SUGARS	
	Low	High
Low	Insipid, tasteless	Sweet
Moderate to High	Sour, tart	Best flavor combination

Soluble solids measured by a refractometer = sugars, but also organic acids, soluble pectins, anthocyanins, phenolics, ascorbic acid, others

General Principles

- Fresher the product (time), better the quality, flavor, and nutrition
  - True for vegetables
  - More complicated for fruits that require ripening
- Adhering to storage and handling guidelines results in better quality
- Postharvest treatments may extend the storage -life but not necessary preserve quality attributes

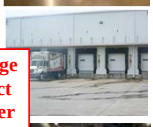
Examples of Contributions of Fruits and Vegetables to Human Health

Constitutent	Sources	
Antioxidants		
Vitamin C	Broccoli, cantaloupe, citrus, guava, leafy greens, pepper, strawberry tomato, pineapple	
Vitamin A	Dark-green leafy vegetables, orange vegetables (sweetpotato), orange-flesh fruits (papaya, tomato)	Cancer, cataracts, heart disease, stroke, and more
Vitamin E	Nuts	
Flavonoids, Phenolics	Red, blue and purple fruits (berries, grapes, plum, pomegranate)	
Fiber	Most fruits and vegetables, nuts	Diabetes, heart disease
Folate (Vit B9)	Dark-green leafy vegetables; oranges, peas	Birth defects, cancer, heart disease
Potassium	Potato, sweetpotato, banana, greens	Hypertension, stroke

http://ucce.ucdavis.edu/files/datastore/234-104.pdf

How do we successfully move so many products through diverse transportation/distribution channels? How long to market? What storage life is needed? What quality is needed?






1-2 days to harvest, cool, store
1-2 days local transport
7-21 days truck or marine transport
1-3 days to distribution center
1-3 days at retail
1-3 days at consumer
Total = 12 - 34 days

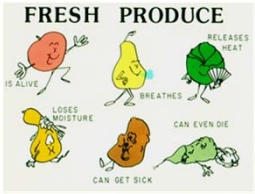
More knowledge about a product allows for better decision making.

Product under ideal conditions? UNLIKELY!

Factors Contributing to Postharvest Deterioration and Losses

- Respiration
- Ethylene
- Water loss
- Damage
- Diseases
- Continued growth
- Physiological disorders
- Light

TIME and TEMPERATURE



10 Basic Postharvest Handling Principles

1) **Harvest at correct maturity**
2) **Reduce physical handling**
3) **Protect product from sun**
4) **Keep packingline or area simple and clean; ensure good worker hygiene**
5) **Select, classify, and pack carefully**
6) **Align cartons, strap pallet**
7) **Cool as soon as possible**
8) **Know market and product requirements**
9) **Coordinate efficient & rapid handling**
10) **Train and compensate workers adequately**

WHY ARE WE HERE?

Postharvest Quality of Fruit & Vegetables

- Successful marketing depends on effective biology-technology interface
- Products are diverse but there are common underlying biological processes
  - Respiration, Transpiration, Compositional changes
- Careful handling reduces mechanical damage and resulting decay
- **Temperature management** is **THE** key technology to manage postharvest quality
- Concept of controlled water loss
- Modified atmospheres can be useful or problematic
- Ethylene also has a positive or negative role