Vegetable Meeting

Food Safety and Postharvest Handling of Vegetables
UC, Santa Maria, Sept 2, 2011

Postharvest Handling Update for Vegetables:

1. **General Considerations**
2. **Broccoli Iceless Product and Varieties**
3. **Cutting vegetables for fresh-cut products**

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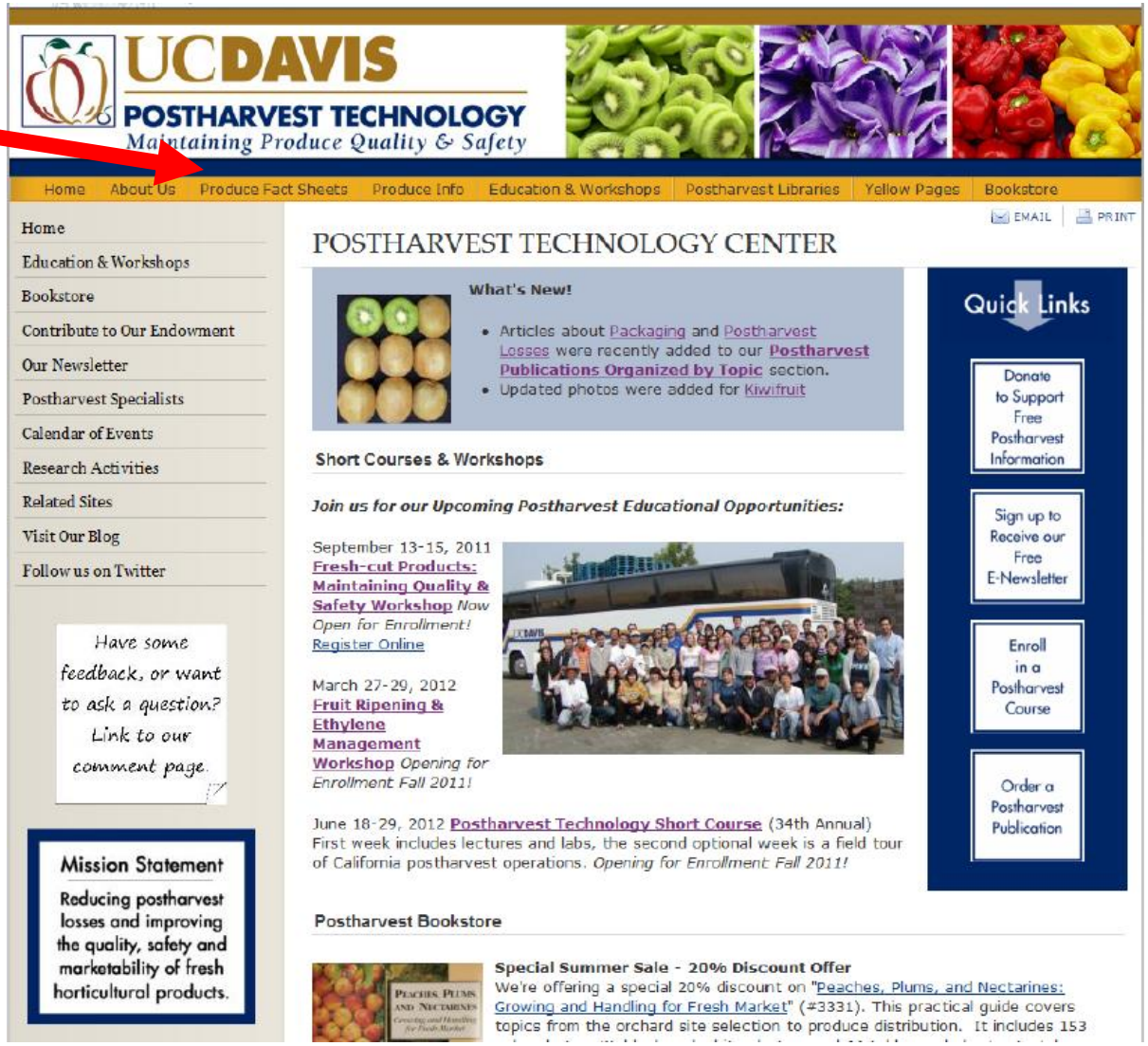
UCDAVIS POSTHARVEST TECHNOLOGY

http://postharvest.ucdavis.edu

Produce Facts

- Harvest indices
- Quality indices
- Temperature and RH
- Freezing point/damage
- Respiration rates
- Ethylene production
- Effects of ethylene
- Effects of modified atmospheres
- Physiological disorders
- Postharvest diseases
- Mechanical injury
- PHOTOS

140
Fruits
Vegetables
Flowers



10 Basic Postharvest Principles

1) Harvest at correct maturity
2) Reduce physical handling
3) Protect product from sun
4) Keep packingline 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

Causes of Quality & Postharvest Losses

Leafy Vegetables

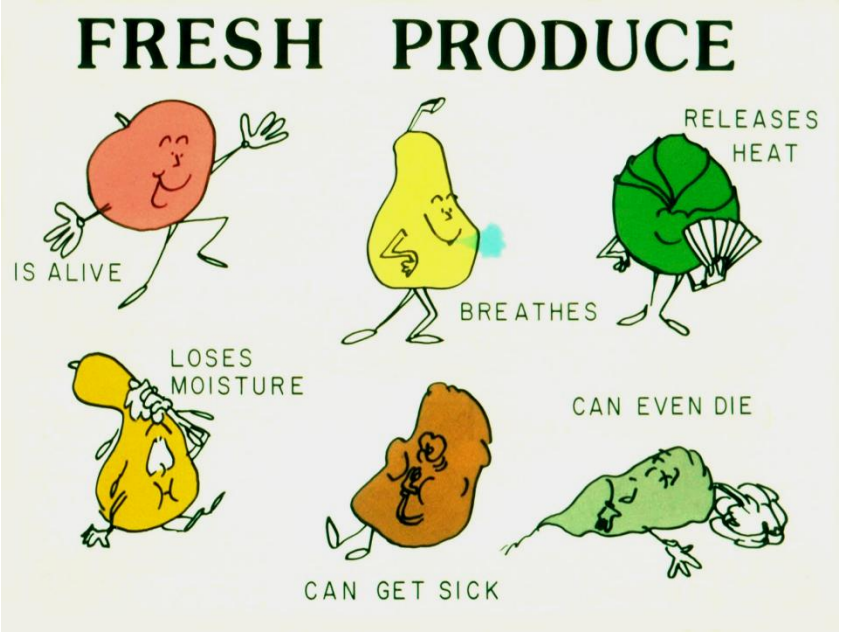
- Lettuces
- Spinach
- Cabbage
- Chard
- Broccoli
- Celery
- Herbs
- Endives
- Asparagus

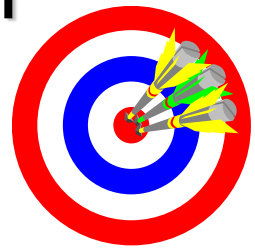
- ♦ Water loss
- ♦ Mechanical damage
- ♦ Loss of chlorophyll and other nutrients
- ♦ Respiration rates
- ♦ Microbial growth
- ♦ Sensitivity to ethylene

Almost all require low storage temperature

Fresh Produce Deterioration

- **Metabolic changes:**
  - **respiration, ethylene,**
  - **texture, aroma, etc.**
- **Growth and development**
- **Transpiration**
- **Mechanical injury**
- **Physiological disorders**
- **Decay; microbial growth**





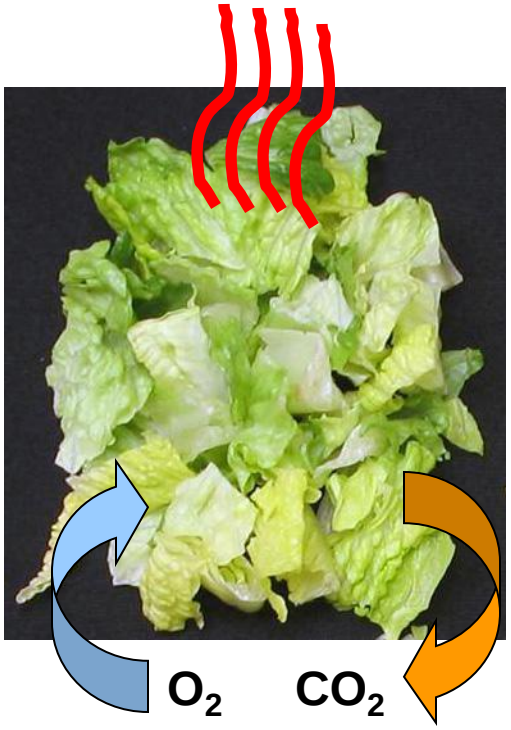
Temperature Affects All Causes of Deterioration

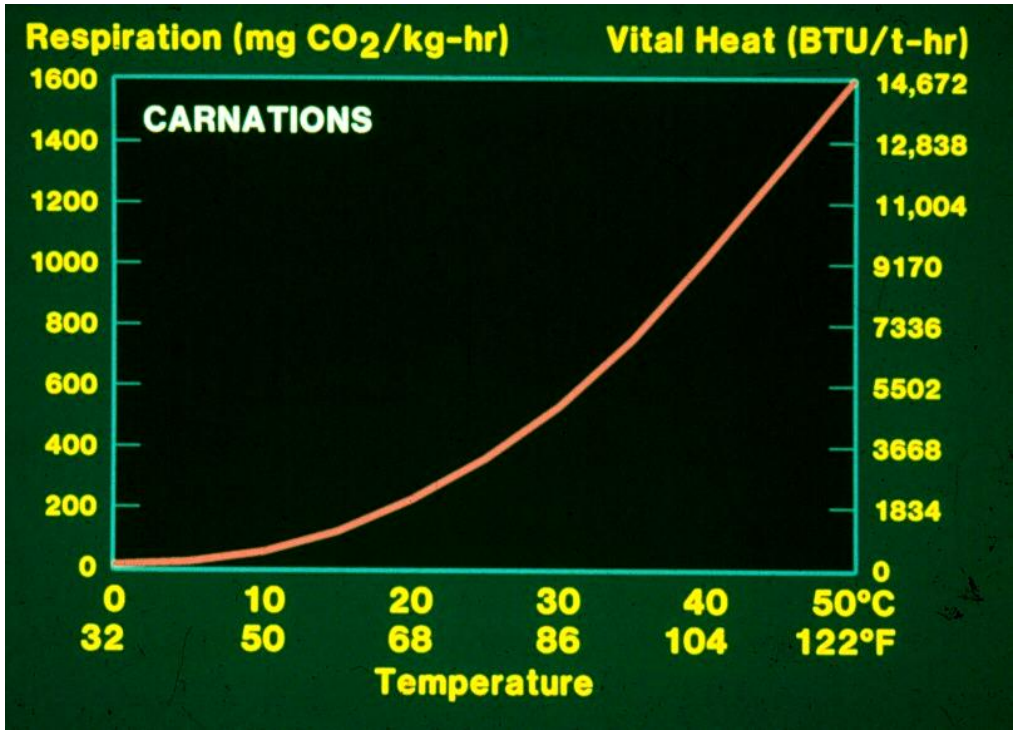
Temperature - why is it important?

- Rate of deterioration α rate of respiration
- Respiration:

  Sugar + O_2 ➡➡➡ CO_2 + H_20 + Energy (Heat)

- Respiration increases exponentially with T





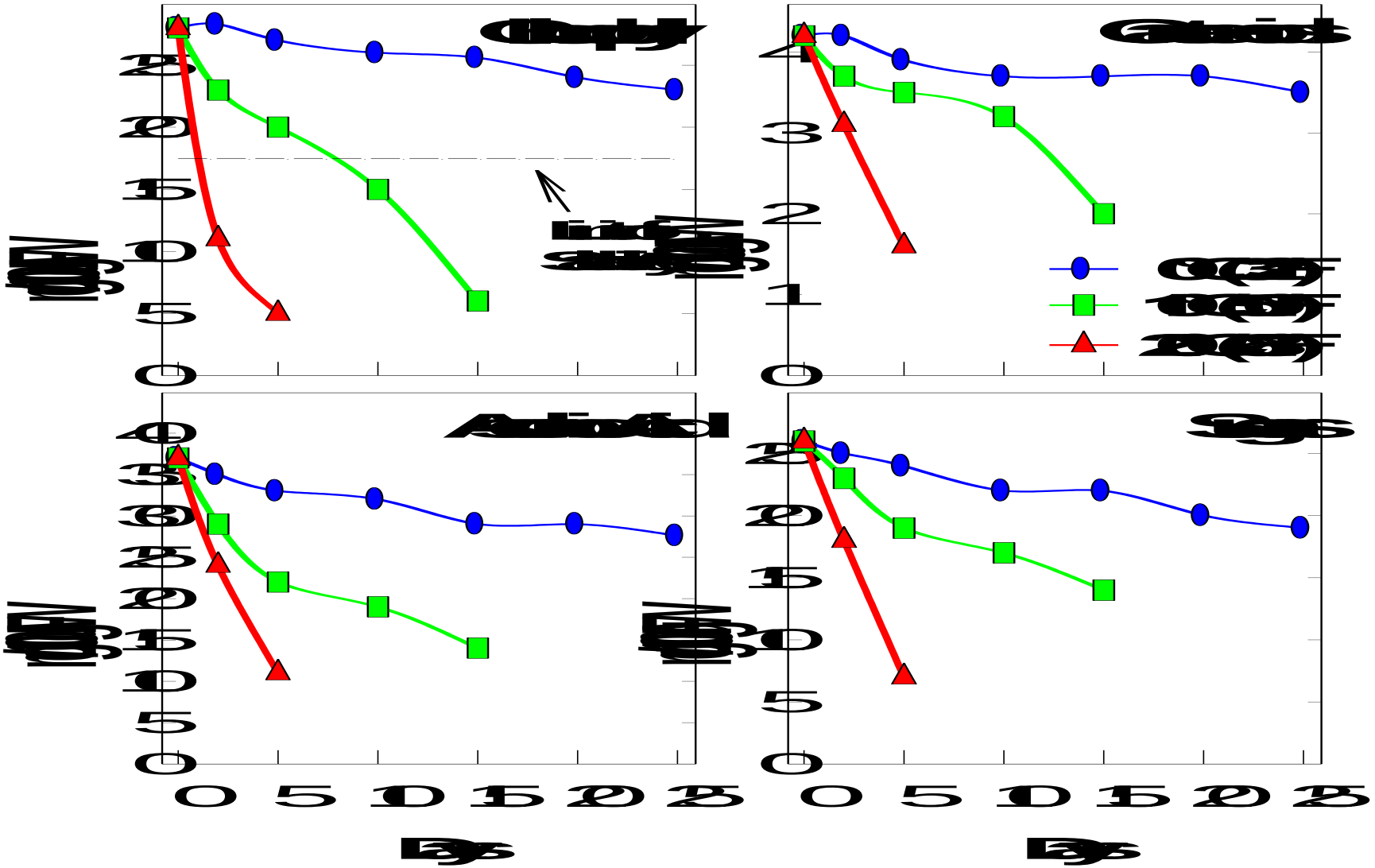
Effect of Temperature on Deterioration

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

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

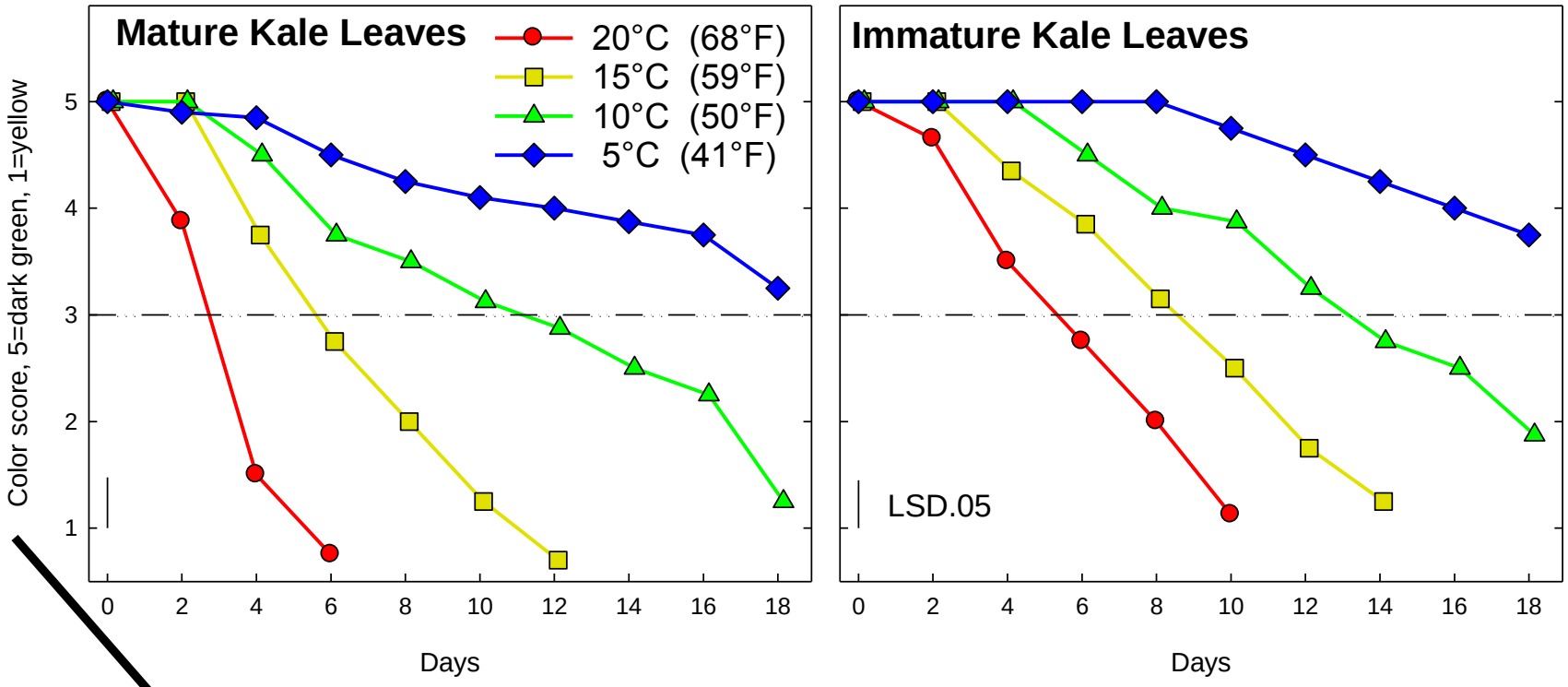
Note: Applies to most, but not all leafy & stem vegetables

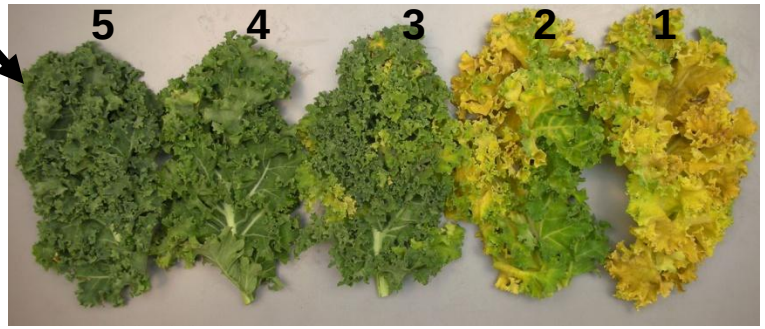
Broccoli Compositional Quality and Storage Temperature



Cantwell, unpublished

Loss of green color by **mature** and **immature Kale** leaves stored at 4 temperatures for up to 18 days.





Transpiration (water loss)

Loss of Salable Weight
Loss Fresh Appearance
Loss of Texture

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

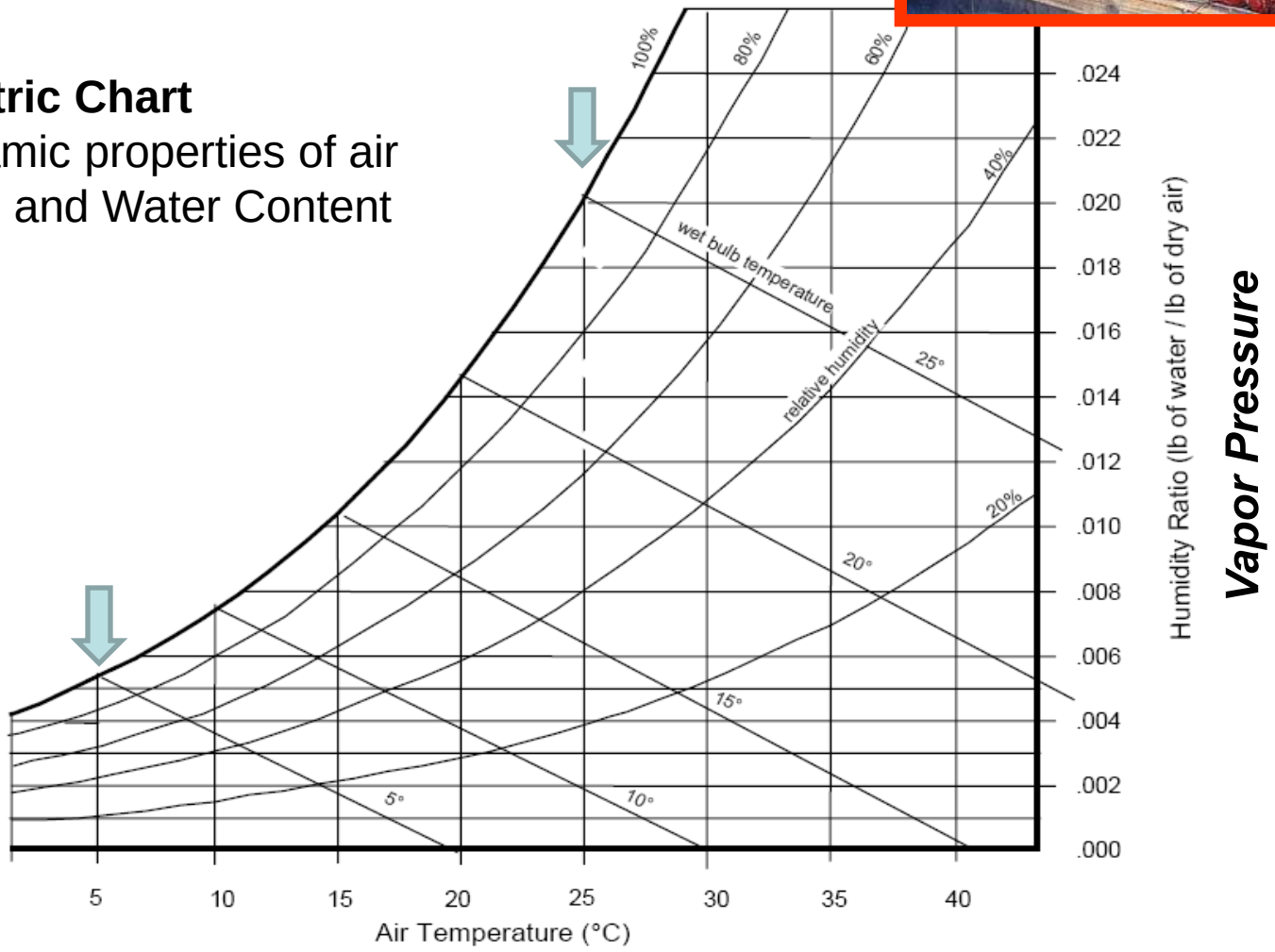
Water loss is Cumulative

Wt loss (%/day) = product K x VPD

Water loss and temperature

Wt loss (%/day) = product K x VPD

Psychrometric Chart
Thermodynamic properties of air
Temperature and Water Content



Vapor Pressure

Modified or Controlled Atm

- 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 (C2H4) (1 ppm)

Temperature Management

- Insures best product quality
- Longest shelf life
- Reduces microbial growth
- Required for MA packaging

Melon MA: Bag in box

Modified Atmospheres

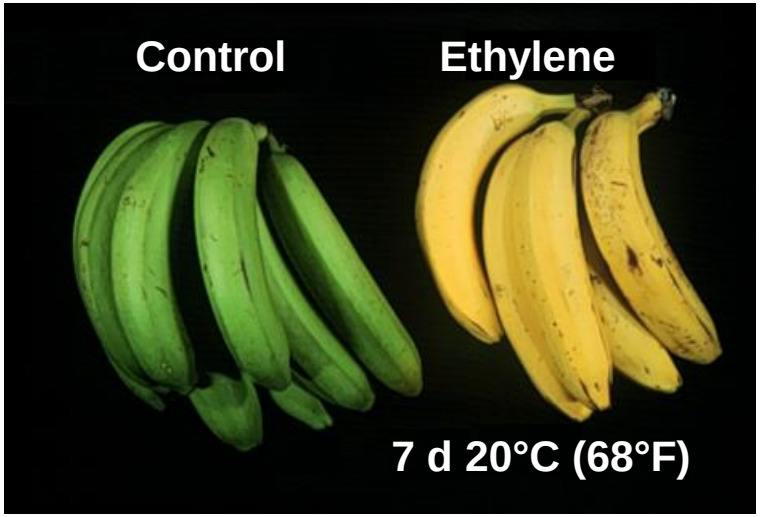
- Can be an important supplement to temperatu
- Can retard deterioration
- Can retard discoloration in fresh-cuts
- Can retard microbial growth

MA Strawberry pallet

MAP cut salad products

Ethylene - an important factor

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



Manage Ethylene

Incompatible products
Low temperature
Minimize exposure time

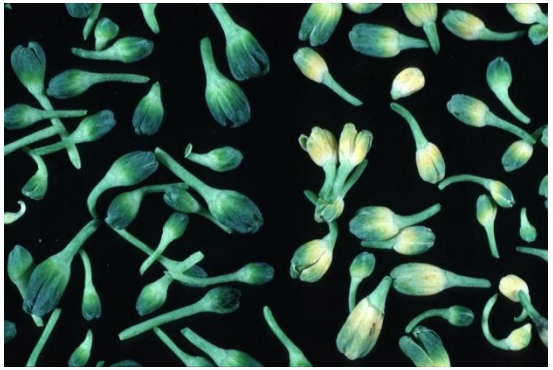
1. **Avoid**
   Products, forklifts, smoke
2. **Remove**
   Ventilate, oxidize, absorb
3. **Inhibit production and action**
   Low temperature, modified atmospheres, chemical inhibitors, molecular antisense technology
4. **Germplasm selection/engineering**

What is wrong with this picture?

Taken 2 days ago

Mixed load: onions, watermelon, others?

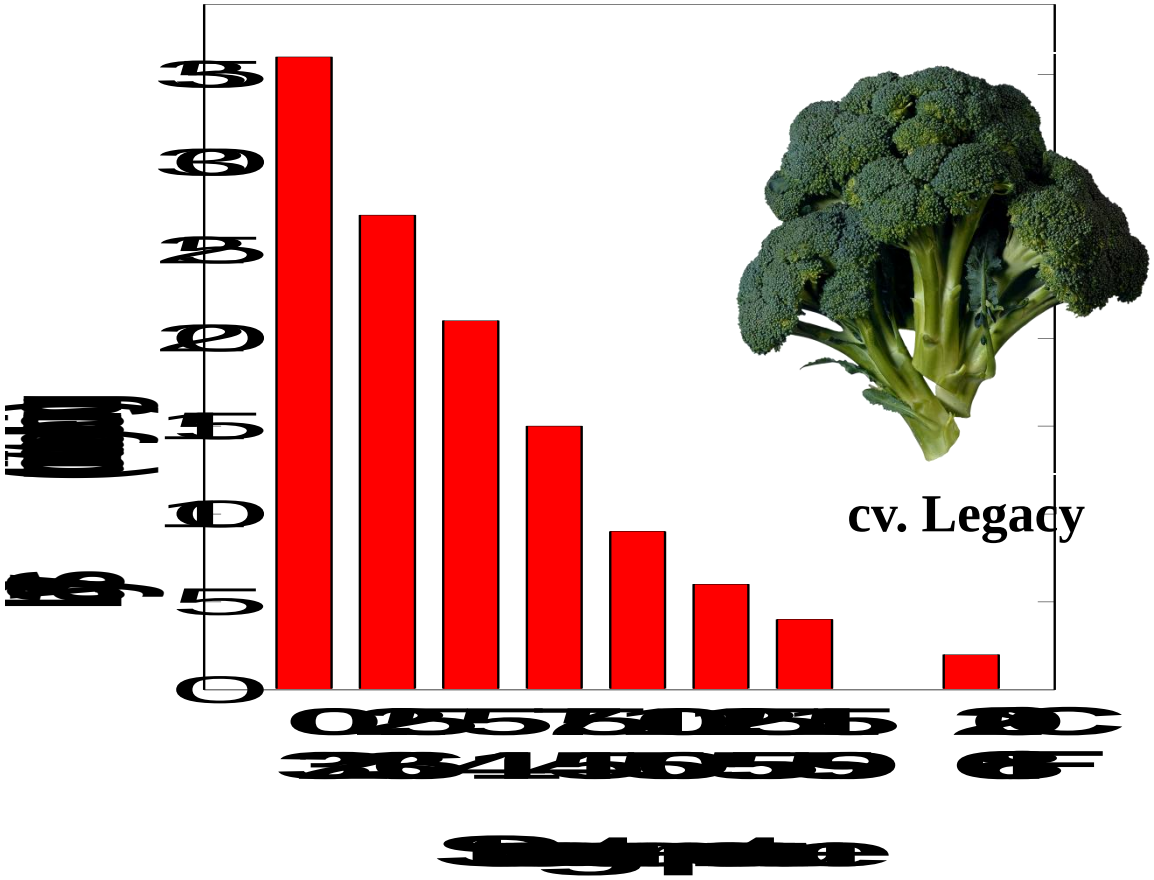
Loading ripening tomatoes

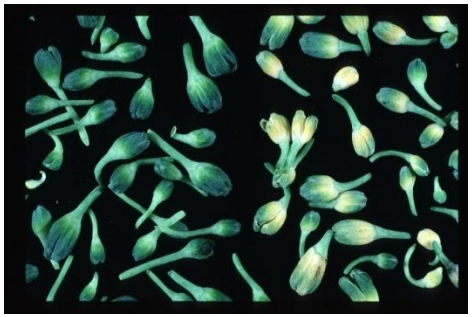


Broccoli Quality

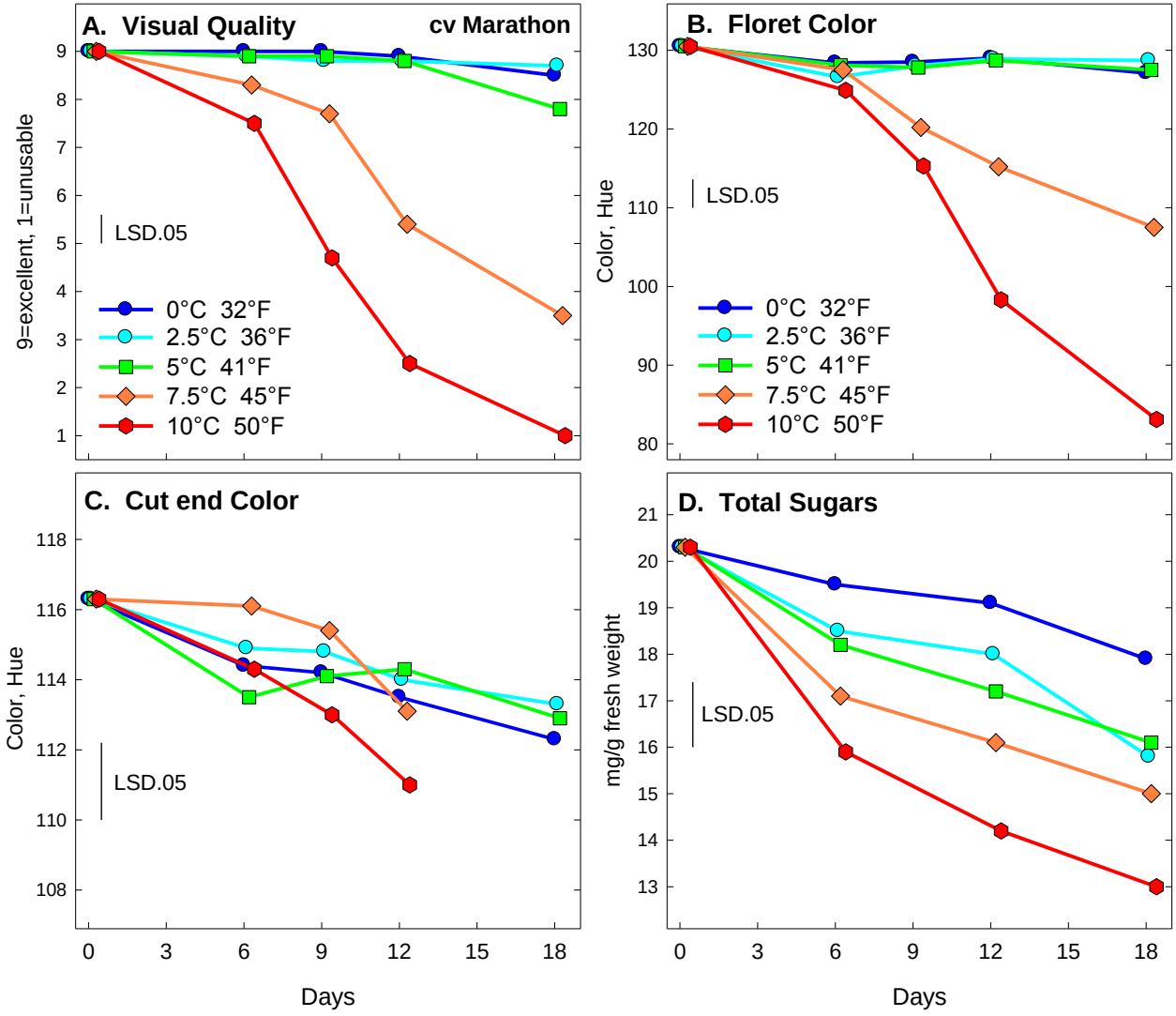
- Fresh appearance
- Green florets
- Tender stem
- No discoloration
- No breakage or decay
- No off-odors

Broccoli Shelf-life & Temperature





Impact of Temperature on Broccoli Floret Quality



Cantwell, UC Davis

Broccoli Storage

- 0°C, high RH
- MA 5-8% O2 + 7-10% CO2

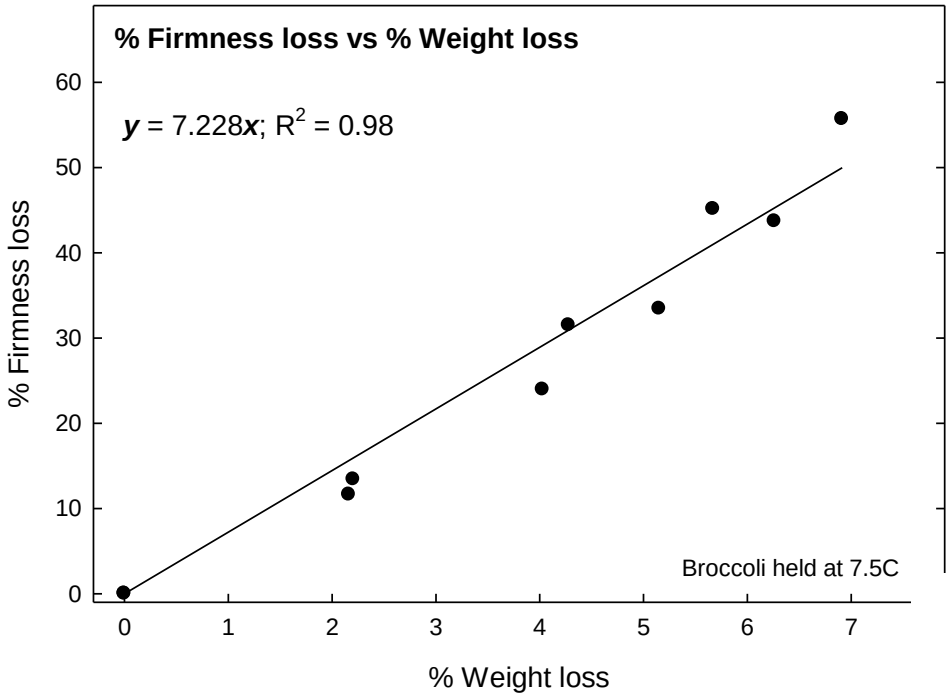
Iceless Broccoli

Temperature-yellowing
Moisture loss-softening

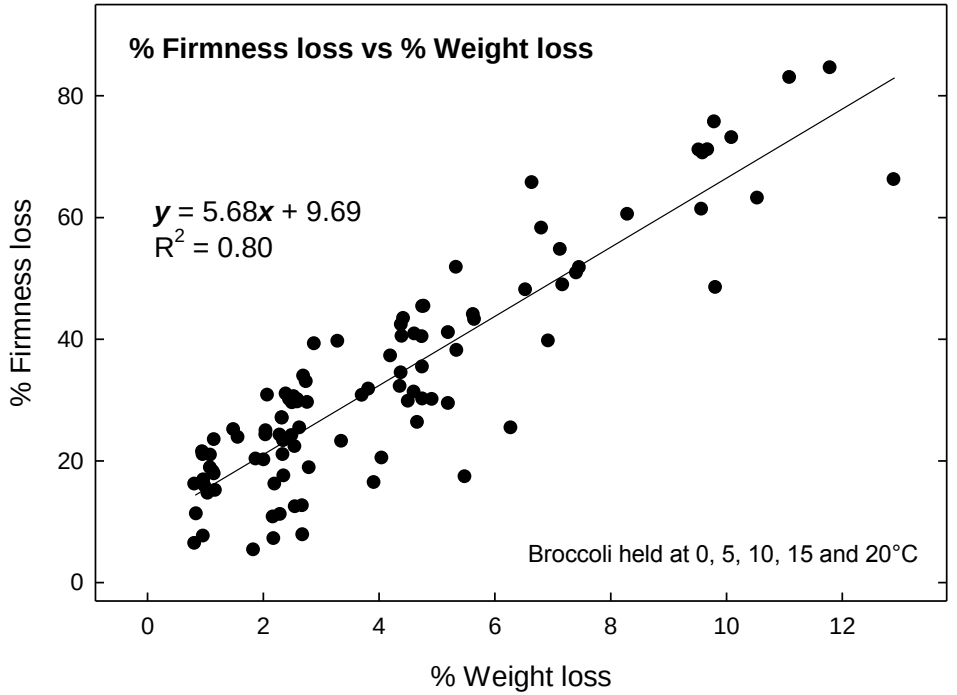
ICELESS BROCCOLI

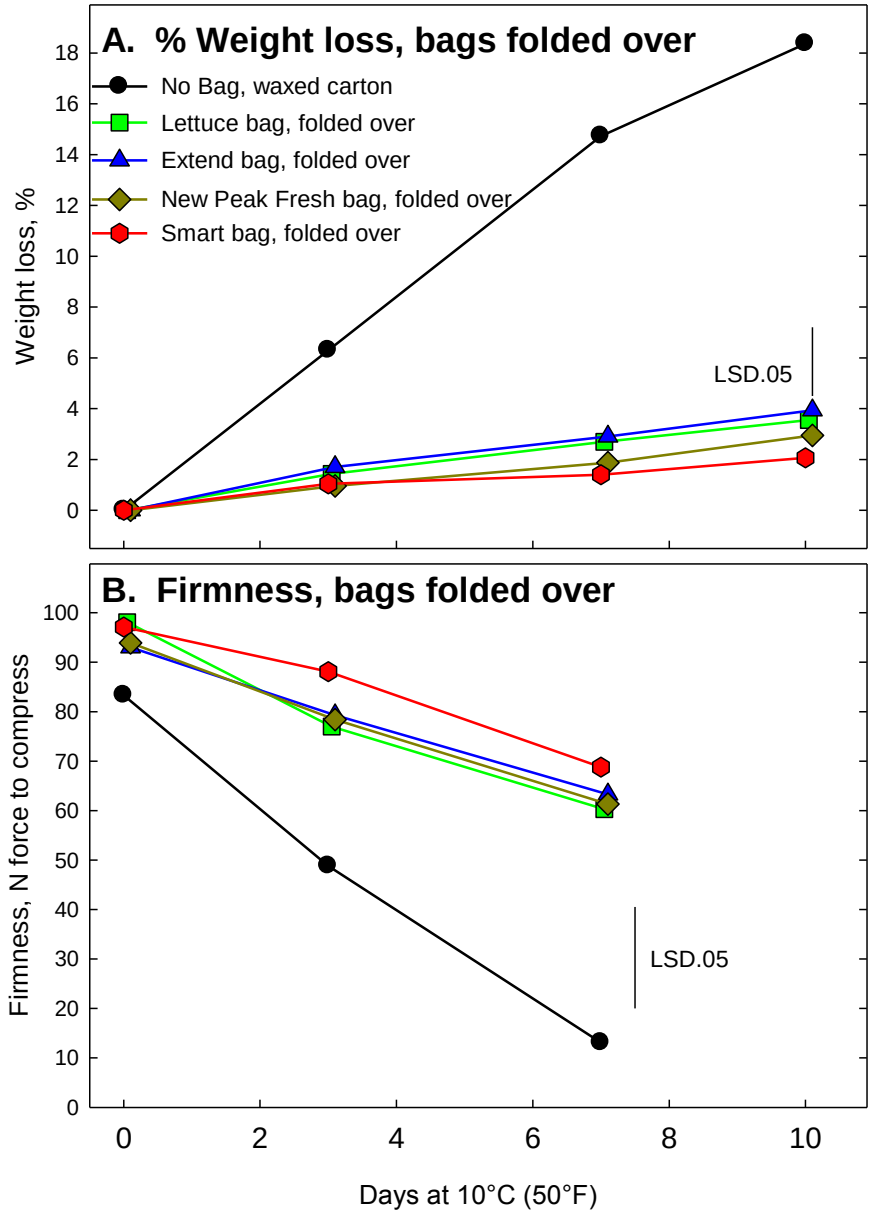
- Minimize delay from harvest to cooling
- Use plastic liners to reduce water loss
- Keep product cold

Loss of Broccoli Head Firmness is Correlated to Water Loss



About 4% weight loss results in 30% decrease in firmness and this is likely the point at which a buyer would consider the head soft.





Broccoli weight loss and firmness loss can be minimized with plastic liners.

Simple perforated PE lettuce or basil liners perform as well as more expensive plastic films.

Cantwell, UC Davis, 2009

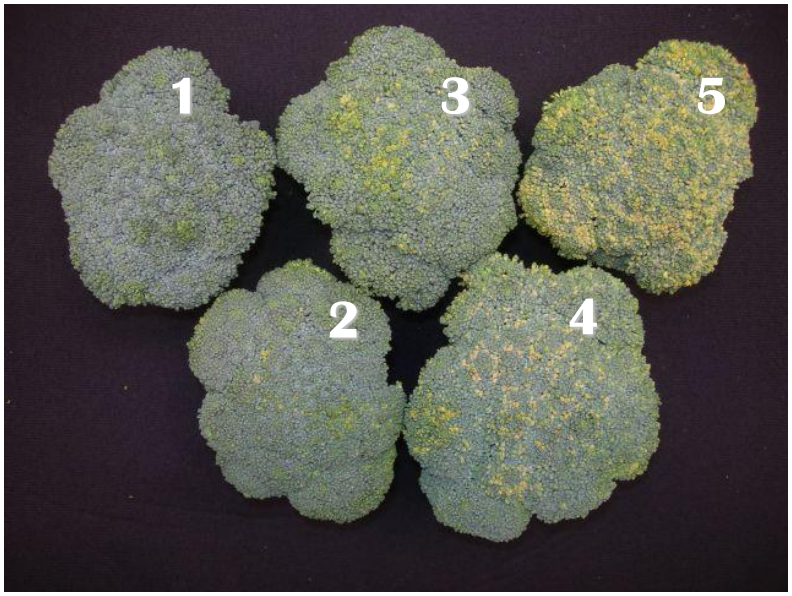
Broccoli Quality and Variety Evaluations

- Head Size, floret uniformity
- Floret/Head Color
- Head Firmness and Stem Texture
- Water loss and firmness loss
- Decay susceptibility
- Discoloration cut ends
- Shelf-life
- Composition
  - % dry weight
  - Sugars
  - Vitamin C
  - Pigments
  - Glucosinolates (glucoraphanin)
  - Antioxidant activity

Broccoli Maturity has consequences for shelf-life

Inmature Mature Overmature

Cat-eye
Hollow-stem
Nitrogen fertilization

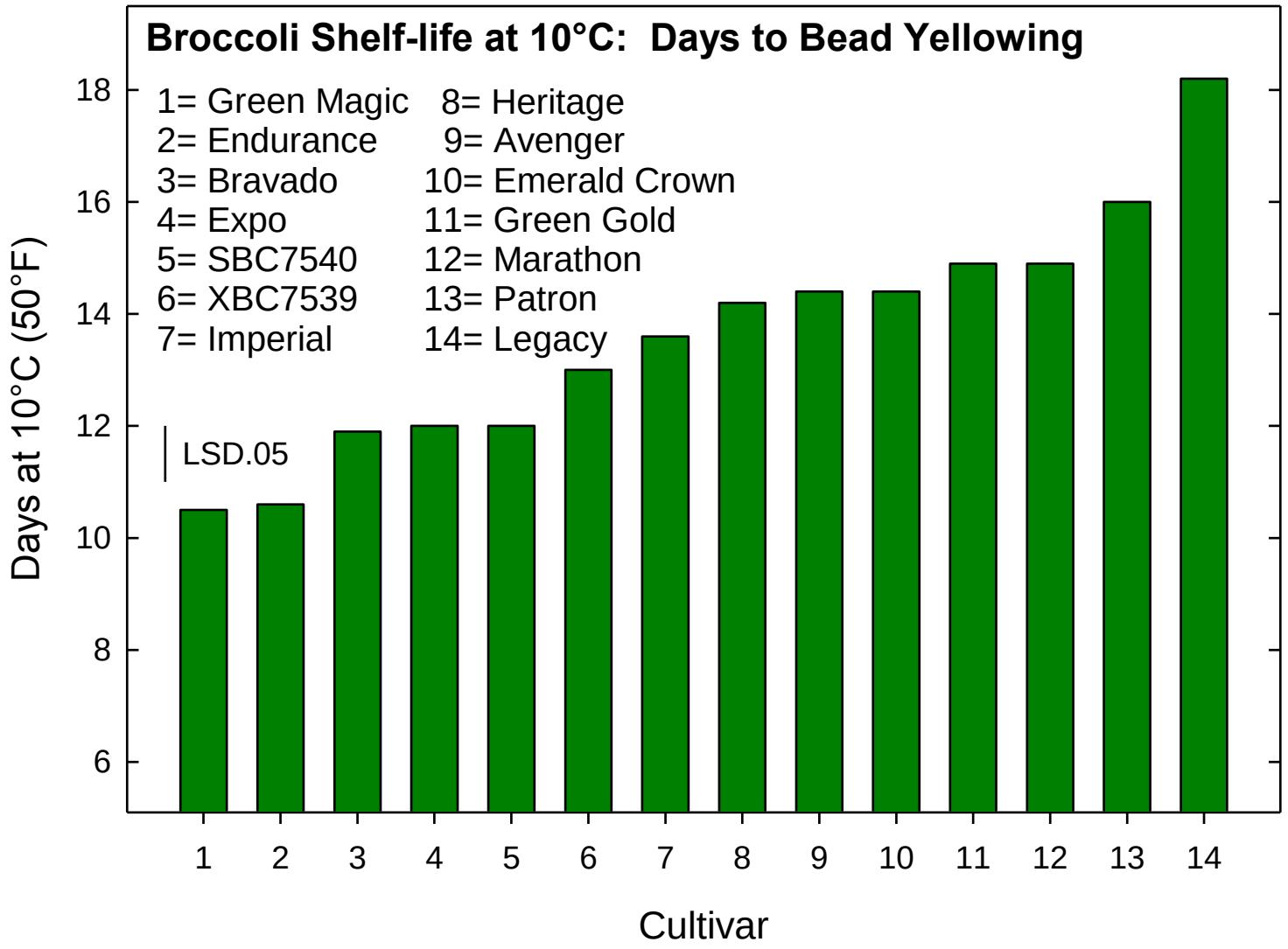


Shelf-life is number of days to reach score of 2

Broccoli Color Rating Scale and Corresponding Color Values and Pigment Concentrations.

Yellowing Score	L Color Value	Hue Color Value	Chroma Color Value	Total Chlorophyll mg/100g FW	Total Carotenoids mg/100g FW
1	42.0	135.0	11.0	34.1	7.3
2	43.3	127.5	15.9	28.2	6.4
3	45.9	125.4	16.9	24.4	5.8
4	47.1	123.3	17.7	17.5	5.5
5	49.8	115.3	21.8	16.5	5.0

Date average of 3 replicates at each color stage

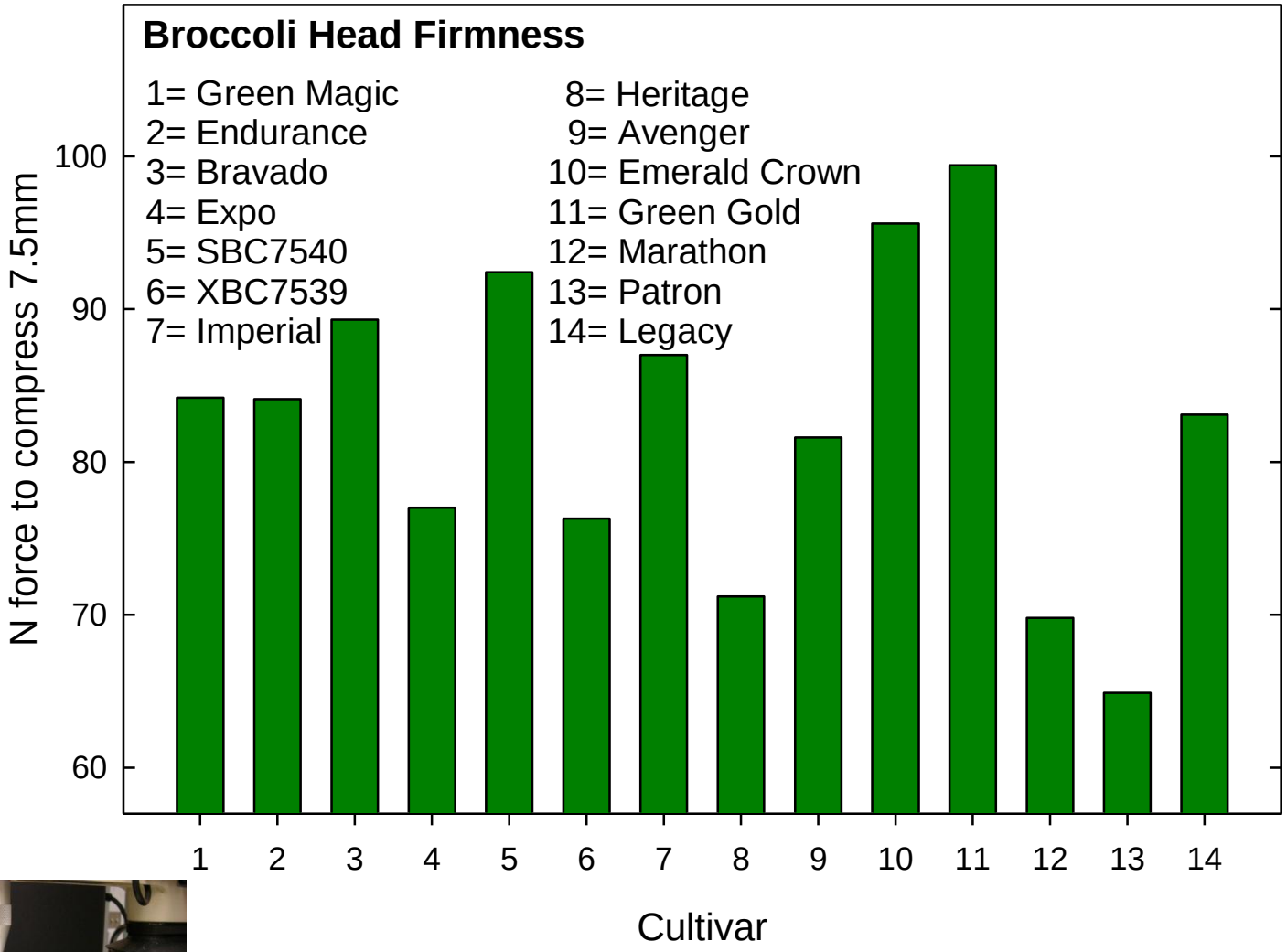

Broccoli Shelf-life at 10°C: Days to Bead Yellowing
1= Green Magic
2= Endurance
3= Bravado
4= Expo
5= SBC7540
6= XBC7539
7= Imperial
8= Heritage
9= Avenger
10= Emerald Crown
11= Green Gold
12= Marathon
13= Patron
14= Legacy
LSD.05
Days at 10°C (50°F)
18
16
14
12
10
8
6
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Cultivar

Trial #2, 2010

Composition of Florets of Different Broccoli Cultivars

Cultivar	Dry Wt. %	Chlorophyll mg/100g FW	Sugar mg/g FW	Vitamin C mg/100g FW	Antioxidant Activity µmole TE/g FW	Glucoraphinin µmole/g DW
Heritage	11.9	19.5	12.5	147.1	52.5	8.3
Avenger	11.9	12.3	15.0	143.5	51.7	5.6
Marathon	11.8	12.8	11.9	159.3	63.9	3.7
Legacy	11.4	10.5	11.5	150.3	71.8	2.9
Green Magic	11.8	16.1	8.8	166.2	72.0	5.7
Patron	11.6	15.1	10.0	147.6	66.2	4.2
Ironman	12.0	14.6	13.3	151.3	56.2	4.4
Bravado	12.8	13.6	11.1	153.4	51.8	5.3
Emerald Crown	12.1	13.3	10.6	153.2	39.5	3.4
Imperial	11.1	15.4	14.8	139.2	35.0	6.2
Expo	11.8	12.1	26.6	140.8	46.1	4.0
FBC9423	12.0	13.4	17.6	151.6	36.8	4.1
Average	**11.8**	**14.1**	**13.6**	**150.3**	**53.6**	**4.8**
LSD.05	**0.3**	**0.3**	**4.2**	**7.6**	**5.4**	**1.6**

Trial #1, 2010



Initial head firmness, no water loss, Trial #2, 2010

Legacy

Marathon

Heritage

Patron

Firmness and Water Loss of Crowns of Broccoli Cultivars

Cultivar	Crown weight, g	Initial Firmness N	% weight loss 20h 15C 70%RH	Final Firmness N	% firmness loss
1	215.5	52.8	5.27	33.0	38.3
2	198.9	63.5	5.24	38.7	39.3
3	200.3	60.0	3.62	48.2	20.6
4	187.5	63.8	3.73	49.2	24.7
5	195.8	58.1	3.66	45.3	21.6
6	181.5	75.6	3.57	62.4	17.9
7	197.2	96.6	3.73	87.0	9.9
8	222.7	113.3	4.80	82.7	28.0
9	227.5	71.5	5.30	53.3	23.9
Average	203.0	72.8	4.32	55.5	24.9
LSD.05	ns	17.2	0.79	16.3	10.8

Trial #1, 2010

Broccoli Research Update

- Broccoli cultivars differ substantially in shelf-life and composition
- Head firmness is related to morphology and water loss
- Cultivars differ in head firmness and rate of water loss
- Iceless broccoli requires
  - Rapid cooling after harvest
  - Protective plastic liners or packaging
  - Excellent temperature control

Retard yellowing
Minimize weight loss

Postharvest Evaluations Broccoli Varieties

- Bead and floret yellowing
- Stem toughening
- Stem and cut end discoloration
  - Fresh-cut products
- Floret and head morphology
  - Uniform color for fresh-cut
  - Minimal loss of beads
- Rate of water loss (for iceless product)
- Head rot susceptibility

Water-jet Cutting Project

- Third party assessment of performance
- 6 products for fresh-cut
  - romaine, iceberg, celery, cabbage, broccoli, apple
- 2 types of orifices (sharp, fuzzy)
- 3 pressures (35, 45, 55K PSI)
- 3 traverse speeds
- Cut surface appearance
- Shelf-life and quality commercially cut product and waterjet cut products

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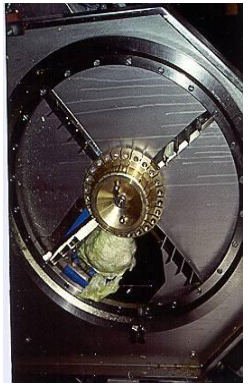
Lettuce Salad Preparation

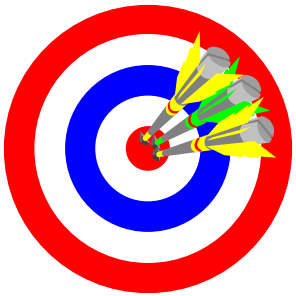
A ‘mature’ fresh-cut product

Standardized operations

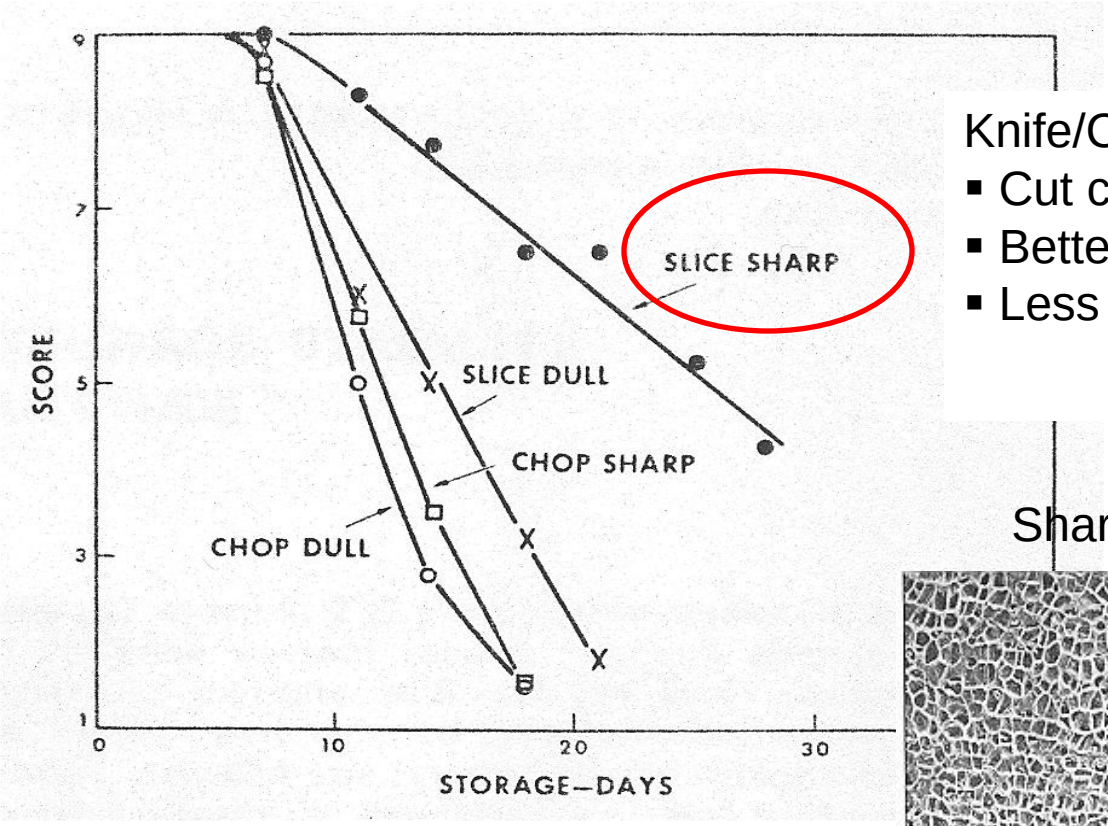
- Harvest
- Trim, core, defect removal
- Cool and/or MA
- Dump, mechanical cut
- Cooling, disinfection
- Drying, centrifugation
- Component blending
- Weigh and package
- Metal detector, pack, palletize
- Temporary cold storage



Maintain Quality & Safety of Fresh-cut Vegetable Products



1. Maintain Use highest quality raw material
2. Minimize mechanical damage; sharp knives
3. Rinse cut surfaces; remove excess water
4. Maintain strict sanitation; chlorinated water
5. Use appropriate package and atmosphere
6. product temperature at 1-2°C



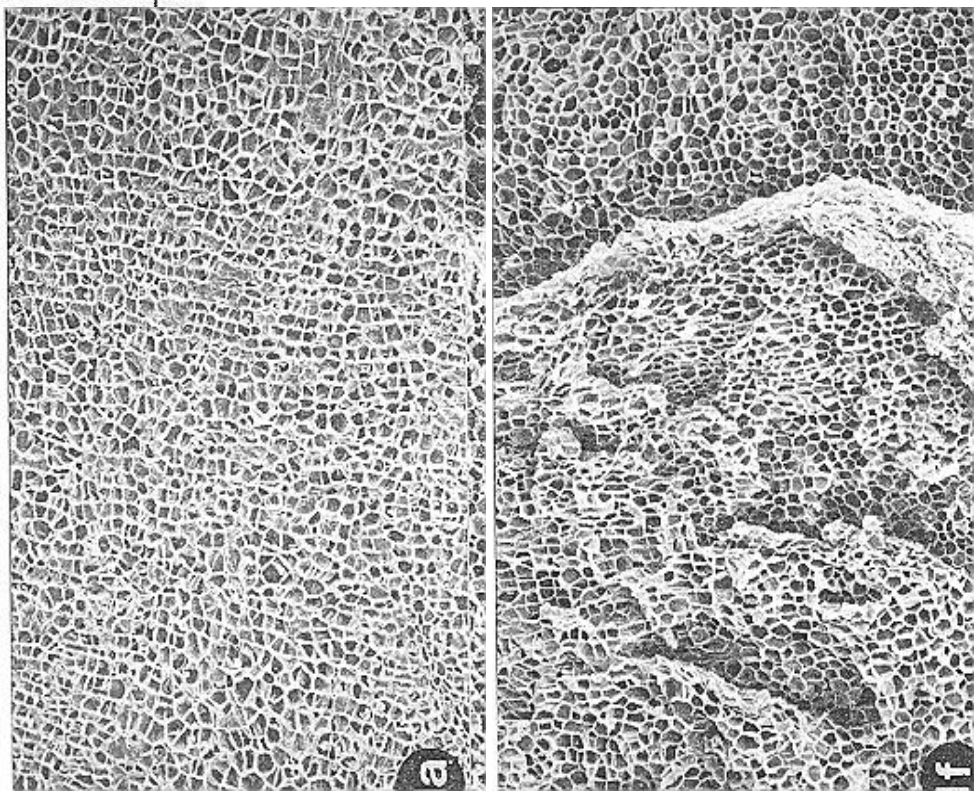
Quality of Cut Iceberg Lettuce
(Huxsoll & Bolin, 1977)

Knife/Cutting Blade Sharpness

- Cut cleanly not crush
- Better shelf-life
- Less browning of cut edges

CARROT

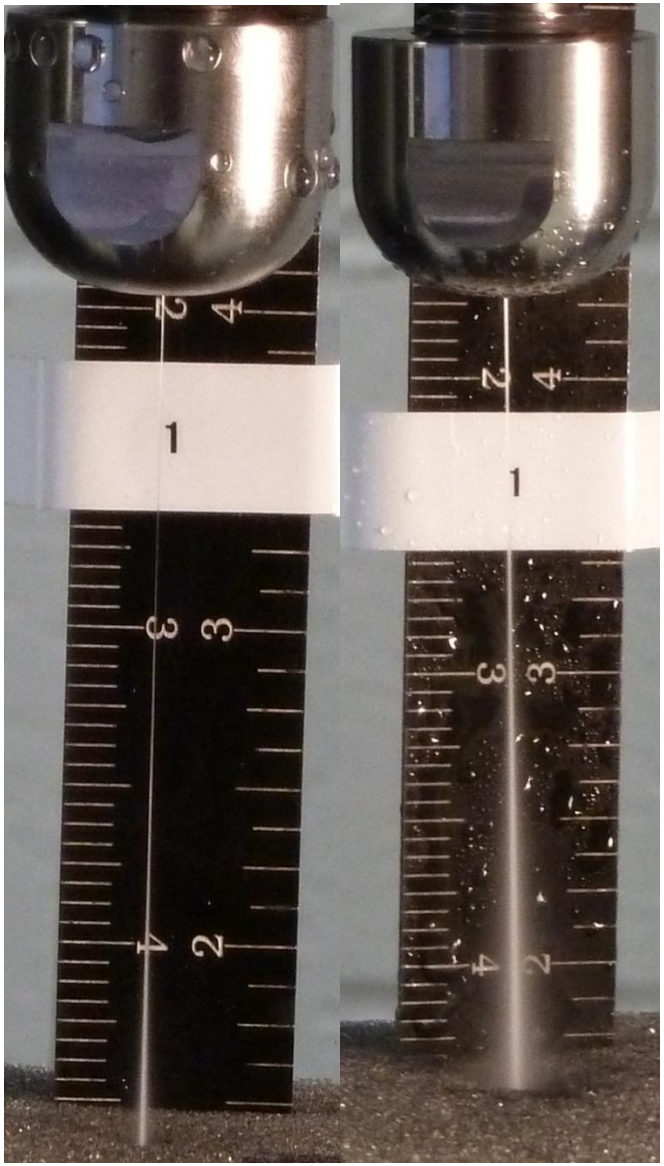
Sharp Razor Dull Knife



Scanning electron microscopy, Tatsumi & Watada, 1991

Knife sharpness, replacement
Need for metal detector

SHARP FUZZY



Waterjet cutting

- Used in processing fish and meat
- Cutting romaine heads in the field
- Fresh-cut celery
- Cutting parameters and cutting costs depend mainly on material to cut
- Multitude of different parameters influencing the cutting power of high-pressure water jet

Video of cutting romaine lettuce
http://www.kmtwaterjet.com/food.aspx

Cutting Parameters of a Water-jet System

Hydraulic parameters	**Mixing and acceleration parameters**	**Cutting parameters**
Pump pressure	Focus diameter	Traverse velocity
Water orifice diameter	Focus length	Standoff distance
Water flow rate		Impact angle

Sharp vs Dull knife; 3 days air 5°C

- Sharp vs dull effect on product quality
- Guidelines for knife sharpness vary
- Dangerous and costly to replace/maintain
- Packaged products through metal detector as CCP because of potential for metal shavings

Water jet cutting of romaine lettuce

http://www.ramsayhighlander.com/products/romaine/green-leaf-lettuce-harvester.htm

Best WJ

Worst WJ

Dull Knife

Sharp Knife

Romaine April 16, 2011; 4 days 5°C; 7, 12, dull, sharp

Best WJ

Worst WJ

Dull Knife

Sharp Knife

Broccoli, 2days 5°C; 7 (55, slow, sharp); 12(35, fast, fuzzy)