Postharvest Handling Update for Vegetables:

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

Marita Cantwell
Dept. Plant Sciences, UC Davis
micantwell@ucdavis.edu
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

http://postharvest.ucdavis.edu
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 $\propto$ rate of respiration

• Respiration:
  \[ \text{Sugar} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{Energy (Heat)} \]

• Respiration increases exponentially with T
# Effect of Temperature on Deterioration

<table>
<thead>
<tr>
<th>Temp. °F</th>
<th>Temp. °C</th>
<th>Q_{10}</th>
<th>Relative Velocity of Deterioration</th>
<th>Relative Shelf-life</th>
<th>Daily Loss (%)</th>
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<tbody>
<tr>
<td>32</td>
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<td>1.0</td>
<td>100</td>
<td>1</td>
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<td>104</td>
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<td>1.5</td>
<td>22.5</td>
<td>4</td>
<td>25</td>
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</tbody>
</table>

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

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
Modified or Controlled Atmospheres

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

<table>
<thead>
<tr>
<th>Composition of Normal Air</th>
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</thead>
<tbody>
<tr>
<td>78.08% Nitrogen (N₂)</td>
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<tr>
<td>20.95% Oxygen (O₂)</td>
</tr>
<tr>
<td>0.93% Argon (Ar)</td>
</tr>
<tr>
<td>0.03% Carbon dioxide (CO₂)</td>
</tr>
<tr>
<td>0.0001% Ethylene (C₂H₄) (1 ppm)</td>
</tr>
</tbody>
</table>
Temperature Management

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

Modified Atmospheres

- Can be an important supplement to temperature management
- Can retard deterioration
- Can retard discoloration in fresh-cuts
- Can retard microbial growth
Ethylene - an important factor

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

- **Problematic:**
  - Accelerates ripening
  - Causes abscission
  - Accelerates senescence
Manage Ethylene

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**

Incompatible products
Low temperature
Minimize exposure time
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

Storage temperature vs. days to initiate yellowing for cv. Legacy.

Soydie
Impact of Temperature on Broccoli Floret Quality

A. Visual Quality

B. Floret Color

C. Cut end Color

D. Total Sugars

0°C  32°F
cv Marathon
2.5°C  36°F
5°C  41°F
7.5°C  45°F
10°C  50°F

0°C  32°F
2.5°C  36°F
5°C  41°F
7.5°C  45°F
10°C  50°F

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

<table>
<thead>
<tr>
<th>Yellowing Score</th>
<th>L Color Value</th>
<th>Hue Color Value</th>
<th>Chroma Color Value</th>
<th>Total Chlorophyll mg/100g FW</th>
<th>Total Carotenoids mg/100g FW</th>
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<tr>
<td>1</td>
<td>42.0</td>
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<td>3</td>
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<td>4</td>
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<tr>
<td>5</td>
<td>49.8</td>
<td>115.3</td>
<td>21.8</td>
<td>16.5</td>
<td>5.0</td>
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</table>

Date average of 3 replicates at each color stage

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

Days at 10°C (50°F)

Trial #2, 2010
## Composition of Florets of Different Broccoli Cultivars

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Dry Wt. %</th>
<th>Chlorophyll mg/100g FW</th>
<th>Sugar mg/g FW</th>
<th>Vitamin C mg/100g FW</th>
<th>Antioxidant Activity µmole TE/g FW</th>
<th>Glucoraphinin µmole/g DW</th>
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<tr>
<td>Heritage</td>
<td>11.9</td>
<td>19.5</td>
<td>12.5</td>
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<td>12.8</td>
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<td>159.3</td>
<td>63.9</td>
<td>3.7</td>
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<td>Legacy</td>
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<td>150.3</td>
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<td>Ironman</td>
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<td>11.1</td>
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<td>Emerald Crown</td>
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<td><strong>Average</strong></td>
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<td><strong>13.6</strong></td>
<td><strong>150.3</strong></td>
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<td>4.2</td>
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<td>5.4</td>
<td>1.6</td>
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</table>

Trial #1, 2010
Broccoli Head Firmness

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

Initial head firmness, no water loss, Trial #2, 2010
## Firmness and Water Loss of Crowns of Broccoli Cultivars

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Crown weight, g</th>
<th>Initial Firmness N</th>
<th>% weight loss 20h 15C 70%RH</th>
<th>Final Firmness N</th>
<th>% firmness loss</th>
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<td>20.6</td>
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<td>4</td>
<td>187.5</td>
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<td>3.73</td>
<td>49.2</td>
<td>24.7</td>
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<td>5</td>
<td>195.8</td>
<td>58.1</td>
<td>3.66</td>
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<td>21.6</td>
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<td>6</td>
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<td>87.0</td>
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<td>0.79</td>
<td>16.3</td>
<td>10.8</td>
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</table>

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
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

Scanning electron microscopy, Tatsumi & Watada, 1991
Knife sharpness, replacement
Need for metal detector

**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
# Cutting Parameters of a Water-jet System

<table>
<thead>
<tr>
<th>Hydraulic parameters</th>
<th>Mixing and acceleration parameters</th>
<th>Cutting parameters</th>
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</thead>
<tbody>
<tr>
<td>Pump pressure</td>
<td>Focus diameter</td>
<td>Traverse velocity</td>
</tr>
<tr>
<td>Water orifice diameter</td>
<td>Focus length</td>
<td>Standoff distance</td>
</tr>
<tr>
<td>Water flow rate</td>
<td></td>
<td>Impact angle</td>
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</tbody>
</table>
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

Romaine April 16, 2011; 4 days 5°C; 7, 12, dull, sharp
Broccoli, 2 days 5°C; 7 (55, slow, sharp); 12 (35, fast, fuzzy)