Postharvest Handling Update for Leafy Vegetables

1. Water relations and texture--broccoli
2. Appearance and Nutritional Quality of Vegetables
3. Fresh-cut Kale and importance of maturity
4. Fresh-cut processing: Compare water-jet with blade cutting

Santa Maria Vegetable Meeting
Sept 17, 2013

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Critical levels for many products

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

Impacts on Quality

- Loss of Salable Weight
- Loss Fresh Appearance
- Gloss
- Shrivel
- Pitting, sunken areas
- Loss of Texture, Turgidity
- Changes in Product Physiology

Water loss is Cumulative
Iceless Broccoli
Temperature-yellowing
Moisture loss-softening

ICELESS BROCCOLI
❖ Minimize delay from harvest to cooling
❖ Use plastic liners with holes to reduce water loss
❖ Keep it cold
❖ About 3-4% weight loss = soft head

Texture and Water loss

% Firmness loss vs % Weight loss

\[ y = 7.228x; R^2 = 0.98 \]
Firmness Testing of Broccoli

Head Firmness

Firmness test of the heads using a 50 mm aluminium flat cylinder probe.

Stem Firmness

Bending of the stems, using a 3 point bending rig.
Broccoli (cv Ironman) harvested into perforated bags and placed immediately in coolers with ice.

Storage: perforated plastic bags inside waxed carton boxes at 5°C (41°F)
Storage: perforated plastic bags inside waxed carton boxes at 5°C (41°F)
Stem Firmness

Storage: perforated plastic bags inside waxed carton boxes at 5°C (41°F)
Visual Quality and Shelf-life

Days to reach score 2

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>30 min hydrate</th>
<th>2 hour hydrate</th>
<th>3% weight loss</th>
<th>3% w loss + 30 min hydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>b</td>
<td>b</td>
<td>a</td>
<td>a</td>
</tr>
</tbody>
</table>

1. 1
2. 2
3. 3
4. 4
5. 5
Broccoli Firmness and Water loss

- 3% weight loss results in noticeable loss of firmness
- Minimize delays to cool
- Use plastic liners to reduce water loss and allow cooling (vacuum, forced air)
- Keep product cold
- Sealed plastic packaging is not necessary to control water loss
- Sealed packaging will create MA which can be beneficial in range of at 3-8% O2 and 5-12% CO2
WIC Project 2011

Postharvest Quality of Vegetables

Objectives

– Determine whether visual cues for quality are indicative of good nutrient content
– Evaluate a range of leafy and fruit vegetables
– Evaluate a range of potential storage temperatures
– Want to retain a minimum 80% of initial nutrients

Artichoke, Arugula, Asparagus, Bean, Broccoli, Cauliflower, Kale, Snap Pea, Spinach, Zucchini
WIC 2011
Postharvest Quality of Vegetables

- Purchased from wholesaler within 1-2 days of harvest
- Held at 0, 10 or 20°C (32, 50 or 68°F) in unsealed bags
- Evaluated after 0, 4, 8, 12 days; 3 replicates
- **Visual quality** (9=excellent, 1=unusable; 6 is limit of marketability)
- **Decay/deterioration** (1=none, 5=severe)
- **Vitamin C** (total ascorbic acid activity, mg/100g FW)
- **Antioxidant activity** (mg Trolox/100g FW)

Determine time to retain 80% of original content
Is visual appearance (score 6) a good indicator of nutritive value?
Postharvest Quality of Vegetables Nutritional Value based on Vitamin C and Antioxidant Activity

• **Vitamin C**
  – a specific vitamin required by humans
  – 90% of Vitamin C comes from fruits and vegetable
  – needed for cell repair; protects against oxidative stress
  – Is a labile vitamin (degrades easily)
  – Often measured in storage studies of fruits and vegetables

• **Antioxidant activity**
  – With aging, there is increase in oxidative damage of human cells
  – Antioxidants can reverse early stages of oxidation
  – In fruits and vegetables, many constituents provide antioxidant activity (phenols, Vitamin C, Vitamin E, carotenoids and others
  – Various assays can estimate total activity of antioxidant compounds in fruits and vegetables
## Initial Composition of 10 Vegetables

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Dry weight %</th>
<th>Vitamin C mg/100g FW</th>
<th>Antioxidant Activity mg Trolox/100g FW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artichoke</td>
<td>17.2</td>
<td>95.4</td>
<td>347.0</td>
</tr>
<tr>
<td>Arugula</td>
<td>10.2</td>
<td>211.0</td>
<td>160.7</td>
</tr>
<tr>
<td>Broccoli</td>
<td>11.9</td>
<td>193.9</td>
<td>146.4</td>
</tr>
<tr>
<td>Kale</td>
<td>11.6</td>
<td>179.6</td>
<td>157.0</td>
</tr>
<tr>
<td>Spinach</td>
<td>9.8</td>
<td>99.5</td>
<td>169.5</td>
</tr>
<tr>
<td>Asparagus</td>
<td>8.9</td>
<td>39.2</td>
<td>125.1</td>
</tr>
<tr>
<td>Snap Pea</td>
<td>13.8</td>
<td>105.2</td>
<td>110.5</td>
</tr>
<tr>
<td>Bean, green</td>
<td>10.6</td>
<td>55.1</td>
<td>19.1</td>
</tr>
<tr>
<td>Zucchini</td>
<td>6.7</td>
<td>55.1</td>
<td>11.2</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>8.0</td>
<td>93.4</td>
<td>41.6</td>
</tr>
<tr>
<td>LSD.05</td>
<td>0.5</td>
<td>12.2</td>
<td>18.4</td>
</tr>
</tbody>
</table>
Arugula (a Brassica) is very responsive to storage temperature. Low temperature retained Vitamin C but antioxidants decreased at all temperatures. Arugula has high Vitamin C content and high antioxidant activity.
## Arugula

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Days to limit of marketability</th>
<th>Days to 80% Vitamin C</th>
<th>Days to 80% Antioxidant activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°C (32°F)</td>
<td>8</td>
<td>&gt;12</td>
<td>6.5</td>
</tr>
<tr>
<td>10°C (50°F)</td>
<td>3.5</td>
<td>6</td>
<td>3.5</td>
</tr>
<tr>
<td>20°C (68°F)</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**CONCLUSIONS:**
Buying arugula based on visual appearance would ensure good nutritional quality. Antioxidant activity declines faster than Vitamin C content.
# Shelf-life based on visual and nutrient aspects

<table>
<thead>
<tr>
<th>VEGETABLE</th>
<th>Days that remain visually marketable*</th>
<th>Days that retain 80% nutrient value**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0°C (32°F)</td>
<td>10°C (50°F)</td>
</tr>
<tr>
<td>Artichoke</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Arugula</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Asparagus</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Bean, green</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Broccoli</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Kale</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Snap Pea</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Spinach</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Zucchini</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td><strong>12.3</strong></td>
<td><strong>7.4</strong></td>
</tr>
</tbody>
</table>

* Number of days to reach a score of 6 from a 9 to 1 scale, where 9=excellent, 8=very good, 7=good, 6=moderately good and marketable, 5=fair but unmarketable, 4=low, 3=poor, 2=almost unusable and 1=unusable

**Number of days to retain 80% Vitamin C and antioxidant activity
Is visual appearance a good indicator of nutritive value? **Generally YES!**

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artichoke</td>
<td>Yes</td>
</tr>
<tr>
<td>Arugula</td>
<td>Yes</td>
</tr>
<tr>
<td>Asparagus</td>
<td>No</td>
</tr>
<tr>
<td>Bean, green</td>
<td>Yes</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Partially</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>yes</td>
</tr>
<tr>
<td>Kale</td>
<td>Yes</td>
</tr>
<tr>
<td>Snap Pea</td>
<td>Yes</td>
</tr>
<tr>
<td>Spinach</td>
<td>Yes</td>
</tr>
<tr>
<td>Zucchini</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Used 80% retention of Vitamin C and Antioxidant Activity at the limit of marketability as criteria to answer the question.
How important is leaf maturity for quality and shelf-life of kale products
Fresh-cut Kale

Importance of Leaf Maturity

1. Determine the impact of maturity on performance of kale leaves in fresh-cut format at two storage temperatures

2. Determine relationships between composition analyses and indicators of the senescence process
**Materials and methods**

- Kale cv. Lacinato
- Leaves were harvested at three maturity stages based on:
  - Length (petiole included)
  - Width (Point of maximum leaf expansion)
- Unlike other cultivars, color is not a maturity criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Immature</th>
<th>Mature</th>
<th>Overmature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>&lt;20 cm</td>
<td>20-30 cm</td>
<td>&gt;35 cm</td>
</tr>
<tr>
<td>Width</td>
<td>&lt;4 cm</td>
<td>4-5 cm</td>
<td>&gt;5 cm</td>
</tr>
</tbody>
</table>
Materials and methods

• Preparation at 7.5°C (45°F)
  - Trim, cut 1 cm strips across midrib
  - Wash chlorinated water (50 ppm NaOCl)
  - Drain, centrifuge
  - Package unsealed plastic PE bas on covered tray at 0.5 and 5°C (33 and 41°F) for up to 42 and 28 days

• Evaluations
  - Marketability assessment (visual quality, defects)
  - Composition (chlorophyll, carotenoids, ammonia, malondialdehyde)
Critical differences in maturity
Marketability evaluations

Yellowing
1=None   5=Severe

Decay/Deterioration
1=None   5=Severe

Discoloration
1=None   5=Severe

0.5°C (33°F)  5°C (41°F)

- Important differences between 0.5 and 5°C
- Overmature leaves had the higher defect scores

Storage time (Days)
Ammonia is an indicator of senescence
• Increases as nitrogen compounds are metabolized
• Significant differences due to temperature
• 0°C: No significant differences between maturity stages
• 5°C: Significant increases after day 14. Differences between maturity stages: higher in overmature leaves. Lower in immature leaves.
Ammonia and Leafy & Floral Tissues

• Ammonia can be useful to monitor stressful CA/MA as well as senescence

• Consequences of increases in ammonia
  – Relate to sensory and other quality attributes
  – Relate to physiology and freshness of leafy greens

• Tissue ammonia correlated to ammonia in package atmospheres?
  – Use as a rapid indicator of stress and/or temperature abuse for leafy veggies (broccoli, spinach, asparagus)
Water-jet Cutting Project

• Assessment of performance
• 6 products for fresh-cut
  – Lettuces, celery, cabbage, broccoli
• 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
Commercial blade cut

Waterjet cut (sharp nozzle)

6 days 5°C; no modified atmosphere
Commercial blade cut

8 days 5°C; packaged, no modified atmosphere

Waterjet cut (sharp nozzle)
Sharp vs Dull knife; 3 days air 5°C

- Sharp vs dull effect on product quality
- Guidelines for knife sharpness?
- Sharp knives make a difference but how to quantify the effect and blade quality
Used or Dull blade  New or sharp blade  Fuzzy nozzle  Sharp nozzle

Packaged, no MA, 18 days at 2.5°C (36°F)

Test#1 FrEx 2013
Used and sharpened blades

Sharp new blades

Sharp nozzle (slow speed, high pressure)

Package, no MA; 8 days at 2.5C in air

Test #2 FrEx 2013
- Overall appearance
- Decay
- Discoloration (pinking or browning)
- Drying or whitening cut edges

**Romaine Lettuce**

**A. Visual Quality**

Data average of 50 pieces per rep per evaluation per treatment, evaluating at both cut ends; 4 reps.

Test#1 FrEx 2013
B. Discoloration

Data average of 50 pieces per rep per evaluation per treatment, evaluating at both cut ends; 4 reps.

Test#1 FrEx 2013
Waterjet Cutting

• Quality of some fresh-cut vegetables is better with waterjet cutting than blade cutting (celery, romaine lettuce)
• No differences in microbial (TPC) between waterjet and blade cutting in romaine
• Nozzle type is key component of waterjet technology; pressure and speed play minor roles
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

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Fruits
Vegetables
Flowers

Free, content-rich website averages over 3 million views annually,
And encompasses more than 640 pages and 1750 pdf documents.
Upcoming Workshops at UC Davis

• **Fresh-cut Products: Maintaining Quality and Safety.** Workshop, 18th annual, September 24-26, 2013.

• **Produce Safety: A Science based Framework Workshop.** 1st annual. November 5-7, 2013. This interactive workshop will improve awareness and appreciation of the tools used for effective hazard analysis and quantitative risk assessment.

• **Methods of Measuring Fruit and Vegetable Quality: Color, Flavor, Texture.** January 22, 2014.

• **Fruit Ripening and Retail handling Workshop.** March 25-26, 2014. 20th Annual.

• Postharvest Technology Short Course. 36th annual. June 16-27, 2014. This course will be held June 16-20, 2014 at UC Davis with an optional Field Tour June 23-27.

• **Fresh-cut Products: Maintaining Quality and Safety.** Workshop, 19th annual, September 23-25, 2014.

• **Produce Safety: A Science based Framework Workshop.** 2nd annual. November 4-6, 2014.

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