## 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

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### Effect of Temperature on Deterioration

<table>
<thead>
<tr>
<th>Temp. °F</th>
<th>Temp. °C</th>
<th>Q&lt;sub&gt;10&lt;/sub&gt;</th>
<th>Relative Velocity of Deterioration</th>
<th>Relative Shelf-life</th>
<th>Daily Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>0</td>
<td>--</td>
<td>1.0</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>3.0</td>
<td>3.0</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>68</td>
<td>20</td>
<td>2.5</td>
<td>7.5</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>86</td>
<td>30</td>
<td>2.0</td>
<td>15.0</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>104</td>
<td>40</td>
<td>1.5</td>
<td>22.5</td>
<td>4</td>
<td>25</td>
</tr>
</tbody>
</table>

Q<sub>10</sub> = rate of deterioration at T+10°C
rate of deterioration at T
Opportunities related to more nutritious lettuces

<table>
<thead>
<tr>
<th>Constituent (fresh wt. basis)</th>
<th>Romaine</th>
<th>Iceberg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorophyll (mg/100 g)</td>
<td>21.5</td>
<td>5.1</td>
</tr>
<tr>
<td>Carotenoids (mg/100 g)</td>
<td>5.9</td>
<td>1.6</td>
</tr>
<tr>
<td>Sugar (mg/g)</td>
<td>20.4</td>
<td>20.0</td>
</tr>
<tr>
<td>Vitamin C (mg/100 g)</td>
<td>23.9</td>
<td>7.5</td>
</tr>
<tr>
<td>Phenolics (A$_{320}$)</td>
<td>0.44</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Cantwell and Ermen 2006
Respiration rates of specialty salad greens and full size lettuces.

From M. Cantwell, UC Davis 1998
**Lettuce Maturity**

Head firmness  
Size, number of leaves

**Russet Spotting**  
Ethylene-induced Disorder on Lettuces

Large differences among varieties in susceptibility

Russet spot scores ~ 1 (none), 3, 6 and 9, respectively.
Development of Russet Spot Disorder on Iceberg and Romaine Lettuces.

Intact heads were stored in 5ppm ethylene at 5°C (41°F) plus 1 week in air.

Russet spotting was evaluated on a scale of 1 to 9, where 1=none, 3=slight, 5=moderate, 7=moderately severe and 9=severe.

1-MCP Prevents Russet Spot Disorder on Iceberg Lettuce

Test#2, midribs; 1000 ppb 1-MCP; Tarraza and Cantwell, Nov 2002
Lettuce disorders
- Brown stain—CO2
- Pink rib—overmature heads
- Heart leaf injury—O2/CO2

Symptoms of Freezing in Lettuce

Romaine

Normal

Frozen

Freeze Injury
If the lettuce head is of marketable quality, no reduction in shelf-life occurs if the roots are infected.

Lettuce Storage Conditions

- 0°C (32°F) but freezing point is -0.2°C (31.5°F)
- Shelf-life:
  - 0°C (32°F): >4 weeks
  - 5°F (41°F): ~3 weeks
- High relative humidity, avoid free moisture
- Controlled atmospheres
  - Low O2 beneficial, CO2 >3% damaging
- Ethylene sensitive
Photos from http://www.ramsayhighlander.com

Lettuce mobile packing units

Broccoli mobile packing unit

Field Pack & Palletize
Vacuum Cool
Traditional Packing of Romaine:
- Do not place cut lettuce on the ground
- Waxed cartons rather than crates
Simple packaging to reduce water loss. Need to cool product (usually hydrocooling) before packaging or used vented packaging and vacuum cool (romaine lettuces)
Lettuces and other leafy greens in supermarket displays

Belgian Endive
Spinach Quality Parameters

- Green and uniform color
- Minimum breakage
- No dirt; Clean and disinfected
- No decay
- Composition
  - nitrates, oxalates
- Shelf-life

Manual harvest of bunched Spinach; vacuum cooled
Note: no longer use slickers, use aprons

Ocean Mist, Salinas, 2006
Mechanical harvest of young spinach for washed and packaged product

http://www.ramsayhighlander.com

Spinach varieties differ in rate of chlorophyll loss during storage

Low temperature is very effective in reducing chlorophyll loss of spinach
Quality categories (leaf damage) for commercial packaged spinach

<table>
<thead>
<tr>
<th>Category number and name</th>
<th>Category Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No damage Intact leaves with no or only minor damage</td>
</tr>
<tr>
<td>2</td>
<td>Slight damage Intact or near intact* leaves with 1 notable damaged area (tear, fracture)</td>
</tr>
<tr>
<td>3</td>
<td>Moderate damage Intact or near intact* leaves with several damaged areas</td>
</tr>
<tr>
<td>4</td>
<td>Severe damage Partial leaves and partial leaves with numerous damaged areas</td>
</tr>
<tr>
<td>5</td>
<td>Leaf Pieces Leaf pieces comprised of &lt;25% of leaf area</td>
</tr>
</tbody>
</table>

*Near intact refers to leaves cut at the base with mechanical harvester

DEFECTS ON FIELD-GROWN PACKAGED LEAFY GREENS
DAMAGE FOLLOWED BY DECAY, MOSTLY BACTERIAL
August 2008

White chard

Green romaine

Tango

Red chard

Red romaine

Stored 7d 5C
Impact of Temperature on Quality Changes

Spinach:
- washed and bagged
- product stored at 4 temperatures

BUT…
- Target Temp.
- 0°C (32°F)

Changes in ammonium, chlorophyll and carotenoid concentrations in spinach after 0 and 21 days in air at 5°C (41°F). Data averaged from 11 spinach cultivars.
Ethylene exposure increases deterioration in leafy vegetables.

A new technology, 1-MCP (SmartFresh™, AgroFresh) blocks ethylene effects.

1-MCP treatment maintained low levels of ammonia in spinach, even when stored at 10°C.

High N results in more fragile leaves; associated with more breakage during harvest, washing, packaging—increased decay and reduced shelf-life.

Older Leaf 8

Gutierrez and Cantwell 2007
**Spinach Storage**

- Young and mature spinach leaves respond similarly to storage conditions
- Young leaves have less physical damage
- Excessive N fertilization results in weaker leaves
- Low temperatures are essential for adequate shelf-life
  - 0°C (32°F): 3 weeks
  - 5°C (41°F): 2 weeks
- Modified atmospheres, keep CO2 at 5% or less
- High CO2 atmospheres stressful to spinach
Storage Conditions for Fresh Herbs

• 0°C (32°F) but freezing point is -0.2°C (31.5°F)
  – Shelf-life at 0°C (32°F): 3-4 weeks
  – Shelf-life at 5°C (41°F): 2-3 weeks
  - Shelf-life based on aroma quality: 1-2 week
  - Exception: chilling sensitive basil 12.5°C (55°F) best

• High relative humidity, protective packaging, but avoid free moisture condensation

• Modified atmospheres can be beneficial

• Ethylene sensitive

Visual Quality

<table>
<thead>
<tr>
<th>Temperature</th>
<th>0°C</th>
<th>5°C</th>
<th>10°C</th>
<th>15°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Quality</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Aroma</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>% Decay</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green color</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Commercially washed & packaged cilantro 8 days

O2=12-17%
CO2=3-5%
CILANTRO AND ITALIAN PARSLEY LEAVES
Color scores, color values and pigment concentrations

<table>
<thead>
<tr>
<th>Color Score</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L</strong>*</td>
<td>49.5</td>
<td>52.4</td>
<td>62.2</td>
<td>68.1</td>
<td>71.7</td>
</tr>
<tr>
<td>Chroma</td>
<td>23.9</td>
<td>28.2</td>
<td>41.5</td>
<td>44.4</td>
<td>46.2</td>
</tr>
<tr>
<td>Hue</td>
<td>125.5</td>
<td>125.1</td>
<td>118.3</td>
<td>111.1</td>
<td>108.1</td>
</tr>
<tr>
<td>Chlorophyll*</td>
<td>1.77</td>
<td>1.61</td>
<td>0.85</td>
<td>0.60</td>
<td>0.40</td>
</tr>
<tr>
<td>Carotenoids*</td>
<td>0.28</td>
<td>0.25</td>
<td>0.17</td>
<td>0.12</td>
<td>0.06</td>
</tr>
</tbody>
</table>

*mg/g FW

Detrimental ethylene effects

Yellowing
Epinasty
Abscission
**Basil**
Highly susceptible to water loss
Very chilling sensitive

**Situation:**
Excellent quality crop
Harvesting late in day
High temperatures, ~30°C
Low RH, ~50%;
Little protection from ambient
Long delays to packinghouse

What can be done to improve this handling???
Basil loses moisture very rapidly

Basil is very chilling sensitive

Basil stored 2 days in plastic bags