I. Introduction

• Definition of “Fresh-cut Produce”
  – Fruits or vegetables that have been trimmed, peeled, and/or cut into 100% usable product to offer consumers high nutrition, convenience, and value while still maintaining its freshness (IFPA, 1997)

• Total sales of fresh-cut estimated at $27 billion (2011 figures)
  – ~60% Packaged Salads
  – ~27% Vegetables
  – ~12% Fruits

• About 22% of U.S. total produce sales (>$122 billion)
• Most (~60%) sold through food service
  – Restaurants, caterers, hospitals, schools
I. Introduction

• Examples of Fresh-cut Vegetables
  - broccoli and cauliflower (florets and slaws)
  - cabbage (shreds and coleslaw)
  - carrots (shreds, sticks and baby peeled)
  - celery (chopped and sticks)
  - lettuce (shredded, chopped, halved, cored; salad mixes)
  - onions (slices, dices, and whole peeled)
  - peppers (chopped and rings)
  - spinach (washed and trimmed)
  - squash and zucchini (slices)

• Examples of Fresh-cut Fruits
  - Fruit salads
  - Grapes (washed and de-stemmed)
  - Cantaloupes, honeydews, and watermelons (halves and cubes)
  - Pineapple (cored, slices and cubes)
  - Apple, nectarine/peach, mango, and papaya slices

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Intact vs. Fresh-cut

<table>
<thead>
<tr>
<th>Intact</th>
<th>Fresh-cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wounding avoided</td>
<td>Wounding normal</td>
</tr>
<tr>
<td>Epidermal layer controls water and gas exchange and limits pathogen entry</td>
<td>Epidermal layer removed and interior tissues exposed</td>
</tr>
<tr>
<td>Onset of ripening avoided to extend shelf life of climacteric fruits</td>
<td>Fresh-cut fruits must be ripe and “ready-to-eat”</td>
</tr>
<tr>
<td>Chilling injury limits shelf life of subtropical &amp; tropical crops</td>
<td>Wounding-induced senescence limits shelf life</td>
</tr>
</tbody>
</table>
Wound Physiology

- The injuries to which fresh-cut produce items are subjected in their preparation, trigger shifts in the metabolism of the injured tissues that result in accelerated senescence, ripening, and deterioration.

Shorter shelf life

Wound Physiology

- Response depends on the extent or severity of wounding
  - Peeling, abrasion, slicing, chopping, and shredding:
    - Force applied
    - Implement sharpness
  - Unit size or wounded area
  - Also affected by temperature.

Consequences of Wounding

- Induction of ethylene synthesis.
  - Increased tissue sensitivity to ethylene.
  - Ethylene effects:
    - Phenolic synthesis (browning, bitter flavor).
    - Tissue softening/toughening.
    - Yellowing (chlorophyll degradation).
- Elevated respiration
  - Up to 200% ↑
  - Decreased respiratory quotient (CO₂/O₂)
Romaine lettuce wound respiration at 5 and 15 °C

<table>
<thead>
<tr>
<th>Temp. (°C)</th>
<th>Time (h)</th>
<th>CO₂ prod. (ml kg⁻¹ h⁻¹)</th>
<th>O₂ cons. (ml kg⁻¹ h⁻¹)</th>
<th>RQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4</td>
<td>9.87</td>
<td>15.77</td>
<td>0.63</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>8.44</td>
<td>8.01</td>
<td>1.05</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>7.78</td>
<td>6.60</td>
<td>1.18</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>28.94</td>
<td>43.58</td>
<td>0.66</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>28.90</td>
<td>36.68</td>
<td>0.79</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>28.24</td>
<td>33.07</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Brecht and Emond, unpublished

Consequences of Wounding

- Enhanced water loss
- Oxidative browning (PPO + phenolics)
- Membrane lipid degradation
  - Increased membrane permeability & ion leakage → water soaked tissues
- Aroma volatile production
  - “Normal” vs. wound-induced aroma volatiles (e.g., cucumber, onion, tomato)
  - Loss of aroma during storage

Fresh-cut Broccoli Browning Rating Scale
Fresh-cut Romaine Lettuce: Rating Scale for Discoloration

Brown Stain Rating Scale for Salad-cut Lettuce

Cut potato browning score

Produce Quality Rating Scales and Color Charts. 2006. Kader & Cantwell
Rates of evaporation from intact and peeled potatoes

<table>
<thead>
<tr>
<th>Type</th>
<th>Evaporation (mg cm⁻² h⁻¹ mbar⁻¹)</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>Peeled</td>
<td>3.3-3.9</td>
<td>470-556%</td>
</tr>
</tbody>
</table>

From Burton, 1982

Interrelationship among the responses of tissue to wounding

![Diagram of Interrelationship among the responses of tissue to wounding](image)

Saltveit, 2003

Fresh-cut Preparation Steps

1. Produce is harvested from the field and put into large bins for the processor
2. “This bulk produce is emptied onto a trim-and-core processing line to remove unusable parts such as the outer leaves, stems and peelings
3. “The trimmed produce then goes through a cutting machine

*Refrigerated operation
**Fresh-cut Preparation Steps**

1. *An inspection is done to make sure all produce is uniform*
2. *The cut produce is then vigorously washed as many as three times with cold, sanitized (usually chlorinated) water*
3. *Finally, the washed produce is dried and put into special packaging designed to preserve its freshness (MAP)*

*Refrigerated operation

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**Processing Line**

- Dumper
- Hopper
- Cutter
- Flume
- Chiller
- Shaker
- Spinner
- Pack
- Weigh

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Special Treatments

- Anti-microbial compounds
  - Sorbate or benzoate
- Control of tissue softening (fruits)
  - Calcium salts (chloride, acetate, lactate)
- Control of browning
  - Acidification (citric acid), antioxidants (Ca ascorbate, Ca erythorbate)

Temperature Control

- To insure maximum shelf life
- Maintain quality
- Prevent/reduce microbial growth
- Allow modified atmosphere packaging to perform well
Temperature Control - Steps
- Bulk produce - precool as usual
- Processing facilities - 2-7°C
- During processing - chilled (0°C) water
  - Immersion
  - Shower
- Packaging/storage - 0 to 5°C

Packaging
- Isolate the product (sanitary)
- Reduce water loss (wilting)
- Modify the atmosphere
- Promote sales (attractive appearance)

Monitoring and Control Measures
- Temperature control
- Water sanitation
- Microbiological testing
  - Processing equipment
  - Packaged produce samples
Microbiology
- Spoilage organisms
  - Fresh cuts are more susceptible to inoculation and decay than intact produce
  - Spoilage organisms are harmless to humans
- Human pathogens and parasites
  - Bacteria, viruses, and parasites
  - Pathogens can grow (proliferate) on fresh cuts

Spoilage Organisms
- Fungi & lactic acid bacteria on fruit.
- Bacteria on vegetables.
- Cut surfaces make nutrients readily available with no energy expenditure.

Human Pathogenic Organisms
- Escherichia coli
- Salmonella spp.
- Shigella spp.
- Vibrio cholerae
- Bacillus cereus
- Clostridium botulinum
- Listeria monocytogenes
- Cryptosporidium parvum
- Giardia lamblia
- Cyclospora cayetanensis
- Toxoplasma gondii
- Norwalk and hepatitis A viruses
Factors Affecting Microbes

- Temperature control and relative humidity
- Chemical treatments (sanitizers & antimicrobials)
- Modified atmosphere packaging (esp. high CO2)
- Natural plant antimicrobial compounds
  - Hexanal, methyl jasmonate, various aldehydes & glucosinolates

Temperature & RH

- Low temperatures slow microbial growth
  - Relationship to marketing.
- High RH, *per se*, doesn’t promote microbial growth as much as free, liquid water
  - Centrifugation used during processing to remove surface water

Chemical Control of Microbes

- Sanitizers (chlorine, etc.)
  - Maintain water microbiological quality rather than disinfect produce
  - No residual effects
- Anti-microbial compounds
  - Sorbate or benzoate remain on produce or in coatings
Edible Coatings on Carrots

- Hygroscopic materials to maintain moist surface appearance
- Sometimes also used to create an internal modified atmosphere

Sanitizing Compounds

- Water sanitizers
  - Chlorine (hypochlorous acid & chlorine dioxide)
  - Peroxyacetic acid (Tsunami™)
  - Hydrogen peroxide
  - Ozone
- Equipment & facility sanitizers
  - Bromine, iodine, trisodium phosphate (TSP), quaternary ammonia

Fresh-cut Products

Semipermeable Film (MAP) Packages
Modified Atmosphere Packaging

- Film permeability, film area, and produce respiration rate interact to create a modified atmosphere.
  - Reduced O₂ levels (1-10%)
  - Elevated CO₂ levels (1-20%)

Packaging Application

- Select film based on:
  - Cost
  - Appearance (clarity)
  - Sealing properties & strength
  - Printing quality
  - Gas permeability (varies 300-fold)
  - CO₂/O₂ permeability ratio (0.8 to 8)

Modified Atmosphere Effects

- Reduced O₂ & elevated CO₂ slow respiration and inhibit ethylene synthesis and action, respectively
- Reduced O₂ also inhibits oxidative browning reactions
- Elevated CO₂ also retards microbial growth
Microbial Competition

- Treatments that suppress one group of organisms may allow other groups to flourish.
  - *e.g.*, *L. monocytogenes* grew faster after epiphytic bacteria populations were reduced by MAP or H2O2 treatments.

Recommended Conditions

- Prepare fresh-cut products at refrigerated temperature (2-7°C)
- Minimize wounding in preparation
  - Use sharp blades
- Use good equipment and employee sanitation practices
- All hydrohandling steps require cold (0°C), sanitized water

Recommended Conditions

- Use appropriate chemical treatments to control:
  - Microbes
  - Browning
  - Texture changes
- Package product in MAP
- Handle final product at 0-5°C
- Expected shelf life still only 7-10 days