Fresh-cut Products: Overview and Challenges

- Examples of products
- Physiology of fresh-cut products
- Preparation and handling
- Quality aspects of fresh-cut products

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Fresh-cut Produce

"Fresh-cut produce" is defined as any fresh fruit or vegetable or any combination thereof that has been physically altered from its original form, but remains in a fresh state. Regardless of commodity, it has been trimmed, peeled, washed and cut into 100% usable product that is subsequently bagged or prepackaged to offer consumers high nutrition, convenience and value while still maintaining freshness.

IFPA-UFFPA

Fresh-cut Produce Sales via Supermarket Channels,* 2005, $6 Billion Total

Fruit 21%
Veggies* 26%
Salads 53%
Carrots=50% of vegetables

*Data for 90.2% of grocery ACV, projected as total grocery over $2 million/store channel.

Source: The Perishables Group – The FreshFacts on Fresh Cut, 2006

Fresh-cut Products References

(Summaries on Specific Products)

- FRESH-CUT FRUITS (J. Beaulieu, J. Gorny)
- FRESH-CUT VEGETABLES (M.Barth, H. Zhuang, M. Saltveit)
  Commercial Storage of Fruits, Vegetables & Ornamentals
  (K.Gross et al., eds.); http://www.ba.ars.usda.gov/hb66
Differentiation of Prepared Salads; Salad Meals

- Standard iceberg
- Plus “color”
- European style salads
- Romaine; Caesar Salad

Differentiation of Salads; Salad Meals

- Standard iceberg
- Plus “color”
- About 1996
- Salad kits, 2006

CARROT CHIPS™
CARROT DIPPERS™
CARROT SNACKS™
for Horses!

Food Service Presentations

http://www.grimmway.com

Sweetpotato for Food service

Strips taro, celeriac, sweetpotato

• Fresh Garlic
• Whole Peeled Garlic Cloves
• Roasted Garlic Cloves
• Garlic Braids
• Elephant Garlic
• Jarred Garlic Products
• Fresh Chopped Garlic
• Chopped & Minced Garlic in Water

Resealable bags

Single serve Snack packs

Time-temperature indicators
RFID tags, labels
Thermochromic inks
Thiolase indicators
Doneness indicators
Microorganism indicators
Preservable indicators
Intelligent/Smart Packaging

Rigid containers

Biobased packaging
PLA resin

Immediate Physical Effects

- **Mechanical shock to tissue**
  - Bruises, cracks, fractures in tissue
- **Removal of protective epidermal layer**
  - Alter gas diffusion
  - Provide entry for contaminants
- **Cell fluids on cut surface**
  - Reduced gas diffusion
  - Provides substrate for microbes
- **Exposure to contaminants**
  - Microbial, Chemical

Physiological Effects of Fresh-cut Processing

- Increased respiration rates
- Altered ethylene production rates
- Increases in other biochemical reactions
  - Discoloration and Color
  - Texture
  - Aroma and Flavor
  - Nutritional quality

Main strategy to minimize changes in physiology is low temperature

Careful peeling causes a substantial increase in respiration rates. Mechanical compressed air peeling doubles rates. Rates are significantly less at 5°C. Quality best maintained at 0°C.

<table>
<thead>
<tr>
<th>Storage Temperature</th>
<th>Unpeeled</th>
<th>Manually Peeled</th>
<th>Compressed Air Peeled</th>
</tr>
</thead>
<tbody>
<tr>
<td>5°C</td>
<td>10.6</td>
<td>17.4</td>
<td>21.2</td>
</tr>
<tr>
<td>10°C</td>
<td>18.1</td>
<td>29.3</td>
<td>48.6</td>
</tr>
</tbody>
</table>

Commercially Peeled Garlic Stored 9 Days
### Respiration rate (mL CO₂ · kg⁻¹ h⁻¹)

<table>
<thead>
<tr>
<th>Product</th>
<th>0°C</th>
<th>5°C</th>
<th>10°C</th>
<th>15°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full size leaves</td>
<td>8</td>
<td>12</td>
<td>29</td>
<td>33</td>
</tr>
<tr>
<td>Small leaves</td>
<td>14</td>
<td>21</td>
<td>42</td>
<td>57</td>
</tr>
<tr>
<td>Chopped (2 x 2 cm pieces full size leaves)</td>
<td>15</td>
<td>23</td>
<td>46</td>
<td>53</td>
</tr>
<tr>
<td>Shredded (0.3 cm pieces full size leaves)</td>
<td>17</td>
<td>28</td>
<td>59</td>
<td>68</td>
</tr>
</tbody>
</table>

### Preparation of Lettuce Salads

1. **Harvest**
   - lettuce from first harvest results in better quality
   - trim outer leaves

2. **Field-pack & local transport**
   - transport on flatbed trucks; if distances far, transport in refrigerated trailer

3. **Vacuum or forced-air cooling**
   - field temperatures and delay determine need to cool
   - vacuum and forced-air cooling most common

4. **Reception, dump, trim and core**
   - revision and selection of heads on conveyer
   - further trimming outer leaves; removal of stem tissue with coring device

5. **Chop/shred/tear**
   - continuous-feed cutter for salad pieces (3 x 3 cm) or shreds (<0.5 cm)
   - manual cutting for some lettuce types (romaine)
   - very sharp knives reduce damage and subsequent browning

6. **Wash and Cool**
   - cold water containing disinfectant, usually chlorine
   - residence time form 15-30 sec; may use processing aides to reduce browning

7. **Centrifugation or other drying technique**
   - vibration screens remove large volumes of water
   - centrifugation and air tunnels remove moisture so surface of product dry

8. **Combine different products for salad mixes**
   - or “color” items may be added after washing and centrifuged together

9. **Package in plastic film bags**
   - centrifuged product dumped onto conveyor feeding filler
   - manual or automated form-fill-seal machines
   - vacuum or gas-flushing with nitrogen
   - check for leaks in pressurized water chamber

10. **Box, palletize and store temporarily**
    - bags through a metal detector, conveyor to boxing and palletizing area
    - Temporary storage <5°C (<41°F); 0°C (32°F) is optimum

11. **Transport to food service outlets and/or retail markets**
    - Pre-cooled clean trucks, thermostat at <5°C (41°F)
    - Load at enclosed docks to maintain cold chain
Processing Baby Peeled Carrots

- Washing
- Disinfecting
- Rapid cooling
- Cut to 2 inch sections
- Mechanical Peeling
- Mechanical shaping
- Disinfection
- Cooling
- Computerized quality and color sorting
- Packaging (form, fill, seal)

Onion Processing

- Raw material quality
- Packaging and odors
- Physical damage
- Temperature control

SANITARY PLANT DESIGN
Focus: Implementation of GMP's

- Design efficient, easy to clean & sanitize processing plants
- Mobility of equipment
- 2-3 areas to separate production steps

Rudi Groppe; http://www.heinzen.com/products/

Total Microorganisms at Different Steps of a Fresh-cut Salad Process Line

<table>
<thead>
<tr>
<th>Operation</th>
<th>Number/Sq. Inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bin Dump</td>
<td>92,000</td>
</tr>
<tr>
<td>Coring Belt</td>
<td>210</td>
</tr>
<tr>
<td>Cutter</td>
<td>2,290</td>
</tr>
<tr>
<td>Transfer Belt</td>
<td>40</td>
</tr>
<tr>
<td>Cooling Water</td>
<td>5</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>10</td>
</tr>
<tr>
<td>Package Filler</td>
<td>3,350</td>
</tr>
</tbody>
</table>

Modified from Hurst, Univ. Georgia, 1990

Many large volume (lettuce) products are mechanically cut, but manual preparation generally results in superior quality

- cutting romaine by hand; eliminate defects
- manually peeled garlic vs compressed air peeled
- broccoli and cauliflower florets manually trimmed
- manually trimmed and cut melons, pineapples
Fresh-cut Products

**Food Safety Requirements**

- Meticulous cleanliness of equipment, employees and product
- Rigid maintenance of refrigerated temperatures
- Complete integrity of packages
- Strict adherence to product use by dates & handling instructions

“Best if used” by dates

USDA Inspection guidelines but no standards

Wounds induce phenolic metabolism

Leading to unsightly brown pigments

**Enzymatic Browning**

PAL = phenylalanine ammonia-lyase

PPO = polyphenol oxidase

**Salad Lettuce**

- Cut edge browning
- Wound induction of PAL and brown pigments
- Lettuce types and varieties differ in PAL and browning

**Romaine lettuce**: leaf position/age effect on respiration, discoloration and composition

- Phenolics highest in outer leaves; browning highest in outer leaves
- Sugars highest in heart leaves
- Chlorophyll/carotenoids highest in outer leaves
- Vitamin C not much affected by leaf age or position

Ermen, Hong, Cantwell, 2006
Prevention of enzymatic/oxidative browning
- Refrigeration (slows enzymatic reactions)
- Exclusion of oxygen (CA, MAP, edible films)
- Inhibition of PAL (lettues & veggies)
- Inhibition of PPO (fruits)
- Use of reducing agents (ascorbic acid, etc.)
- Other chemical agents

Packaged Salad Quality Study
- 4 salad products from 5 processors
- 4 production dates, product purchased
- Products stored at 5°C (41°F)
- Components: Size, Color
- Visual Quality and defects: 0, 10, 15 & 20d
- Composition: Sugar, Vit C, EtOH, Acetald.
- Microbiological Tests: APC, Coliforms (0, 10, 20d)
- Sensory: 18 panelists, 5 criteria (texture, aroma, flavor, visual, Buy), 0 & 10D

Flavor quality good to 10 days, shelf-life expected 14-16 days

Romaine Salad-cut lettuce
Vitamin C content and modified atmospheres

High CO2 atmospheres result in decreased Vitamin C
High CO2 also reduces crispiness of lettuce

H. Emers, G. Hong, M. Cantwell 2006

Lettuce Alternatives
Intact Baby size
Clean Whole leaves
Hearts
Rely on temperature
No modified atmospheres
There are many opportunities for damage to spinach leaves:
- Harvest
- Bin dump, sort area
- Wash and centrifuge
- Packing

Good Temperature Control throughout handling and distribution is a Necessity for Fresh-cut Products

Fresh-cut produce Chill Chain Temperatures During Shipping, Distribution and Retail Display.

Information courtesy of Dr. G.S. Mudahar, Salad Time Farms, Inc.

We can do better!!

Good Temperature Control throughout handling and distribution is a Necessity for Fresh-cut Products
Vegetable trays
- want 18 day shelf-life
Products in tray and compatibility issues
  - raw material sourcing and handling before prepare
  - shelf-life of individual products in tray varies
  - temperature; 5°C too low for grape tomatoes
  - modified atmospheres—not good for all products in tray

<table>
<thead>
<tr>
<th>Products</th>
<th>Potential post-cutting storage life at 2-5°C (36-41°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEGETABLES</td>
<td>Days</td>
</tr>
<tr>
<td>Baby carrots, peeled onions, peeled garlic</td>
<td>&gt;21</td>
</tr>
<tr>
<td>Lettuce salads, lettuce separated leaves, lettuce mixes, spinach leaves, peeled potatoes</td>
<td>14-18</td>
</tr>
<tr>
<td>Broccoli &amp; cauliflower florets, shredded cabbage, lettuce and broccoli, celery &amp; carrot sticks</td>
<td>10-14</td>
</tr>
<tr>
<td>Pepper and tomato dices, cucumber slices, squash slices, mushroom slices, jicama sticks</td>
<td>4-9</td>
</tr>
<tr>
<td>FRUITS</td>
<td></td>
</tr>
<tr>
<td>Apple wedges, pineapple chunks, pomegranate arils, kiwi slices</td>
<td>10-14</td>
</tr>
<tr>
<td>Strawberry slices, melon &amp; mango cubes, citrus segments, peach &amp; pear wedges, grape berries</td>
<td>2-9</td>
</tr>
</tbody>
</table>

Baby Carrots and Variety Selection
- Uniform, bright orange color
- Small or no core
- High sugars with no harshness/bitterness
- Smooth exterior to minimize peeling loss
- No green should or green core problems
- Strong tops for mechanical harvest
- Balance between juicy texture and resistance to shatter

Fresh-cut tomato for food service
Stage of maturity/ripeness for cutting
- Color
- Texture; slice integrity
- Composition-flavor

High Quality Raw Material is Necessary for High Quality Fresh-cut Product
- Brassicas have higher respiration rates than lettuces.
- Freshness of color and flavor ingredients.
Preprocessing Storage
Example: Lettuce heads stored at 5°C (41°F)
Longer heads are stored, greater browning on cut salad pieces

![Graph of Browning of Cut Edges](image)

### Current Fresh-cut Challenges
Meal Solutions
- Protein component
- Starch component

### Fresh-cut Fruits
- Apples
- Melons
- Pineapple
- Citrus

### Fresh-Cut Apples
- 64,000,000 Pounds
- 29,000,000 Kg
- .5 Million/19Kg Boxes
- 1.5% USA Apple Supply
- 13,500 McD Restaurants

### Commercial Pomegranate Aril Extraction and Packaging
From Adel Kader

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Supermarket Mix of Value-Added Fresh Fruit: Quantity Sold, 2004

- 14% Apples
- 12% Other Melons
- 2% Watermelon
- 2% Honeydews
- 1% Citrus
- 3% Tropicals
- 3% Pineapple
- 2% Cantaloupe
- Mixed
- Other

Source: The Perishables Group

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Ripeness Stage & Storage Temperature Effects

Enzymatic Browning

PAL
Phenylalanine → cinnamonic acid ← other phenolics

PPO
(polyphenol oxidase)

+ O₂

(Laccase)

complex brown polymers ← quinones

PAL = phenylalanine ammonia-lyase
PPO = polyphenol oxidase

Genotypic Differences in Browning Potential of Apples

Challenges for Fresh-cut Melon products

• Maturity: sugars vs firmness
• Taste-life vs Shelf-life
• Color
• Texture
• Flavor

Melon Defects and Internal Quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Good Quality</th>
<th>Ground Spot</th>
<th>Sunburn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firmness (N)*</td>
<td>10.7</td>
<td>9.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Soluble Solids (%)</td>
<td>11.5</td>
<td>10.5</td>
<td>7.9</td>
</tr>
<tr>
<td>Color (chroma)</td>
<td>32.4</td>
<td>32.2</td>
<td>31.7</td>
</tr>
</tbody>
</table>

* 5 mm diameter probe
**Relative Importance of Temperature and Modified Atmospheres for Fresh-cut melon**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Atmosphere</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5°C (45°F)</td>
<td>Air 1% O2</td>
<td>0 5 10 15</td>
</tr>
<tr>
<td>5°C (41°F)</td>
<td>Air + 10% CO2</td>
<td>0 5 10 15</td>
</tr>
<tr>
<td>2.5°C (36°F)</td>
<td>1% O2 + 10% CO2</td>
<td>0 5 10 15</td>
</tr>
</tbody>
</table>

**Translucency Defect**
- Differences among melon cultivars
- Probably growing & nutrient conditions affect

**Experimentally Induced Translucency**
BL = blunt blade
SH = sharp blade

Translucency not reduce firmness
Calcium chloride dips reduce translucency

**Fresh-cut Cantaloupe: Temperature and Atmosphere**

**The Successful Fresh-cut Fruit Processor**

A) Increased Technical & Managerial Sophistication
B) Understand & Manage Fruit Ripening
C) Overcome Sourcing Issues
D) Reduce Labor Costs
E) Retain Flavor and Aroma

**Management of Ripening of Intact and Fresh-cut Fruits - Considerations**

1. Stages of fruit development
2. Fruits that must ripen on the plant
3. Fruits that can ripen on or off the plant
4. Role of ethylene in fruit ripening
5. Efficacy of 1-methylcyclopropene in extending shelf-life of fresh-cut fruits
Cut ripe pineapple cubes have a longer post-cutting life than those cut green

Classification of fresh-cut fruit products according to their potential post-cutting-life at optimum handling conditions (0-5°C and 90-95% RH)

<table>
<thead>
<tr>
<th>Potential storage-life</th>
<th>Fresh-cut fruit products</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-14 days</td>
<td>Apple wedges, kiwifruit slices, mango cubes, pineapple slices and wedges, pomegranate arils</td>
</tr>
<tr>
<td>2-9 days</td>
<td>Banana slices, citrus segments, grape berries, melon cubes, nectarine and peach wedges, papaya cubes, pear wedges, persimmon slices, strawberry slices</td>
</tr>
</tbody>
</table>

Fresh-cut Fruit Roadblocks to Success

- Labor Intensive Production
- High Cost per pound-yields and price
- Fruit availability
  - Offshore
  - Stage of ripeness
- Perishability of cut product

Shelf-life Drivers

A) Modes of Failure: Browning, Softening, Microbes
B) Cultivar
C) Maturity at Cutting
D) Storage History

Maintain Quality & Shelf-life of Fresh-cut Vegetable Products

1. 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. Maintain product temperature at 1-2°C

Fresh-cut Products Opportunities and Challenges

- Packaging; MAP
- Nutritional Quality
- Sensory Quality
- Microbial Food Safety
- Temperature Control
- Raw Material Quality