



Postharvest Biology & Handling of Fresh-cut Vegetables & Fruits


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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 it’s freshness (IFPA, 1997)




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I. Introduction





- Total sales of fresh-cut estimated at \$27 billion (2016 figures)
 - ~61% 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



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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)

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I. Introduction

- **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

Intact	Fresh-cut
Wounding avoided	Wounding normal
Epidermal layer controls water and gas exchange and limits pathogen entry	Epidermal layer removed and interior tissues exposed
Onset of ripening avoided to extend shelf life of climacteric fruits	Fresh-cut fruits must be ripe and “ready-to-eat”
Chilling injury limits shelf life of subtropical & tropical crops	Wounding-induced senescence limits shelf-life



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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**

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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.



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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)

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Romaine lettuce wound respiration at 5 and 15 °C

Temp. (°C)	Time (h)	CO ₂ prod. (ml kg ⁻¹ h ⁻¹)	O ₂ cons. (ml kg ⁻¹ h ⁻¹)	RO
5	4	9.87	15.77	0.63
	8	8.44	8.01	1.05
	12	7.78	6.60	1.18
15	4	28.94	43.58	0.66
	8	28.90	36.68	0.79
	12	28.24	33.07	0.85

Brecht and Emond, unpublished

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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

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Fresh-cut Broccoli Browning Rating Scale

Produce Quality Rating Scales and Color Charts, 2006. Kader & Cantwell

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**Fresh-cut Romaine Lettuce:
Rating Scale for Discoloration**

1 3 5

Produce Quality Rating Scales and Color Charts. 2006. Kader & Cantwell

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Brown Stain Rating Scale for Salad-cut Lettuce

1 2 3 4 5

Produce Quality Rating Scales and Color Charts. 2006. Kader & Cantwell

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Cut potato browning score

Red skin cv

White skin cv

1 3 5

Produce Quality Rating Scales and Color Charts. 2006. Kader & Cantwell

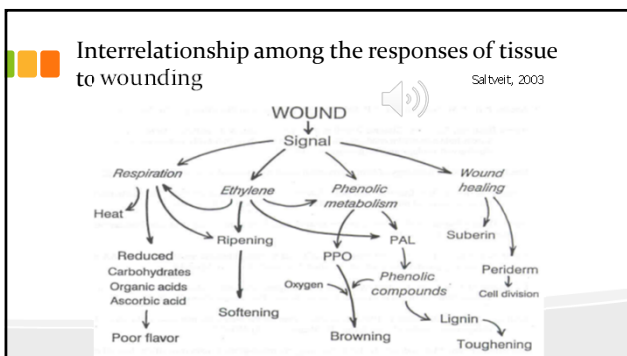
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Rates of evaporation from intact and peeled potatoes

Type	Evaporation (mg cm ² h ⁻¹ mbar ⁻¹)	% increase
Intact	0.007	
Peeled	3.3-3.9	470-556%

From Burton, 1982

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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

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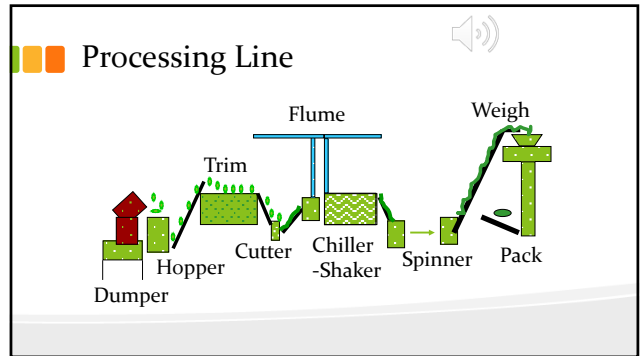
Fresh-cut Preparation Steps

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



*Refrigerated operation

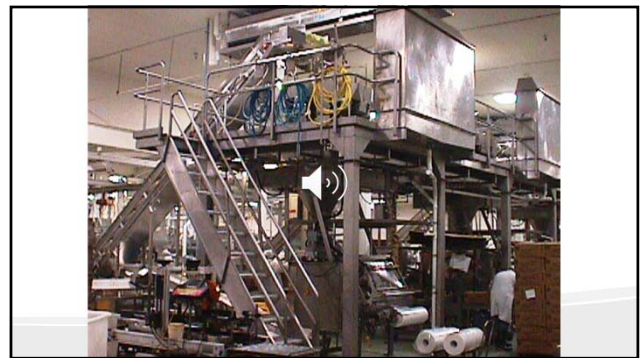
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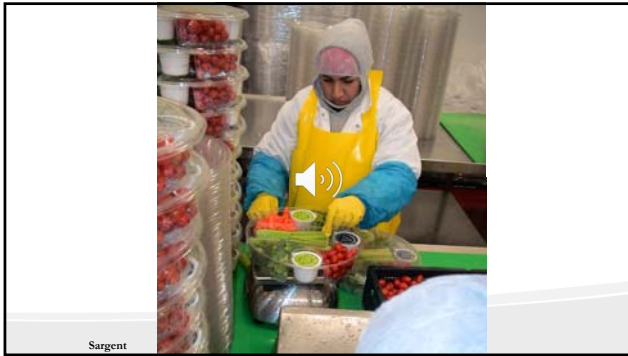
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Special Treatments

- 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)

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Temperature Control

- To insure maximum shelf life
- Maintain quality
- Prevent/reduce microbial growth
- Allow modified atmosphere packaging to perform well

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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

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Packaging

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

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Monitoring and Control Measures

- Temperature control
- Water sanitation
- Microbiological testing
 - Processing equipment
 - Packaged produce samples

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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

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Spoilage Organisms

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

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Human Pathogenic Organisms

- *Escherichia coli*
- *Salmonella* spp.
- *Shigella* spp.
- *Vibrio cholerae*
- *Bacillus cereus*
- *Clostridium botulinum*
- *Listeria monocytogenes*
- *Cryptosporidium parvum*
- *Giardia lamblia*
- *Cyclospora cayentanensis*
- *Toxoplasma gondii*
- Norwalk and hepatitis A viruses

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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
 - Essential oils like thymol, from thyme (the seasoning)

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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



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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

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Edible Coatings on Carrots

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

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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

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Fresh-cut Products

Semipermeable Film (MAP) Packages

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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%)

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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)

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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

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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.



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Recommended Conditions

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



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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



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