Postharvest Biology & Handling of Fresh-cut Vegetables & Fruits

Dr. Jeffrey K. Brecht

Horticultural Sciences Department, Gainesville

Dr. Mark A. Ritenour

Indian River Research and Education Center, Fort Pierce

1

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)

2

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

3

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)

4

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

5

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

6

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

7

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.

Sargent

8

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 (CO_2:O_2)

9

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})	RQ
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

10

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

11

Fresh-cut Broccoli Browning Rating Scale

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

12

Fresh-cut Romaine Lettuce: Rating Scale for Discoloration

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

13

Brown Stain Rating Scale for Salad-cut Lettuce

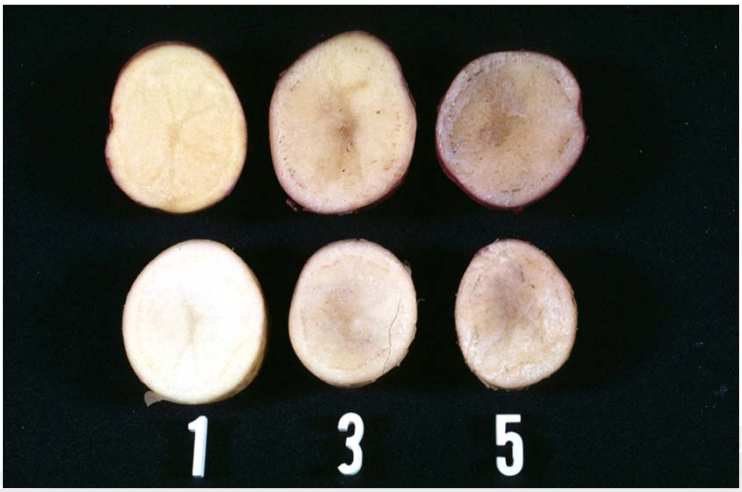
Produce Quality Rating Scales and Color Charts. 2006. Kader & Cantwell

14

Cut potato browning score

Red skin cv

White skin cv



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

15

Rates of evaporation from intact and peeled potatoes

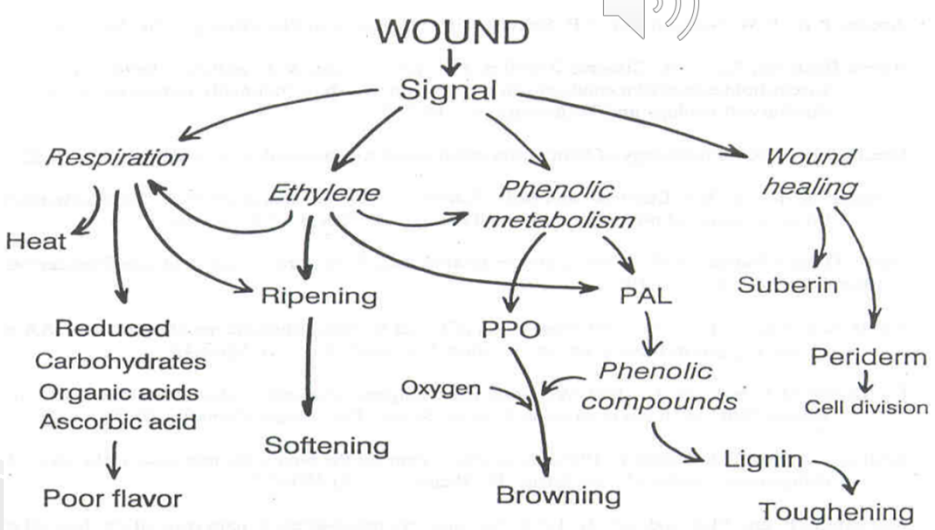
Type	Evaporation (mg cm^{-2} h^{-1} $mbar^{-1}$)	% increase
Intact	0.007	
Peeled	3.3-3.9	470-556%

From Burton, 1982

16

Interrelationship among the responses of tissue to wounding

Saltveit, 2003



17

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

18

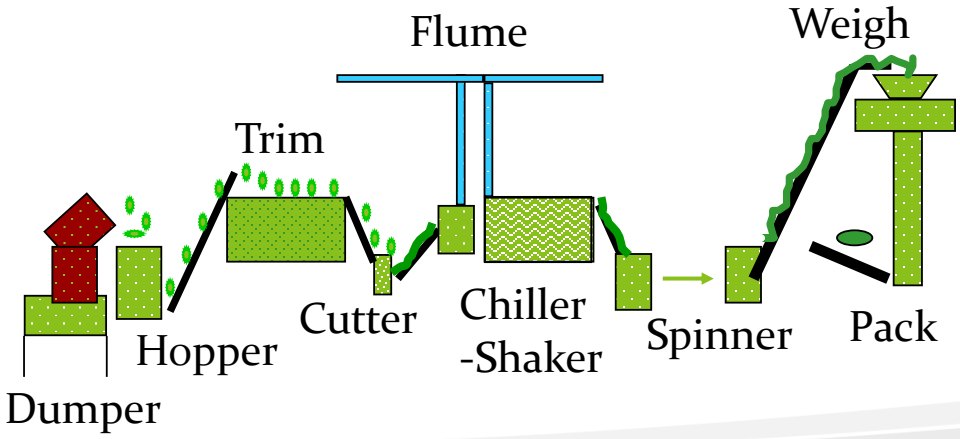
Fresh-cut Preparation Steps

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

19

Processing Line



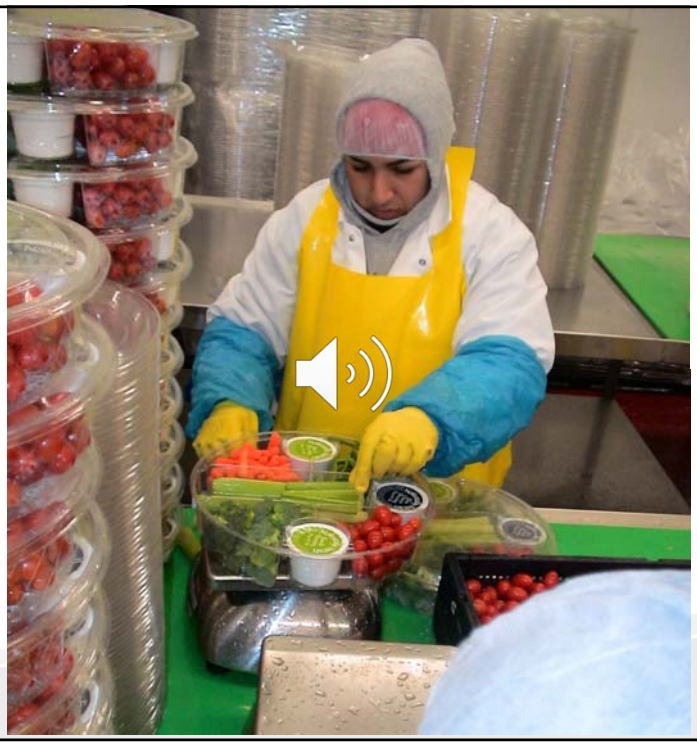
20

21

22

23

24



Sargent

25

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)

26

Temperature Control

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

Sargent

27

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

28

Packaging

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

29

Monitoring and Control Measures

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

30

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**

31

Spoilage Organisms

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

32

Human Pathogenic Organisms

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

33

Factors Affecting Microbes

- Temperature control and relative humidity
- Chemical treatments (sanitizers & antimicrobials)
- Modified atmosphere packaging (esp. high CO_2)
- Natural plant antimicrobial compounds
  - Hexanal, methyl jasmonate, various aldehydes & glucosinolates
  - Essential oils like thymol, from thyme (the seasoning)

34

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

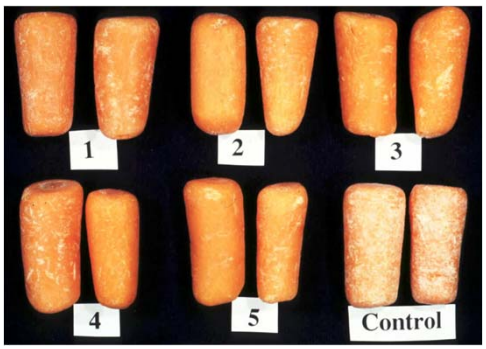
35

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

36

Edible Coatings on Carrots



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

37

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

38

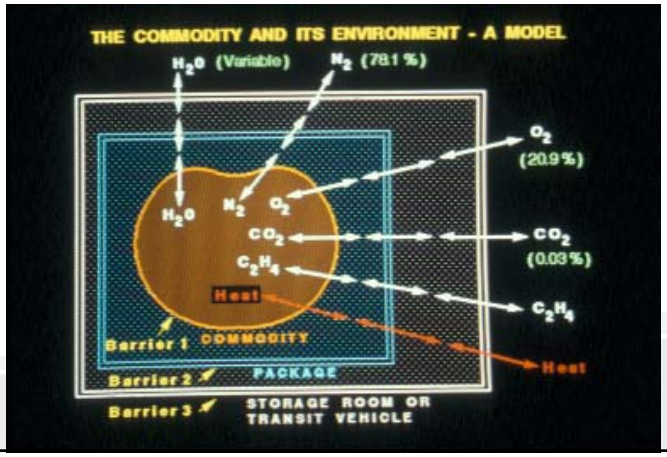
Fresh-cut Products

Semipermeable Film (MAP) Packages

39

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%)



40

Packaging Application

- Select film based on:
  - Cost
  - Appearance (clarity)
  - Sealing properties & strength
  - Printing quality
  - Gas permeability (varies 300-fold)
  - CO_2/O_2 permeability ratio (0.8 to 8)

41

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

42

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 H_2O_2 treatments.

43

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

44

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

45