Causes of Quality & Postharvest Losses

Leafy & Stem 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

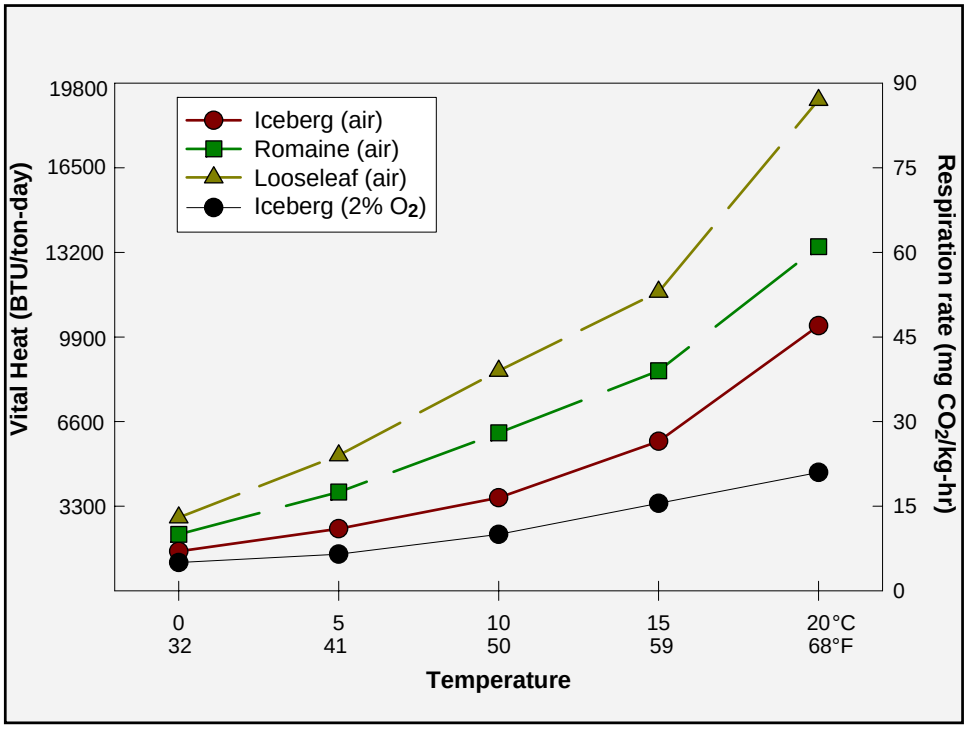
Opportunities related to more nutritious lettuces

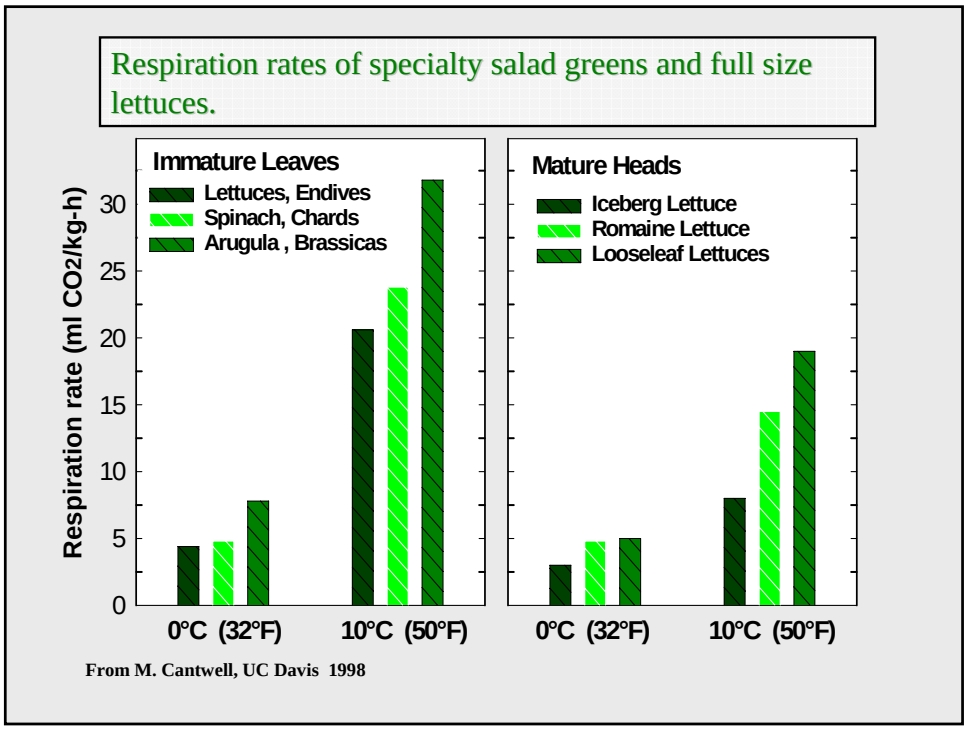
Constituent (fresh wt. basis)	**Romaine**	**Iceberg**
Chlorophyll (mg/100 g)	21.5	5.1
Carotenoids (mg/100 g)	5.9	1.6
Sugar (mg/g)	20.4	20.0
Vitamin C (mg/100 g)	23.9	7.5
Phenolics (A_{320})	0.44	0.22

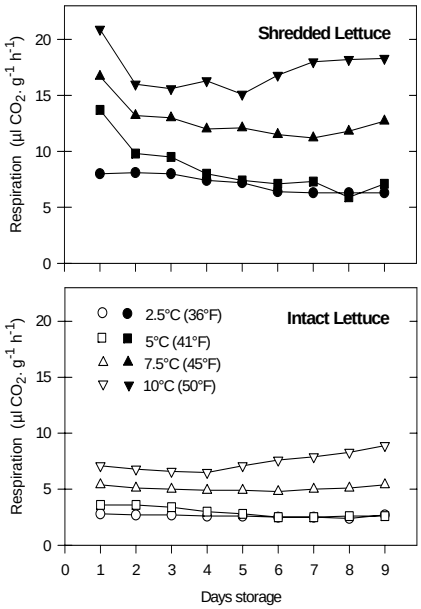
Cantwell and Ermen 2006

Variation due to leaf position in the head

1. Composition
   - Individual sugars
   - Ascorbic acid
   - Carotenoids
   - Chlorophyll
   - Phenolic compounds
2. Respiration rates
3. Visual quality changes


Iceberg (air)
Romaine (air)
Looseleaf (air)
Iceberg (2% O2)
Vital Heat (BTU/ton-day)
Respiration rate (mg CO2/kg-hr)
19800
16500
13200
9900
6600
3300
90
75
60
45
30
15
0
0
32
5
41
10
50
15
59
20°C
68°F
Temperature


Respiration rates of specialty salad greens and full size lettuces.
Immature Leaves
Lettuces, Endives
Spinach, Chards
Arugula , Brassicas
Mature Heads
Iceberg Lettuce
Romaine Lettuce
Looseleaf Lettuces
Respiration rate (ml CO2/kg-h)
30
25
20
15
10
5
0
0°C (32°F)
10°C (50°F)
0°C (32°F)
10°C (50°F)
From M. Cantwell, UC Davis 1998

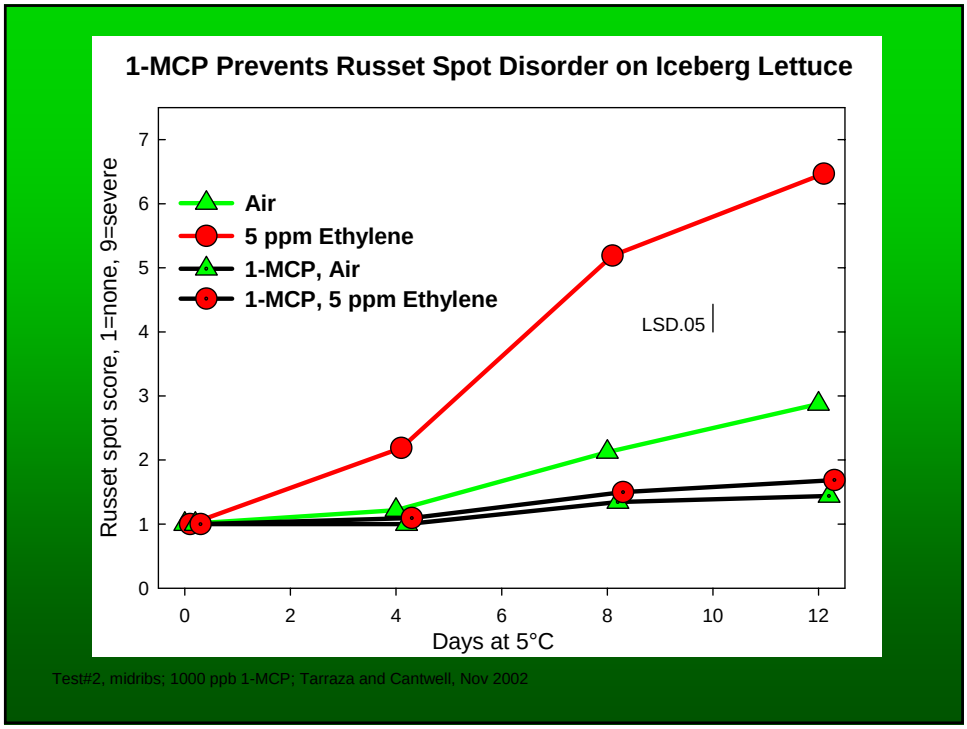


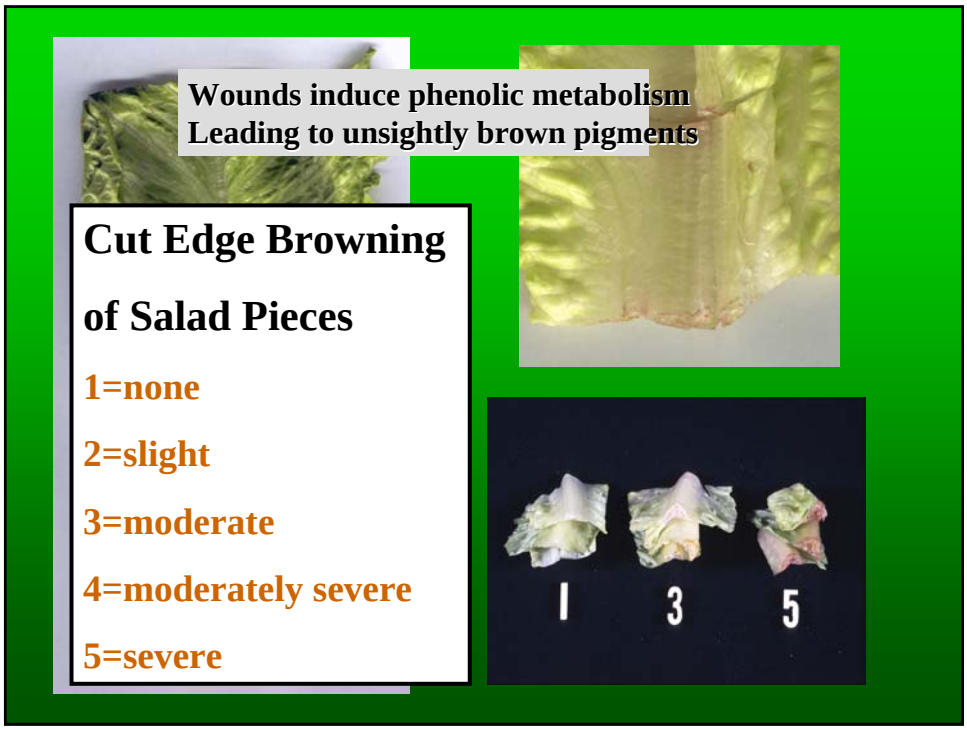
Respiration rates of Intact and Shredded Lettuce

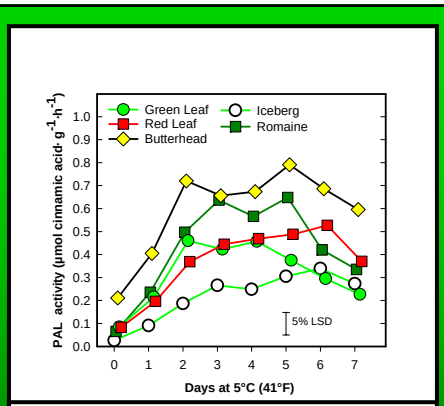
Russet Spotting
Ethylene-induced Disorder on Lettuces

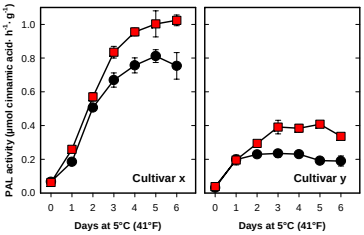
Russet spot scores ~ 1 (none), 3, 6 and 9, respectively.

Large differences among varieties in susceptibility


1-MCP Prevents Russet Spot Disorder on Iceberg Lettuce
Russet spot score, 1=none, 9=severe
Air
5 ppm Ethylene
1-MCP, Air
1-MCP, 5 ppm Ethylene
LSD.05
Days at 5°C
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
Test#2, midribs; 1000 ppb 1-MCP; Tarraza and Cantwell, Nov 2002


Wounds induce phenolic metabolism
Leading to unsightly brown pigments
Cut Edge Browning
of Salad Pieces
1=none
2=slight
3=moderate
4=moderately severe
5=severe
1
3
5



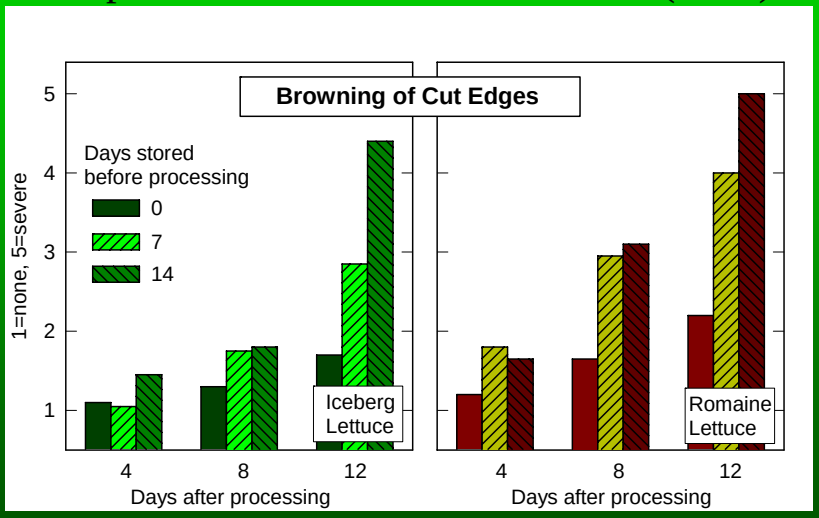


Lettuce types differ in rates of browning of cut pieces; PAL activity of pieces differs.

Iceberg Lettuce varieties differ in PAL activity of the cut pieces.

Preprocessing Storage

Example: Lettuce heads stored at 5°C (41°F)




Brown Stain
CO2 >3%
Lettuce disorders
• Brown stain—CO2
• Pink rib –overmature heads
• Heart leaf injury– O2/CO2
Pink rib

Risk of freezing at just below 0°C (32°F)

Romaine, normal and frozen

Green Leaf, frozen, thawed, normal

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**

Raw material variability remains a challenge

- Lettuce cultivar—romaine varies greatly
- Growing conditions: soils, fertilizers
- Climatic conditions
- Pre-processing handling and storage

IMPACTS
Visual quality (Cut edge browning/pinking)
Shelf-life
Flavor quality
Compositional quality
Textural quality

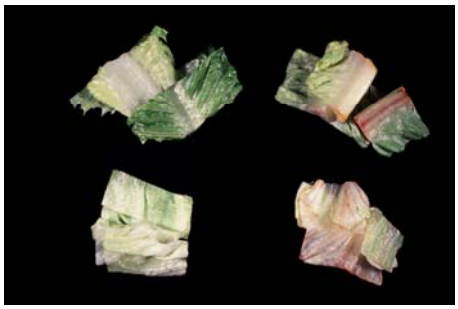
Lettuce Salad Quality Parameters

- **Fresh appearance**
- **No decay**
- **No discoloration**
- **Crisp texture**
- **Good aroma and flavor**

Intact and Fresh-cut Products may differ in response to modified atmospheres

Intact lettuce

- ♦ susceptibility to ethylene
- ♦CO2 >3% is damaging
- ♦Low O2 beneficial

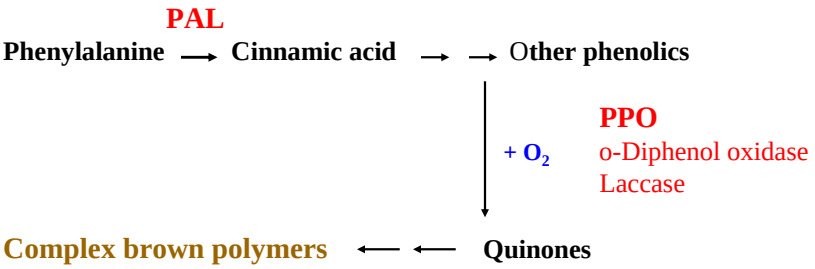


Fresh-cut lettuce

- ♦ edge browning is major defect
- ♦ very low O2 and high CO2 used to control discoloration
- ♦ ethylene is not important

High CO2 injury in salad pieces

Enzymatic Browning



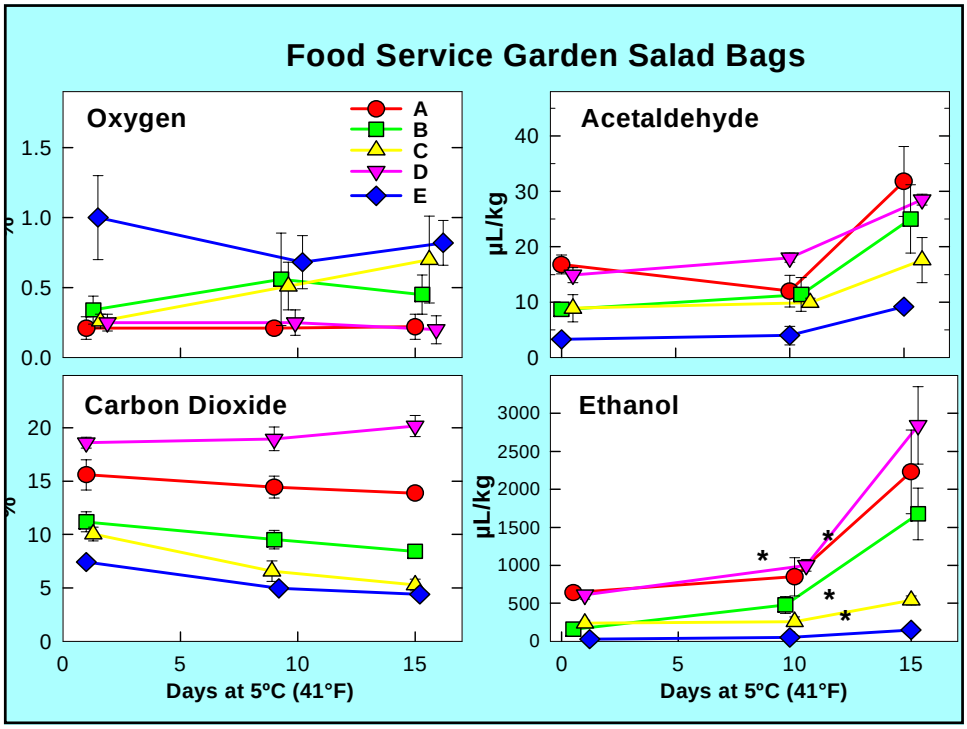
PAL = phenylalanine ammonia-lyase
PPO = polyphenol oxidase

Differentiation of Prepared Salads; Salad Meals

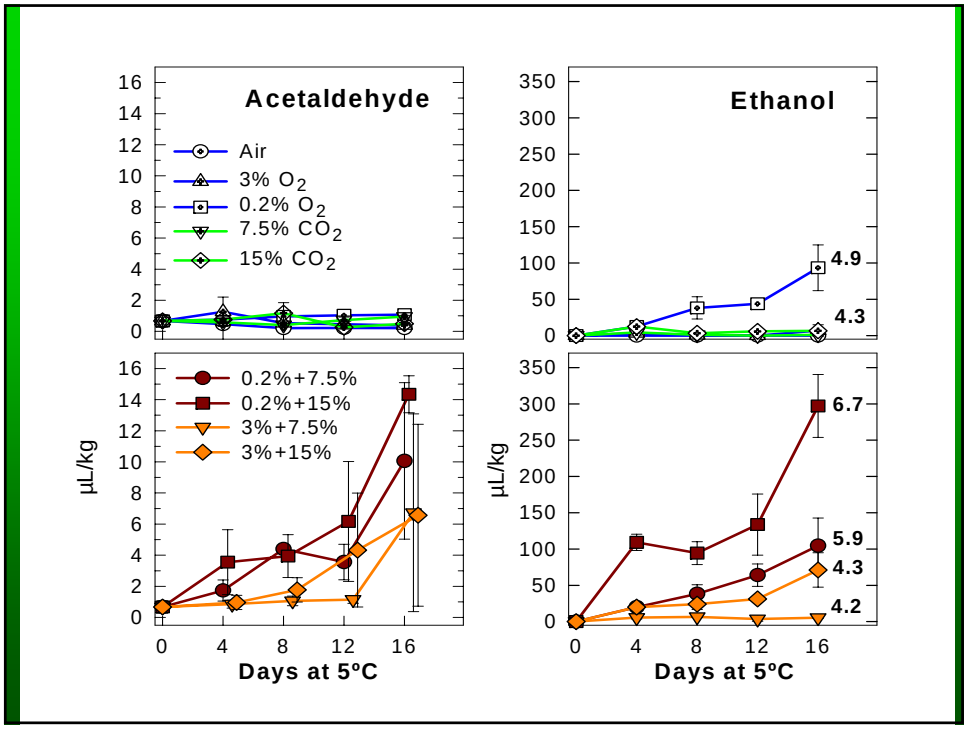
Standard iceberg
Plus "color"

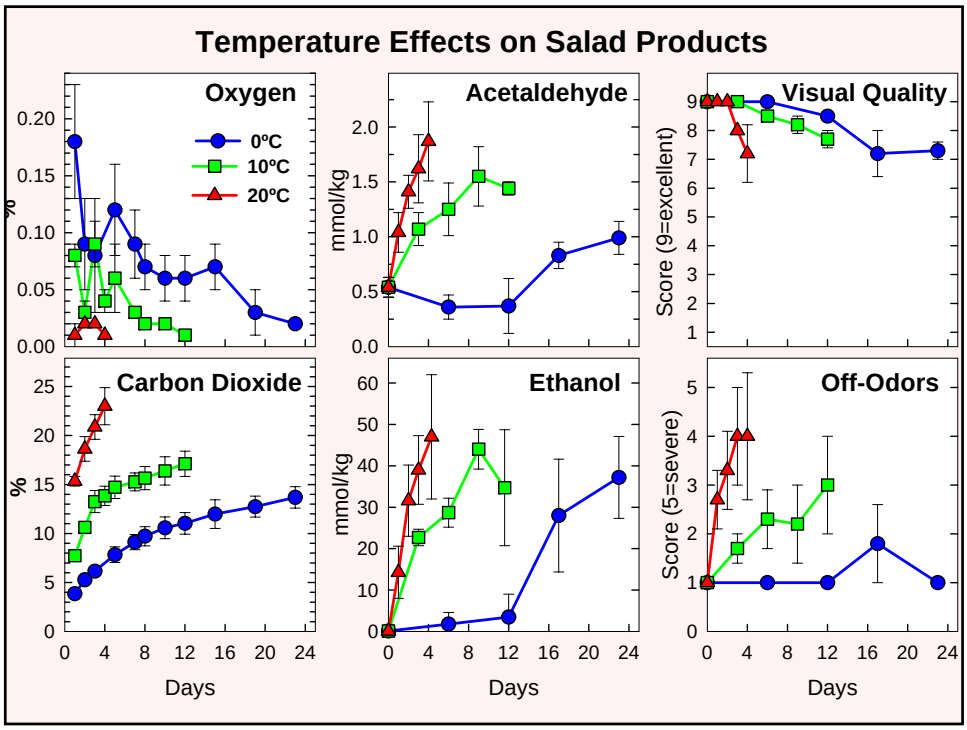
Romaine; Caesar Salad

European style salads

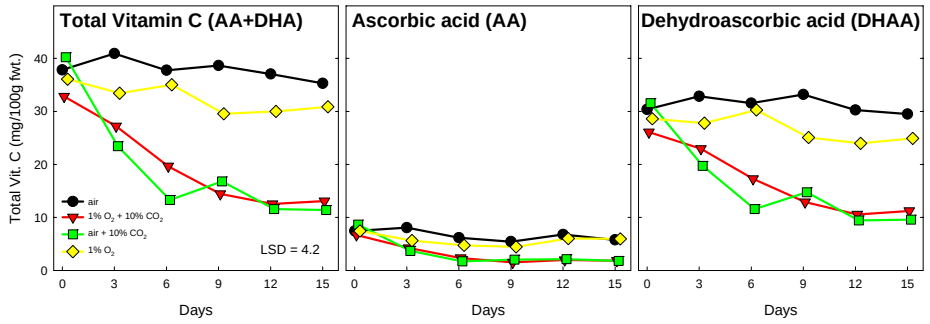

Food Service Garden Salad Bags
Oxygen
A
B
C
D
E
%
Acetaldehyde
µL/kg
Carbon Dioxide
%
Ethanol
µL/kg
Days at 5ºC (41°F)
Days at 5ºC (41°F)

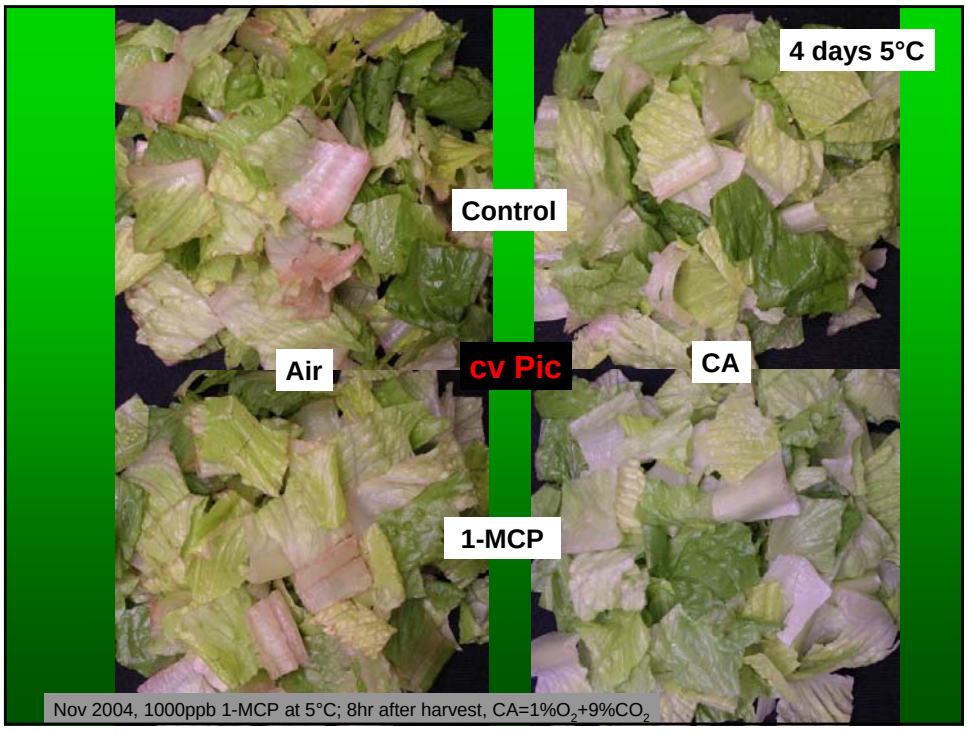

0.8*8
0.1*8


Acetaldehyde
Air
3% O2
0.2% O2
7.5% CO2
15% CO2
Ethanol
4.9
4.3
0.2%+7.5%
0.2%+15%
3%+7.5%
3%+15%
µL/kg
6.7
5.9
4.3
4.2
Days at 5ºC


Temperature Effects on Salad Products
Oxygen
0ºC
10ºC
20ºC
%
Acetaldehyde
mmol/kg
Visual Quality
Score (9=excellent)
Carbon Dioxide
Ethanol
Off-Odors
Score (5=severe)
Days

Romaine Salad-cut lettuce
Vitamin C content and modified atmospheres



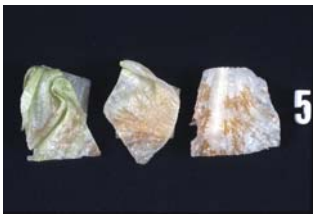


Packaged Salad Quality Study

- Products stored at 5C (41F)
- Components: Size, Color
- Visual Quality Analyses:
  Score for VQ and defects; 0, 10, 15 & 20d
- Composition: Sugar, Vitamin C, Ethanol, acetaldehyde
- Gas Analyses:O_2, CO_2, C_2H_4,every 5 days
- Microbiological Tests: APC, Coliforms (0, 10, 20d)
- Sensory: 18 panelists, 4 criteria, days 0 & 10

Salad Lettuce Evaluations

- **Overall visual quality,** 9 (exc.) to 1 (not use)
- **Shelf-life** is number of days to reach a score of 6 and/or a defect score of 3
- **Edge browning**, 1 to 5 scale; % pieces affected and calculate index
- **Decay/breakdown/sliminess**, 1 to 5; index
- **Aroma** (immediately after open package and again 30 min later; 5 to 1 scale
- **Texture**: break pieces at midrib, 5 (crisp) to 1 (limp, soft)



Wholeaves™

Quadruple-washed &Ready to Eat

Naturally intact; hand-separated from stem

Have a 17 day shelf life; no MA needed

Resealable bag to maintain freshness.

Process patented by The Great Northern Produce Co.; marketed by Mills and RiverRanch, Salinas.

Wholeaves™
Green Leaf
Red Leaf
Romaine
Cascade Mix

http://www.riverranchfreshfoods.com

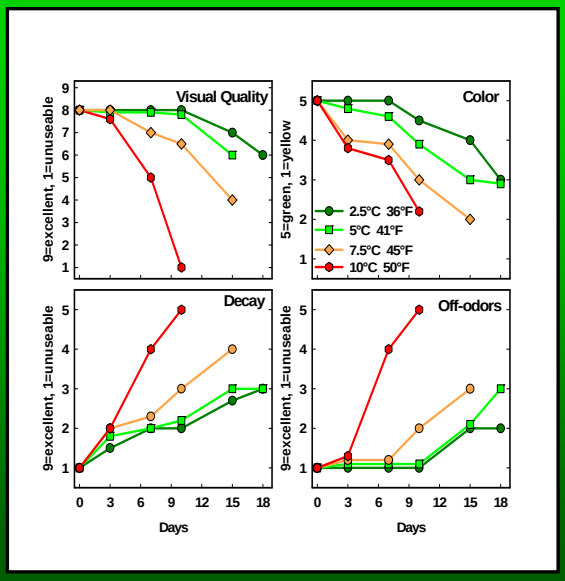
http://www.millsag.com/products/frm_prod.htm

Spinach Quality Parameters

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

Spinach varieties differ in rate of chlorophyll loss during storage

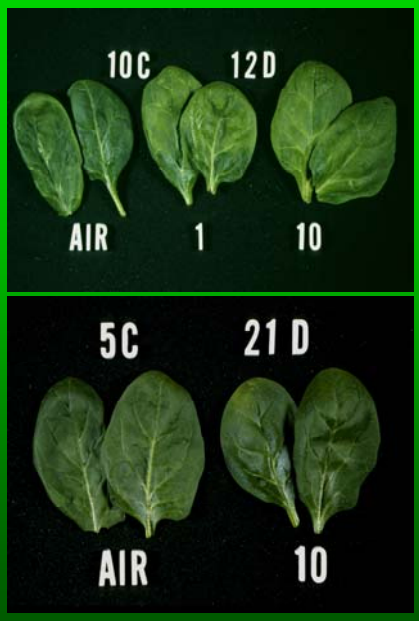
Low temperature is very effective in reducing chlorophyll loss of spinach



Changes in Spinach quality:

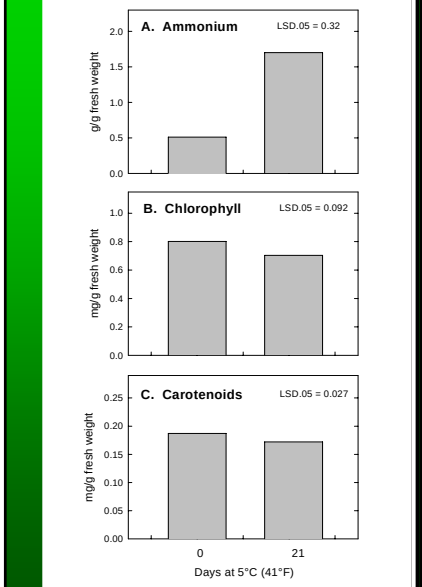
washed and bagged product stored at 4 temperatures

Cantwell, 1999

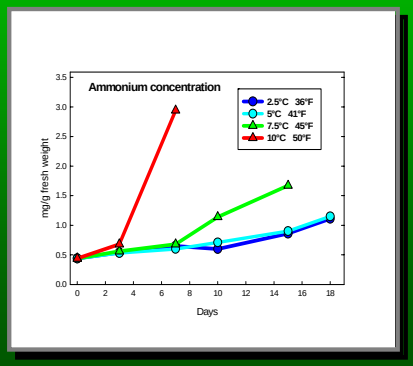


Ethylene increases yellowing at warm temperatures

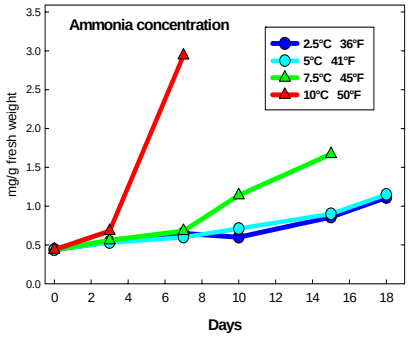
1-MCP reduces loss of chlorophyll

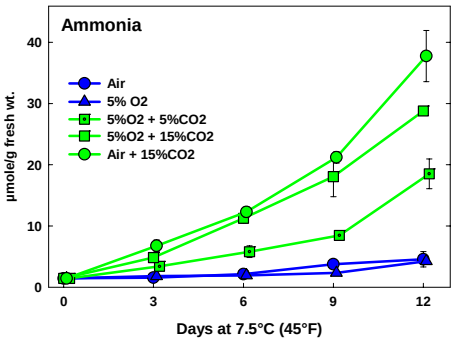


Ammonia is toxic to plant cells; Changes in ammonia greater than other compositional changes



Ammonia increases are associated with senescence and stress (storage time and temperature, modified atmospheres) in spinach and other green leafy vegetables.

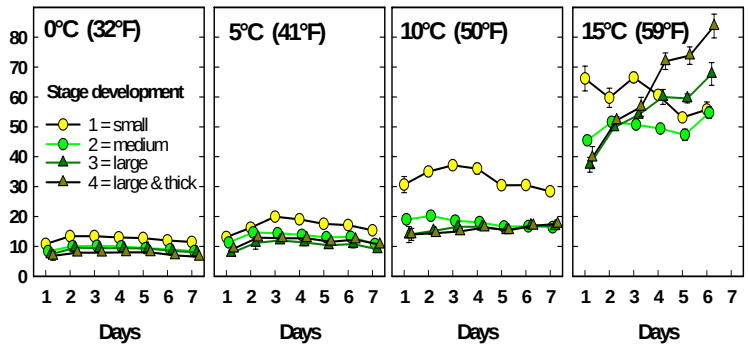




Controlled atmospheres maintain visual quality of spinach

Immature Leaves

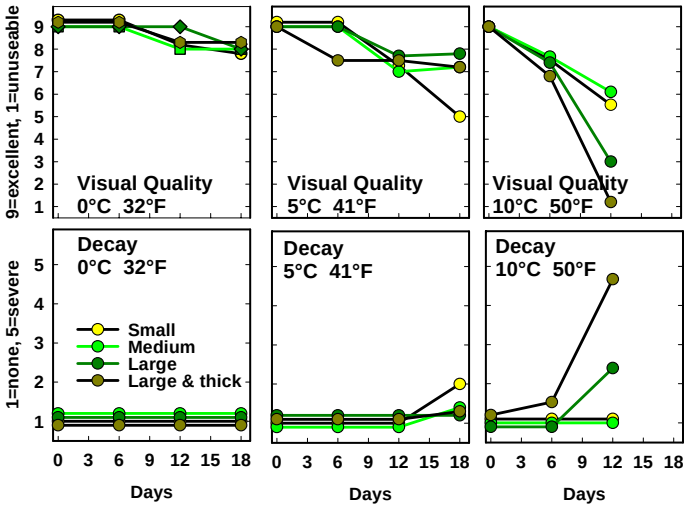
Respiration rates* of Spinach Leaves: 4 stages of leaf development; 4 temperatures



* Respiration rate: µL CO_2/g-h

Cantwell, 1999

Spinach Deterioration and Leaf Maturity

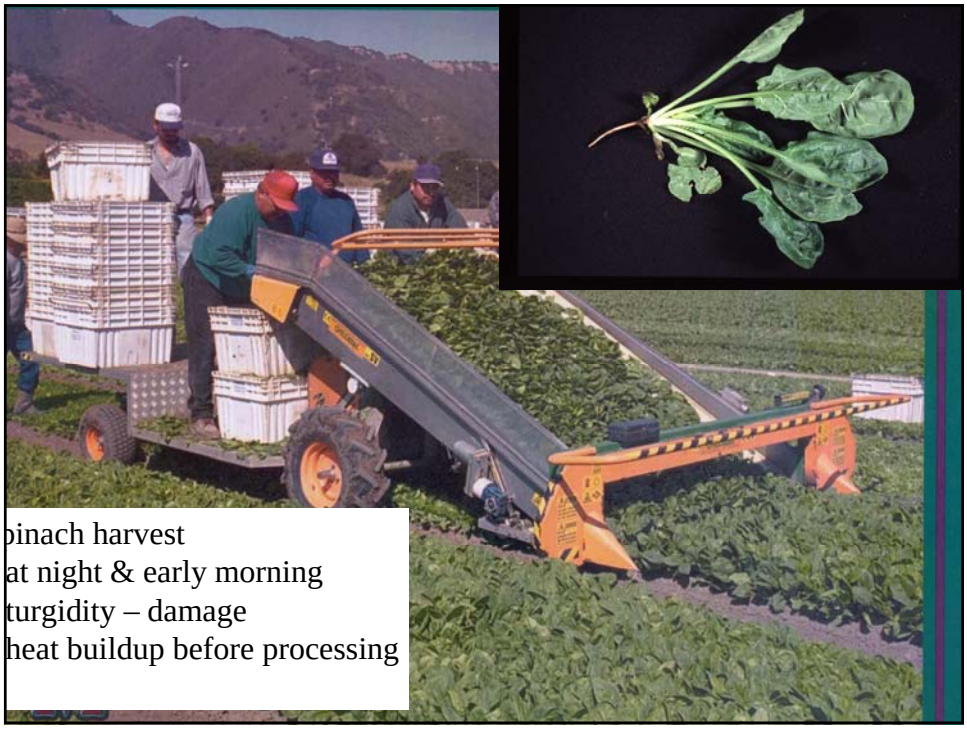


From field, unwashed; Fresh Valley, 1998

Cantwell, 1999

Spinach Storage

- Young and mature spinach leaves respond similarly to storage conditions, but young leaves have less physical damage
- Low temperatures are essential for adequate shelf-life
  - 0°C (32°F): 3 weeks
  - 5°C (41°F): 2 weeks
- Modified atmospheres slightly beneficial
- High CO_2 atmospheres stressful to spinach



pinach harvest
at night & early morning
turgidity – damage
heat buildup before processing

There are many opportunities for damage to spinach leaves during washing and processing

Improved Understanding of Production and Handling Procedures That Impact the Quality of Washed and Packaged Spinach

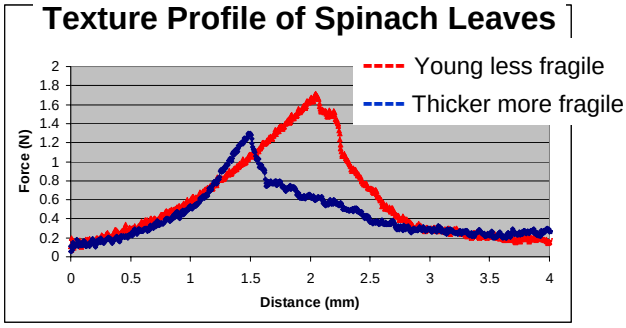
General Problem: **Spinach is inconsistent in performance**

- To better understand the impact of N fertilization regimes and other production factors on spinach quality and shelf-life
- To better understand the relationship between production conditions and mechanical damage during processing

– Greenhouse
  - Hydroponic experiments under controlled conditions
  - Spinach subjected to standardized evaluation
  - 2 experiments with nutrient fertilization
    – 25, 125, 250 ppm NO3; 125 ppm NH4/NO3
  - 2 experiments with changes in photoperiod
  - 2 experiments with foggy conditions

– Field
  - Sampling of spinach (raw material and finished product) from different fields, cultivars and seasons from different processors
  - Subject to standardized evaluation protocol

Young less fragile: less ‘crisp’, more force & work to break
Thicker more fragile: ‘crisper’, less force & work to break



Leaves between plates; punctured with rounded cylindrical probe, 0.95 mm^2