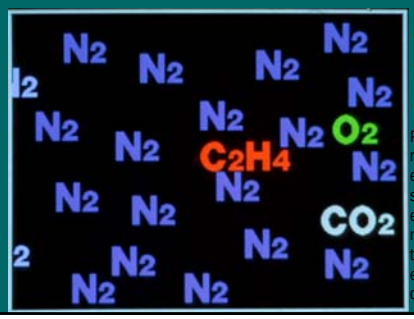
Future of Modified Atmosphere Research

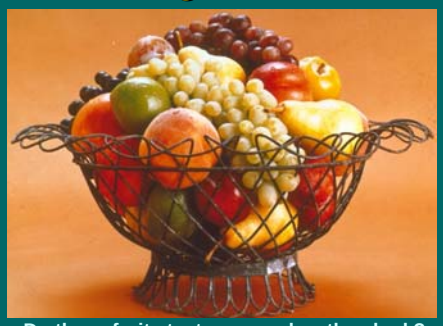


Presented on July 8 , 2005 at the 9th International Controlled Atmosphere Research Conference, East Lansing, Michigan, USA

presented

Adel Kader
UCDavis

Flavor Quality of Fruits and Vegetables



Do these fruits taste as good as they look?

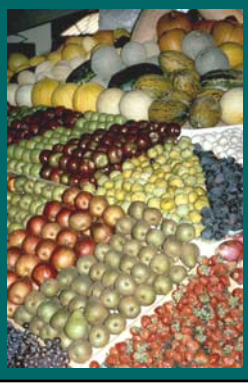
Composition vs Flavor

Flavor attribute	Constituents
Sweetness	Sugars
Sourness	Acids
Astringency	Tannins
Bitterness	Isocoumarins
Aroma	Odor-active volatiles
Off-flavors	Acetaldehyde, ethanol, ethyl acetate
Off-odors	Sulfurous compounds

Sensory Characteristics of Textural Quality

- Firmness
- Hardness
- Softness
- Juiciness, succulence
- Turgidity, flaccidity
- Chewiness
- Crispness
- Fiberousness, toughness
- Mealiness, grittiness
- Oiliness

Phytochemicals



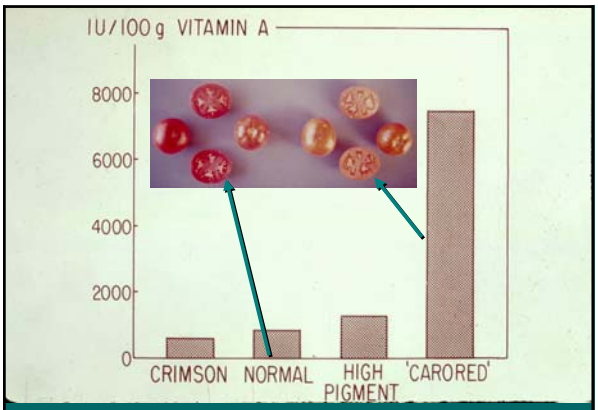
- Phenolic compounds
  Proanthocyanins
  Anthocyanidins
  Flavonones
  Flavonols
  Phenolic acids
- Carotenoids
  Lycopene
  Beta-carotene
  Xanthophylls
- Monoterpenes
  Limonene
- Sulfur compounds
  Glucosinolates
  Indoles
  Allicin

Proposed Action Plan for Providing Consumers with Good Flavored Fruits and Vegetables

1. Replace poor flavor cultivars with good flavor cultivars from among those that already exist and/or by selecting new cultivars with superior flavor and good texture

Constituent (unit)	Cultivar	
	Champaka	Premium Select
Total solids (%)	16.9 ± 0.9	22.2 ± 0.8
Soluble solids (%)	12.7 ± 1.2	16.9 ± 0.3
Titratable acidity (%)	0.67 ± 0.1	0.54 ± 0.0
pH	3.60 ± 0.1	3.92 ± 0.0
Total ascorbic acid (mg/100g FW)	8.5 ± 0.7	30.8 ± 1.0
Beta carotene (μg/100g FW)	323.3 ± 94.2	929.9 ± 84.2
Total phenolics (mg/100g FW)	31.4 ± 0.9	63.5 ± 4.7
Antioxidant activity [DPPH] (μM/100g FW)		
Ascorbic acid equivalent	62.0 ± 9.8	217.0 ± 22.2
Trolox equivalent	59.4 ± 9.8	206.8 ± 22.2

Intercultivar Differences in Composition of Pineapples



Genotypic Variation in Carotenoids

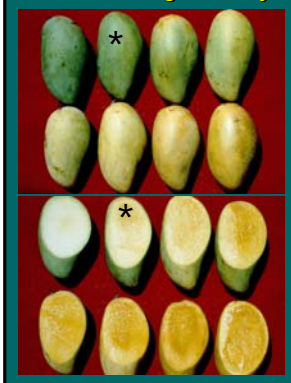
Proposed Action Plan for Providing Consumers with Good Flavored Fruits and Vegetables

2. Identify optimal cultural practices that maximize flavor quality, such as optimizing crop load and avoiding excess nitrogen and water

Proposed Action Plan for Providing Consumers with Good Flavored Fruits and Vegetables

3. Encourage producers to harvest fruits at partially-ripe to fully-ripe stages and vegetables at their optimal maturity stages by developing handling methods that protect these commodities from physical damage

Mango Maturity and Ripeness Stages



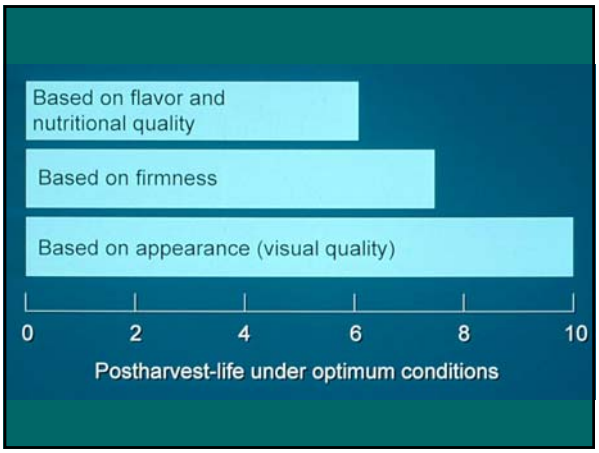
Manilla

Kent

*Minimum Stage for Harvest

Proposed Action Plan for Providing Consumers with Good Flavored Fruits and Vegetables

4. Identify optimal postharvest handling conditions (time,temperature, relative humidity, atmospheric composition) that maintain flavor quality of fruits and vegetables and their value-added products. Postharvest-life should be determined on the basis of flavor rather than appearance.



Average optimum storage conditions of apples

Cultivar	Temp. °C	$\%O_2$	$\%CO_2$	Duration (months)
Braeburn	0.7	1.8	1.0	6-9
Fuji	0.3	1.4	1.0	7-11
Gala	1.3	1.7	1.6	2-9
Golden Delicious	0.5	1.6	2.3	7-11
Granny Smith	0.6	1.4	2.0	7-11
Idared	1.9	2.1	2.5	7-10
Jonagold	0.9	1.4	2.7	5-10
McIntosh	2.5	2.1	2.9	5-10
Red Delicious	0.0	1.6	1.8	6-11
Royal Gala	-0.2	1.5	1.8	5-8

CA Delays Ripening of Bartlett Pears

Optimum ranges of CA conditions of pears

Cultivar	$\%O_2$	$\%CO_2$	Duration at 0°C (months)
Anjou	1.0-2.5	0-0.5	7-8
Bartlett	1.0-2.0	0-0.5	3-5
Bosc	1.0-2.5	0.5-1.5	4-8
Comice	1.5-4.0	0.5-4.0	5-6
Conference	1.0-2.5	0.5-1.5	6-8
Packhams Triumph	1.5-2.0	1.5-2.5	7-9

Trends in Marketing Fresh Produce

- Globalization of produce marketing
- Consolidation or formation of alliances among producers and marketers from various production areas
- Consolidation of retail marketers
- Demand for year round supply of many produce items with better flavor

Impact of Globalisation on Need for CA Storage of Pome Fruits and Kiwifruit

A more open global economy

↓

Year round supply from northern and southern hemispheres

↓

Eliminating price incentives to domestic produces for "out-of-season" produce

↓

Reduce the need for CA storage beyond 6 months in either hemisphere

↓

Provide better flavor-quality fruits to consumers

Modified Atmospheres (MA) Chain

Handling Step	Storage Atmospheres		
Harvest			
↓			
Preparation for market	MAP		
↓			
Storage at shipping point	MA	MA	MA
↓			
Transport	MA	MA	Air
↓			
Storage at destination	MA	Air	Air
↓			
Retail markets	Air	Air	Air
↓			
Consumers			

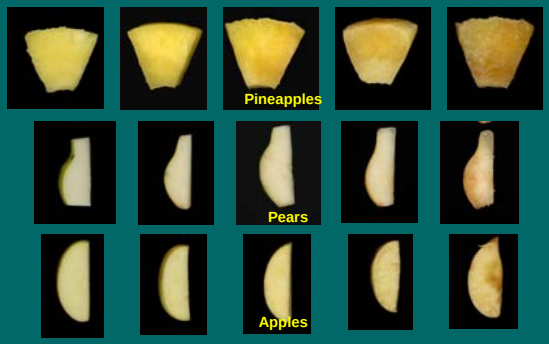
Proposed Action Plan for Providing Consumers with Good Flavored Fruits and Vegetables

5. Develop ready-to-eat, value-added products with good flavor

Brown Stain Rating Scale for Salad-cut Lettuce

Fresh-cut Romaine Lettuce: Rating Scale for Discoloration

Deterioration due to Browning and Softening of Fresh-cut Fruits



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Proper Packaging is Essential to Maintaining Quality of Fresh-cut Fruits via Physical Protection, Reducing Water Loss, and Delaying Softening and Browning if Optimal Modified Atmospheres are kept

Fresh-cut Fruits in Corn-based PLA(Polylactic acid) Packages

Fresh-cut Produce Packaging Evolution

Contribution of MAP to Maintaining Quality of Fresh-cut Fruits and Vegetables

Providing optimal temperature range	MAP	
	Minimizing water loss	Retarding deterioration

0 70 85 100

Post-cutting Life (%)

Proposed Action Plan for Providing Consumers with Good Flavored Fruits and Vegetables

6. Optimize maturity/ripeness stage at the time of processing and select processing methods to retain good flavor of the processed products

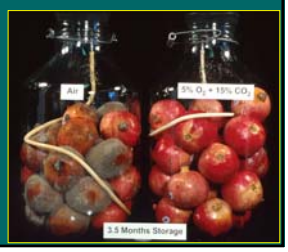
Future Research Needs :

1. The synergistic effects of MA and the ethylene-action-inhibitor, 1-methylcyclopropene, on delaying ripening of partially-ripe climacteric fruits and on senescence of vegetables

Extending Yellow-life of Bananas by Modified Atmospheres

Future Research Needs :

2. MA as a component of postharvest integrated pest management (decay and insect control)



Future Research Needs :

More research is needed to determine the efficacy of low O_2 (< 1%) and/or elevated CO_2 (40-60%) for insect control in some fresh horticultural crops and dried fruits, vegetables, and nuts.

Future Research Needs :

4. The biological bases of MA effects on fresh horticultural perishables

Mode of CA Action on Postharvest Biology of Perishables

Growth and development	General effects of <5%O_2	>5%CO_2
1. Cell division	- or +	- or +
2. Cell enlargement	- or +	- or +
3. Endogenous growth regulators	?	?
4. Periderm formation	- (<5%)	- (>10%)

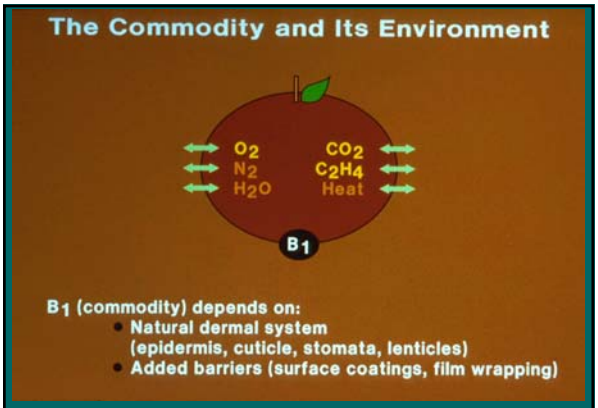
- = decrease, 0 = no effect, + = increase

Mode of CA Action on Postharvest Biology of Perishables

Respiratory Metabolism	General effects of <5%O_2	>5%CO_2
1. Respiration rate	-	-, 0, or +
2. Shift from aerobic to anaerobic respiration	+ (<1%)	+ (>20%)
3. Energy produced	-	-

- = decrease, 0 = no effect, + = increase

The end of flavor-life results from losses in sugars, acids, and aroma volatiles (especially esters) and/or development of off-flavors (due to fermentative metabolism or odor transfer from fungi or other sources)



Reduced Gas Diffusion Induces Fermentative Metabolism and Off-odors

Mode of CA Action on Postharvest Biology of Perishables

Ethylene biosynthesis & action	General effects of <5%O_2	>5%CO_2
1. Methionine to SAM	0	?
2. Synthesis of ACC synthase	-	-
3. ACC synthase activity	0	-
4. Synthesis of ACC oxidase	-	-
5. ACC oxidase acitivity	-	- or +
6. Ethylene action	-	-

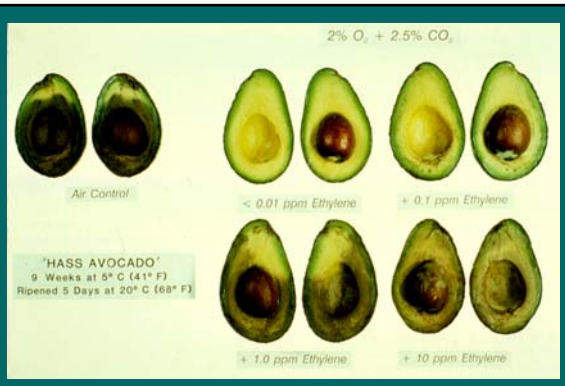
- = decrease, 0 = no effect, + = increase

Low Pressure (LP) Delays Ripening of Mature-green (MG), Breaker (B), and Light-pink (LP)Tomatoes

Mode of CA Action on Postharvest Biology of Perishables

Physiological disorders	General effects of <5%O_2	>5%CO_2
1. Chilling injury	+	- or +
2. Scald on apples & pears	-	-
3. C_2H_4-induced disorders	-	- or +
4. CA-induced disorders	+	+

- = decrease, 0 = no effect, + = increase



CA Reduces, but Ethylene Increases Severity of Chilling Injury on Hass Avocado

Mode of CA Action on Postharvest Biology of Perishables

Pathological breakdown	General effects of <5%O_2	>5%CO_2
1. Susceptibility of pathogens	- or +	- or +
2. Fungal growth	- (<1%)	- (>10%)
3. Bacterial growth	- or 0	- or 0

- = decrease, 0 = no effect, + = increase

Future Research Needs :

3. MA in relation to food safety considerations (Microbial Contamination and Growth)

Postharvest Biology And Quality Of Fruits Kept In Superatmospheric Oxygen Atmospheres

Respiratory metabolism	+, 0, -
Ethylene biosynthesis	+, 0, -
Ethylene action	+
Ripening rate	+
Physiological disorders	+, 0,-
Pathological breakdown	0,-

Future Research Needs

- How do high O2 concentrations alone and in combination with elevated CO2 levels influence growth of decay-causing bacteria and fungi and human pathogens (food safety related)?
- Can superatmospheric O2 levels reduce elevated CO2-induced disorders and off-flavors?
- What are the effects of beneficial elevated O2 levels alone and in combination with elevated CO2 levels on textural, flavor, and nutritional quality of target commodities?

Future Applications of CA/MA will Depend on the Return On Investment (ROI) in each Case

$$\text{ROI (\%)} = \frac{\text{Revenues - Expenses}}{\text{Expenses}} \times 100$$

Return on Investment Using Modified Atmospheres (MA)

In a comparison of losses due to decay during retail marketing of strawberries shipped in air and those shipped in MA (15% CO_2-enriched air), it was observed that use of the MA reduced losses by 50% (average of 20% losses in air vs 10% losses in MA). The economic loss of 10% value ($50-75 per pallet) was much greater than the cost of using MA ($15-25 per pallet).

Return on Investment in Using MA During Transport

Use of modified atmosphere (MA) during marine transportation can extend the postharvest-life of many fruits and vegetables with short postharvest-life potential and allow use of marine transportation instead of air transport. Savings realized with the use of marine transportation are much greater than is the added cost of MA service.

Questions and Comments are Welcome