


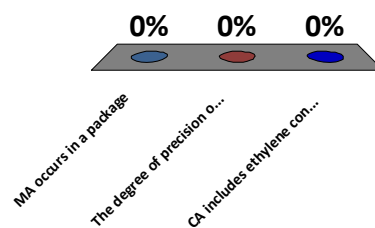
## *Modified and Controlled Atmospheres during Transit and Storage*

Beth Mitcham  
University of California, Davis



What is the difference between Controlled Atmospheres (CA) and Modified Atmospheres (MA)?

- A. MA occurs in a package
- B. The degree of precision of atmosphere control
- C. CA includes ethylene control



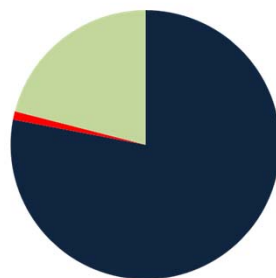
## Modified or Controlled Atmospheres

### What is it?

- Reduced oxygen
- Increased carbon dioxide
- Removing carbon dioxide
- Removing ethylene and other volatiles
- Degree of precision differentiates MA and CA

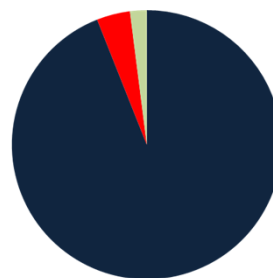
## Gas Composition

*Normal Atmosphere*



■ Nitrogen (78%)  
■ Carbon Dioxide (0.03%)  
■ Oxygen (21%)

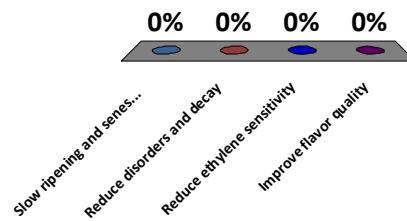
*Typical Desired Atmosphere*



■ Nitrogen (94%)  
■ Carbon Dioxide (4%)  
■ Oxygen (2%)

What are the benefits of CA and MA?  
Choose all that apply.

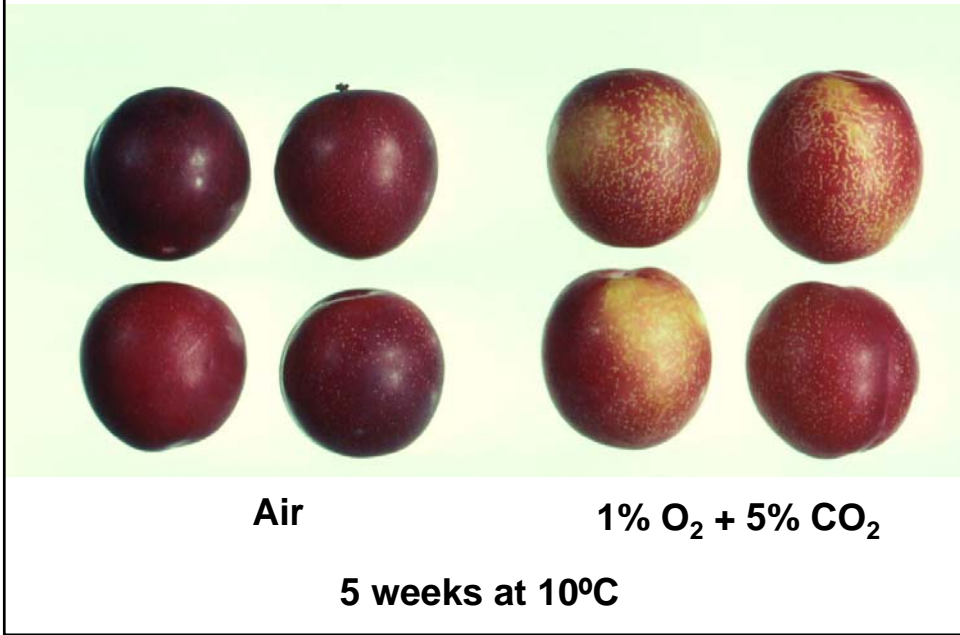
- A. Slow ripening and senescence
- B. Reduce disorders and decay
- C. Reduce ethylene sensitivity
- D. Improve flavor quality



## Modified or Controlled Atmospheres Potential Benefits

- Retards senescence or ripening
- Reduces respiration rate
- Reduces ethylene production
- Reduces ethylene sensitivity
- Alleviates certain physiological disorders
- May reduce decay; indirectly or directly
- Insect control

***Low O<sub>2</sub> Delays Ripening of 'Santa Rosa' Plums***



***Six Months Storage of Bartlett Pears***



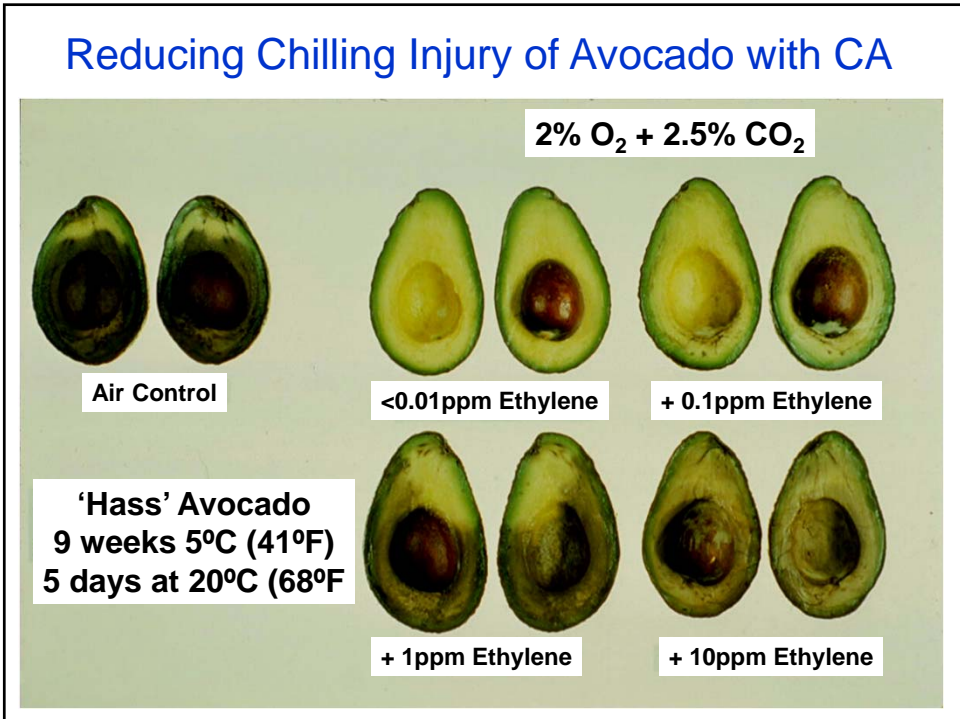


**Low O<sub>2</sub> Retards Ripening of Partially Ripe Tomato Fruit**



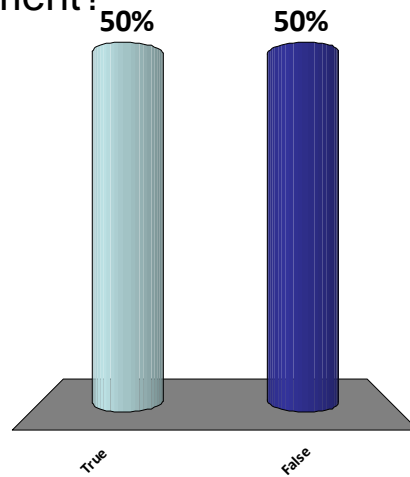
**Delayed Ripening of Chili Peppers**





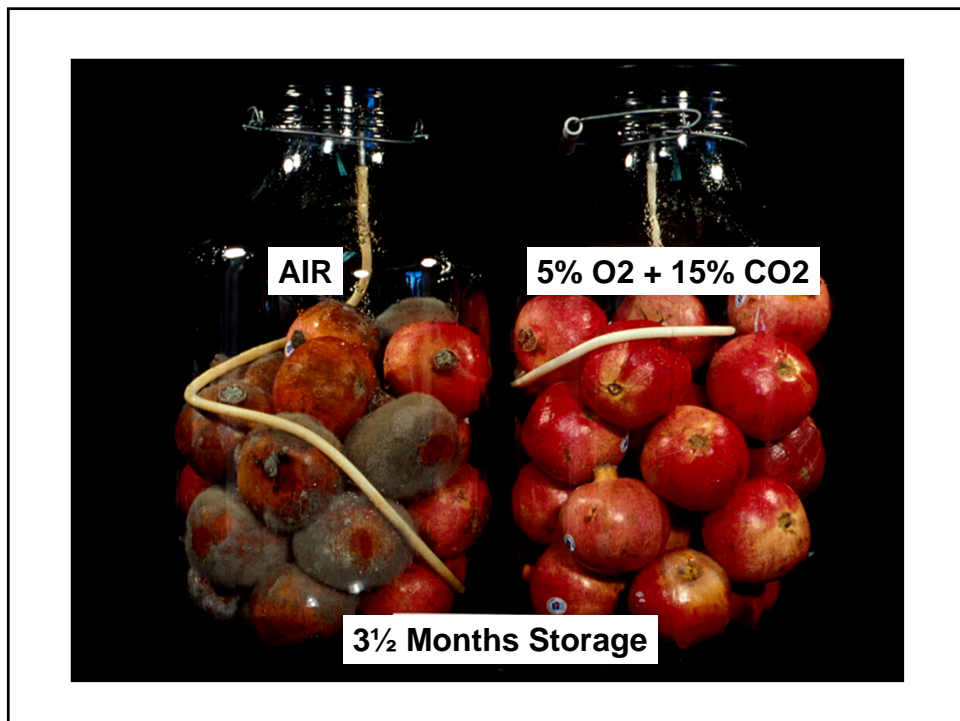
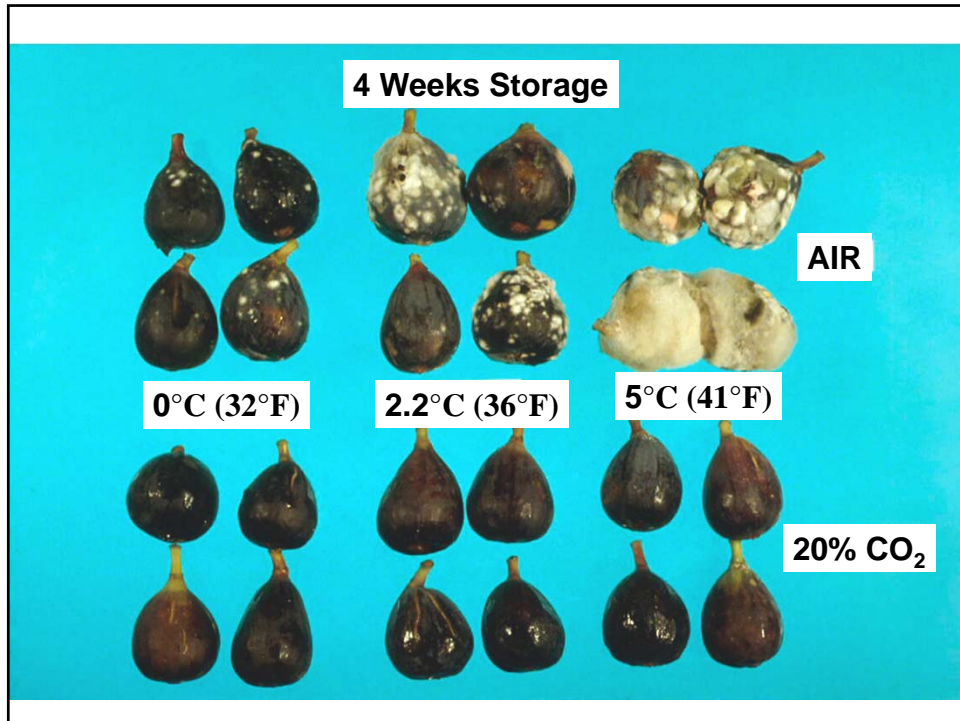
Does Controlled Atmospheres reduce product sensitivity to injury at chilling temperatures or merely inhibit symptom development?

- A. True
- B. False



## CA Treatments for Decay Control

- Oxygen concentrations < 1%
- Carbon dioxide concentrations >10%

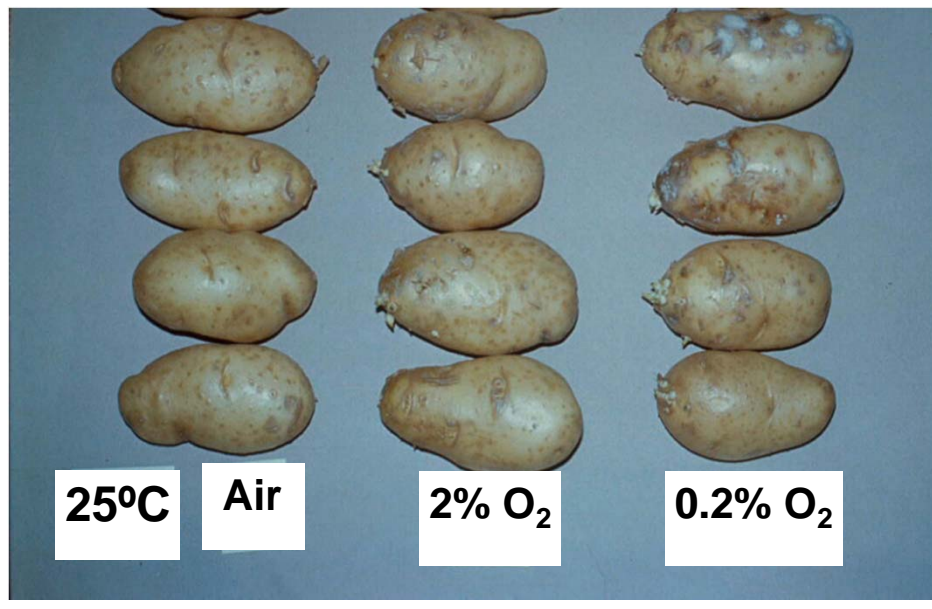




## Modified or Controlled Atmospheres Potential Hazards

- Causes or aggravates physiological disorders in product
- Causes irregular ripening
- Induces off-flavors/odors
- Increases decay susceptibility

### Low O<sub>2</sub> Stimulates Sprouting and Increases Decay



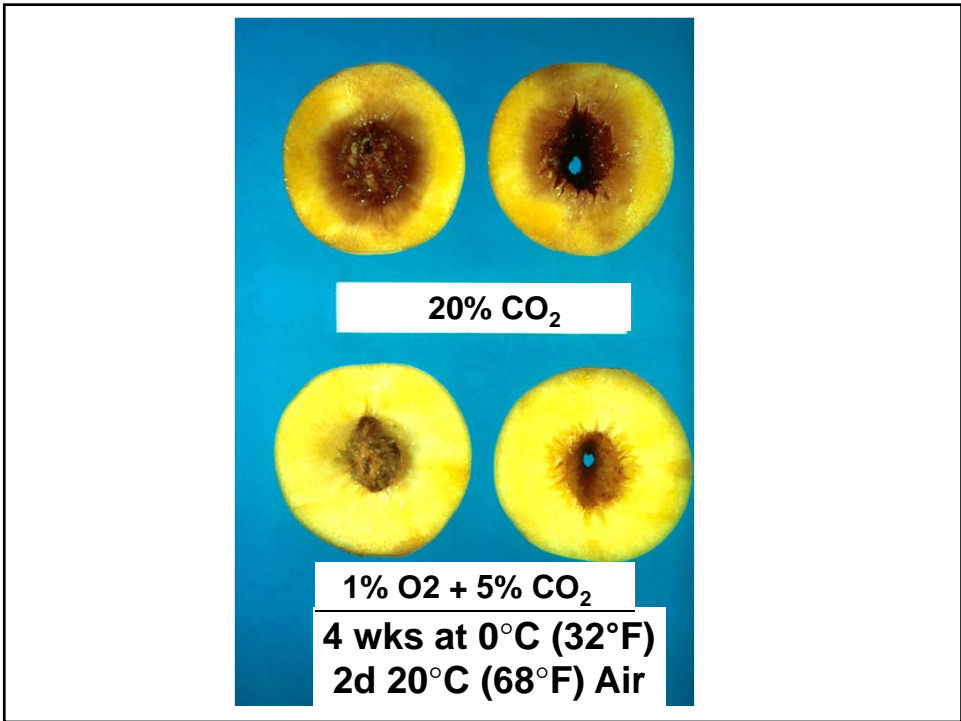
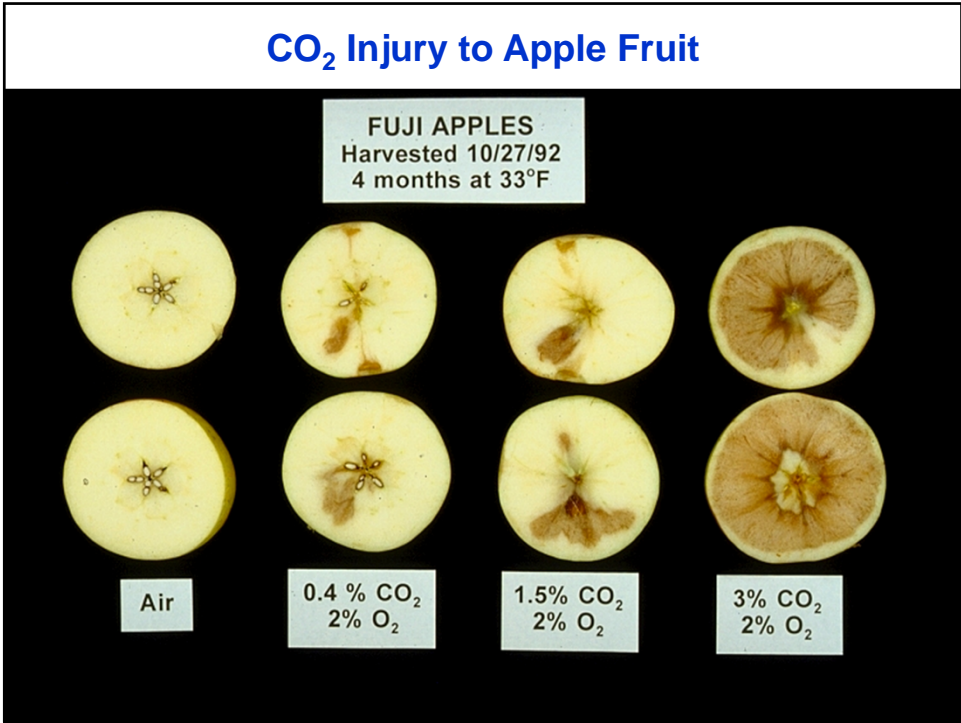
**Low O<sub>2</sub> Injury in Apples**



**Brown Stain**



**2% O<sub>2</sub> + 5% CO<sub>2</sub> at 0°C for 1 week or longer**



## Modified or Controlled Atmospheres Potential for Benefit or Hazard Depends upon

- Commodity
- Cultivar
- Physiological age
- Atmospheric composition
- Temperature
- Duration

## Tolerance to Low Oxygen

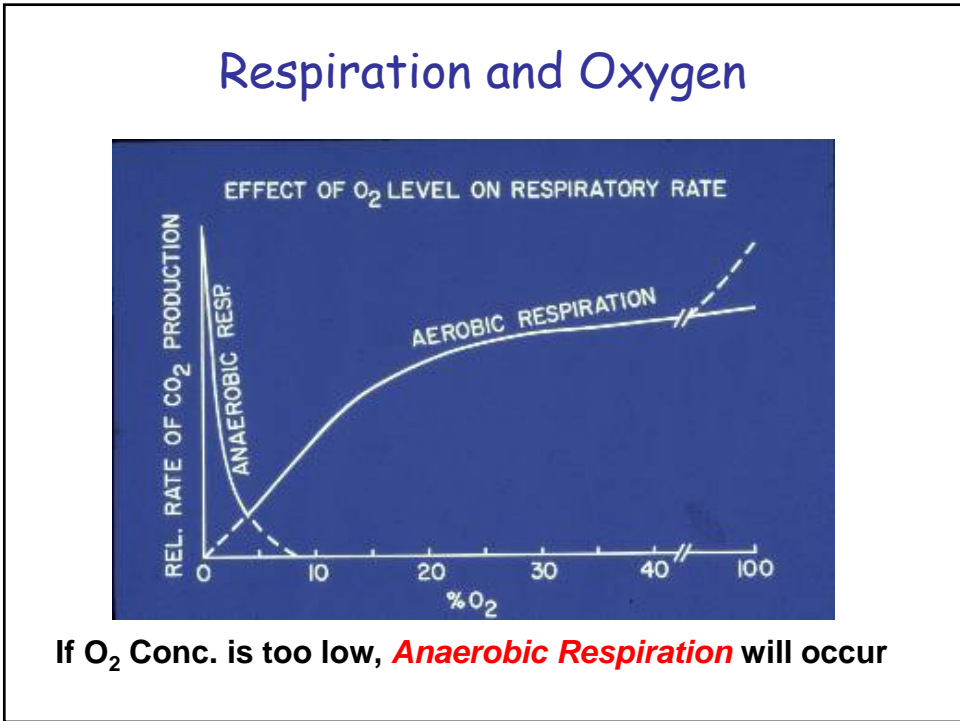
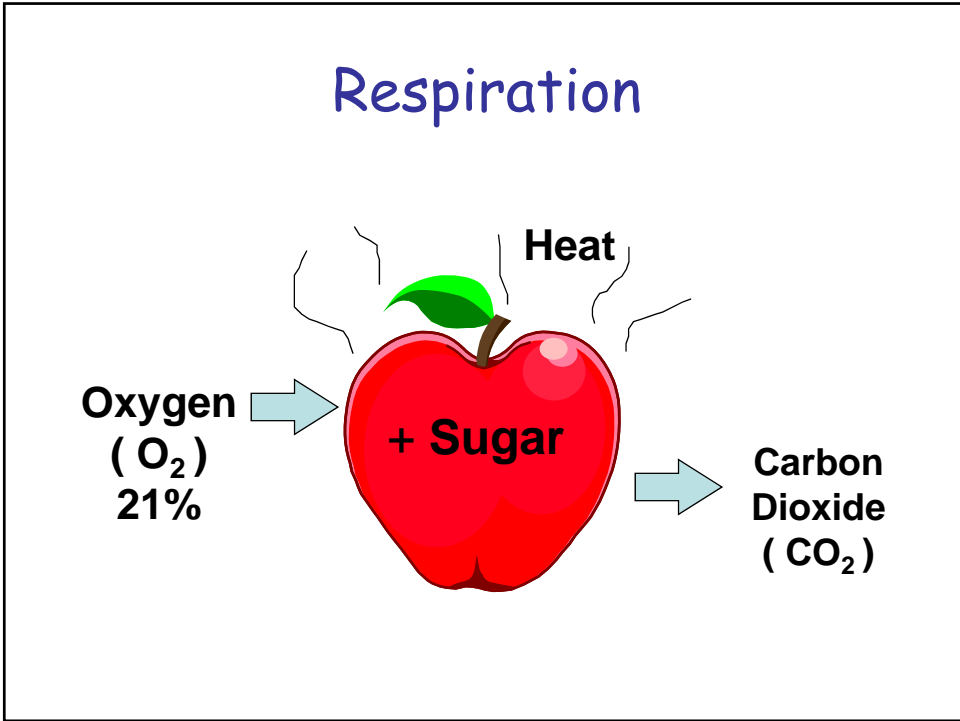
Min. %O <sub>2</sub>	Commodities
0.5	Tree nuts, dried fruit & vegetables
1.0	Some cultivars of apples & pears, broccoli, most fresh cut F&V, mushrooms
2.0	Most cultivars of apples and pears, kiwifruit, peach, strawberry, cantaloupe, lettuce, cabbage
3.0	Avocado, persimmon, tomato, pepper, cucumber
5.0	Citrus, asparagus, potato, sweet potato



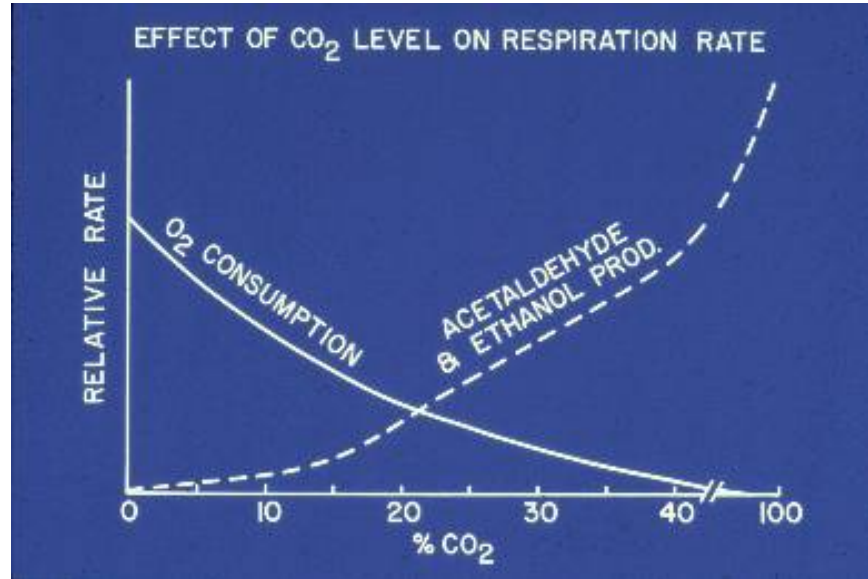
## Tolerance to Elevated Carbon Dioxide

Max. %CO <sub>2</sub>	Commodities
1	Some cultivars of apples (Fuji, Pink Lady, Braeburn)
2	Some apples & pears, apricot, pear, grape, tomato, lettuce, celery, artichoke
5	Some apples and pears, kiwifruit, peach, plum, orange, grapefruit, lemon, lime, avocado, banana, cauliflower
10	Persimmon, pineapple, cucumber, asparagus, broccoli
15	Strawberry, blueberry, raspberry, cherry, cantaloupe, sweet corn

How Does CA/MA  
Affect the Product?



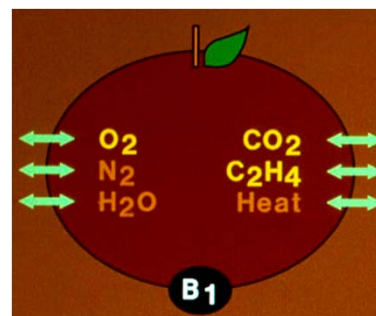
## Effect of $\text{CO}_2$ Level on Respiration Rate



## The Commodity and Its Environment

### Commodity:

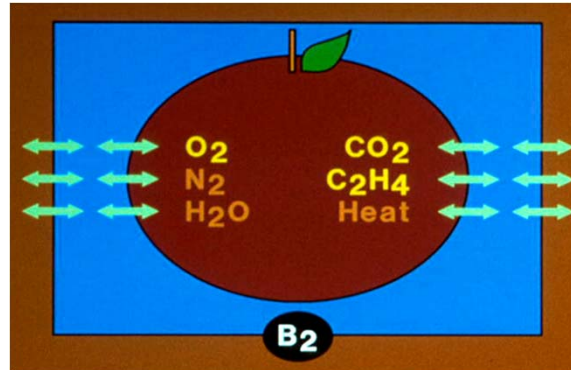
- \*Respiration and ethylene production of commodity
- \*Natural dermal system epidermis, cuticle, lenticels
- \*Additional barriers added film wrapping, waxes, coatings



## The Commodity and Its Environment

### Package:

- Permeability of packaging materials
- Ventilation openings
- Plastic liners

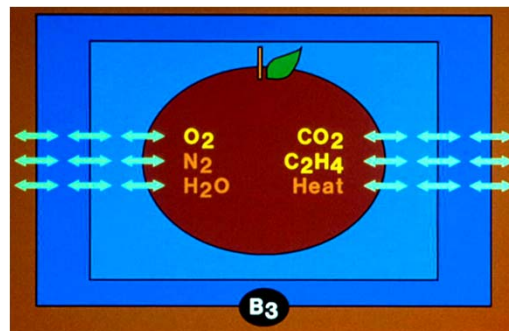


## The Commodity and Its Environment

### Storage room/transit vehicle:

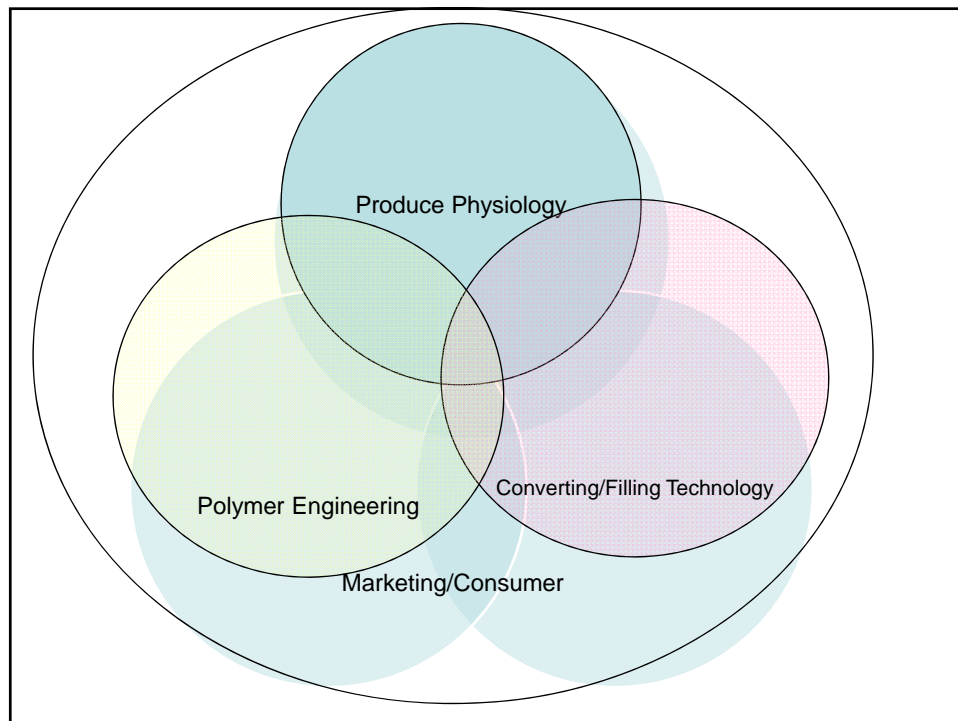
- \*Degree of gas tightness
- \*Ventilation systems
- \*Atmosphere modification

Must consider all barriers  
to gas exchange when  
CA/MA is used



## Commodity-Generated MA Methods to Restrict Gas Exchange

- Waxes or other surface coatings
- Use of polyethylene liners in shipping containers
- Packaging in film wraps or bags
- Use of plastic package with diffusion windows
- Use of pallet covers
- Manipulation of shipping container vents

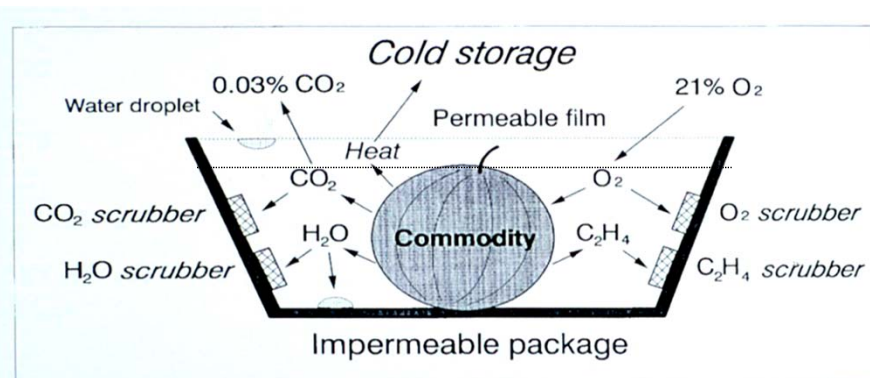


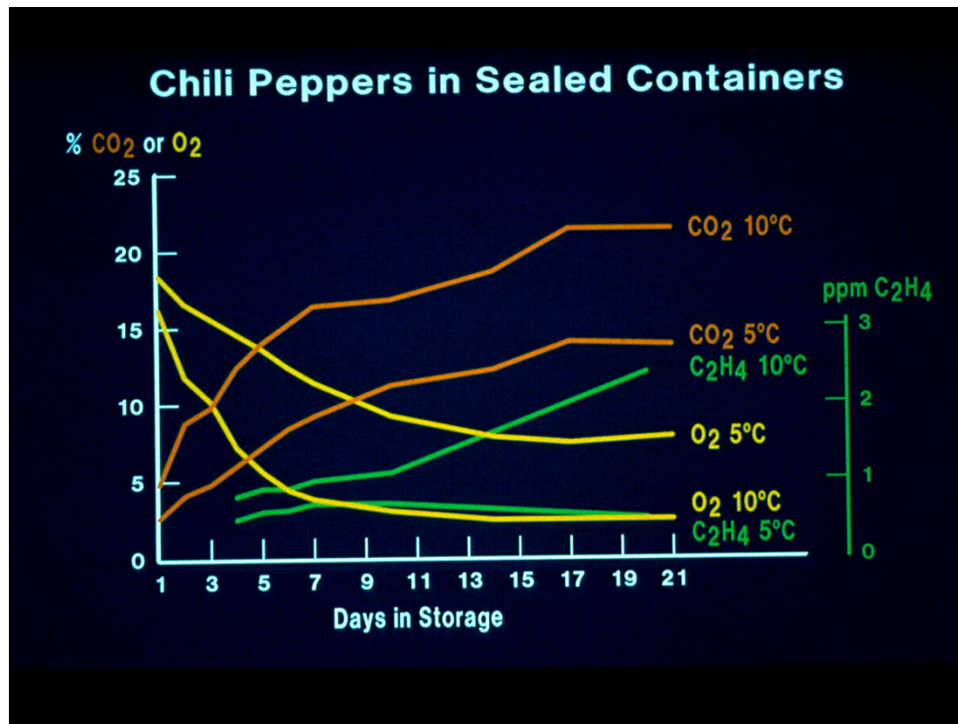
## Produce Physiology Requirements

- Produce Type
- Growing Region
- Pre-harvest Conditions
- Postharvest Handling
- Postharvest Processing
- Temperature
- Respiration Rate
- Desired Shelf Life



## Modified Atmosphere Packaging





## Polymer Engineering Requirements

- Target OTR
- Package Dimensions
- Package Style
- Product Weight
- Stiffness
- Optics







Structure	Characteristics
Monolayer Films	One resin one film (single layer).
Engineered Blended Mono Films	Different resins blended together to produce one mono-layer film.
Laminations	Different film types are joined together with some type of adhesive or molten polymer.
Coextrusions	Multiple film layers are incorporated into a single structure during the manufacturing process to produce one film.

•Recent advancements in Coextrusion technology have lead to a line of Coextruded films with OTR values up to 1500cc/100 sq. in. while at the same time providing excellent optics and increased stiffness.


**LDPE-EVA Blend**



**LDPE-EVA Coextrusion**



**LDPE-EVA Lamination**







Box liner for sweet cherries develops MA to reduce decay and keep stems green



## Modified Atmosphere Packaging



- Injection of gas
- Twist-tie or zip-closing bags works fine

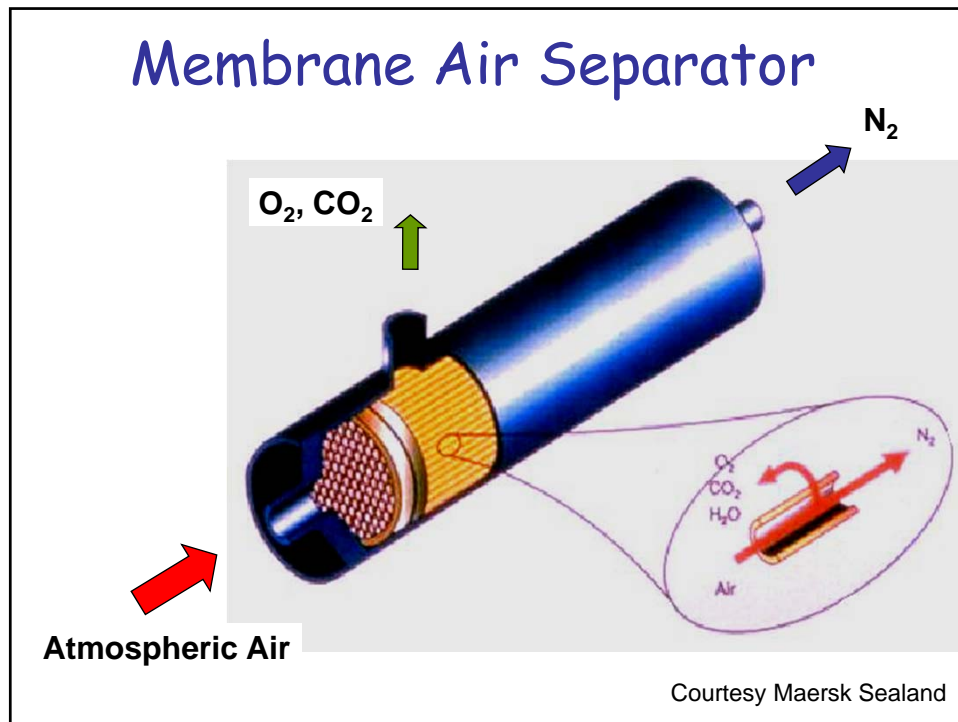
## Pallet Covers for Carbon Dioxide Treatment of Strawberries during Transport



## Controlled Atmosphere for Storage



- Capital investment
- Store 2 to 12 months
- Constant monitoring of gas composition
- Size room to market product quickly after opening
- Monitoring/sampling window



## Equipment for Carbon Dioxide Removal

- Absorbers
  - Water
  - Sodium hydroxide
  - Ethanolamine
  - Hydrated lime
- Adsorbers
  - Activated charcoal
  - Membrane sieves

25 to 30 lbs.  
fresh hydrated lime  
per ton of apples

Can also be placed in a  
separate room outside  
of the CA room



## Use of CA for Long Term Storage

Months of Storage	Commodities
>12	Nuts and dried fruits and vegetables
6 - 12	Some cultivars of apples and pears
3 - 6	Cabbage, chinese cabbage, kiwifruit, some cultivars of asian pears
1 - 3	Avocado, olive, some cultivars of peach, plum, nectarine, persimmon, pomegranate

## Use of CA for Short Term Storage

Benefits	Commodities
Delays ripening and avoids chilling injury	Avocado, mango, banana, melon, nectarine, papaya, peach, plum, tomato (MG, RR)
Controls decay	Blackberry, blueberry, cherry, fig, grape, raspberry, strawberry
Delays senescence & compositional changes	Asparagus, broccoli, lettuce, sweet corn, fresh herbs, fresh cut

## Use of CA/MA during transport

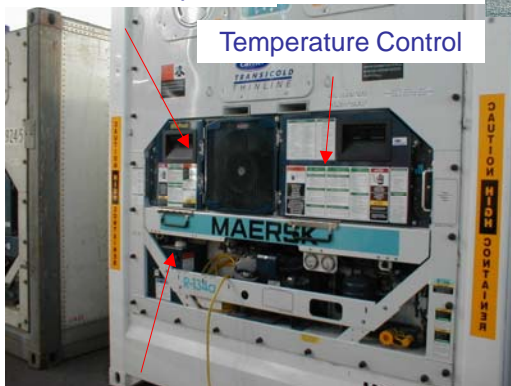
- Avocados from Mexico to Japan and Hong Kong
- Blueberries from Chile to US
- Mangoes from Indonesia to Middle East
- Stone fruits from US to Taiwan
- Papayas from Taiwan to Canada

## CA Unit for Break Bulk Loads in Ship Hulls



## Shipment in Marine Containers

Controlled Atmosphere



Humidity Control

Courtesy Maersk Sealand

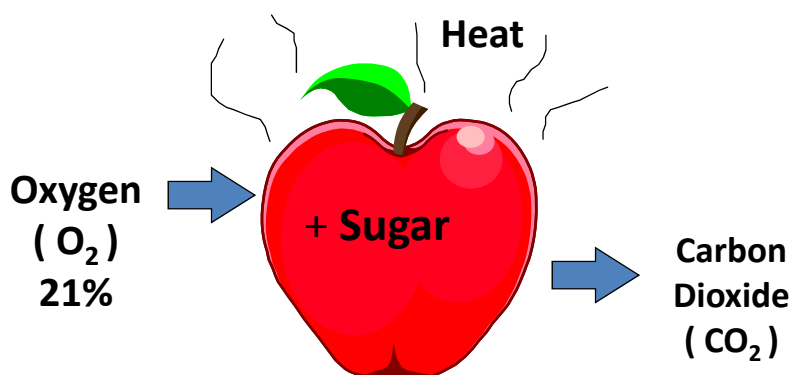


## Modes of Atmosphere Modification

1. Automated Vent Management
  - a) Elevated  $\text{CO}_2$  via product respiration
  - b) Unintentional Modified Atmosphere
2. Assisted Modified Atmosphere
3. Controlled Atmosphere



## Respiration



## Automated Vent Management

- Automated Vent Management
  - Can change venting according to preset times or when temperature setpoint is reached
  - Add gas analyzer and change based on O<sub>2</sub> and CO<sub>2</sub> levels
- Advantages
  - Lower energy consumption, faster cooling
  - Less dehydration of product
  - Allows atmosphere modification by product (MA)
- eAutofresh (Carrier), AFAM<sup>+</sup> (ThermoKing), AV<sup>+</sup> (MCI)



## AV+ Automatic Ventilation



- Manual Air Exchange closed
- Operation Menu for CO<sub>2</sub>/O<sub>2</sub> setting
- Auto ventilation active indicator
- O<sub>2</sub>/CO<sub>2</sub> Set points and actual value indicators
- All parameters (AirEx, CO<sub>2</sub>/O<sub>2</sub> SP/Actual logged)

OPERATION	
001 Setpoint	0.0 C
002 QUEST	AUTO
003 Air flow mode	NORMAL
004 Humidity setpoint	OFF %
005 Datalog interval	60 m
006 PROGRAMS	>
007 O2 min	OFF %
008 CO2 max	2.0 %
009 Active application	AV+

SETPOINT	SUPPLY
0.0	-07
RET	2.9
O2 set	15.0
O2 act	-
CO2 set	6.0
CO2 act	-

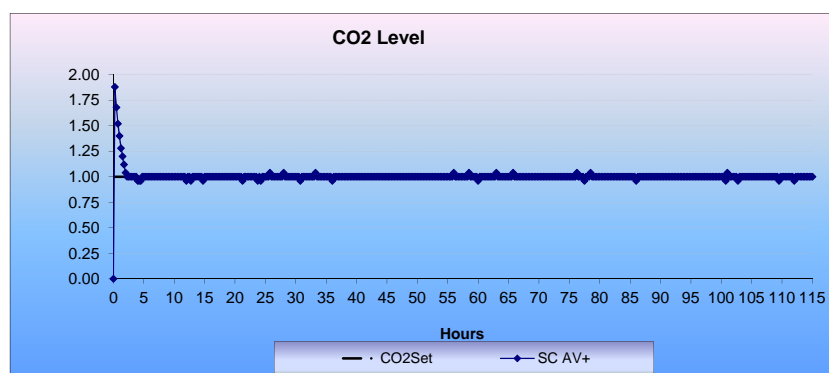
Star Cool

Maersk Container Industries





## AV+ Auto = Simple



Automatic air exchange – set at 1% CO<sub>2</sub>  
 = the container atmosphere remains almost the same as air  
without the excessive air exchange and associated problems



AV+ Automatic Ventilation



eAutoFresh  
Carrier Transicold

Automatic Ventilation Panel  
Based on atmosphere sensing



AFAM+ – ThermoKing



## Unintentional MA through Automated Vent Management

- Could allow CO<sub>2</sub> to build up slightly and provide some benefit for minimum investment
  - What benefit would there be?
    - Reduced respiration rate
    - Reduction in ripening rates?
- Change in O<sub>2</sub> would be inconsequential
- What about accumulation of ethylene???
  - Various methods to control ethylene & effects



**Assisted Modified Atmosphere**



## Modified & Controlled Atmosphere Options

	Star Cool CA	Everfresh	Maxtend	Transfresh
Reduce O2	Respiration	Nitrogen flushing	Nitrogen flushing	Nitrogen flushing
Increase O2	Air	Lower purity N2/Air	Air	Air
Reduce CO2	Membrane	Nitrogen flushing	Hydrated lime	Hydrated lime
Increase CO2	Respiration	Respiration (CO2 flushing)	Respiration	Respiration



## Modified & Controlled Atmosphere Options

	Star Cool CA	Everfresh	Maxtend	Transfresh
Reduce O2	Respiration	Nitrogen flushing	Nitrogen flushing	Nitrogen flushing
Increase O2	Air	Lower purity N2/Air	Air	Air
Reduce CO2	Membrane	Nitrogen flushing	Hydrated lime	Hydrated lime
Increase CO2	Respiration	Respiration (CO2 flushing)	Respiration	Respiration



## Curtain Installation



A Curtain is installed across the door to minimize leakage



Courtesy APL

## Maxtend System



Required gas concentration is quickly achieved by N<sub>2</sub> gas flushing



Courtesy APL

# Maxtend system



If necessary CO<sub>2</sub> scrubbers are placed on the top of the load

Low-power miniaturized 'external' MAXtend controller is installed in air exchange port



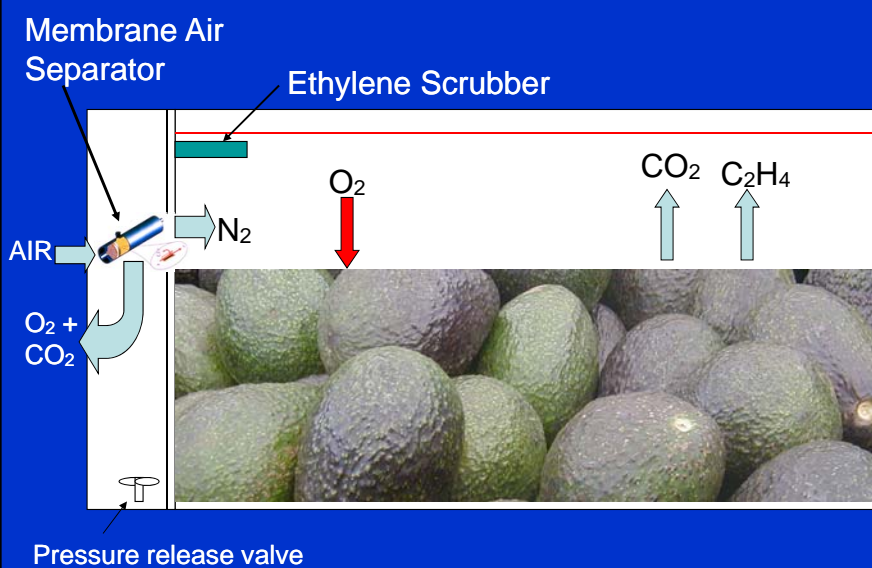
Courtesy APL



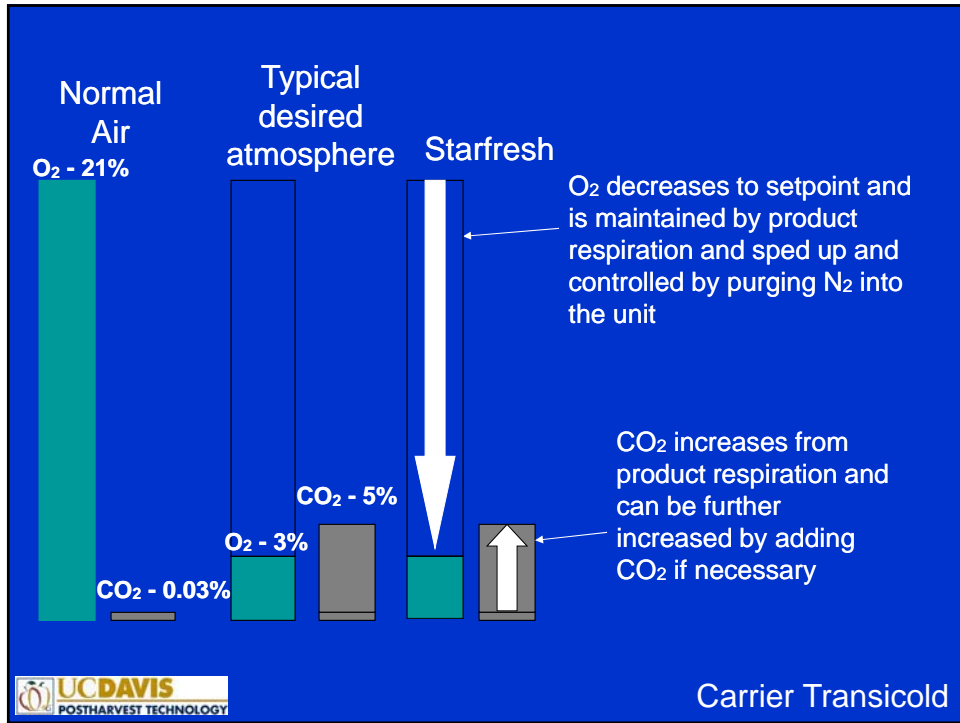
# Controlled Atmosphere Systems



## Everfresh System



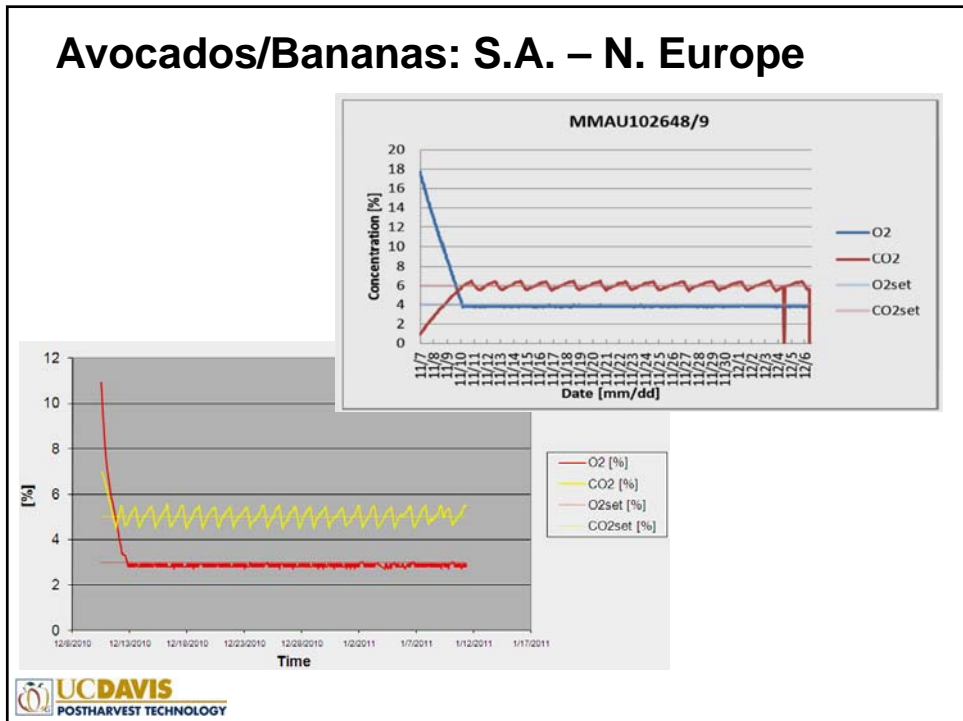
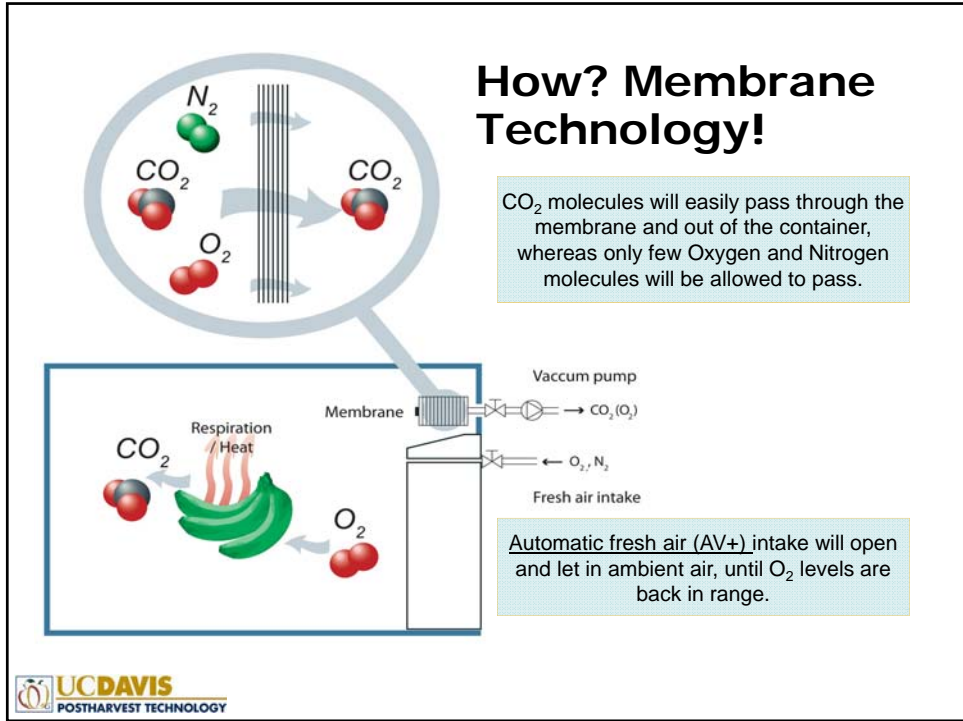
Carrier Transicold



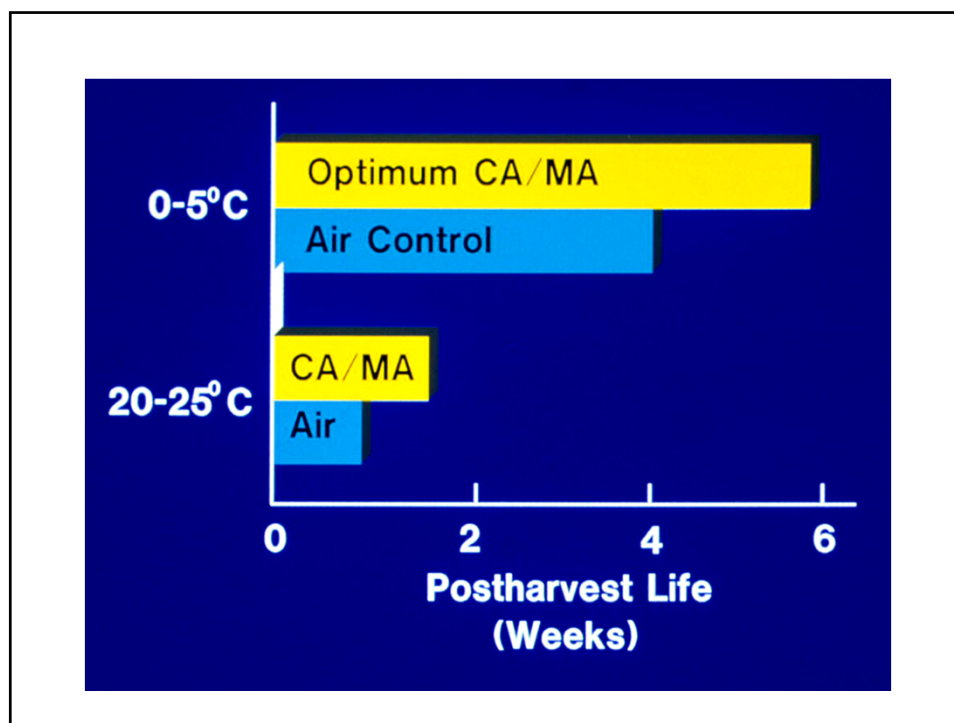
## Star Cool CA Integrated, patented membrane system

- \* Optimised for high respiring commodities
- \* Set-points: CO<sub>2</sub> from 0-12% & O<sub>2</sub> from 3-21%
- \* CA data accessible via Star Cool keypad/display
- \* Control bands CO<sub>2</sub> ± 0.5%, O<sub>2</sub> ± 0.3%
- \* "CA-ready" option
- \* AV<sup>+</sup> (automatic ventilation) included









*Thanks for your attention*

