

# Plastic as a Vector of Food Security and Reduced Hunger in the World

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# Packaging for Food Has 4 Functions:

- Protection
- Shelf life extension
- Convenience
- Communication



# Levels of Packaging:



1<sup>st</sup>



2<sup>nd</sup>



3<sup>rd</sup>





# Protection from Injury



# Protection from the Environment

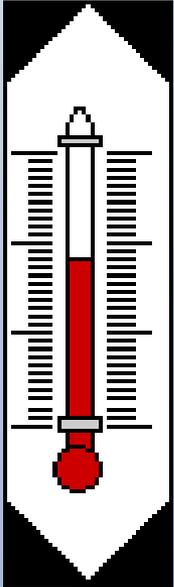




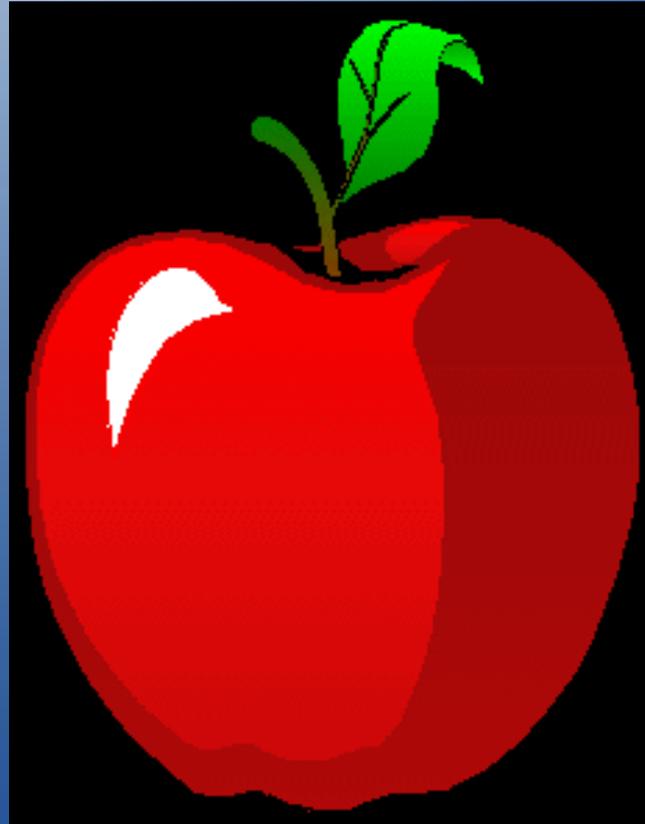
Light



Humidity



Temperature

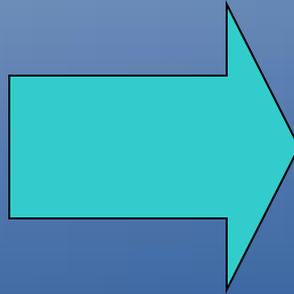
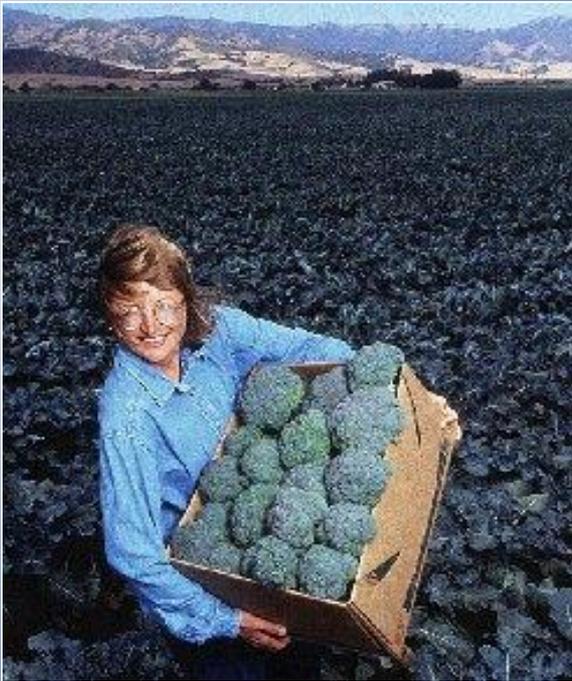


$O_2$   
Oxygen

# Minimize Water Loss



# Compatibility with the Distribution Chain



# Compatibility with the Handling System



# Produce Cooling

- Package venting should be designed to facilitate contact between produce and cooling medium



**Forced-air Cooling**

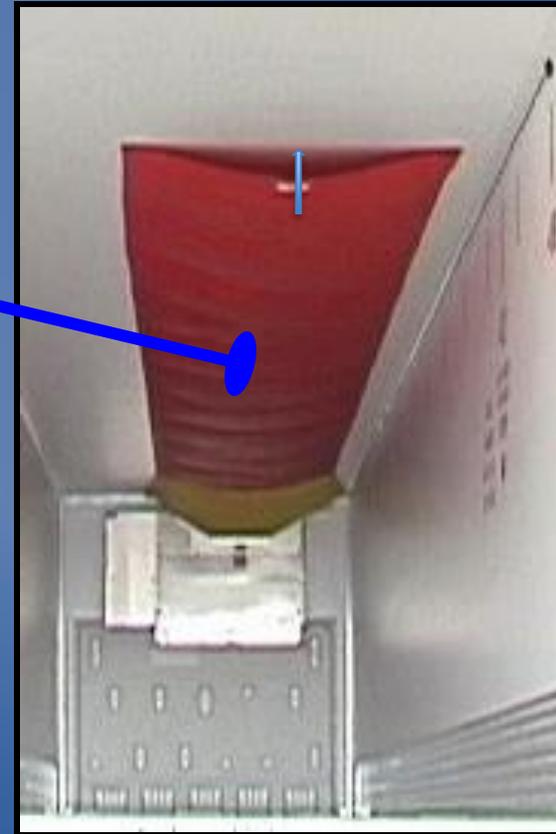
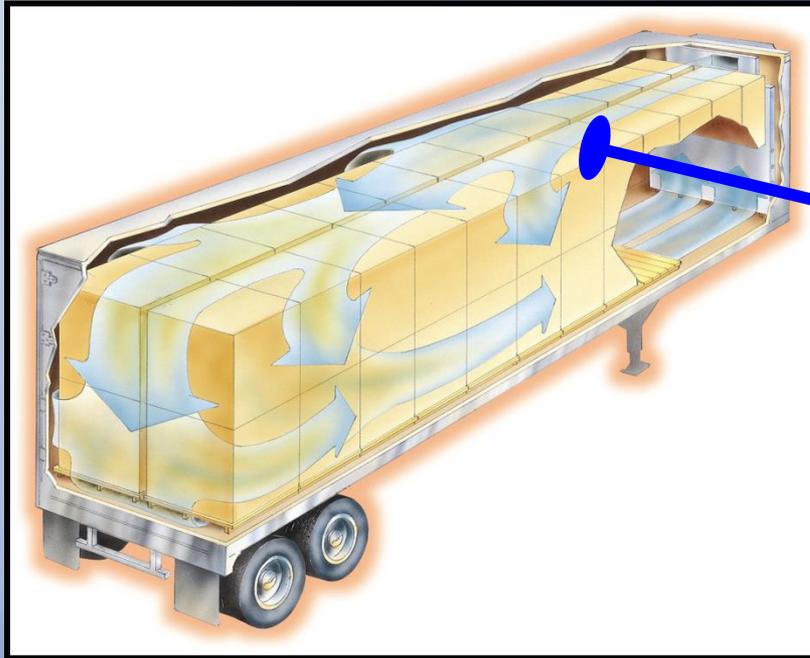


**Hydrocooling**

# Compatibility with the Distribution System



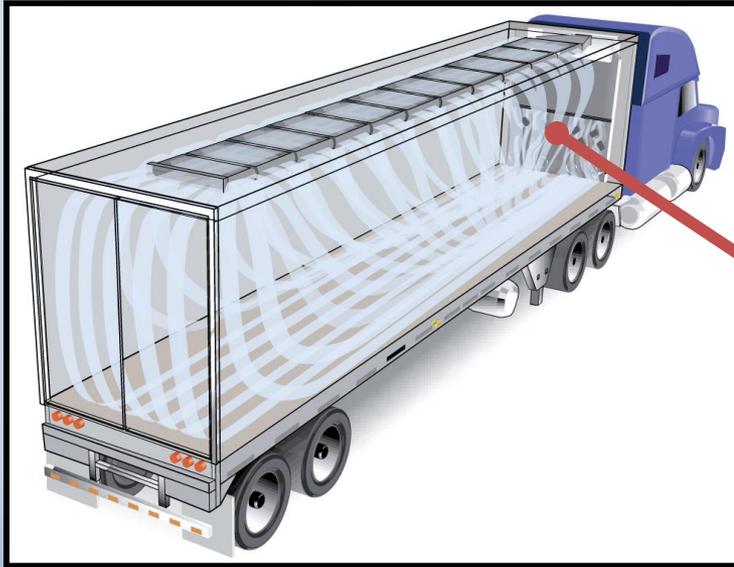
# Refrigerated Truck Airflow Management



## Top-Air Delivery

- Designed to create an envelope of cold air around frozen cargo
- Package venting must line up with horizontal air flow

# Marine Container Airflow Management



## Bottom-Air Delivery

- Package venting must accommodate vertical air flow



**Bulkhead**

Courtesy of Thermo King

# Produce Boxes – mostly corrugated paper



# Returnable Plastic Containers (RPCs)



- A green technology
  - ✓ 39 percent less total energy
  - ✓ 95 percent less solid waste
  - ✓ 29 percent less total greenhouse gas emissions(than corrugated containers)

(Source: PackagingRevolution.net white paper, 2012)

# Consumer packages



# Consumer packages



# Consumer packages of fresh-cut produce



# Plastic Consumer Packages Within Fiberboard Cartons



# Characterizing Plastic Packages

- Tensile Properties
- Tear Strength
- Impact Strength
- Heat-Seal Strength
- Water Vapor Transmission
- Gas Permeability
- Min/Max Temperature
- Stress-crack Resistance

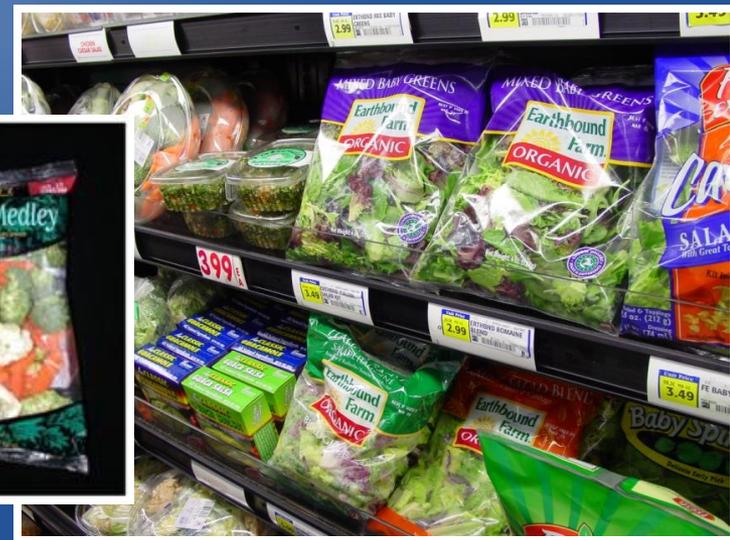
# Principles of Modified Atmosphere Packaging (MAP)

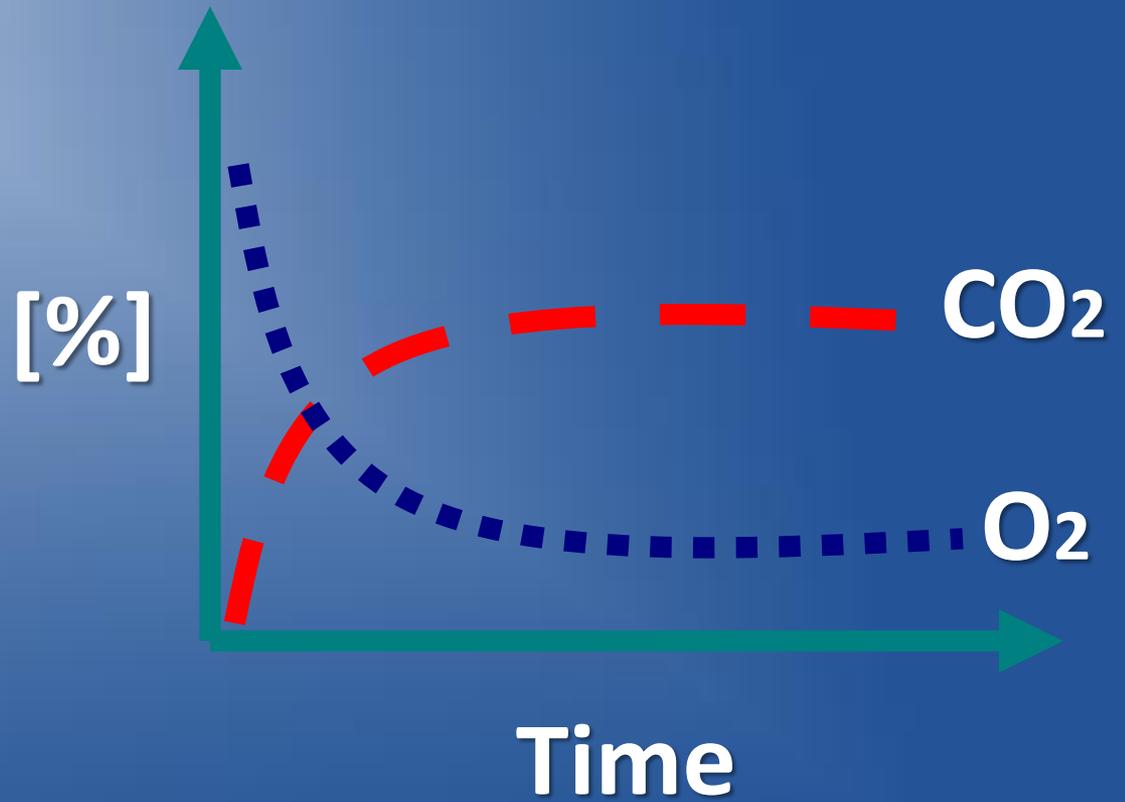
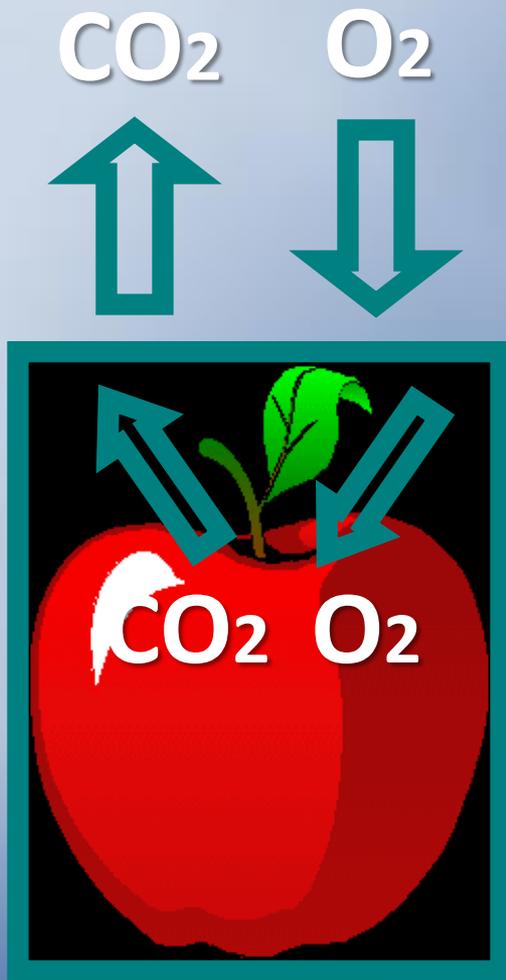
- Modified atmosphere packaging *restricts gas diffusion* via:
  - Semipermeable films
  - Microporous films
  - Microporous patches
  - Perforations



# MAP for Produce

- How Does it Work?
- Match the product respiration rate to the package permeability to achieve the desired atmosphere at a desired temperature
  - 1-5% O<sub>2</sub> to reduce metabolism (respiration)
  - 0-20% CO<sub>2</sub> to inhibit spoilage microorganisms
  - Water vapour barrier





# MAP for Meats

- How Does it Work?
- The main challenge is to retain red color while retarding growth of aerobic spoilage bacteria
  - Barrier films used to maintain 60-80% O<sub>2</sub> (favors red oxymyoglobin) and 20-40% CO<sub>2</sub> (inhibits aerobic spoilage bacteria)
  - Red meat like beef needs higher O<sub>2</sub> than pork or poultry



# MAP for Fish and Seafood

- **How Does it Work?**
- Bacteria and enzymes that degrade the flesh (protein) may or may not require  $O_2$
- Fatty fish turn rancid in the presence of  $O_2$ 
  - Barrier films used to maintain 20-50%  $CO_2$  (inhibits aerobic spoilage bacteria)
  - Remainder of atmosphere contains  $O_2$  and/or  $N_2$  in product-specific amounts



# Principles of MAP for Produce

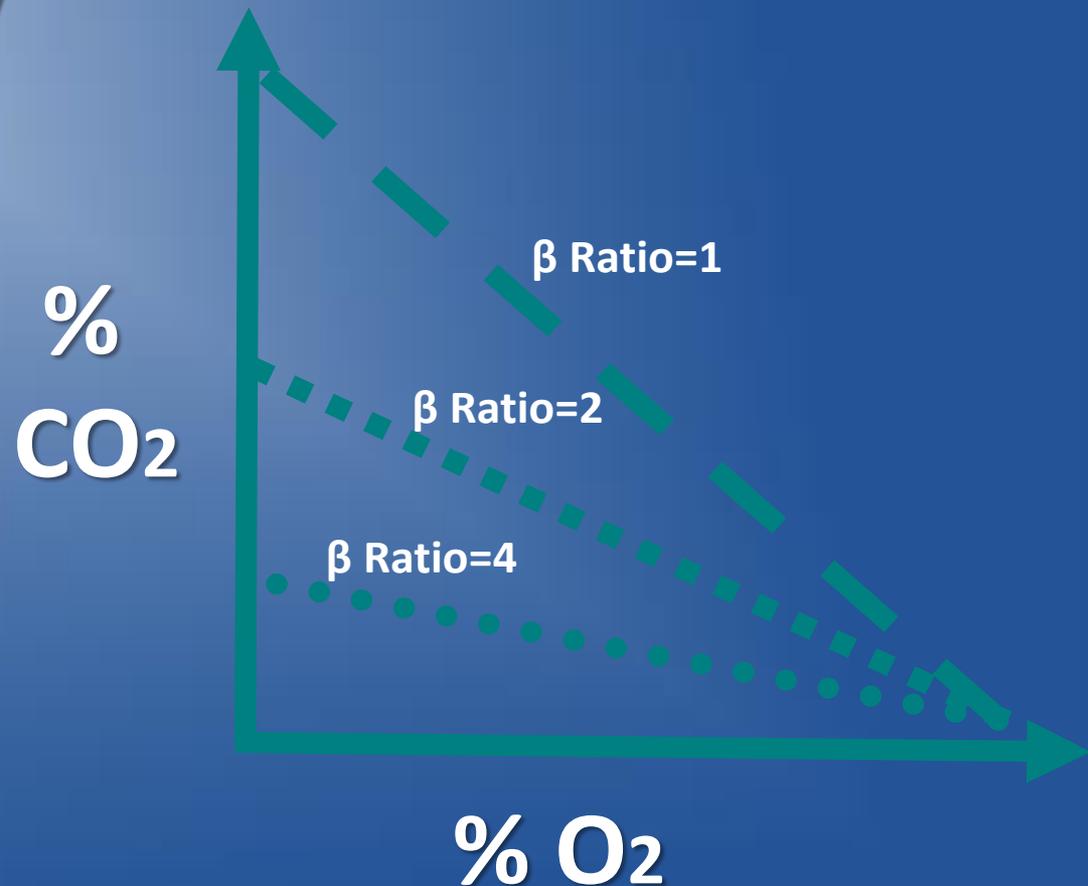
- **Product respiratory quotient (RQ):**

- $\text{CO}_2/\text{O}_2 = 1$

- **Film permeability ratio ( $\beta$ ):**

- $\text{CO}_2/\text{O}_2 = 4-6$  for films

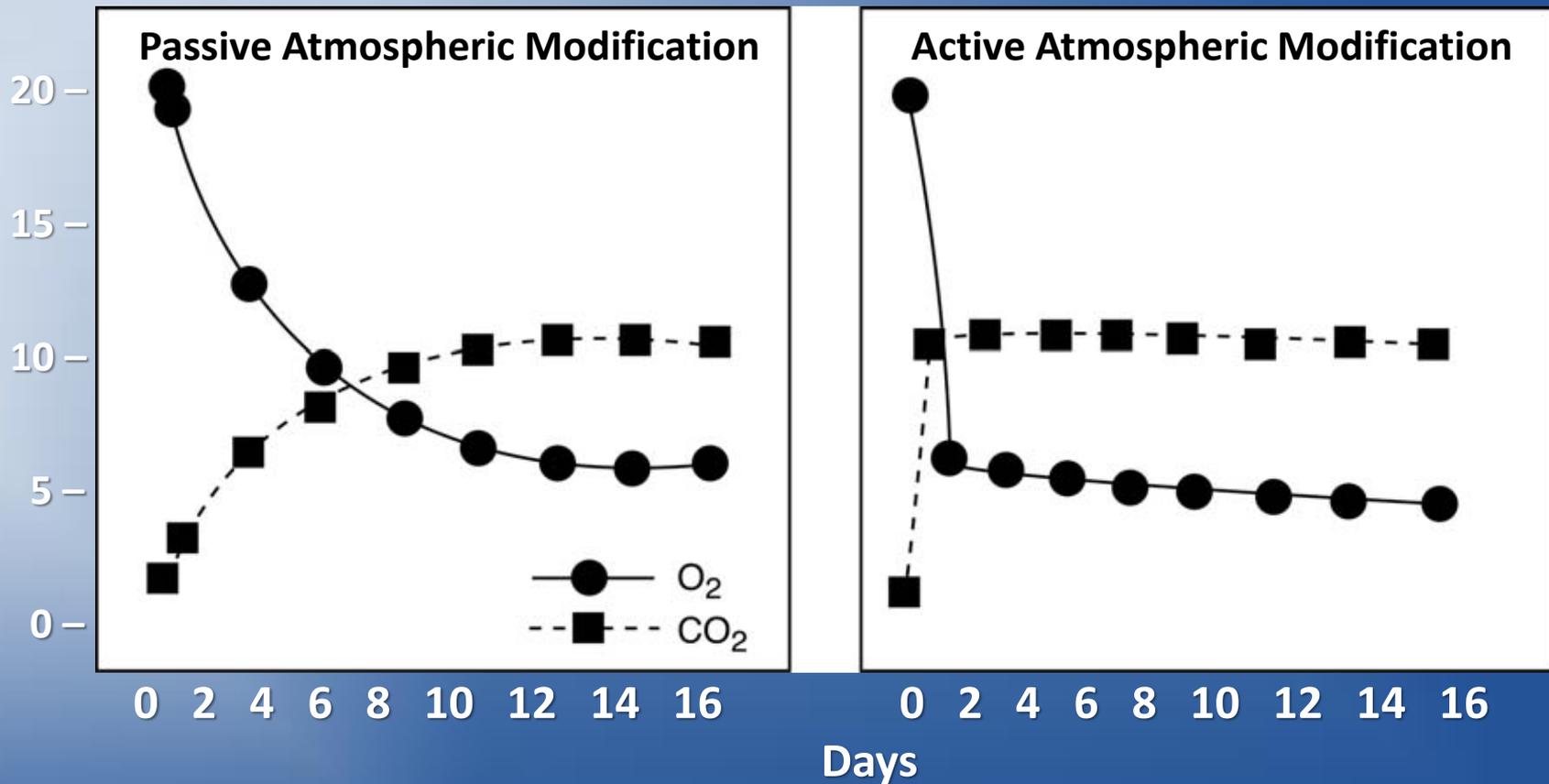
- $\text{CO}_2/\text{O}_2 = 0.8$  for perforations



# Principles of MAP for Produce

- **Passive versus active MAP:** establishing the steady state atmosphere
  - Active MAP = gas flushing before sealing to create the expected steady state atmosphere
  - Rapid establishment of the modified atmosphere is critical for prevention of cut surface browning

# Effects of passive and active atmospheric modification on the O<sub>2</sub> and CO<sub>2</sub> concentrations within a theoretical MAP.



Adapted from: D. Zagory and A.A. Kader, 1988. Modified atmosphere packaging of fresh produce. Food Technol. 42(9):70-77.

# Films for MAP Systems

- Common types of plastics for fresh produce MAP and their properties:

<b>Material</b>	<b>OTR</b> (cc/100 in <sup>2</sup> /day at 77°F & 0% RH)	<b>β Value</b> (CO <sub>2</sub> TR/OTR)	<b>Heat Seal Temperature Range (°F)</b>	<b>Haze (%)</b>
HDPE	100-200		275-310	3
LDPE	500	2-5.9	250-350	
LLPE	150-600		220-340	6-13
EVA	1600-900		150-350	2-10
PP	240	3.3-5.9	325-400	
OPP	100-160		200-300	3
BOPP	160		190-265	
PET	3-6		275-350	2
PVC	30-600	3.6-6.9	280-340	1-2
OPS	200-350		250-350	1

Adapted from Jenkins and Harrington, 1991. Packaging Foods with Plastics. Technomic Publishing Co. Inc. Lancaster, Basel.

# Films for MAP Systems

- **Monolayer films**: one resin – one film
- **Blended films**: different resins blended to produce a monolayer film
- **Multilayer films**
  - **Coextruded films**: multiple film layers extruded together as one film
  - **Laminated films**: multiple film layers joined together with adhesive or molten polymer

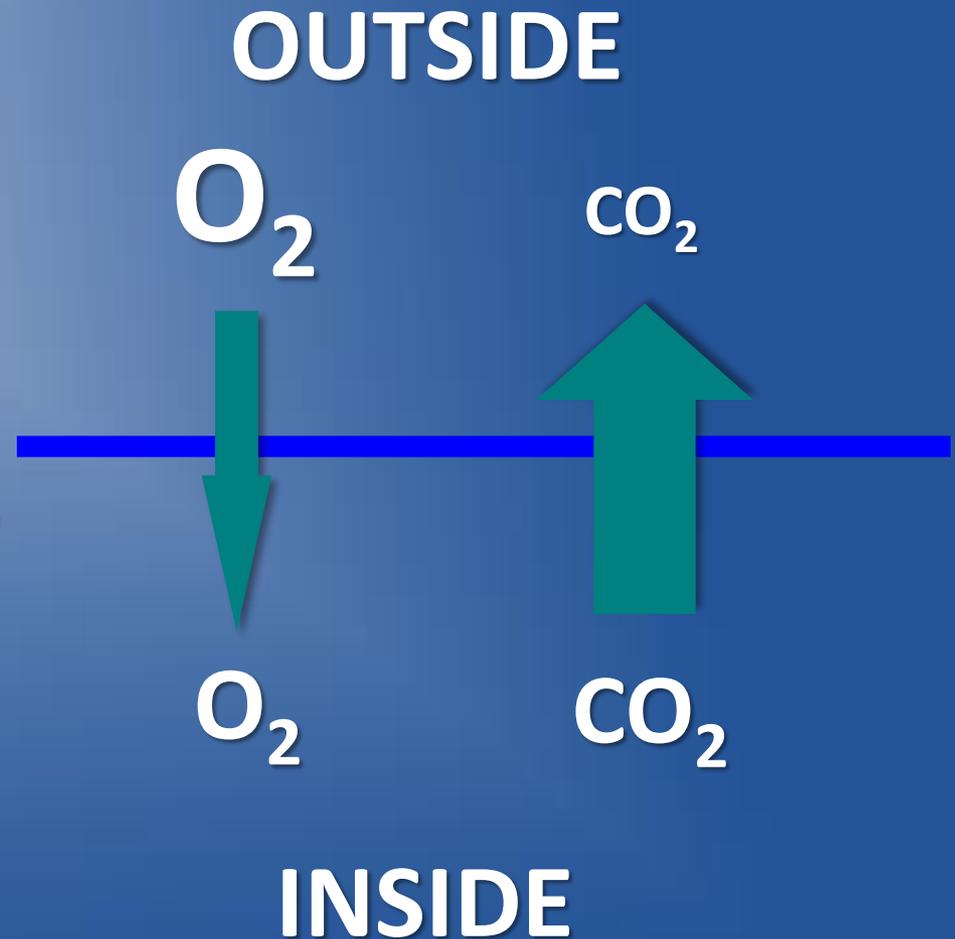
# Films for MAP Systems

- **Metallocene films:** new generation PE films
  - Reduced variation in polymer chain length for better control of film density, sealing characteristics, and permeability
  - Also good clarity and sealing characteristics

# Film-based MAP Systems

- $\beta$  ratio = 4-6
- $\text{CO}_2$  moves through the film 4-6X faster than  $\text{O}_2$
- So the  $\text{O}_2$  reduction is approximately 4-6X the  $\text{CO}_2$  increase in the MAP

➤ e.g., 4%  $\text{O}_2$  + 3%  $\text{CO}_2$



# Film-based MAP Systems



# Microperforated MAP Systems

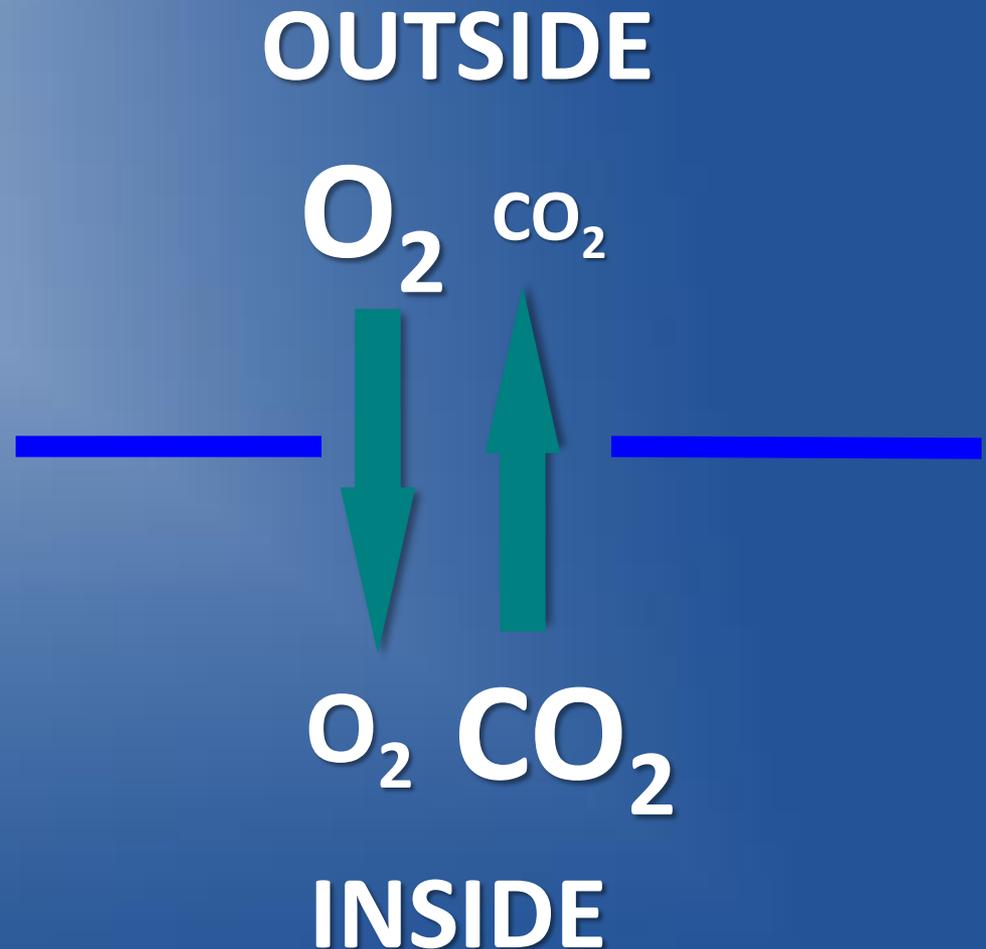
- Microperforated films contain small holes that are approximately 40-200  $\mu\text{m}$  in diameter
  - Microperforations are created in plastic films by mechanical means, sparks or (mostly) laser
  - Microperforated films allow for the development of an elevated  $\text{CO}_2$  environment while maintaining moderate  $\text{O}_2$  levels



# Microperforated MAP Systems

- $\beta$  ratio = approximately one
- $O_2$  and  $CO_2$  move at approximately the same rate through the perforation
- So the  $O_2$  reduction is approximately equal to the  $CO_2$  increase in the MAP

➤ e.g., 4%  $O_2$  + 15%  $CO_2$



# Microporous MAP Systems

- Microporous film may be the major component of a package or a microporous membrane may be placed over a large perforation in an oxygen impermeable film
  - The membrane has very small pores of 0.2-3  $\mu\text{m}$  in diameter, which are made by incorporating calcium carbonate or silica into the membrane during the manufacturing process

# Microporous MAP Systems



# Temperature and MAP

- Produce respiration rates change much more with temperature than film permeability
  - Storage/transport, retail display
- Thus, a MAP cannot maintain beneficial atmospheres when products are exposed to different temperatures

# Temperature and MAP

- Respiration rate *versus* temperature:
  - Fruits and vegetables:  $Q_{10} = 2$  to 4
- Film permeability *versus* temperature:
  - $Q_{10} = 1.2$  to 1.3 for films
  - $Q_{10} = 1$  for perforations

# Temperature and MAP

- Typical solutions include:
  1. Design the MAP for a compromise temperature (e.g., fresh-cuts at 7° C)



# Temperature and MAP

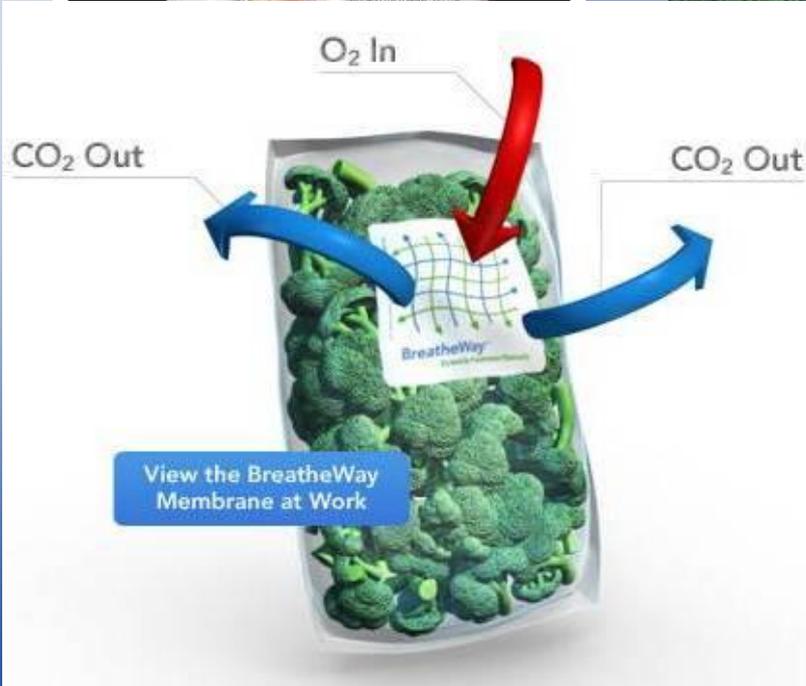
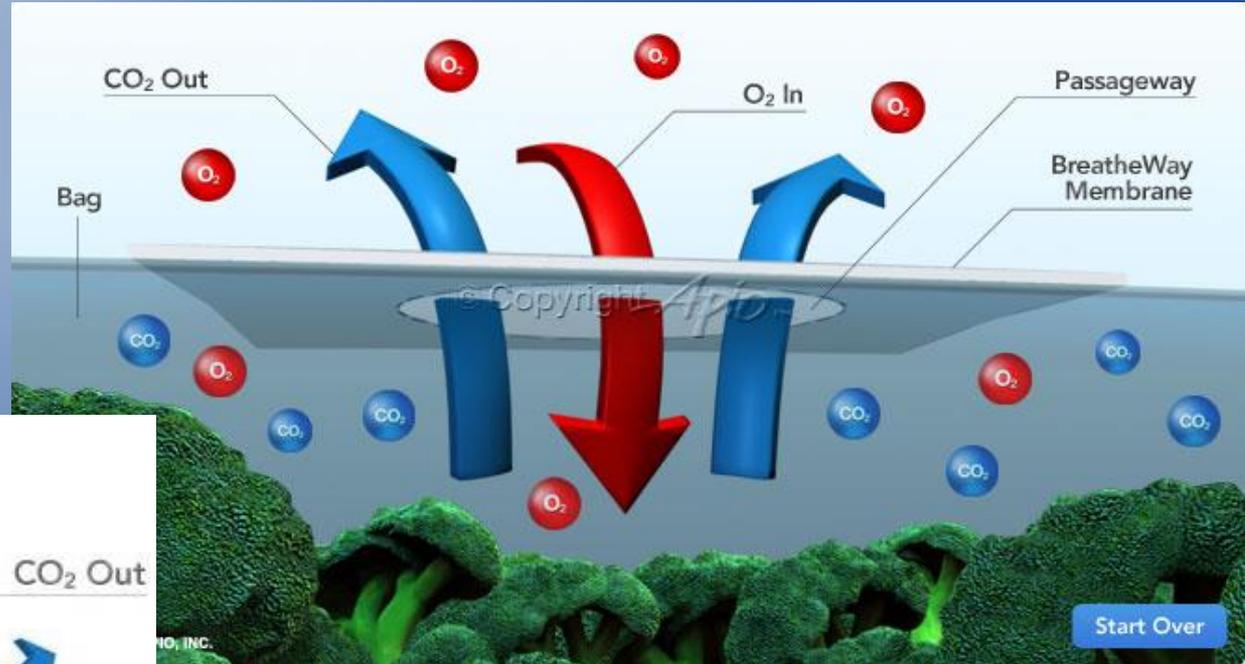
- Typical solutions include:
  2. Design the MAP for storage/transport conditions and remove the product from the MAP before retail display (carton liners and pallet covers)



# Side Chain Melting of Branched Polymers to Increase Permeation

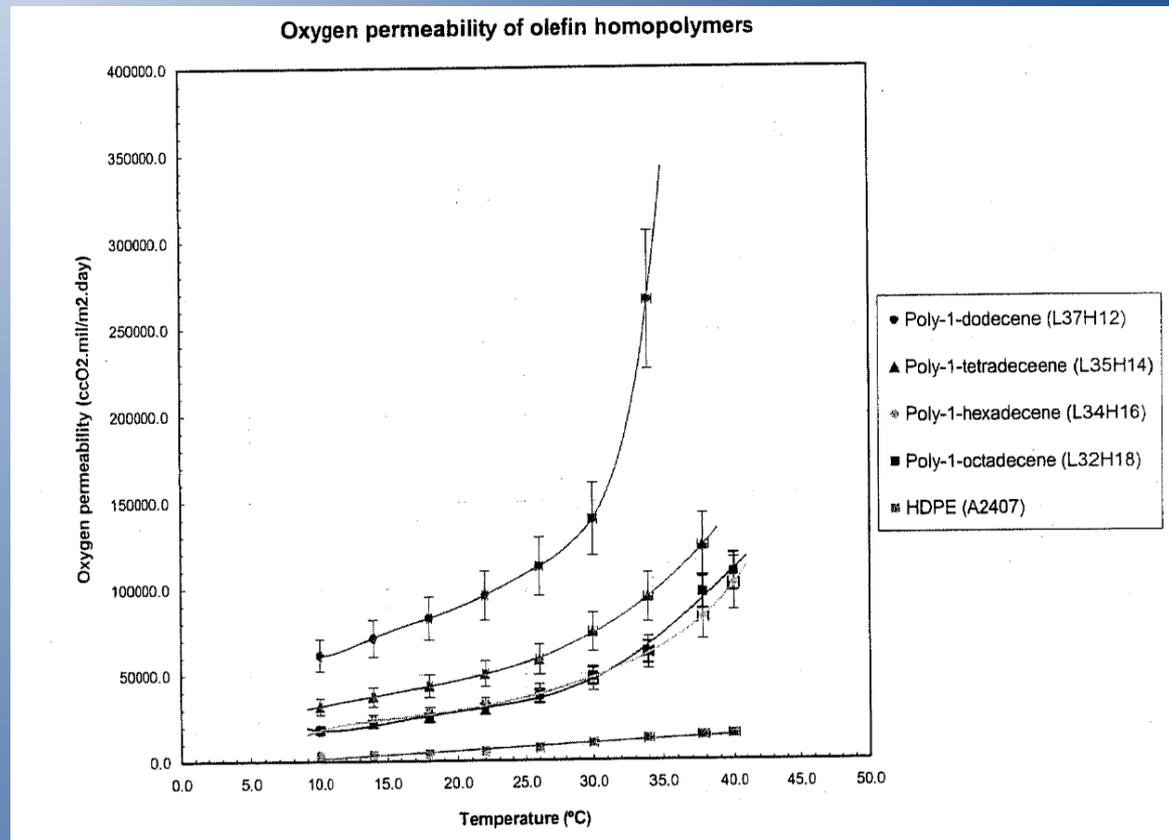
- Branched polymers with crystalline side chains
- Relative permeability varies with the proportion of crystalline fraction since diffusion occurs through the amorphous phases in semi-crystalline materials
- With melting, the crystalline fraction is transformed to an amorphous phase
- Therefore, gas transmission rate increases significantly when the temperature exceeds the melting point of the lateral chains

# Landec/Apio Temperature Responsive MAP System



A macroperforation is covered by a microporous patch coated with a acrylate polymer mixture that changes phase (liquefies) at a chosen temperature

# Oxygen permeability of comb-structured olefin homopolymers compared to HDPE over a temperature range of 0 to 40° C (Lunardi, 2000. Ph.D. Diss. UF)



Though retaining a semi-rigid form above the side chain melting point, these films must be coextruded between films with greater structural integrity for commercial use.

# Microwaveable Packages



Cooking is achieved primarily by the steam generated when water in the package boils rather than by direct microwave heating of the produce.

# Other Considerations

- Printing considerations and film color
- Machine compatibility (e.g., friction or sealing considerations)
- Film clarity & glossiness
- Film texture (flexible, crinkly)
- Anti-fog properties
- Rigid packages; reclosable packages
- Recyclability, biodegradability

# Active and Intelligent MAP

- Ethylene scrubbing
- O<sub>2</sub> & CO<sub>2</sub> absorbents
- Desiccants
- Antimicrobials
- Aroma-release
- Remote monitoring of the package environment (StePac Xsense™)



Thank you for your  
attention

