Modified and Controlled Atmospheres during Transit and Storage

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

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**Gas Composition**

**Normal Atmosphere**
- Nitrogen (78%)
- Carbon Dioxide (0.03%)
- Oxygen (21%)

**Typical Desired Atmosphere**
- Nitrogen (94%)
- Carbon Dioxide (4%)
- Oxygen (2%)

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**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

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**Low O₂ Delays Ripening of ‘Santa Rosa’ Plums**

- Air
- 1% O₂ + 5% CO₂

5 weeks at 10°C

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**Six Months Storage of Bartlett Pears**

- +1°C (30°F) in Air
- -1°C (30°F) in 2% O₂
Low O₂ Retards Ripening of Partially Ripe Tomato Fruit

Delayed Ripening of Chili Peppers

CA Reduces Chilling Injury and Resulting Decay

Reducing Chilling Injury of Avocado with CA

CA Treatments for Decay Control

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

'Hass' Avocado
9 weeks 5°C (41°F)
5 days at 20°C (68°F)
Modified or Controlled Atmospheres

Potential Hazards

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

Low O₂ Stimulates Sprouting and Increases Decay

- 25°C Air
- 2% O₂
- 0.2% O₂

Low O₂ Injury in Apples

- 2% O₂ + 5% CO₂ at 0°C for 1 week or longer

Brown Stain

CO₂ injury to apples
Modified or Controlled Atmospheres
Potential for Benefit or Hazard Depends upon

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

Tolerance to Low Oxygen

<table>
<thead>
<tr>
<th>Min. % O2</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>Tree nuts, dried fruit &amp; vegetables</td>
</tr>
<tr>
<td>1.0</td>
<td>Some apple and pear cultivars, broccoli, most fresh cut F&amp;V, mushrooms</td>
</tr>
<tr>
<td>2.0</td>
<td>Most apple and pear cultivars, kiwifruit, peach, strawberry, cantaloupe, lettuce, cabbage</td>
</tr>
<tr>
<td>3.0</td>
<td>Avocado, persimmon, tomato, pepper, cucumber</td>
</tr>
<tr>
<td>5.0</td>
<td>Citrus, asparagus, potato, sweet potato</td>
</tr>
</tbody>
</table>

Tolerance to Elevated Carbon Dioxide

<table>
<thead>
<tr>
<th>Min. % CO2</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Some apple cultivars</td>
</tr>
<tr>
<td>2</td>
<td>Some apple and pear cultivars, apricot, grape, tomato, lettuce, celery, artichoke</td>
</tr>
<tr>
<td>5</td>
<td>Some apple and pear cultivars, kiwifruit, peach, plum, orange, avocado, banana, cauliflower</td>
</tr>
<tr>
<td>10</td>
<td>Grapefruit, lemon, lime, persimmon, pineapple, cucumber, asparagus, broccoli</td>
</tr>
<tr>
<td>15</td>
<td>Strawberry, blueberry, raspberry, cherry, cantaloupe, sweet corn</td>
</tr>
</tbody>
</table>

Successful CA depends the following:

- Knowing the requirements of the commodity
- Speed of establishment to maximize benefit
- Exclusion of ethylene
- Monitoring of conditions
  - Temperature: Threshold for high CO2/low O2 damage is modulated by temperature
  - Presence of ethylene can negate positive benefits (i.e. apple, kiwifruit)
The presence of ethylene reduces benefits

2% O₂ + 2.5% CO₂

Air Control
+0.01ppm Ethylene
+ 0.1ppm Ethylene
+ 1ppm Ethylene
+ 10ppm Ethylene

‘Hass’ Avocado
9 weeks 5°C (41°F)
5 days at 20°C (68°F)

How Does CA/MA Affect the Product?

Respiration

Oxygen (O₂) 21%

Heat

Sugar

Carbon Dioxide (CO₂)

Respiration and Oxygen

If O₂ Conc. is too low, Anaerobic Respiration will occur

Effect of CO₂ Level on Respiration Rate

The Commodity and Its Environment

Commodity:
- Respiration and ethylene production of commodity
- Natural dermal system: epidermis, cuticle, lenticels
- Additional barriers such as film wraps, waxes, coatings
The Commodity and Its Environment

**Package:**
- Permeability of packaging materials
- Ventilation openings
- Plastic liners

**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

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

Recent advancements in Coextrusion technology have led 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.

Types of MA Packages

Polyethylene Liner (1.5 mil) Delays Ripening of Bananas

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

Types of CA Storage

- Rapid CA
  - Establish in 1 to 3 days instead of 20 days
- Ultra low O₂ CA
- Sequential CA
  - 2 wks 0.5% O₂, then 2% O₂ thereafter
- Dynamic CA
  - Harvest Watch (Satlantic) – chlorophyll florescence
  - Ethanol monitoring system (ATO, Netherlands)

Portable, Low-Cost Tent for Controlled Atmospheres or Modified Atmosphere

Sources of Nitrogen for CA/MA

- Liquid nitrogen
- Pressure swing adsorption (PSA) separators
- Membrane separators (Generon, Permea)

Nitrogen is used to replace Oxygen
Atmospheric Air

**Membrane Air Separator**

N₂

O₂, CO₂

Atmospheric Air

Courtesy Maersk Sealand

**Equipment for Carbon Dioxide Removal**

- **Absorbers**
  - Water
  - Sodium hydroxide
  - Ethanolamine
  - Hydrated lime

- **Adsorbers**
  - Activated charcoal
  - Membrane sieves

**Use of CA for Long Term Storage**

<table>
<thead>
<tr>
<th>Months of Storage</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;12</td>
<td>Nuts, dried fruits and vegetables</td>
</tr>
<tr>
<td>6 – 12</td>
<td>Some apple and pear cultivars</td>
</tr>
<tr>
<td>3 – 6</td>
<td>Cabbage, chinese cabbage, kiwifruit, some asian pear cultivars</td>
</tr>
<tr>
<td>1 – 3</td>
<td>Avocado, olive, some peach, plum, nectarine cultivars, persimmon, pomegranate</td>
</tr>
</tbody>
</table>

**Use of CA for Short Term Storage**

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

**Use of CA/MA during transport**

- Liquid nitrogen
- Pressure swing adsorption (PSA) separators
- Membrane separators (Generon, Permea)

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

Use of CA for Short Term Storage

Use of CA/MA during transport
Examples of CA Shipments

- 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
**Maxtend system - APL**

Low-power miniaturized ‘external’ MAXtend controller is installed in air exchange port. Courtesy APL

**CO₂ Scrubber - APL**

CO₂ scrubbers are packed in a protective carton. If necessary CO₂ scrubbers are placed on the top of the load. Courtesy APL

**Curtain Installation**

A Curtain is installed across the door to minimize leakage. Courtesy APL

**Gas flushing**

Required gas concentration is quickly achieved by gas flushing. Courtesy APL

**eAutoFresh – Carrier Transicold**

Automatic ventilation panel. Also has ozone capability through PureFresh system.
Thanks to E.J. Mitcham for sharing parts of this presentation.