Modified and Controlled Atmospheres during Transit and Storage

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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

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

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
- Typical Desired Atmosphere

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 O₂ Delays Ripening of ‘Santa Rosa’ Plums

- Air
- 1% O₂ + 5% CO₂

5 weeks at 10°C

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

`Hass` Avocado
- 9 weeks 5°C (41°F)
- 5 days at 20°C (68°F)
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 O₂ Stimulates Sprouting and Increases Decay

25°C Air 2% O₂ 0.2% O₂

Low O₂ Injury in Apples
**Brown Stain**

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

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### CO₂ Injury to Apple Fruit

<table>
<thead>
<tr>
<th>Atmosphere</th>
<th>Image Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>Images of apples under different CO₂ levels.</td>
</tr>
<tr>
<td>0.4% CO₂ 2% O₂</td>
<td>Images of apples under different CO₂ levels.</td>
</tr>
<tr>
<td>1.5% CO₂ 2% O₂</td>
<td>Images of apples under different CO₂ levels.</td>
</tr>
<tr>
<td>3% CO₂ 2% O₂</td>
<td>Images of apples under different CO₂ levels.</td>
</tr>
</tbody>
</table>

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### Modified or Controlled Atmospheres

**Potential for Benefit or Hazard Depends Upon**

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

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### 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 cultivars of apples &amp; pears, broccoli, most fresh cut F&amp;V, mushrooms</td>
</tr>
<tr>
<td>2.0</td>
<td>Most cultivars of apples and pears, 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>

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### Tolerance to Elevated Carbon Dioxide

<table>
<thead>
<tr>
<th>Max. %CO₂</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Some cultivars of apples (Fuji, Pink Lady, Braeburn)</td>
</tr>
<tr>
<td>2</td>
<td>Some apples &amp; pears, apricot, pear, grape, tomato, lettuce, celery, artichoke</td>
</tr>
<tr>
<td>5</td>
<td>Some apples and pears, kiwifruit, peach, plum, orange, grapefruit, lemon, lime, avocado, banana, cauliflower</td>
</tr>
<tr>
<td>10</td>
<td>Persimmon, pineapple, cucumber, asparagus, broccoli</td>
</tr>
<tr>
<td>15</td>
<td>Strawberry, blueberry, raspberry, cherry, cantaloupe, sweet corn</td>
</tr>
</tbody>
</table>
How Does CA/MA Affect the Product?

Respiration and Oxygen

If O$_2$ Conc. is too low, **Anaerobic Respiration** will occur

Effect of 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

**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

Chili Peppers in Sealed Containers

% CO₂ or O₂

Days in Storage
Polymer Engineering
Requirements

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

<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 monolayer 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 1500 cc/100 sq. in. while at the same time providing excellent optics and increased stiffness.

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

Membrane Air Separator

Atmospheric Air

N₂

O₂, CO₂

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>
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<tbody>
<tr>
<td>&gt;12</td>
<td>Nuts and dried fruits and vegetables</td>
</tr>
<tr>
<td>6 - 12</td>
<td>Some cultivars of apples and pears</td>
</tr>
<tr>
<td>3 - 6</td>
<td>Cabbage, Chinese cabbage, kiwifruit, some cultivars of Asian pears</td>
</tr>
<tr>
<td>1 - 3</td>
<td>Avocado, olive, some cultivars of peach, plum, nectarine, persimmon, pomegranate</td>
</tr>
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</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 &amp; compositional changes</td>
<td>Asparagus, broccoli, lettuce, sweet corn, fresh herbs, fresh cut</td>
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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

Temperature Control

Humidity Control

Courtesy Maersk Sealand

Modes of Atmosphere Modification

1. Automated Vent Management
   a) Elevated CO₂ via product respiration
   b) Unintentional Modified Atmosphere
2. Assisted Modified Atmosphere
3. Controlled Atmosphere

Respiration

Oxygen (O₂) 21% + Sugar → Heat

Carbon Dioxide (CO₂)

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 O₂ and CO₂ levels
- Advantages
  - Lower energy consumption, faster cooling
  - Less dehydration of product
  - Allows atmosphere modification by product (MA)
- eAutofresh (Carrier), AFAM* (ThermoKing), AV* (MCI)

*Note: AFAM and AV are types of atmosphere management systems used in shipping and storage.
AV+ Automatic Ventilation

- Manual Air Exchange closed
- Operation Menu for CO2/O2 setting
- Auto ventilation active indicator
- O2/CO2 Set points and actual value indicators
- All parameters (AirEx, CO2/O2 SP/Actual logged)

Star Cool
Maersk Container Industries

AV+ Auto = Simple

Automatic air exchange – set at 1% CO2
- the container atmosphere remains almost the same as air without the excessive air exchange and associated problems.

Automatic Ventilation Panel
Based on atmosphere sensing

eAutoFresh
Carrier Transicold

AFAM+ – ThermoKing

Unintentional MA through Automated Vent Management

- Could allow CO2 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 O2 would be inconsequential
  - What about accumulation of ethylene???
    - Various methods to control ethylene & effects

Modified & Controlled Atmosphere Options

<table>
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<tr>
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<th>Increase O2</th>
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<td>Star Cool CA</td>
<td>Evenfresh</td>
<td>Maxtend</td>
<td>Transfresh</td>
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<tr>
<td>Respiration</td>
<td>Nitrogen flushing</td>
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</tr>
<tr>
<td>Air</td>
<td>Lower purity N2/Air</td>
<td>Air</td>
<td>Air</td>
</tr>
<tr>
<td>Membrane</td>
<td>Nitrogen flushing</td>
<td>Hydrated lime</td>
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- **Curtain Installation**
  - A Curtain is installed across the door to minimize leakage

- **Maxtend System**
  - Required gas concentration is quickly achieved by N2 gas flushing
  - Courtesy APL

- **Maxtend system**
  - Low-power miniaturized ‘external’ MAXtend controller is installed in air exchange port
  - If necessary CO2 scrubbers are placed on the top of the load
  - Courtesy APL

- **Controlled Atmosphere Systems**
**Star Cool CA Integrated, patented membrane system**

- Optimised for high resiping commodities
- Set-points: CO₂ from 0-12% & O₂ from 3-21%
- CA data accessible via Star Cool keypad/display
- Control bands CO₂ ± 0.5%, O₂ ± 0.3%
- “CA-ready” option
- AV⁺ (automatic ventilation) included

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**How? Membrane Technology!**

CO₂ molecules will easily pass through the membrane and out of the container, whereas only few Oxygen and Nitrogen molecules will be allowed to pass.

Automatic fresh air (AV⁺) intake will open and let in ambient air, until O₂ levels are back in range.

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**Avocados/Bananas: S.A. – N. Europe**

Optimum CA/MA

Air Control

CA/MA

Air

Postharvest Life (Weeks)

0-5°C

20-25°C
Thanks for your attention