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

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

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 O₂ Delays Ripening of ‘Santa Rosa’ Plums

5 weeks at 10°C

Air 1% O₂ + 5% CO₂

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)

Air Control <0.01ppm Ethylene + 0.1ppm Ethylene + 1ppm Ethylene + 10ppm Ethylene
Does CA reduce product sensitivity to injury at chilling temperatures or 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 O₂ Stimulates Sprouting and Increases Decay
Low O₂ Injury in Apples

Brown Stain

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

CO₂ Injury to Apple Fruit

Modified or Controlled Atmospheres
Potential for Benefit or Hazard
Depends upon

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

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>
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

Heat

Oxygen (O₂) 21% → + 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 added film wrapping, waxes, coatings
The Commodity and Its Environment

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

Redox reactions:
- $O_2$ and $H_2O$
- $CO_2$ and $CH_4$ Heat

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

<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 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.

Fresh-cut Packaging

- Bags (LDPE) with holes
  - No modified atmosphere
- Bags with microperforations
  - Often PP
  - Permeability of O2:CO2 = 1:1
- Bags with patches
- Differentially permeable films
  - Layered plastics
  - Co-extruded plastics
  - Gas permeability ratios vary

Prepared Vegetables for Home Cooking/Grilling

Examples fresh-cut fruit products

United Fresh Produce Dallas, May 2012
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 fluorescence
  - Ethanol monitoring system (ATO, Netherlands)
Sources of Nitrogen for CA/MA
Nitrogen is used to replace Oxygen

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

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 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>
</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 &amp; 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)

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

CA Unit for Break Bulk Loads in Ship Hulls

Shipment in Marine Containers

Controlled Atmosphere

Temperature Control

Humidity Control

Controlled Atmosphere Options

Extending post harvest life by altering container atmosphere
- Oxygen level (21% ambient) is lowered and controlled
- CO₂ level (0.03% ambient) prevented from increase due to respiration

<table>
<thead>
<tr>
<th>Star Cool CA</th>
<th>Everfresh</th>
<th>Mastend</th>
<th>Transfresh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce O₂</td>
<td>Respiration</td>
<td>Nitrogen flushing</td>
<td>Nitrogen flushing</td>
</tr>
<tr>
<td>Increase O₂</td>
<td>Respiration</td>
<td>Nitrogen flushing</td>
<td>Nitrogen flushing</td>
</tr>
<tr>
<td>Reduce CO₂</td>
<td>Respiration</td>
<td>Nitrogen flushing</td>
<td>Hydrated lime</td>
</tr>
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<td>Nitrogen flushing</td>
<td>Hydrated lime</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Initial investment</th>
<th>Medium</th>
<th>Very High</th>
<th>Low/None</th>
<th>Medium on provision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per trip cost</td>
<td>Low</td>
<td>Medium/High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>Low</td>
<td>High</td>
<td>None</td>
<td>Medium</td>
</tr>
<tr>
<td>CA revenue</td>
<td>Owner</td>
<td>Owner</td>
<td>Master/Owner</td>
<td>Transfresh/11</td>
</tr>
<tr>
<td>CA control display</td>
<td>Yes</td>
<td>Yes</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Data integrated</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Curtain Installation

A Curtain is installed across the door to minimize leakage

Courtesy APL

Gas flushing

Required gas concentration is quickly achieved by N₂ gas flushing

Courtesy APL

Maxtend system - APL

If necessary CO₂ scrubbers are placed on the top of the load

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

Courtesy APL

AV+ Automatic Ventilation

• Manual Air Exchange closed
• Operation Menu for CO₂/O₂ setting
• Auto ventilation active indicator
• O₂/CO₂ Set points and actual values 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 is outside without the excessive air exchange and associated problems

eAutoFresh – Carrier Transicold

Automatic ventilation panel
Also has ozone capability through PureFresh system
**Star Cool CA Integrated, patented membrane system**

- Optimised for high respiring 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

**Controlled Atmosphere Options**

<table>
<thead>
<tr>
<th>Reduce O₂</th>
<th>Increase O₂</th>
<th>Reduce CO₂</th>
<th>Increase CO₂</th>
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<tbody>
<tr>
<td>Star Cool CA</td>
<td>Everfresh</td>
<td>Maxtend</td>
<td>Transfresh</td>
</tr>
<tr>
<td>Respiration</td>
<td>Nitrogen flushing</td>
<td>Nitrogen flushing</td>
<td>Nitrogen flushing</td>
</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>
<td>Hydrated lime</td>
</tr>
<tr>
<td>Respiration</td>
<td>Respiration (CO₂ flushing)</td>
<td>Respiration</td>
<td>Respiration</td>
</tr>
</tbody>
</table>
Thanks for your attention