MODIFIED ATMOSPHERE PACKAGING (MAP)
(The Half Guide)

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Imagine This

Carbon Dioxide

10%

Oxygen

~0%

Nitrogen

90%
Will anybody survive?
The obvious answer is **NO**

Let’s Now answer why so
This is because all living beings respire and require $O_2$ for respiration

- Living beings include
  - Animals
  - Plants and
  - Microorganisms*

*(only for aerobic microorganisms, anaerobic need $CO_2$)
Respiration

In simple terms respiration* is:

\[ \text{O}_2 + \text{Sugar} \rightarrow \text{CO}_2 + \text{Energy} + \text{Heat} \]

* Unlike Animals and microorganisms fruits and vegetables respire even after harvesting.
Post Harvest Scenario

Factors which effect Fruit & Vegetables post harvest

• **Intrinsic Factors** (Inherent to product)
  - Respiration
  - Acidity
  - Water Activity
  - Ethylene Produce

• **Extrinsic Factors** (External factors)
  - Temperature variation
  - Water loss
Post harvest Respiration

Post harvest, Fruits and vegetables continue to respire.

\[ \text{O}_2 + \text{Sugar} \rightarrow \text{CO}_2 + \text{Heat} \]

This respiration aids in ripening process. Hence respiration needs to be controlled in order to avoid over ripening/ Perishability

Graph 1 and 2 show the relation of Respiration Rate and \( \text{O}_2/\text{CO}_2 \)
Respiration Rate and $O_2$

Graph - 1

If $O_2$ concentration is too low, Anaerobic Respiration will occur.
Effect of CO$_2$ on respiration rate

Graph - 2

- Respiration Rate
- % CO$_2$

The graph shows a decrease in respiration rate as the % CO$_2$ increases.
### Tolerance to Low Oxygen Conc.

<table>
<thead>
<tr>
<th>Min. $O_2$ %</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>Tree nuts, dried fruits &amp; vegetables</td>
</tr>
<tr>
<td>1.0</td>
<td>Some Cvs. apples &amp; pears, broccoli,</td>
</tr>
<tr>
<td></td>
<td>most min. processed F &amp; V, mushrooms</td>
</tr>
<tr>
<td>2.0</td>
<td>Most Cvs. apples &amp; pears, kiwifruit,</td>
</tr>
<tr>
<td></td>
<td>peach, strawberry, cantaloupe, lettuce</td>
</tr>
<tr>
<td></td>
<td>cabbage</td>
</tr>
<tr>
<td>3.0</td>
<td>Avocado, persimmon, tomato, pepper,</td>
</tr>
<tr>
<td></td>
<td>cucumber</td>
</tr>
<tr>
<td>5.0</td>
<td>Citrus, asparagus, potato, sweet potato</td>
</tr>
</tbody>
</table>

### Tolerance to Elevated Carbon Dioxide Conc.

<table>
<thead>
<tr>
<th>Max. $CO_2$ %</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Apple (Golden Delicious), apricot, pear,</td>
</tr>
<tr>
<td></td>
<td>grape, tomato, lettuce, celery, artichoke</td>
</tr>
<tr>
<td>5</td>
<td>Most Cvs. apples, peach, plum, orange, avocado,</td>
</tr>
<tr>
<td></td>
<td>banana, kiwifruit, cauliflower</td>
</tr>
<tr>
<td>10</td>
<td>Grapefruit, lemon, lime, persimmon,</td>
</tr>
<tr>
<td></td>
<td>pineapple, cucumber, asparagus, broccoli</td>
</tr>
<tr>
<td>15</td>
<td>Strawberry, cherry, cantaloupe, sweet corn</td>
</tr>
</tbody>
</table>
Acidity

- Influences the type of spoilage/Food poisoning microorganisms.
- Fruits generally have pH < 4.5
  - *C. botulinum* (pathogen) can’t grow
- Vegetables generally have > 4.5
  - *C. botulinum* able to grow under anaerobic conditions
- pH is also related to $a_w$
The interaction between pH and Aw controls microbial growth in food-products.

More Pathogens
Water Activity ($a_w$)

- Water activity ($a_w$) is the amount of water that is available to microorganisms.
- Many microorganisms prefer an $a_w$ of 0.99 and most need an $a_w$ higher than 0.91 to grow.
- Relative humidity and $a_w$ is related. Water activity refers to the availability of water in a food or beverage. Relative humidity refers to the availability of water in the atmosphere around the food or beverage.

**Relative Humidity (RH) vs. Water Activity**

$$RH = a_w \times 100$$
Water Activity

- **Raoult's Law**
  - \( a_w = \frac{p}{p_0} \)
  - \( a_w = \) water activity
  - \( p = \) vapor pressure of a solution
  - \( p_0 = \) vapor pressure of pure water

- Water activity may be the most important factor in controlling spoilage. Most bacteria, for example, do not grow at water activities below 0.91, and most molds cease to grow at water activities below 0.80.

- Fresh fruits and vegetables \( a_w \) is near 0.91 - 1.00.

- Hence susceptibility to growth of spoilage microorganisms is high.
Ethylene Production

• Ethylene, a growth stimulating hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it.

• Damaged or diseased fruits and vegetables produce high levels of ethylene and stimulate the other to ripen too quickly. As the fruits ripen, they become more susceptible to diseases.
Some examples of ethylene effects include:

- Yallowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower
- Accelerated softening of cucumbers
- Softening and off-flavor in watermelons
- Discoloration and off-flavor in sweet potatoes;
- Sprouting of potatoes;
- Increased ripening and softening of mature green tomatoes
- Increased toughness in turnips and asparagus
- Bitterness in carrots and parsnips;
Temperature

• Fresh products exposed to extremes of heat or cold may sustain serious physiological damage, leading to rapid deterioration.
• Exposure to alternating cold and warm temperatures may result in moisture accumulation on the surface of commodities (sweating), which may enhance decay development.
Symptoms of heat injury include:

- Commodities exposed to direct sunlight or excessively high temperatures can be damaged.
- **Symptoms of heat injury include:**
  - bleaching, surface burning or
  - scalding, uneven ripening, excessive softening, and desiccation (water loss).
Water Loss

- Relative humidity, the temperature of the product and its surrounding atmosphere, and air velocity all affect the amount of water lost from fresh fruits, vegetables.
- Water loss from warm products to warm air is particularly serious under windy conditions or during transport in an open vehicle.
- Effects of water loss –
  - Fruits and vegetables become shriveled
  - Water loss represents salable weight loss and reduced profits.
Post harvest Scenario

- The best possible quality of any commodity exists at the moment of harvest.
- From that point on, quality cannot be improved, only maintained.
- The shelf life of the fruits and vegetables begins after harvesting.
Post harvest Scenario

• The major challenge is to maintain the quality and extend the shelf life of fruits and vegetable.
• For extending the shelf life all the above factors viz. Intrinsic and Extrinsic should be controlled.
• MAP has the ability to extend the shelf life of fruits and vegetables, by controlling the above factors.
Let's hold this thought

Now let's see what happens in case of animal products and animal bi-products.
Animal and Bi Products

Factors which effect the Animal products

• **Intrinsic**
  - Autolysis (Seen in case of fish)

• **Extrinsic**
  - Oxidation
  - Microbial Spoilage
Meat and Poultry

- **Raw red meat**: Microbial growth and oxidation of the red oxymyoglobin pigment are the main spoilage mechanisms that limit the shelf life of raw red meats.

- **Raw Poultry**: Microbial growth, particularly of *Pseudomonas* and *Achromobacter* species, is the major factor limiting the shelf life of raw poultry.
Fish and fish products

- Spoilage of fish and shellfish results from changes caused by three major mechanisms:
  - The breakdown of tissue by the fish's own enzymes (autolysis of cells),
  - Growth of micro-organisms, and
  - Oxidative reactions.
- MAP can be used to control Growth of micro-organisms and Oxidative Reaction but has no direct effect on autolysis.
Dairy Products

- These include fat-filled milk powders, cheeses and fat spreads etc.
- In general these products spoil due to the development of oxidative rancidity in the case of powders and or the growth of micro-organisms, particularly yeasts and moulds, in the case of cheese.
Animal and Bi - Products

• To maintain the quality and extend the shelf life the factors viz, $O_2$ levels and Microbe attack should be controlled.

• MAP has the ability to do both
Let’s now learn about MAP
Overview

• Why MAP
• What’s MAP
• How to MAP
• Where to MAP
• MAP Machinery
• MAP Regulations
MAP - Modified Atmospheric Packaging
Why MAP?
• **Major Reason**
  - To extend shelf life
  - Reducing food related hazards
  - The need to ensure product safety and Quality

• **Others**
  - Changing eating habits
  - Creating a greater choice
  - Changing lifestyles
  - Extend geographic markets
  - Improving the presentation
  - Development of other packaging technologies
  - Use of centralized production and distribution facilities
Shelf - Life

- **Shelf life** is that length of **time** that **food**, **drink**, **medicine** and other perishable items are given before they are considered unsuitable for sale or **consumption**.
- As discussed in slides 6 – 23 in this presentation, shelf life of the products is influenced by Intrinsic and Extrinsic factors.
- These factors determine the growth of spoilage/Food poisoning micro organisms.
The rate at which food spoilage sets in depends on these factors:

- The physical structure and properties of the food itself.
- The type of micro-organisms present.
- The environment in which the food is kept.
Ecological Determinants
Environmental conditions and stress

Composition
Intrinsic factors
Water relations
salts, sugars, pH
Preservatives
”Traditional”/”Natural”
(spices, herbs, enzymes)
Fat
Nutrients

Microbial interaction
Biotic factors
Microbiota
Positive and negative interaction in food systems

Processing
Disturbance
Heat treatment
Cleaning & Sanitation
High pressure
Non Thermal processing
Fumigation, smoke

Storage conditions
Extrinsic factors
Temperature, Humidity
Gas composition (CAS, MAP)
Other gases (CO, C2H4)
Active packaging
Packaging material (Permeability, Biobased)
Time

Product
Packaging
Transport and storage

020908A MAP
www.packagingconnections.com
The different type of microorganisms

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Yeast</th>
<th>Moulds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreads on contact</td>
<td>Spreads on contact</td>
<td></td>
</tr>
<tr>
<td>Spore formers are</td>
<td>Spore formers are</td>
<td></td>
</tr>
<tr>
<td>more resistant</td>
<td>more resistant</td>
<td></td>
</tr>
<tr>
<td>Growth demands</td>
<td>Growth demands</td>
<td></td>
</tr>
<tr>
<td>(high humidity,</td>
<td>(medium high</td>
<td></td>
</tr>
<tr>
<td>neutral pH)</td>
<td>humidity)</td>
<td></td>
</tr>
<tr>
<td>Sensitive to drying</td>
<td>Sensitive to drying</td>
<td></td>
</tr>
<tr>
<td>out</td>
<td>out</td>
<td></td>
</tr>
<tr>
<td>Forms biofilm</td>
<td>Forms biofilm</td>
<td></td>
</tr>
</tbody>
</table>

**Moulds**

**Mycelium**
Not spread by contact
Limited resistance
Sensitive to drying out

**Conidia**
Hydrophobicity varies
Spread by air and dust

**Ascosporer**
Very resistant to heat and drying out
“Spores can be activated and start swelling and germination, when environmental conditions becomes favorable”
Food Ecology: All food products have their own specific group of microorganisms associate to them – The Microbiota

Spoilage

Fermentation
Successful packaging concepts

Milk stored in calf's stomach
Olives in brine
Herring in brine
Grass or corn in piles

Cheese
Fermentation - safe

Mummification (2.500 BC)

Air tight
Antimicrobial spices and herbs
Resins (myrrh)
Palm vine

Whisky maturation
What is MAP?
Background

• The first major commercial application of MAP took place in 1974, by a French company SCOPA started selling MAP meat.
• Was pioneered by Marks & Spencer in the late 1970’s.
• Was in use in every major UK supermarket by the late 1980’s.
• Since 1997 must be declared on the pack by the phrase “packed in a protective atmosphere”
MAP is a form of food packaging where the earth’s normal breathable atmosphere has been modified in some way to prolong a foods shelf life.

This can be done in two ways:

- By creating a vacuum in the package (VP) - where there is almost a complete absence of gas.
- VP would be considered a modified atmosphere package within this definition.

- By using special films to allow naturally respiring produce to form its own atmosphere without the addition of external gases.
MAP

Impermeable Package

Permeable Film
Types of modified gas packaging

- MAP - Modified Atmospheric Packaging
- CAP - Controlled Atmospheric Packaging
- VP - Vacuum Packaging
- VSP - Vacuum skin packaging
- GP/GF - Gas packaging/Gas Flushing
- EMA - Equilibrium modified atmosphere
Packaging Gases

- Normal Atmospheric levels

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>O₂</td>
<td>21%</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.03%</td>
</tr>
<tr>
<td>N₂</td>
<td>78%</td>
</tr>
<tr>
<td>Ar</td>
<td>1%</td>
</tr>
</tbody>
</table>

- The O₂, CO₂, N₂ are the major gases used in MAP
- Other tried include: SO₂, N₂O, NO, O₃, He, H₂, Ne, Ar etc
Gas Composition within the pack

- This is unlikely to remain constant through the shelf life of the product because:
  - Physical interaction between gas and product
  - Effects of microbial and product metabolism
  - Gas permeation through the packaging material
Interaction between gas and product

• Dissolving of the gases into the food
  – Mainly CO₂ into the aqueous and fat phases of the food
• Trapped gases (e.g. between slices) can be released into pack
• Gases dissolved in the food may be released into pack atmosphere
Effects of microbial and product metabolism

- Conversion of \( \text{O}_2 \) to \( \text{CO}_2 \) by respiration of microorganisms or tissues of food.
- \( \text{O}_2 \) levels deplete
- \( \text{CO}_2 \) levels rise
- Atmosphere becomes anaerobic
  - This can cause serious problems
Gas permeation through the packaging

• No pack is a perfect barrier
• All films are permeable to a greater or lesser extent
• Permeability depends on:
  – Nature of gas
  – Structure and thickness of material
  – Temperature
  – Relative humidity for some materials
  – Partial pressures

• A **Optimal Modified Atmosphere** can be achieved by considering all the above factors
Modified Atmospheres Involves

- Reduced oxygen
- Increased carbon dioxide
- Removing carbon dioxide
- Removing ethylene and other volatiles
- Degree of precision differentiates MA
Modified Atmospheres
Potential Benefits

• Retards senescence (aging) or ripening by
  – Reducing respiration rate
  – Reducing ethylene production
• Reduces ethylene sensitivity
• Alleviates certain physiological disorders
• May reduce decay either indirectly or directly
• Insect control
## Typical Modified Atmospheres

<table>
<thead>
<tr>
<th>Product</th>
<th>$O_2(%)$</th>
<th>$CO_2(%)$</th>
<th>$N_2(%)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Meat</td>
<td>80</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>White Meat &amp; Pasta</td>
<td>30</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>Low fat white fish &amp; Shellfish</td>
<td>30</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Produce</td>
<td>5</td>
<td>5</td>
<td>90</td>
</tr>
<tr>
<td>Hard Cheeses</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Baked goods</td>
<td></td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>
How to MAP?
MAP

• There are two major types of MAP
  - Passive
  - Active
Passive MAP
Passive MAP

• The produce is sealed within the pack with pack flushed with required gas mix or with no modification to the atmosphere. Subsequent respiration of the produce and the gas permeability of the packaging allow an equilibrium - modified atmosphere to be reached.

• Passive MAP is also called Equilibrium modified atmospheric packaging.
Passive MAP

- Lower $O_2$ concentrations → To reduce Respiration Rate
- Increase $CO_2$ concentration → To prevent microbial growth
- Maintain high RH → To avoid dehydration
Gases used for MAP

- Oxygen (O₂)
  - Preserves colour of meat
  - Respiration/growth rate
  - Composition of flora

- Nitrogen (N₂)
  - No antimicrobial effect
  - No colour effect
  - Insoluble, prevents collapse

- Carbon dioxide (CO₂)
  - Antimicrobial effect
  - Composition of microbiota (flora)
Package Design

Parameters to be considered while designing the pack

• Produce Physiological requirement.
• Optimal modified atmosphere
• Polymer engineering
• Converting/filling machine requirements
• Marketing / consumer requirements
• Environmental safety
Produce Physiology Requirement

- Produce Type
- Desired shelf life
- Respiration rate
- Temperature
- Growing region
- Pre harvest Conditions
- Post harvest Conditions
Physiological Calculation

- \[ OTR = RR_{O_2} \times t \times \frac{W}{A} \times (O_{2\text{atm}} - O_{2\text{pkg}}) \]

Where
- \( RR \): Respiration Rate of \( O_2 \) (Oxygen consumption)
- \( t \): Thickness of film (mils)
- \( W \): Product weight (Kgs)
- \( A \): Film surface area
- \( O_{2\text{pkg}} \): Desired \( O_2 \) concentration in the package (\( O_2 \) Target atmosphere)
Polymer Engineering Requirements

- Target OTR
- Package Dimensions
- Package style
- Product Weight
- Stiffness
- Optics
Atmospheric Modification
Polymeric Film Packages

• Film permeability
  – Type, thickness, surface area of film, ventilation
• Commodity respiration rate
  – Type, maturity, quantity, temperature
• Other factors
  – Initial free volume, initial atmospheric
• Composition and external environment
• The physical properties of machinability and strength
• Integrity of closure (Heat sealing), fogging of the film as a result of product respiration
• Printability
Packaging Material Properties

- WVTR
- OTR
- Heat Sealability
- Transparency
- Thermoformability
### WVTR and OTR of films

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Material</th>
<th>OTR*</th>
<th>WVTR**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EVOH***</td>
<td>0.16 – 1.6</td>
<td>24 -120</td>
</tr>
<tr>
<td>2</td>
<td>PVdC</td>
<td>1.2 – 9.2</td>
<td>0.8 – 3.2</td>
</tr>
<tr>
<td>3</td>
<td>Nylon 6***</td>
<td>80</td>
<td>200</td>
</tr>
<tr>
<td>4</td>
<td>PET</td>
<td>50 – 100</td>
<td>20 – 30</td>
</tr>
<tr>
<td>5</td>
<td>PCTFE(Aclar)</td>
<td>110 – 230</td>
<td>0.4 – 0.7</td>
</tr>
<tr>
<td>6</td>
<td>HDPE</td>
<td>2100</td>
<td>6 – 8</td>
</tr>
<tr>
<td>7</td>
<td>PS</td>
<td>2500 – 5000</td>
<td>110 – 160</td>
</tr>
<tr>
<td>8</td>
<td>PP</td>
<td>3000</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>PC</td>
<td>4300</td>
<td>180</td>
</tr>
<tr>
<td>10</td>
<td>LDPE</td>
<td>7100</td>
<td>16 – 24</td>
</tr>
<tr>
<td>11</td>
<td>EVA</td>
<td>12000</td>
<td>110 – 160</td>
</tr>
</tbody>
</table>

*Units : cc/m².d.atm 230 C: dry  
**Units : g/m².d.38 0C 90% r.h.  
*** Water Sensitive
Factors affecting permeability

- Pressure
- Temperature
- The nature of gas
- Nature of film
# Gas Permeability

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Material (25 mic.)</th>
<th>O₂</th>
<th>N₂</th>
<th>CO₂</th>
<th>PO₂/PN₂</th>
<th>PCO₂/PN₂</th>
<th>PCO₂/PO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PVdC</td>
<td>10</td>
<td>2.1</td>
<td>53</td>
<td>5.0</td>
<td>25</td>
<td>5.0</td>
</tr>
<tr>
<td>2</td>
<td>PET</td>
<td>79</td>
<td>16</td>
<td>240</td>
<td>5.0</td>
<td>15</td>
<td>3.0</td>
</tr>
<tr>
<td>3</td>
<td>PVC</td>
<td>180</td>
<td>79</td>
<td>760</td>
<td>2.4</td>
<td>9.7</td>
<td>4.1</td>
</tr>
<tr>
<td>4</td>
<td>Nylon 6</td>
<td>240</td>
<td>66</td>
<td>1600</td>
<td>3.6</td>
<td>24</td>
<td>6.7</td>
</tr>
<tr>
<td>5</td>
<td>HDPE</td>
<td>1840</td>
<td>70</td>
<td>7900</td>
<td>3.9</td>
<td>6.7</td>
<td>4.3</td>
</tr>
<tr>
<td>6</td>
<td>LDPE</td>
<td>8900</td>
<td>3160</td>
<td>44700</td>
<td>2.8</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>PP</td>
<td>3200</td>
<td>950</td>
<td>7900</td>
<td>3.3</td>
<td>8.3</td>
<td>2.5</td>
</tr>
<tr>
<td>8</td>
<td>PS</td>
<td>4500</td>
<td>1050</td>
<td>31600</td>
<td>4.3</td>
<td>30</td>
<td>7</td>
</tr>
</tbody>
</table>

The gas permeability of gases are \( \text{CO}_2 > \text{O}_2 > \text{N}_2 \)

\( \text{PCO}_2/\text{PO}_2 \) and \( \text{PO}_2/\text{PN}_2 \) are usually approx. 5. So it is often possible to estimate the permeability of a material to \( \text{CO}_2 \) or \( \text{N}_2 \) when permeability to \( \text{O}_2 \) is know
## Structures

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Structure</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Monolayer Films</td>
<td>One resin one film (single layer)</td>
</tr>
<tr>
<td>2.</td>
<td>Engineered Blended Mono Films <em>(fig. 1)</em></td>
<td>Different resins blended together to produce one mono-layer film</td>
</tr>
<tr>
<td>3.</td>
<td>Laminations <em>(fig. 2)</em></td>
<td>Different film layers are joined together with some type of adhesive or molten polymer</td>
</tr>
<tr>
<td>4.</td>
<td>Co-extrusion <em>(fig. 3)</em></td>
<td>Multiple film layers are incorporated into a single structure during the manufacturing process to produce one film.</td>
</tr>
</tbody>
</table>

To provide packaging films with wide range of physical properties, many of these individual films are combined through processes like lamination and co – extrusion.
Packaging Calculation

\[
\text{OTR} = \frac{1}{\frac{t_1}{\text{OTR}_1} + \frac{t_2}{\text{OTR}_2} + \frac{t_3}{\text{OTR}_3}}
\]

t: thickness

OTR: Oxygen Transmission rate
Package Style

- Flexible Packaging - Pouches
- Semi – rigid lidded tray
- Rigid lidded tray
Commercial Use of MAP for Fresh Produce

- Oriented polypropylene (OPP) Films
- Bag in box films or film-laminated boxes
- Cling films
- Temperature-responsive films
- Microperforated films
- Microperforated Patch
- Activated earth films
- PLA films (polylactic acid)
MAP Packaging Material

- Thermoform Base web
  - 200μ UPVC/70μ LDPE
  - 400μ UPVC/100μ LDPE
  - 650μ UPVC/100μ LDPE
  - 400μ APET/100μ LDPE
  - 300μ Barex/100μ LDPE
- In addition to these, some specifications based on polystyrene/ EVOH/LDPE and smaller percentages of APET/EVOH/PE

- Lidding laminate
  - 15μ polyester-PVdC/60μ LDPE/ antifog coating
  - 12μ polyester-PVdC/ co-extruded polyethylene
  - 15μ oriented PA (nylon)/ 60μ LDPE
  - 21μ coated co-extruded PP/50μ LDPE

Note: The potential list is extensive, but this is an indication of the range of specifications available.
MAP Packaging Material

• Preformed trays
  - APET, CPET, UPVC or HDPE based specifications

• Lidding lamination
  - 15μ polyester-PVdC/60μ LDPE/antifog coating
  - 12μ polyester-PVdC/ co-extruded polyethylene
  - 15μ oriented PA (nylon)/ 60μ LDPE
  - 21μ coated co-extruded PP/50μ LDPE

Note: The potential list is extensive, but this is an indication of the range of specifications available.
MAP PACKAGING

Barrier Shrink Films
CRYOVAC BDF®
MAP tray overwrap
Traditional quality

Barrier Shrink Films
Cryovac Lidys®
MAP tray lidding
Transparent & fresh

Barrier Shrink Films
Cryovac Slicepak® Plus
Highly differentiated
merchandising

Shrink Barrier Bags
Cryovac TBG®
Bonegard protection
and tenderness
Semi rigid Trays

Barrier shrink lidding part
Permeable shrink sealant part
Leak proof sealing area
Vacuum and gas re-injection
Barrier liner
Expanded polystyrene layer

Gap between the two films is filled by the MAP, which provides high oxygen pressure also in the meat-to-film contact areas, and hence no meat discolouration.

Shrink lidding film
Leak-proof seal area
Barrier liner
Modified atmosphere
Expanded polystyrene tray
Rigid Trays
# MAP Packaging Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
<th>Structures</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyolefins</td>
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<td></td>
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<tr>
<td>LDPE</td>
<td>Low WVTR, High OTR</td>
<td>Laminates, extrusion coated, Co – extrusion</td>
<td>Lidding, Base Webs, trays</td>
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<tr>
<td>LLDPE</td>
<td>Good impact , tear, tensile, puncture</td>
<td>Laminates, extrusion coated, Co – extrusion</td>
<td>Lidding, Base web</td>
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<tr>
<td>HDPE</td>
<td>Superior barrier properties than above</td>
<td>Co – extrusion</td>
<td>Lidding</td>
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<tr>
<td>OPP</td>
<td>Low WVTR, Low OTR</td>
<td>Co – extrusion</td>
<td>Lidding</td>
</tr>
<tr>
<td>COPP</td>
<td>Low WVTR, Low OTR</td>
<td>Laminated, co extrusion, perforation</td>
<td>Lidding, breathable films</td>
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<tr>
<td>Inomers</td>
<td>High Tack, similar to LDPE</td>
<td>Co – extrusion</td>
<td>Lidding</td>
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<tr>
<td>Vinyl</td>
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<td>Polymer</td>
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<tr>
<td>EVA</td>
<td>High WVTR &amp; OTR (higher than LDPE)</td>
<td>Laminates, extrusion coated, Co – extrusion</td>
<td>Lidding, Base Webs, trays</td>
</tr>
<tr>
<td>PVC</td>
<td>Good gas barrier, moderate O$_2$ barrier</td>
<td>Milled and calendared</td>
<td>Thermoformed Trays</td>
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<tr>
<td>PVdC</td>
<td>Outstanding Barrier properties</td>
<td>Extrusion coated, Co – extrusion</td>
<td>Lidding</td>
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<tr>
<td>EVOH</td>
<td>Very high gas barrier, moisture sensitive</td>
<td>Co – extrusion, laminates</td>
<td>Base webs, lidding</td>
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<tr>
<td>Styrene</td>
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<tr>
<td>HIPS</td>
<td>High tensile, low barrier prop.</td>
<td>Laminate, Co - extrusion</td>
<td>Thermoformed Trays</td>
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<tr>
<td>Polyamide</td>
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<tr>
<td>Nylon -6</td>
<td>Good barrier</td>
<td>Laminates, extrusion coated</td>
<td>Lidding</td>
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<td>Polyesters</td>
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<td>PET</td>
<td>High Clarity</td>
<td>Lamintes, sheet</td>
<td>Lidding, Therformed trays(APET)</td>
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<td>Others</td>
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<td>PC</td>
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<td>Thermoformed Trays</td>
</tr>
<tr>
<td>ABS</td>
<td></td>
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</tr>
</tbody>
</table>
Selective films toward gases
\((O_2 \text{ et } CO_2)\)
Passive MAP

- MAP to change gas composition to reduce respiratory activity of fresh fruits and vegetables.

Ethylene remover

Film Bag
Types of Passive MAP
Active MAP
Active MAP

• When packaging performs an additional role, other than just exhibiting itself as an inert barrier to external influences.
• The concept of active packaging has been developed to correct the deficiencies in passive MAP.
Active MAP

- **Oxygen scavengers**
  - Iron powder oxidation
  - Sachets or labels
  - Ageless (Mitsubishi GC)
  - Freshilizer (Toppan)
- Extends shelf-life
- Reduces need for
- Extremely low $O_2$ in MAP
  - Increased line speed
- No study and application with fresh fruits and vegetables


O₂ scavengers

- Reagents: Iron, enzyme (glucose oxidase), ascorbic acid.
- Applications: Meat, bakery products

**LDPE (Low density polyethylene, thickness= 50μm)**

**Gas permeability**

**Vegetable (tomatoes / endive)**

**Respiration rate**

**O₂ Absorption Kinetics**

- Fe → Fe²⁺ + 2e⁻
- \( \frac{1}{2} \text{O}_2 + \text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{OH}^- \)
- Fe²⁺ + 2 OH⁻ → Fe(OH)₂
- Fe(OH)₂ + \( \frac{1}{4} \text{O}_2 + \frac{1}{2} \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3\text{O}_2 \)
Active MAP

- **CO₂ scavengers**
  - Reagents: Ca(OH)$_2$
  - To avoid packaging destruction
  - Applications: coffee

\[
\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}
\]

- **CO₂ emitters**
  - Reagents: ascorbic acid
  - To avoid food deterioration
  - Applications: meat, poultry, fish, cheese

CO₂ scavengers-ATCO®CO-450 (StandaIndustrie, France)
Active MAP

- **Moisture absorbers**
  - Reagents: Activated carbon, zeolite, silica gel, cellulose and derivatives
- To control excess moisture in packaged food
- To reduce water activity on the surface of food in order
- To prevent growth of moulds, yeast and spoilage bacteria.
- Applications: meat, fish, bakery products, fruits and vegetables
Active MAP

- **Ethylene scavengers**
  - Reagents: Potassium permanganate, Japanese oya, activated carbon
- To prevent too fast ripening and softening (climacteric fruits and vegetables)
- Applications: apple, banana, mango, kiwi, tomatoes, avocado, carrots

\[(12\text{KMnO}_4 + 3\text{CH}_2=\text{CH}_2 \rightarrow 12\text{MnO}_2 + 12\text{KOH} + 6\text{CO}_2)\]
Active MAP

• Gas flux
  – Reagents: N₂
• To reduce O₂ level
• Applications: Cut salads
• This system is expensive and needs high barrier film.
Sources of Nitrogen for MA

- Nitrogen is used to replace Oxygen
- Liquid nitrogen
- Pressure swing adsorption (PSA) separators
- Membrane separators (Generon, Permea)
Membrane Air Separator

Atmospheric Air

$\text{CO}_2, \text{O}_2$

$\text{N}_2$
“Freshness” indicator labels

- Storage temperature OK
- Modified atmosphere OK
- Product quality OK

Fresh

- Storage temperature too high
- Package leaking
- Product spoiled

Reject
ACTIVE MAP

- Antimicrobial packaging
  - Reagents: Organic acids (sorbic acid), spice and herb extracts, allylisothiocyanate, Ag-substituted zeolithe, ethanol, SO$_2$
- To reduce or delay growth of spoilage and pathogenic bacteria
- Applications: Meat, fish, bread, fruits and vegetables.

\[ \text{H}_2\text{O} + \text{Na}_2(\text{SO}_2-\text{O-SO}_2) \rightarrow \text{SO}_2 + 2\text{NaOH} \]
Active MAP

- Oxygen scavenging film
  - OS1000 from Cryovac
  - Activated by UV close to fill point
Smart Films

- Landec’s Intelimer Polymers

![Diagram showing Crystalline to Amorphous transition and permeability properties](image-url)
Time Temperature Indicators

• Function
  – Provides information on exceeding a temperature threshold or a cumulative time temp history
  – Informs that correct storage conditions have or have not been adhered to

• Benefits
  – Reassurance
  – Real information rather than implied fitness
  – Highlights problems and Reduces shrinkage
Influence of packaging conditions on the greening and browning of endive after 7 days of storage at 20°C

No MAP  Passive MAP  Active MAP (O₂ absorber)
MAP during Transport

- Storage room/transit vehicle:
- Degree of gas tightness
- Ventilation systems
- Atmosphere modification
Use of MA During Transport

- Within a retail or consumer package
- Polymeric film liner within a carton
- Within a plastic film cover for a pallet
- In a rail car
- In an inter modal container
- Within a refrigerated storage compartment aboard ship
MAP in Transportation

• Use of air-tight cold storage rooms
• 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
Advantages of MAP

• Potential shelf-life increase of 50-400%
• Extended transit time
• Active Inhibition of bacteria, mould and fungi and post harvest respiration.
• Reduces economic loss
• Products distributed over larger distances
• Provides higher quality product
• Easier separation of slices
• Improved presentation
• Little or no need for preservatives
Disadvantages of MAP

• Visible additional costs
• Temperature control necessary
• Different gas formulations required
• Special equipment and training
• Food safety concerns
• Increased pack volume
• Benefits lost when pack opened or leaks
• Not universally effective
• Atmospheric Maintenance
• Specialized training and equipment are necessary
• Different gas formulation required for each product type
Where to MAP
Products

- Raw meats
- Poultry
- Cooked and cured meats
- Fish and shellfish
- Dairy Products
- particularly cheeses
- Ready meals
- Fresh Pasta
- Bakery products
- Fruit and vegetables
- Snacks
- Dried Foods
- Liquid food and beverages
Let’s now see

Some examples
Fruits and Vegetables
Low O$_2$ Delays Ripening of Plums

Six Months Storage of Bartlett Pears

AIR 1% O$_2$ + 5% CO$_2$

5 weeks at 10°C
Low O₂ Retards Ripening of Partially Ripe Tomato Fruit

Delayed Ripening of Chili Peppers
Apricot- 4 days at 20 deg C

Strawberry- 3 days at 10 deg C
Lemon - 5 days at 20 deg C

Banana - 9 days at 20 deg C

Lychee - 3 days at 20 deg C

Parsnip - 9 days at 20 deg C
Pomegranate - 4 months at 6 deg C

Passion Fruit - 5 days at 20 deg C

Fig - 4 days at 20 deg C

Mango - 35 days at 20 deg C
Cantaloupe - 5 days at 20 deg C

Water Melon - 40 days at 20 deg C

Charentais - 5 days at 20 deg C

Honey Dew - 5 days at 20 deg C
Roccola - 5 days at 10 deg C
Coriander - 3 days at 10 deg C
Mint - 3 days at 10 deg C
Parsely - 7 days at 10 deg C
Okra - 5 days at 18 deg C
Green Onion - 3 days at 10 deg C
Leek - 3 days at 20 deg C
Cucumber - 3 days at 20 deg C
Dilli - 3 days at 10 deg C
Green Beans - 5 days at 10 deg C

Bell Pepper - 4 days at 20 deg C

Broccoli - 5 days at 10 deg C

Brussel - 7 days at 10 deg C
### Appendix I

#### Storage Conditions for Vegetables and Fruits

<table>
<thead>
<tr>
<th>Item</th>
<th>Temperature F</th>
<th>% Relative Humidity</th>
<th>Precooling Method</th>
<th>Storage Life Days</th>
<th>Ethylene sensitive</th>
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</thead>
<tbody>
<tr>
<td>Apples</td>
<td>30-40</td>
<td>90-95</td>
<td>R,F,H</td>
<td>90-240</td>
<td>Y</td>
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<td>Apricots</td>
<td>32</td>
<td>90-95</td>
<td>R,H</td>
<td>7-14</td>
<td>Y</td>
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<tr>
<td>Asparagus</td>
<td>32-36</td>
<td>95-100</td>
<td>H,I</td>
<td>14-21</td>
<td>Y</td>
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<tr>
<td>Avocados</td>
<td>40-65</td>
<td>85-90</td>
<td></td>
<td>14-28</td>
<td>Y</td>
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<td>Bananas</td>
<td>56-68</td>
<td>90-95</td>
<td></td>
<td>7-28</td>
<td>Y</td>
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<td>Beans, snap</td>
<td>40-46</td>
<td>95</td>
<td>R,F,H</td>
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<tr>
<td>Beans, lima</td>
<td>37-41</td>
<td>95</td>
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<td>Beets, root</td>
<td>32</td>
<td>98-100</td>
<td>R</td>
<td>90-150</td>
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<tr>
<td>Blackberries</td>
<td>31-32</td>
<td>90-95</td>
<td>R,F</td>
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<td>Blueberries</td>
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<td>R,F</td>
<td>10-18</td>
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<tr>
<td>Broccoli</td>
<td>32</td>
<td>95-100</td>
<td>I,F,H</td>
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<td>Brussels sprouts</td>
<td>32</td>
<td>95-100</td>
<td>H,V,I</td>
<td>21-35</td>
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<tr>
<td>Cabbage</td>
<td>32</td>
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<td>R,F</td>
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<tr>
<td>Cantaloupe</td>
<td>36-41</td>
<td>95</td>
<td>H,F</td>
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<td>Carrots, topped</td>
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<td>98-100</td>
<td>I,R</td>
<td>28-180</td>
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<td>Cauliflower</td>
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<td>90-98</td>
<td>H,V</td>
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<td>Celery</td>
<td>32</td>
<td>98-100</td>
<td>I</td>
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<td>Cherries, sweet</td>
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<td>90-95</td>
<td>H,F</td>
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<td>Corn, sweet</td>
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<td>H,I</td>
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<td>Cranberries</td>
<td>36-40</td>
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<td>Cucumbers</td>
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<td>E,H</td>
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### Storage Conditions for Vegetables and Fruits

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Temperature F</th>
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<th>Precooling Method</th>
<th>Storage Life Days</th>
<th>Ethylene sensitive</th>
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<td>Limes</td>
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<td>F,R,H</td>
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<td>Peas, in pods</td>
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<td>F,H,I</td>
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<td>Y</td>
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<td>Peppers, bell</td>
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<td>90-95</td>
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<td>Peppers, hot</td>
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<td>50-70</td>
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<td>Pineapple</td>
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<td>Plums</td>
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<td>90-95</td>
<td>F,H</td>
<td>14-25</td>
<td>Y</td>
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<td>90</td>
<td>R,F</td>
<td>55-140</td>
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<td>90</td>
<td>R,F</td>
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<td>R</td>
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<td>R,F</td>
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<td>Sweet potatoes</td>
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<td>N</td>
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<td>62-66</td>
<td>90-95</td>
<td>R,F</td>
<td>7-26</td>
<td>Y</td>
</tr>
<tr>
<td>Turnips</td>
<td>32</td>
<td>95</td>
<td>R,H,V,I</td>
<td>120-150</td>
<td></td>
</tr>
<tr>
<td>Watermelon</td>
<td>50-60</td>
<td>90</td>
<td></td>
<td>14-21</td>
<td></td>
</tr>
</tbody>
</table>

**F=** forced-air cooling, **H=** hydrocooling, **P=** package icing, **R=** room cooling, **V=** vacuum cooling, **N=** no precooling needed

Sources: USDA Agricultural Marketing Service, Kansas State University Cooperative Extension Service
Meat, Poultry and fish
Case Study
Studies Conducted at IIP

• Shelf-life studies of some meat and meat products, poultry and poultry products were carried out at the IIP Institute for development of consumer packaging systems using the MAP Technology.

• The following products were considered for developing consumer packs:
  - Chilled goat meat
  - Chilled beef
  - Whole dressed chicken
  - Pig meat - Ham
Packaging Material and gas combination

- The packaging materials selected were:
  - 10μ PET / 45μ HD – LD - Co-extruded
  - LDPE – BA – Nylon – BA – LLDPE – 100μ
- The types of packages exposed were:
  - Ordinary pack
  - Vacuum pack
  - Gas packaging (MAP) using following gas mixtures
    - 80% O2 + 20% CO2 (gas I)
    - 70% O2 + 20% CO2 + 10% N2 (gas II)
    - 50% N2 + 50% CO2 (gas III)
    - 100% CO2 (gas IV)
- The consumer packages were exposed to refrigerated temperature of 0°C to 4°C.
Gas Mixtures used

- Gas mixtures I & II were used for packing chilled goat meat and chilled beef while gas.
- Mixtures III & IV were used for packing whole dressed chicken. Gas mixture IV was used.
- For packaging ham samples. The shelf-life of the meat and meat products in the different types of pack is given in the Table below.
Shelf-life of the Meat and Meat Products in Different Types of Packs (in days)

<table>
<thead>
<tr>
<th>Material</th>
<th>Chilled Goat</th>
<th>Chilled Beef</th>
<th>Whole Dressed Chicken</th>
<th>Ham</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ordinary Pack</td>
<td>Vacuum Pack</td>
<td>Gas I &amp; GasII</td>
<td></td>
</tr>
<tr>
<td>10μ PET/45μ HD - LD Co - extruded</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>9</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>28</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>LDPE - BA - NYLON - BA - LLDPE-100μ</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>28</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>
Seafood
Fish
Meat & Poultry
Dairy Products
MAP

Machinery

www.packagingconnections.com
Converting Requirements

- Dimensions
- COF
- Construction Type
- Anti Fog
- Seal Type
- Stiffness
- Re-seal type
- Desired OTR
Filling Requirements

- Seal Type
- Filling: Manual or Automatic
- Sealing Conditions
- Differential COF
- Heat resistance differential
- Antifog
- Bulk or fractional pack
Machinery types

- There are 4 distinct methods of producing modified atmosphere packs
  - Flow wrapping
  - Vertical form-fill-seal
- Above 2 with atmosphere change by displacement
  - Thermoform-fill seal
  - Rigid pack fill and seal
- Above 2 with atmosphere replacement by evacuation
- Choice of pack style/machine depends largely on the product to be packed
Horizontal Flow Wrap

• Flexible Materials
  - 15µ polyester-PVdC/60µ LDPE/antifog coating
  - 12µ polyester/ 38µ LDPE
  - 30µ co-extruded PP
  - 15µ/co-extruded PP/30µ LDPE
  - 28µ coated co-extruded PP

• Note: The potential list is extensive, but this is an indication of the range of specifications currently in use.
Horizontal Flow Wrap
Horizontal Flow Wrap

- Gas replacement by continuous flow of gas from a tube situated close to the seal area
- Typical products: hard cheese, baked products, produce.
- Speeds: typically 50-90 packs per min
- Manufacturers: Hayssen, Ilapak, Rose Forgrove, PFM
- Variations: bottom film feed, tear tape, reseal facility
Vertical form-fill-seal.

- Gas displacement from tube adjacent to the seal
Thermoform-fill-seal
Bulk gas packs

- Flexible Materials
- LDPE/PA (nylon)/LDPE
- PA (nylon)/ EVHOH/MDPE
- LDPE/EVOH/LDPE

- Note: The potential list is extensive, but this is an indication of the range of specifications currently in use.
Thermoform-fill-seal

• Gas replacement by evacuation within the vacuum chamber
• Typical products: meat, bacon, fish, cooked meats, pizza
• Speeds: from 5/min semi-auto to 80/min fully automatic
• Manufacturers: Multivac, Mecaplastic, etc
• Variations: several methods of reseal and special application packs
Rigid and bulk pack fill and seal

- Gas replacement by evacuation
- System used widely for “mother packs”
- Typical products: powders, meat, cuts, and products packed in rigid packs
- Speeds dependant on application
- Variations: packing of still drinks
Chicken : Master Pack Tote
Quality and Testing Requirements

- OTR specification and range
- COF specification and range
- Anti fog performance
- Physical properties
- Regulatory requirements
Marketing Requirements

- Appearance
- Construction
- Graphics
- Stiffness
- Economics
- Safety
- Environmental
MAP in practice
Regulations
USDA and FSIS

- FSIS is the USDA public health regulatory agency responsible for the administration of laws and regulations
- Under the Federal Meat Inspection Act (FMIA), FSIS is responsible for determining the efficacy and suitability of food ingredients and additives in meat products as well as prescribing safe conditions of use.
# FSIS Directive 7120.1

**Safe and Suitable Ingredients Used in the Production of Meat and Poultry Products**

## I. Purpose

This directive provides inspection program personnel with an up-to-date list of approved substances for use in the production of meat and poultry products.

## II. Reserved

## III. References

- 2 CFR Chapter III

<table>
<thead>
<tr>
<th>Substance</th>
<th>Purpose/Product</th>
<th>Amount</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide gas as part of the Packr modified atmosphere packaging system (ActivTech 2001)</td>
<td>Packaging fresh cuts of cage ready muscle meat and case ready ground meat to maintain wholesomeness, provide flexibility in distribution, and reduce shrinkage of the meat</td>
<td>The use of carbon monoxide (0.4 percent), carbon dioxide (30 percent) and nitrogen (69.6) as part of the Packr modified atmosphere packaging system (ActivTech 2001)</td>
<td>GRAS Notice 000063</td>
</tr>
</tbody>
</table>

FSIS Directive 7120.1
Attachment 1

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http://www.cfsan.fda.gov/guidance.html,
(Search for - Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (October 26, 1998) in Food and color additives category)
EU Directives

• MAP gases are classed as food additives under two Acts, the Directive of food additives (89/107/EEC) and the Directive of the use of food additives other than colours or sweeteners (95/2/EC).

• The main legislation covering the labelling, presentation and advertising of food is EU Directive 2001/13/EC, European Communities (Labelling, Presentation and Advertising of Foodstuffs) Regulations 2002 (SI 483/2002) and EU Directive 2003/89/EC.
EU Regulations

- [http://europa.eu.int/comm/food/fs/sc/scf/out112_en.pdf](http://europa.eu.int/comm/food/fs/sc/scf/out112_en.pdf)
Imagine again

Carbon Dioxide: 10%
Oxygen: ~0%
Nitrogen: 90%
Will anybody survive?
The answer is

Our food will!
Remember!
MAP

- Can
  - Increase Shelf life
  - Slow Microbial Growth
  - Maintain Nutritional Quality
  - Slow Browning

- Can’t
  - Sub for Temp Control
  - Stop Microbial Growth
  - Improve Quality
MAP is not a cure-all!

- It is not the answer to all food packaging problems
- MAP will generally benefit food and it’s acceptable shelf-life but this is also influenced by
  - the original quality of the food being packed
  - conditions under which the food is stored
- It does not mean temperature controls can be relaxed
- It must be used in conjunction with other preservation techniques
Conclusion

• For successful MAP we need
  - Thorough understanding of requirement and desired result
  - Matching requirements to properties.
  - Selecting the proper package
  - Designing the proper package
  - Quality and testing
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- [http://www.cfsan.fda.gov/guidance.html](http://www.cfsan.fda.gov/guidance.html)
- [www.iip-in.com/foodservice/24_modified.pdf](http://www.iip-in.com/foodservice/24_modified.pdf)
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