Abstract: To extend fresh meat shelf life, retailers have continued to search for an alternative to packaging of meat. There are various methods of packaging of meat. Increasingly, fresh meats are sold in high (70-80%) oxygen MAP, with 20-30% carbon dioxide (CO₂). Shelf life of PVC wrapped meats is only 5-7 days for steaks or roasts and less for ground meats. Vacuum packaged meats have been marketed successfully for years in many countries. However, the dark-purplish color of deoxymyoglobin in vacuum packaged retail beef has not been accepted by US consumers.

Keywords: meat; packaging; MAP; vacuum packaging; methods of packaging.
1. Introduction

Fresh meat requires presence of oxygen for maintaining color for consumer appeal. It has a shorter shelf life. Cured meats degrade in presence of oxygen. Two decisions are important while selecting packaging material i.e. shape or form and material. Selection of packaging material would depend on product factors such as color, stability, storage conditions, microbial condition, preservatives and degree of processing. Market factors which influence are distribution time/shelf-life, package size and cost, pre-market pricing and brand labeling need consideration. Processed products require more sophisticated and extensive packaging because they will be stored at higher temperatures for longer periods than refrigerated products.

2. History

Up to the early 1960’s - carcasses fabricated into primal or sub-primal and packaged in bags or paper. Late 1960’s to the present - carcasses fabricated into primal or sub-primal and placed in vacuum packaged bags; also the advent of modified atmosphere packaging. The 1980’s - the introduction of vacuum packaged or modified atmosphere packaged retail cuts (Table 1).

Table 1. Examples of some of the packaging used for meat products

<table>
<thead>
<tr>
<th>Product</th>
<th>Package form</th>
<th>Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh red meat</td>
<td>Overwrap films</td>
<td>Plasticized stretch PVC, EVA / LDPE stretch and shrink. PS or pulp Polyolefin-covered cellulose EVA/nylon/EVA with or without EVOH EVA/PVdC EVA LDPE</td>
<td>Treated with antifog agents</td>
</tr>
<tr>
<td></td>
<td>Trays</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drip pads</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Club(tube) packs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh fish</td>
<td>Overwrap</td>
<td>Ps pulp trays plasticized PVC wraps</td>
<td></td>
</tr>
<tr>
<td>Fresh poultry</td>
<td>Overwrap films</td>
<td>EVA/LDPE and PVC stretch/shrink</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trays, Bags</td>
<td>EVA and pulp.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shrink bags</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paper cartons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frozen</td>
<td>Shrink film</td>
<td>LDPE</td>
<td></td>
</tr>
</tbody>
</table>
### 3. Primary Functions of Packaging

- Protect against physical change.
- Protect against chemical change.
- Protect against microbes.
- Present the product to the consumer in an attractive manner.

### 4. Characteristics Affecting Packaging Requirements

- Color – The most important single factor affecting consumer acceptance.
- Moisture and gas – The vapor transmission rate (VTR) and oxygen transmission rate required...
(OTR) are to be kept in mind.

- Organoleptic characteristics must also be evaluated.
- Three types of packaging in general are used today i.e. overwrap, vacuum and atmospheric.

5. Advantages of Packaging to Industry and the Consumer

- Economy of scale (cutting and packaging carried out at a limited number of centralized locations).
- Transportation costs reduced.
- Better sanitation is achieved (increased shelf life).
- Better inventory and product control for retailer.
- Trim losses minimized: weight losses due to evaporation also minimized.
- Enhances palatability due to controlled aging.

6. Comparison of Fresh Meat Packaging Methods

Polyvinyl chloride (PVC) was discovered in the 1920s by rubber scientist Waldo Semon, who was hired by B. F. Goodrich to develop a synthetic rubber. After World War II, PVC was used in a number of commercial applications, including packaging of fresh meats. PVC film has relatively high oxygen permeability, which is advantageous because meat surfaces in contact with oxygen develop an attractive bright red color due to reaction with meat myoglobin and residual blood hemoglobin to form oxymyoglobin and oxyhemoglobin, respectively.

Another advantage of PVC packaging is that both the film and related equipment are relatively inexpensive and easy to use, allowing widespread use of this method in retail stores. PVC films are thin and easily heat-sealable but are highly susceptible to punctures and tearing, leading to a significant frequency of “leaky” packages. The greater disadvantage of PVC-wrapped meats, however, is susceptibility to browning due to meat pigment oxidation and formation of metmyoglobin. Shelf life of PVC wrapped meats is only 5-7 days for steaks or roasts and less for ground meats. When surface browning due to metmyoglobin exceeds 40%, retail meats typically are discounted or discarded (Greene et al., 1971). Brown discoloration can be avoided or minimized by vacuum packaging, which is an acceptable method for lightly pigmented cuts of pork and chicken. Vacuum packaged meats have been marketed successfully for years in many countries. However, the dark-purplish color of deoxymyoglobin in vacuum packaged retail beef has not been accepted by US consumers. It is important to note that the relatively rapid browning of PVC-wrapped meats is primarily due to the increased rate of myoglobin oxidation that occurs at low oxygen concentrations (George and Stratmann, 1952) which occurs at the limit of oxygen diffusion into meat in PVC packaging and is
visible as a brown sub-surface band. To prevent browning, meat package oxygen levels must be less than 0.15%. Oxygen levels of 0.15-2.0% predispose fresh beef products to browning.

The elevated oxygen levels used in high-oxygen MAP will delay browning of fresh meats, compared with PVC packaging, because the depth of the bright red surface oxymyoglobin layer is increased by 3-5 mm (MacDougall and Taylor, 1975). Faster bacterial growth is favored in PVC-wrapped meats compared with vacuum packaged meats (Seideman and Durland, 1983). Vacuum packaging lowers total plate count and favors lactobacilli, whereas pseudomonads usually dominate the spoilage microflora of PVC-wrapped meats (Pierson et al., 1970). It is recognized, however, that in PVC packaging, browning occurs due to oxygen stimulated metmyoglobin formation even while bacterial numbers are low. Dipping or injecting fresh meats with an antioxidant solution, typically containing 0.3% sodium tripolyphosphate and 500 ppm sodium ascorbate, reduces the rapid browning that occurs in meats that are still acceptable from a microbiological standpoint (Manu-Tawiah et al., 1991).

7. High-Oxygen Modified Atmosphere Packaging

To extend fresh meat shelf life, retailers have continued to search for an alternative to wrapping with PVC film. Increasingly, fresh meats are sold in high (70-80%) oxygen MAP, with 20-30% carbon dioxide (CO₂). Typically, co-extruded polyamide (nylon) - polyethylene films are used for high-oxygen MAP (Sørheim et al., 1999; John et al., 2005). The nylon provides strength, and the polyethylene provides gas and water vapour barrier properties and heat stability. Meats packaged in high oxygen MAP typically retain acceptable red color for 10-14 days of retail display, compared with 3-7 days for PVC packaged meats.

The MAP film is more puncture-resistant than PVC film, but the primary economic advantage of MAP is the additional 7-10 days of red color stability, allowing retail meat packaging to occur in large volumes at central packaging facilities. Retail packages are shipped to stores in a “case-ready” format for retail display. This allows supermarkets to offer retail fresh meat products at lower cost because the expense of in-store retail meat packaging is avoided (Cornforth, 1994). Air contains 78% nitrogen, 20.9% oxygen (O₂), 0.35% CO₂, water vapour, and traces of inert gases (Church, 1994). Compared with air, the elevated oxygen levels used in high-oxygen MAP saturate meat pigments with oxygen and slow surface metmyoglobin formation.

Carbon dioxide is included in MAP systems for its antimicrobial properties. Bacterial inhibition occurs with > 20% CO₂ in MAP systems (Luno et al., 2000). Australian processors were using CO₂ atmospheres to extend shelf life of fresh meat exports in the 1930s, but the process was replaced with freezing after World War II due to lower costs and longer shelf life. Disadvantages of
high-oxygen MAP include accelerated lipid oxidation and off-flavor development (Jayasingh et al., 2002), bone darkening of bone-in cuts and premature browning during cooking (Charles et al., 2001). Ground beef from high-oxygen MAP developed objectionable oxidized flavors upon cooking after as few as 6 days in an 80% oxygen environment. Oxidized (rancid) flavor development can be slowed by injecting whole muscle cuts with antioxidants, such as sodium tripolyphosphate or rosemary extracts, but at additional expense. However, no satisfactory antioxidant treatment is currently available for ground beef in high-oxygen MAP because non-meat ingredients are not permitted in product labelled “ground beef.”

8. Properties of Packaging Materials


B. Barrier properties versus permeability: (1) Barrier property is a measure of the resistance offered to a permeant - in meat, usually oxygen. The permeant is often the key element in preserving the product. (2) Classifications of barrier classifications for films. Permeability to oxygen (cc-mil/m\(^2\)-atm at 90% R.H. at 23 °C) barrier classification:

- >300 Low
- 300 to 500 Medium
- 50 to 10 High
- <10 Ultra High

Attention should be given to distinguishing between permeability and gas transmission rate to avoid misleading results.

Permeability = Thickness x Transmission Rate

\[(cc-mil/m^2-24h-atm at R.H. at {^\circ}C) (mil) \times (cc/m^2-24h-atm at R.H. at {^\circ}C)\]

9. Boxed Beef Concept

- Beef carcass is chilled 24 - 48 hrs.
- Primal & sub-primal cuts vacuum packaged.
- Shipment to distribution centres or retail markets is fabricated into retail cuts.
- Net advantage is space savings during storage and shipment.

10. Characteristics of Films Used in Vacuum Packaging Systems

- Oxygen transmission rate (OTR) cc/M2 /24 hr/mil.
- Moisture vapor transmission rate (MVTR) G/M2/24 hr/mil.
- Tensile strength — 1000 lb/sq. inch
- Shrink characteristics.

A. Outer layer: Provides resistance against abrasion and scuffing during processing and packaging operation. It must be resistant of temperature required to melt the sealant, yet with food product, it must be capable of being softened by heat for forming into a cavity. Typical materials include polyamides (nylon) or polyesters. In cook-in film, the outer layer is sometimes protected against heat by an additional outer layer of polypropylene.

B. Middle layer: Provides the barrier to gas permeation. Polyvinylidene chloride (PVDC), commonly known as Saran, ethylene vinyl alcohol (EVOH) are generally key components of high-barrier films.

C. Inner layer: Provides a hermetic seal by melting at moderate temperatures.

D. The sealants in common use are polyethylenes, ethylene vinyl acetates (EVA) and ionomers.

11. Packaging Options

A. Bags.
B. Laminates.
C. Casings.
D. Oxygen barrier.
E. Non-oxygen barrier.
F. Temperature characteristics: cook-in packaging.
G. Rigidity options: (1) flexible, (2) semi-rigid, and (3) rigid.
H. Aseptic packaging.

12. Atmosphere Options

A. Vacuum packaging.
B. Controlled atmosphere packaging.

Interest in CAP is because it can eliminate the purple color of vacuum packaged meat. Process by which a mixture of gases of defined composition is either flushed into a gas impermeable package containing meat or injected into a storage container in which meat packaged in a highly gas permeable and moisture impermeable film, such as PVC is being held.

1. Carbon dioxide - limits microbial growth.
3. Oxygen - to stabilize color, but will be conducive to microbial growth.
4. Advantages: (a) does not compact the product, (b) can use to maintain a more "bright,
cherry red” (fresh) color.

(5) Disadvantages: (a) Difficult to monitor - packaged meat is not a stable system. (i) Cellular metabolism continues to a degree within a fresh meat system - mitochondria are absorbing oxygen and producing carbon dioxide - muscle respiration, and (ii) Microorganisms are consuming oxygen and converting it to carbon dioxide. (b) Leakers are difficult to identify. (c) Usually does not increase shelf-life. (d) Larger package - package must be twice as large as the product to allow sufficient head-space for the gas. Result is twice the bulk.

(6) Common combinations of gases: (a) Flushing with 20% CO₂ (to inhibit spoilage bacteria growth) and 80% O₂ (for the development and maintenance of color) directly in the package with the use of an impermeable barrier material has been found to be very effective in extending shelf-life of fresh meat, mainly by maintaining the meat color (Hermansen, 1983). (b) Need at least 60% O₂ in the gas mixture to get color development, but recommended that higher levels used to maintain color, because meat will consume O₂. (c) Nitrogen is also used as a third option in combination. 100% nitrogen will result in brown discoloration.

13. Some Packaging Guidelines for Meat and Meat Products

A. Carcasses, sides, quarters, and primal cuts or combinations if intended to be delivered frozen will be: (1) Bagged in a paper bag and one stockinet, (2) completely wrapped in plastic and one stockinet, (3) completely wrapped with plastic or vacuum packaged and boxed.

B. Carcasses, sides, quarters, and primal cuts or combinations if intended to be delivered chilled, need not be wrapped or boxed unless otherwise specified by the purchaser.

C. Fabricated bone-in and boneless cuts; cured, smoked and dried meat; and edible by-products which are not individually packaged, should be packed into boxes completely lined with plastic bags. Product may be individually wrapped or layer packed with waxed paper or plastic material normally used for this purpose or vacuum packaged.

D. Bulk packaged trimmings and/or coarse ground products which are to be frozen and stockpiled, or are intended for further processing at a later date, should be packed into containers without the use of plastic liner bags. The containers shall be wax impregnated or the interior panels wax lined or plastic film laminated.

E. Bulk ground and diced meat items should be packaged in plastic bags or casings.

F. Filled bags or casings shall have practically all air pockets forced out through the open end and should be closed by metal or plastic clips, tying, or folding to completely cover the product.

G. Portion-cut products should be placed in fibreboard boxes lined with a plastic bag. The open end of the bag should overlap at the top to completely cover the product. Individual layers of
product should be completely separated with waxed paper or plastic material normally used for this purpose. Portion cuts may be individually vacuum packaged.

H. Patties should be packed in boxes completely lined with plastic bags. If stacked, then each patty will be separated by waxed patty paper.

I. Patties which are individually quick frozen (IQF) should be packed in fibreboard boxes lined with a plastic bag.

J. Products such as frankfurters, sliced bacon, sliced dried beef, linked or bulk pork or breakfast sausage, etc., should be packaged and placed in refrigerating containers.

K. Liver and cured product in pickle solution or brine may be vacuum-packaged and placed directly into fibreboard boxes or put in plastic bags and then packed into fibreboard boxes completely lined with appropriate moisture-proof plastic bags.

14. Guidelines for Modified Atmosphere Packaging

- High quality fresh meat should be used for MAP.
- Only relatively high oxygen transmission rate films should be used.
- The gases should be at least 70% CO₂ with the balance N₂ and O₂.
- Product should be chilled to 2.2 °C (28 F) and shipped soon.
- Products should be stored under good refrigerated conditions.

15. Conclusions

Low-oxygen packaging of fresh meat with CO improves red color stability compared with meats in high-oxygen MAP or PVC. Flavor is improved (less oxidized flavor) for meat in low CO compared to high-oxygen MAP. Premature browning (a food safety issue) during cooking occurs nearly 100% of the time in meat packaged in high-oxygen MAP and to a lesser extent in PVC wrapped meats at longer storage times. This phenomenon does not occur in meats packaged in CO-MAP or vacuum. Risk of CO toxicity from the packaging process or from consumption of CO treated meats is negligible. Red color can be maintained in low-CO treated meats that have spoiled, emphasizing the need for adherence to label instructions for product shelf life and the use of odor and overall appearance as spoilage indicators. Both MAP methods (high-oxygen and low-CO) are inhibitory to growth of spoilage and pathogenic bacteria during refrigerated storage compared with meats wrapped in PVC. Due to the residual effect of CO₂ treatment to inhibit bacterial growth even after removal from packaging or when storage temperature is raised (Silliker et al., 1977a,b), fresh meats in MAP containing CO₂ or CO₂ + CO would have less growth of spoilage and pathogenic microorganisms than meats in PVC packaging, if temperature control was temporarily lost during distribution. Overall,
inclusion of CO as a component of MAP systems has both advantages and disadvantages that must be thoroughly considered to develop a packaging technology benefiting both consumers and the meat industry.

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