Retail Packaging Systems for Fresh Red Meat Cuts

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Economic and Marketing Factors

In order to evaluate present and future retail packaging systems, it is necessary to review past fresh red meat (FRM) packaging systems. Prior to 1967, whole beef carcass shipments were traditionally made to retail outlets where carcasses were fabricated into retail items by butchers in individual stores. The "boxed beef" concept was introduced in 1967, dramatically changing beef processing, distribution and retail fabrication, without affecting retail presentation to the consumer. The basis for the boxed beef concept was vacuum packaging in oxygen barrier materials. Vacuum packaging provided a method of prolonging the shelf life and palatability of beef during extended periods of shipment and storage (Seideman and Durland, 1983) over conventional whole carcass distribution.

Presently, beef carcasses are fabricated into primal or sub-primal cuts, vacuum packaged and boxed. Vacuum-packaged boxed beef is then distributed to retail outlets where these primals and subprimals are fabricated into consumer units, overwrapped in oxygen-permeable film on polystyrene foam trays and displayed for sale.

Boxed beef developed rapidly and changed beef distribution dramatically in the United States. In addition to beef, vacuum-packaged boxed pork and lamb followed in the 1970's (Breidenstein, 1982; Terlizzi, 1982). In 1986, approximately 84% of all beef processed in the U.S.A. is vacuum packaged.

Currently, vacuum packaging is the standard method of packaging FRM for wholesale and institutional markets. Investigations into new, improved and more cost-effective packaging systems are currently being explored. Additionally, new systems for retail packaging of FRM are requiring interest at the packer level. These changes will require the adaptation of centrally pre-packaged FRM consumer units.

Fresh red meat is one of the few major food products processed and re-packaged at the retail level. It is costly for retail outlets to equip, maintain and staff complete butcher areas. Small in-store volumes, coupled with increasing equipment and labor costs, will promote changes to central prepackaging where personnel, equipment, material costs and quality can be more efficiently controlled.

One of the first centrally prepackaged meat products was sliced luncheon meats, in the 1950's and 1960's. Later, consumers in the 1970's became accustomed to chub-packaged fresh ground beef. Other prepackaged FRM items have slowly entered the marketplace on a very small scale. Only a few FRM processors had begun to market central prepackaged fresh meats, through several diverse systems, in the mid 1980's.

Central prepackaging allows: 1) greater utilization of resources; 2) better quality control; 3) less waste through utilization of fat, bone and trimmings; 4) more efficient use of manpower and space; 5) improved profits (retailer and processor); 6) use of automated equipment; 7) more uniform products; and 8) better inventory control. Major concerns in central prepackaging are: labor union opposition; retail resistance to accept retail-ready meat; the lack of consumer acceptance of centrally-prepackaged fresh meat products; and the lack of consumer marketing expertise on the part of central packers. Nonetheless, the shift to central prepackaging appears to be beginning.

As retailers concentrate on merchandising, rather than further processing FRM items in the store, central prepackaging will become essential in providing a true case-ready product. The cost of in-store labor is a significant potential savings to store chains. The reduction of back store cutting area will allow increased display or storage space in the store chains, and further provide an impetus for the change to central pre-packaging.

Several reasons for this shift to central prepackaging include: 1) Meat is no longer the only major consideration for choosing a grocery store; 2) Store managers desire more control over the meat department; 3) Retailers desire that packers stand behind the quality of products and be responsible for advertising and promotions of their products; and 4) The poultry industry has been prepackaging centrally for several years, with significant success. The meat industry appears to be prepared to follow their lead in the late 1980's, with marketing programs in central prepackaging of retail fresh meat items.

Technical Factors

Muscle Color

In consideration of packaging systems for retail FRM units, muscle color is an important parameter which must be addressed. The color of fresh meat depends on the relative amounts of the three primary derivatives of myoglobin present at the muscle surface: reduced myoglobin (MB); oxymyoglobin (MBO2); and metmyoglobin (METMB). Reduced myoglobin (purple) is the predominant muscle color form in the absence of oxygen. MBO2 is the oxygenated form of the muscle pigment myoglobin, and is responsible for

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the bright red color of meat. Oxygen (in air or in modified/controlled atmospheres) exposed to the myoglobin molecule normally results in MBO2 formation at the muscle surface. MBO2 or MB may be oxidized to METMB (brown color) in low oxygen pressures or from the oxidation of the iron heme in the myoglobin molecule (Seideman et al., 1984). METMB formation is influenced by a number of factors, and the reaction is normally reversible to MBO2 and MB based on the oxidization/reduction potential and other factors (Clydesdale and Francis, 1971; Seideman et al., 1984).

On freshly-cut muscle surfaces, constant reversible conversions of MB to MBO2 to METMB occur at all oxygen pressures. Oxygen rapidly reacts with MB, MBO2 becomes abundant and METMB is normally minimal on the surface of fresh muscle exposed to atmospheric oxygen.

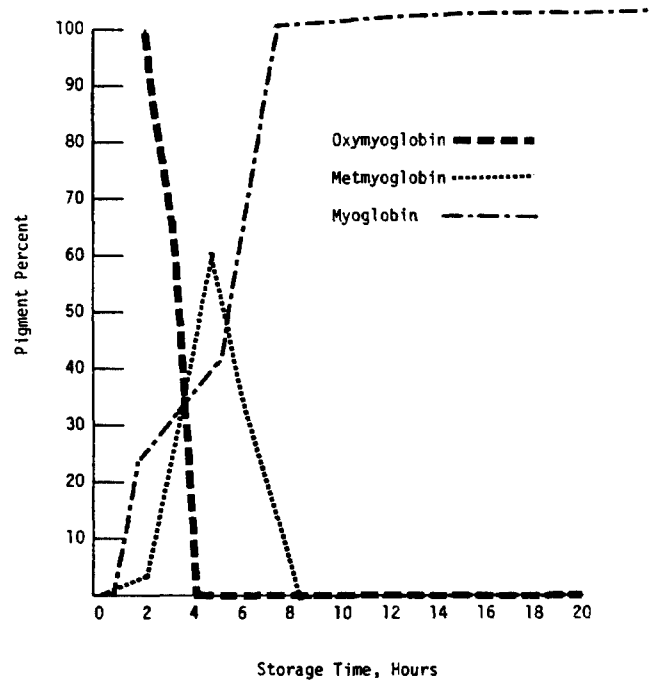
The reaction of MB at certain partial pressures of oxygen is of particular interest in retail fresh meat packaging. Low partial pressures of oxygen must be avoided to reduce METMB formation, with its unappealing brown color. Exposure to oxygen prior to packaging allows oxygen to attach to the surface of the muscle. Vacuumization removes oxygen from the package, but not necessarily from the muscle surface. Shortly after packaging, fresh meat may brown – a result of the lowered partial pressure of oxygen on the muscle surface. This brown color normally subsides after 1 to 8 hours after packaging. Ernst, (1980) noted that with excessive exposure to oxygen prior to vacuum packaging, certain muscles develop METMB immediately after packaging, which results in a temporary brown color. Pierson et al., (1970) observed this initial formation of METMB with a subsequent reduction to MB in a few hours after packaging. The peak of METMB concentration during this short time after packaging is correlated to the lowered pressure of oxygen in the package and on the surface of the muscle (Pierson et al., 1970; Seideman et al., 1984). Retail packaging of fresh red meats should be accomplished within 15 minutes after slicing to minimize METMB formation.

Pierson et al., (1970) (Figure 1) described the transformation of MBO2 through METMB to MB in 0 to 20 hours after packaging. After the oxygen is utilized by muscle respiration or by microorganisms, the partial pressure drops further and METMB formation is no longer favored over MB formation. The characteristic purple color of muscle stored without oxygen is then evident after an approximate 8-hour period. In modified/controlled atmosphere packages, a similar METMB formation exists. When partial pressure of oxygen reaches a critical level, the formation of METMB can also be favored in these systems.

A decision must be made by the retailer or processor to determine the muscle color (oxygenated or non-oxygenated) to be marketed. There are several systems, involving modified atmospheres high in oxygen, which can enhance and improve the bright cherry-red beef color while vacuum packaging systems exclude oxygen, giving the fresh meat product a purple color.

Maintaining muscle in the oxymyoglobin state, using modified atmospheres, will provide normal bloomed color for a relatively short distribution period (8 to 14 days). After this period, deleterious oxidative rancidity, microbial and color changes diminish the acceptability of FRM. With vacuum

Figure 1



The Initial Pigment Changes at 3.3°C of Anaerobically Packaged Beef.

(Adapted from Pierson et al., 1970)

packaging, the muscle color can be suspended in the myoglobin (purple) state. Vacuum packaging can practically double the shelf life of FRM cuts in comparison to modified-atmosphere packaging. Considerable marketing research and education will be necessary to gain acceptance of either system.

Muscle pH

In mentioning muscle color, pH must be noted, since it can influence muscle color prior to and after packaging. Muscle pH can dramatically affect a microflora growth, and fresh muscle must be controlled or selected for pH in retail packaging systems. Meat pH over 6.0 is near the lower borderline for hydrogen sulfide-producing bacteria (Fernandez-Coll and Pierson 1985). Hydrogen sulfide production from bacteria may cause surface greening from sulfmyoglobin and choleglobin formation. Erichsen et al., (1981) and Hermansen, (1980) showed that on high pH meat, hydrogen sulfide bacteria were numerous, while with normal (5.6) pH meat, these bacteria were not significant. It has been documented that high pH meat spoils more rapidly than normal meat (Egan and Shay, 1984; Gill and Penney 1985; Hermansen 1980; Erichsen et al., 1981).

Oxidization of the myoglobin molecule in low-pH environments (less than pH 5.4) is promoted more rapidly than in normal pH situations (Brooks, 1937; Panda, 1979; Walters, 1975; Quartez-Papofio et al., 1980; Seideman et al., 1984). The oxidization of the MB molecule from low pH can also result in a more rapid discoloration of pre-packaged fresh meats.

Fresh meat for retail packaging should be in the normal pH range, and meat pH outside of the normal range should be avoided for retail packaging in central pre-packaging operations.

Vacuum or Gas Selection

The shelf life of meat can be greatly extended by vacuum packaging meat in flexible materials with low permeability. A primary purpose of vacuum packaging is to reduce the oxygen in the package, effectively eliminating the growth of aerobic bacteria. Anaerobic bacteria are then favored, especially the Lactobacilli species (Pierson et al., 1970). The growth of these lactic acid species suppresses the growth of many undesirable spoilage bacteria.

It has been discussed that carbon dioxide has been generated in vacuum packages, and that this generation may be responsible for bacterial inhibition (Enfors and Molin, 1984; Seideman and Durland, 1983). Enfors and Molin (1984) noted that carbon dioxide evolution may play an important role as a shelf-life promoting agent in vacuum-packaged fresh meat. However, the headspace in typical vacuum packages is very small in relation to the total surface area of the product. It is unlikely that this limited headspace with a minute volume of carbon dioxide is responsible for bacterial inhibition in vacuum-packaged fresh meat.

Nitrogen

According to Weast (1984), nitrogen is the most abundant (78% of total gas) component of atmospheric air, followed by oxygen (20.9%), others, and carbon dioxide (.03%). Nitrogen is primarily used as an inert filler to displace or dilute oxygen and to maintain a pillow pack to prevent package collapse from carbon dioxide absorption into the food. Nitrogen is not credited for anti-microbial effects, although it is more effective than air in this property.

Carbon Dioxide

The effect of carbon dioxide on spoilage bacteria has been well documented (Baron et al., 1970; Benedict et al., 1975; Clark and Lentz, 1969; Coyne, 1932; Enfors and Molin, 1984; Enfors et al., 1979; Kraft and Ayres, 1952; King and Nagel, 1965, 1967; Huffman, 1974; Huffman et al., 1975; Silliker and Wolf, 1980; Valley, 1928). These researchers identified the inhibitory effectiveness of carbon dioxide gas on bacterial growth characteristics under various storage conditions.

The application of carbon dioxide at the early stages of bacterial growth provides a greater extension of shelf life (Clark and Lentz, 1969). Therefore, for maximum shelf life extension, carbon dioxide should be used immediately after fabrication of the carcass, when bacterial counts are low.

Gram negative spoilage flora of refrigerated meat are especially sensitive to carbon dioxide, while lactic acid bacteria are less affected (Enfors and Molin, 1984; Grau, et al., 1985; Silliker and Wolf, 1980). The antagonistic properties of lactic acid bacteria may inhibit other carbon dioxide-resistant organisms (which have a more deleterious effect on the meat) and promote increased shelf life (Enfors et al., 1979).

Coyne (1932) postulated that carbon dioxide could act by altering bacterial cell permeability. Bacterial inhibition by carbon dioxide was determined to be part pH and part enzymatic inhibition (King and Nagel, 1967, 1975). Researchers reported that carbon dioxide increased shelf life primarily by lowering the pH of meat (King and Nagel, 1967 and 1975; Kraft and Ayres, 1952). However, Huffman et al., (1975) detected a 0.1 unit pH drop in carbon dioxide stored beef samples and suggested that this pH drop did not account for lowered bacterial counts alone. The present most logical explanation; suppression of bacterial enzymatic decarbozylation rates from carbon dioxide, particularly in high carbon dioxide concentrations, was also postulated by King and Nagel, (1967 and 1975).

Recent research with 15% carbon dioxide has shown microbial suppression (Bala et al., 1977; Bartkowski et al., 1982), while previous research showed that a carbon dioxide concentration of 20% has been found sufficient to prevent bacterial growth (Brooks, 1933; Clark and Lentz, 1969). This 20% concentration has been identified as the lower threshold of carbon dioxide to inhibit several spoilage microorganisms in present-day commercial applications.

An important note for modified atmospheres is that the use of high concentrations of carbon dioxide (over 20%) can cause a detrimental change in the color of beef (Clark and Lentz, 1969; Pahja, 1967; Ledward, 1970; Ogilvy and Ayres, 1951; O'Keefe et al., 1975; Silliker and Wolfe, 1980; Smith et al., 1977). It has been shown that carbon dioxide can decrease muscle pH. Since muscle MB is oxidized to METMB more rapidly at lower pH, it is likely that the reduced surface pH accelerates discoloration of carbon dioxide-flushed muscle. To inhibit the detrimental color change (METMB formation) in gas atmosphere packaging, Ledward (1970) recommended that the modified atmosphere contain 5% oxygen and the carbon dioxide concentration should be limited to 20%.

Oxygen

High concentrations of oxygen in packages can prolong the bright red color of meat during short-term storage (Bartkowski et al., 1982; Clark and Lentz, 1973). The use of oxygen in packaging systems is generally incorporated to improve the bright red color of fresh red meat. Used alone, oxygen (with or without a nitrogen filler) did not significantly inhibit microorganisms over air controls (Clark and Lentz, 1973).

Oxidative rancidity problems have been reported in beef stored in high-oxygen environments (Watts, 1954). This is one major reason that the shelf life of gas-flushed FRM is only 8 to 14 days, compared to 28 to 35 days with vacuum packaging.

Gas Mixtures

Optimum meat color and bacterial inhibition can be accomplished through mixtures of the three major gases (oxygen, carbon dioxide and nitrogen). Researchers have shown that oxygen and carbon dioxide mixtures have extended the keeping quality and preserved the bright red color of fresh meat (Clark and Lentz, 1973; Georgala and Davidson, 1970; Marriott et al., 1977; O'Keefe et al., 1975; Taylor and MacDougall, 1973).

Packaging Materials

Films and systems which provide necessary gas barrier properties, abuse resistance, sealability properties, consumer acceptability, minimize purge, have good product visibility and package optics and have good openability are important in retail packaging systems.

Oxygen transmission characteristics of packaging materials are affected by many factors, including material composition, temperature, and exposure to humidity (Eustace, 1981). Oxygen transmission rate characteristics are very important in any type of retail packaging system. Kraft and Ayres (1952) found that materials with higher oxygen permeabilities, which preserved the bright red color of meat in the early phases of storage, permitted the most rapid proliferation of microorganisms on the surface of the samples. In modified-atmosphere packaging, the permeability of the film may also influence the percentage of the modified gas over periods of time by allowing gaseous diffusion from the inside to the outside atmosphere or vice versa.

Lighting

The effect of lighting on the retail display of fresh meats is very important (Kropf, 1980; Klettner, 1984). Kropf (1980) reviewed the effects of several lighting sources on muscle color. Kroph's review detailed multiple effects of lighting, temperature, storage time on retail display and storage of fresh and frozen meats. Ernst (1980) described that the color of meat can be greatly altered by the display case lighting. The use of "natural" fluorescent lighting is recommended to portray the red color of meats, instead of "cool white" fluorescent lights, which concentrate the white and yellow wavelengths in the visible light spectrum.

Some grocery chains are shifting from "cool white" fluorescent lighting to natural fluorescent lighting in meat display cases; however, this shift is very slow or non-existent. The "natural" wide spectrum lighting brings out red and suggests there is a high portion of lean meat present and that the product is fresh (Klettner, 1984).

Present Retail Packaging Systems

Foam Tray/PVC Overwrap

After slaughter and processing in meat packing plants, carcasses are broken into subprimals and primal cuts. These cuts are typically vacuum packaged and boxed for shipment and distribution. Upon arrival at the store level, these primals and sub-primals are fabricated into consumer portions. These consumer-sized cuts are typically placed into white polystyrene foam trays, and, to a lesser extent, pulpboard or clear polystyrene trays. The trays are then overwrapped with stretchable polyvinyl chloride films having a high oxygen permeability (8,000-12,000 cc/sq.m., 24 hrs., 1 ATM, 73 f) to allow maximum bloom. A film with an oxygen permeability of at least 5000 cc/sq/m., 24 hr, 1 ATM, 73 F is required to retain the red bloom of a fresh meat (Landrock and Wallace, 1955). Consumer packages are then priced, labeled and placed into retail display cases (32° to 50°F). Typical retail display shelf-life of tray-overwrapped FRM is from 3 to 5 days, dependent upon storage conditions and meat quality. Spoilage in this 3 to 5-day period is generally from aerobic microorganisms. Pseudomonas have been identified as a dominant part of the microflora of PVC-overwrapped meats (Enfors et al., 1979; Vanderzant et al., 1982; Vrana et al., 1985).

Chub Packaging

Ground beef has been successfully centrally pre-packaged in chub packages since the early 1970's. In addition to several large FRM processors, several supermarket fabrication facilities process ground beef in bulk form and package it in opaque chub packages. These packages are generally printed with a store chain's logo to mask the MB (purple) color of the ground beef. No retail chains currently package ground beef in clear packages; they use opaque materials (to hide the normal myoglobin-purple muscle color). Many consumers have found that chub-packaged product is generally fresher and more sanitary than in-store processed ground beef.

Vacuum Skin Packaging (VSP)

Skin packaging of thermoplastic film onto adhesive-coated paperboard was first patented in 1955 (Growth, 1955). Work was subsequently adapted to vacuum skin packaging, and the first patent on vacuum skin packaging was assigned in 1970 (Young et al., 1970). In 1972, a patent was assigned for vacuum skin packaging which used a heated dome to heat the packaging material to a semi-molten state (Perdue, et al., 1972).

Commercial applications for vacuum skin packaging are growing at a rapid rate. No product distortion occurs from this process, as the heated films conform to the exact shape of the product.

European meat packers, and now American processors, have adapted VSP systems to fresh red meat products. European consumers began to accept central pre-packaging of meat in the early 1980's. Several beef, pork, veal and lamb processors are centrally pre-packaging and shipping these FRM products to retail markets in Europe. U.S.A. processors have been slower to adapt this technology; however, significant interest has been generated in the last few years.

VSP systems generally rely upon a non-oxygenated system; therefore, considerable marketing research must be accomplished to determine its acceptance in the retail marketplace.

Advantages of these systems are improved shelf-life from high oxygen barrier materials, reduced purge from the total seal (up to the perimeter of the product), improved product appearances and presentations through rigid tray-making capabilities. The shelf life of VSP products is similar to normal vacuum packaging.

Gas Atmosphere Packaging

In 1970, two separate British patents were assigned which were based on 70% to 90% oxygen and 10% to 30% carbon dioxide (Georgala and Davidson, 1970) or 50% to 70% oxygen with 50% to 30% carbon dioxide with a 2:1 oxygen:carbon dioxide ratio (Schweisforth and Aktiengesellschaft 1970). These patents generated interest from the European meat industry in modified-atmosphere packaging

of consumer-sized cuts. Packaging systems were soon commercialized in Europe in the 1970's and, to a lesser extent, evaluated in the American marketplace in the 1980's.

The Atmospack concept uses a unique modified gas atmosphere system coupled with conventional thermoforming roll-stock equipment and low oxygen-permeability materials. Typical thermoforming vacuumizing machines are set up with gas flush capabilities. After vacuumization, the specific gas mixtures are injected and the packages are then hermetically sealed. The meat products packaged in these systems with high (50% to 90%) oxygen concentrations maintain a very desirable oxygenated red color for an 8 to 14-day period. Microbial populations are inhibited by the carbon dioxide gas portion (10% to 50%).

The advantages of the Atmospack systems allow the processor to pre-package retail cuts and distribute them to the retailer with the same color the consumer is accustomed to receiving. The shelf life is often limited to an 8 to 14-day period because of deleterious effects from oxidative rancidity and microbial spoilage. The modified-atmosphere pack is not well suited for freezing (Ernst, 1980), as surface dehydration is observed.

High Permeability/Bulk Gas Flush

This concept has been successful in experimental circumstances and in marketing studies. FRM products are placed on polystyrene foam trays, flushed with a selected gas atmosphere (to displace oxygen and impart an initial bacteriostatic effect), and overwrapped in stretchable, sealable, high oxygen-permeable, flexible packaging films. The overwrapped trayed products (primary package) are then placed into a secondary master package (a large bag or pouch), which is vacuumized, then filled with selected modified atmospheres and sealed. During distribution, the gas in the master package migrates into the overwrapped tray (through its highly permeable film covering) and provides the necessary bacteriostatic effects to insure a reasonable (14-day) shelf life.

At the store level, master packages are opened and the tray-overwrapped packages are placed directly into retail display cases. The product may be pre-priced and labeled by the processor. The oxygen in the atmosphere then migrates into the permeable package, allowing the meat product to bloom. The relative short shelf life of overwrapped FRM has prevented this system from becoming widespread, although newly-developed distribution systems and marketing innovations will enhance this system for more widespread applications to several muscle food products.

Laminate Thermoforming Systems

Typical laminate thermoforming machinery is frequently employed for retail packaging systems. In application to FRM, retail store chains and processors have adapted this equipment to produce vacuum-packaged FRM cuts. These systems adapt vacuum packaging technology with materials that generally consist of flexible and semi-rigid oxygen barrier plastics. This system represents a method for processors and store chains to pre-package FRM for the retail cases and market their products through distribution systems similar to normal boxed beef channels.

Summary

The selection of a retail packaging system for FRM should be based on three factors: 1) marketing; 2) technical; 3) packaging systems. The processor must couple his needs with those of retailers and consumers in the selection of packaging systems for FRM retail packages.

Certain technical parameters (muscle color, pH, packaging materials, retail lighting and vacuum/gas systems) must be evaluated to apply to the desired system.

Atmospack, high permeability/bulk gas flush and tray overwrap packaging systems are available to give the consumer a similar oxygenated color to that which they are accustomed to for the selection of FRM cuts in the store. The drawback of these systems is the relative short shelf life of product packaged in these systems, in comparison to non-oxygenated systems.

Chub packaging, VSP and conventional thermoforming systems emphasize product shelf life and can withstand current distribution parameters in the FRM industry. However, the non-oxygenated (myoglobin) color of FRM packaged in these systems is not common to the typical consumer, and consumer acceptance is not known at this time. Over time, education of the consumer may help propel these systems to the forefront.

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