Chapter **10**

PACKAGING ASPECTS OF MEAT, FISH AND POULTRY

R S Matche

Food Packaging Technology Department
Central Food Technological Research Institute
Mysore 570 020 (INDIA)

Chapter 10

PACKAGING ASPECTS OF MEAT, FISH AND POULTRY

MEAT

In the packaging of red meat, there are two factors of major importance: colour and microbiological. Since the water activity of chilled meat is very high, unprotected meat will lose weight due to water evaporation and its appearance will deteriorate. Further, weight loss will occur when meat is cut, since the exposed surfaces exude liquid which adversely affects the appearance of packaged meat. This can be overcome by including an absorbent pad in the base of the package. Although efficient chilling can reduce the quantity of exudates, a certain amount will always be present when meat cuts are held for retailing. This unattractive bloody exudate found in vacuum packaged meat is referred to as "purge", "weep" and "drip"; 1-2% purge is considered acceptable, while 4% is considered excessive. Values of 2-4% drip can have substantial economic implications if not controlled.

Meat and its products differ in physico-chemical properties including nature of pigments, sensory attributes and microbial flora. The selection of packaging material has to be done very carefully to protect these qualities of meat and its products. The purpose is to retard or prevent the main deteriorative changes and make the products available to the consumers in the most attractive form. However, initial quality of meat has to be very good because packaging can at best maintain the existing quality of meat. It cannot improve it.

Packaging requirements depend upon the type of meat, nature of processing and distribution system.

Colour of Red Meat

Colour of meat is one of the main attributes of meat quality. Consumers associate this colour with good eating quality, although there is little correlation between the two. This association of colour of red meat with freshness has been the dominant factor in retail meat marketing. The loss of this bright red colour is known as loss of "bloom". It is affected by many factors, although the consumer usually relates the colour loss to bacterial growth. Due to the importance of meat colour, various methods of transportation, distribution and packaging of primals and subprimals have evolved which optimize the maintenance of a desirable meat colour. The colour of meat as perceived by the consumer is primarily determined by such factors as the concentration and chemical form of the meat pigment myoglobin, the morphology of the muscle structure and the ability of the muscle to absorb or scatter incident light.

The colour of fresh meat depends chiefly on the relative amounts of the three pigment derivatives of myoglobin present at the surface: reduced myoglobin (Mb), oxymyoglobin (O_2 Mb) and metmyoglobin (met Mb). Reduced myoglobin is purple in colour and predominates in the absence of oxygen. Oxymyoglobin is bright red in colour and results when Mb is oxygenated or exposed to oxygen; this is commonly known as "bloom". Metmyoglobin is brown in colour and exists when the oxygen concentration is between 0.5% and 1% , or when meat is exposed to air for long periods of time. The brown metmyoglobin cannot bind oxygen even though it is oxidized by same oxygen that converts myoglobin to the bright red oxymyoglobin.

During storage, the rate of metmyoglobin accumulation on the surface of red meat is related to many intrinsic factors including pH, muscle type and the age, breed, sex and diet of the animal, as well as extrinsic factors including pre-slaughter conditions and the processing conditions used. During retail display, physical factors such as temperature, oxygen availability, type and intensity of lighting, microbial growth and gas atmosphere surrounding the meat surface influence the shelf life of fresh red meats.

PACKAGING MATERIALS AND TECHNIQUES

Tray with Overwrap

The most common packages for retail fresh meat cuts in Western countries are polystyrene foam or clear plastic trays over wrapped with a transparent film. These trays offer an aesthetically appealing background. The use of blotter underneath eliminates the changes of excessive meat juice accumulation. Meat thus wrapped may keep for approximately 10 days at a temperature of 0°C before it becomes microbiologically unacceptable. However, it can retain the desirable bright red colour only for about 5 days.

Cellophane coated with nitrocellulose on one side was in use for wrapping fresh meat for a considerable period. The uncoated side is kept in contact with meat. Moisture saturation on the film increases its oxygen permeability, while nitrocellulose coating on the outer side prevents excessive moisture loss to the atmosphere. Another grade of cellophane with polyethylene coating on one side can be used for irregular shaped meat though it is not much in use.

The over wrapping film should have excellent optical properties. Among the synthetic plastic films rubber hydrochloride, low density polye-thylene (25

μm), highly plasticised PVC films (18 μm), biaxially oriented polystyrene film can be used.

Vacuum Packaging

Vacuum packaging achieves its preservative effect by maintaining the product in an oxygen-deficient environment. In anaerobic conditions, potent spoilage bacteria are severely or totally inhibited on low-pH (< 5.8) meat. However, their growth on high pH muscle tissue or extensive fat cover of inevitable neutral pH, will spoil relatively rapidly in a vacuum pack. Vacuum packaging can therefore extend the shelf life of primal cuts composed largely of low (normal) pH muscle tissue such as beef and venison by about five fold over that achieved in air. For other meats and small cuts, only a two fold extension of shelf life can be safely anticipated.

Vacuum Packaging System

Buffalo meat and beef carcasses are broken down into primal and sub-primal cuts, separated into boneless and bone-in-cuts, and then vacuum packaged. Since only about two-thirds of beef carcass is usable meat, there are clear advantages in the form of reduced refrigerated space for transportation and storage and less packaging materials when boneless beef rather than bone-in beef or carcasses are stored and distributed. Another advantage is that evaporative weight loss incurred when carcasses are hung in the chill rooms is minimised.

Vacuum packaging involves enclosing boneless joints in flexible plastic containers (usually bags) to prevent moisture loss and exclude oxygen from the meat's surface. Packing under a vacuum reduces the volume of air sealed in with the meat. In packaging fresh meat primals, many cuts contain bones, which are often sharp and abrasive and readily puncture the flexible plastic materials used in vacuum packaging. To overcome this bone puncture, a BONEGUARD material consisting of a wax-impregnated and coated cotton scrim is employed.

Suitable film for vacuum packaging must combine a high resistance to transmission of gases and water vapour with perfect seals and good mechanical strength.

Typical materials in use are :

1. Co-polymer - coated cellulose / PE film laminate.

   Polyester / PE film laminate

   Nylon / PE film laminate

   These are usually with PE inside to promote efficient heat seals.
2. Laminates of plastic film with aluminium foil.
3. PVDC copolymer film
4. EAA/Saran/EAA laminate
5. Nylon / EAA laminate
6. PVDC / polyester / PVDC / PE laminate
7. LDPE / BA / Nylon / BA/ LDPE

Once a piece of meat has been vacuum packaged in an oxygen barrier material having a gas permeability (at 23°C and 75% RH) below 50 ml m^{-2} day^{-1} atm^{-1} and adequately sealed to prevent air reentry, the shelf life of the meat is very much the same regardless of the packaging material. Therefore, the significant differences between the packaging materials and /or systems are not in the structure so much as in the physical properties, the production speeds of the system and the abuse resistance of the package itself.

The oxygen in the small volume of residual air inside a vacuum package will be quickly consumed by meat respiration so that within 2 days the oxygen partial pressure at the surface of the meat will have dropped below 10 mm Hg. At these very low partial pressures the penetration limit of oxygen is very near the surface and the thin brown layer of MetMb which develops cannot conceal the underlying Mb; therefore the visible colour of vacuum packaged beef is purple. Vacuum packaging for retail display packages of red meat has not met with wide success because of consumers' negative perception of the purple colour.

Four basic methods are available for vacuum packaging of meats:

a. Shrink Bag

It involves placing the meat into a heat shrinkable barrier bag of EVA copolymer / PVC /PVdC copolymer / EVA co-polymer / polyamide as the barrier layer and an ionomer as the inner or outer layer and then evacuating the bag prior to sealing. Formerly, sealing was being done by applying a metal clip around the twisted neck of the bag. But these days, it is done by using heated jaws. The bag is then heat shrunk by placing in water at 90°C. After shrinking, the bag conforms closely to the meat and produces a tight vacuum pack. However, if a high vacuum is not drawn, adequate shrink force is present in the film to cause bridging over concave areas, and the voids are

eventually filled with free liquid and increase the quantity of purge.

In the early days, a nozzle evacuation system (which offered low vacuum levels) and a clip closure was used. In typical nozzle vacuumizing machine, the open end of the bag containing the product was placed over nozzle and air drawn by vacuum from inside the bag. With this method, it was difficult to consistently produce packages with higher than 125 mm Hg vacuum since the packaging material began to collapse and block air removal as soon as negative pressure developed. Vacuum levels higher than 250 mm Hg collapsed the bag and sealed the end of the nozzle to air movement.

Today very high vacuum levels are being achieved on single chamber machines which offer heat sealing of shrink bags instead of clipping. Due to the improved productivity and versatility of this type of equipment, rotary single chamber machines have become the industry standard.

b. Non-shrink Bag

In this technique, meat is placed into a pre-formed plastic bag which is then put in an enclosed chamber which is evacuated. When a predetermined low pressure has been reached, heated jaws close and seal. Typical bag constructions consist of laminates or co-extrusions which include polyamide or PET as the outside layer to provide strength and a good oxygen barrier, and inner layers of LDPE, ionomer or EVA copolymer which are good moisture barriers and can be easily heat sealed. A typical structure would be ionomer-polyamide-EVA copolymer.

Because the bags used in this system are not heat shrinkable, purge tends to accumulate in corners during storage. Secondary sealing has been introduced to overcome this problem; it involves passing the vacuum packs through a heating tunnel. Because of the ease with which these films are heat sealed, the excess area of film around the meat is sealed. This prevents purge from spreading into the film wrinkles, folds and corners as well as providing a wider heat seal which, it is claimed, reduces the incidence of leaking bags.

c. Thermoforming

In this method, deep trays are thermoformed in-line from a base web of plastic. Meat is placed in the trays and an upper web of plastic is heat sealed under vacuum to form a lid. Generally, the materials used for thermoforming are laminates of polyamide, PET or PVC, sometimes with a PVC/PVDC copolymer coating and heat-sealing layers such as LDPE, EVA copolymer or ionomer.

This type of vacuum packaging is particularly well suited to hot boned, pre-rigor meat which is difficult to package in bags, the tray providing a certain degree of molding to the meat as it cools. Furthermore, with the correct selection of plastic materials, the sealed package can be processed in boiling water, if desired.

d. Vacuum Skin Packaging (VSP)

In this technique, meat portions are skin packed in a barrier film material, the top web of which is softened by heating before applying a vacuum and sealing. During this operation, the soft film molds itself to the shape of the meat to give a skin-tight package, the meat thus being held under anaerobic conditions. It forms closely around the meat and seals to the base film. Although this type of vacuum pack is an excellent method of presentation, the meat remains in unoxygentated state which is not accepted by most consumers, even though it will still oxygenate to the red colour when exposed to air.

VSP meat remains acceptable microbiologically for up to at least 2 weeks after packing during which time the colour, although not red, is unchanged. However, the meat retains for at least 2 weeks storage at 1°C its ability to develop a bright red colour when exposed to air. As it is typical for vacuum packaged meat, lactic acid bacteria predominate on VSP samples on which spoilage bacteria grow slowly, if at all, resulting in a long, odor-free shelf life. Off-odours develop much more rapidly in MAP packs than in VSP.

Shelf Life of Vacuum Packaged Meats

Vacuum packaged beef of normal pH can be stored at chiller temperatures for periods in excess of 10 weeks. However, high pH, dark, firm, dry beef held under the same conditions will generally spoil within about 6 weeks. There are also advantages in aging beef in vacuum packages as opposed to carcass aging, including less loss due to water evaporation, less necessity for trimming of exposed surfaces and more efficient use of refrigerated space.

Although for many years vacuum packaging was only applied to chill beef, it has been applied in recent years to lamb and pork. Because of their relatively small size, pork and lamb carcasses are only partially boned before packaging, and the presence of bone can lead to puncturing of package unless precautions are taken, like use of strong EVA copolymer film in the package structure. The surface of lamb cuts is adipose, rather than muscle, tissue. Adipose tissue has pH values close to neutrality and has no significant respiratory activity. Packaged lamb can therefore present a heterogeneous environment for microbial growth. This different microbial environment of high pH and, possible relatively high oxygen concentration, gives a shelf life of only 6 to 8 weeks reported for vacuum packaged lamb whereas 11 to 22 weeks is routinely attainable with beef. The longer shelf life of vacuum packaged beef is due to its flora being dominated by lactobacilli which overgrow other spoilage organisms at the low temperature, low pH, low O_2, high CO_2 environment of the package.

Modified Atmosphere Packaging (MAP) of Fresh Meat

Vacuum packaging has the disadvantage that both package and meat are subjected to mechanical strain. Mechanical pressure on the meat may increase drip loss; if bone is present and not adequately covered with a suitable material, the pack may be ruptured. Atmospheric composition inside the package can also be modified to extend the shelf life of meat while retaining the freshness, aroma, colour and weight. In this technique, headspace air in the package is replaced by gases usually nitrogen alone or in combination with carbon dioxide or oxygen.

Oxygen at concentrations of 75% penetrates almost twice as far into the surface of meat as it does at the 21% level in air. This thick layer of oxygenated tissue allows red meat to retain its bright red colour for up to 5-6 days in normal retail display. The relative volumes of gas and meat are important in determining the changes in concentration of gases during storage. The high solubility of CO_2 compared to the relatively low solubility of O_2 and N_2 in meat must be taken into account.

1. High Oxygen MAP

High oxygen MAP systems which have 30% CO_2 and up to 70 % O_2 are used to extend the colour stability and delay microbial spoilage. Although both the colour stability and the time to spoilage are approximately doubled by high O_2 MAP, this extension in shelf life is not adequate. So the use of high O_2 MAP is not widespread for prolonged storage of meat for bulk packaging.

2. Low Oxygen MAP

a. Carbon Dioxide Gas Flush

In these packages, the air is largely displaced by CO_2, either by itself or mixed with N_2 or air. The shelf life extension is similar to that of vacuum packaging, higher concentration of CO_2 leading to a longer shelf life. Low oxygen concentrations lead to formation of oxymyoglobin on the meat surface which prevent the formation of metmyo-globin which leads to discolouration. Low O_2 MAP system is not suitable for retail packs.

b. Nitrogen Gas Flush

As an inert gas, nitrogen is convenient for gas packaging, it generally being considered neutral filler. If the air in the package is removed prior to the addition of nitrogen, the effect on meat is similar to that of vacuum packaging, except that residual oxygen is diluted and metmyoglobin formation on the surface should be less pronounced than with a vacuum. However, although the formation of metmyoglobin on the surface is reduced, the nitrogen also dilutes the CO_2 produced by tissue respiration, prolonging the time required for the concentration to accumulate to levels sufficient to inhibit growth of spoilage bacteria. Although there is little commercial use of nitrogen flushing with fresh meat, several studies have confirmed that 100% nitrogen is as effective as vacuum for storing fresh meat joints, the only advantage being reduced exudates due to less mechanical pressure on meat compared to vacuum package.

3. High Carbon Dioxide MAP

Carbon dioxide is highly soluble in both water and oils. Therefore, when CO_2 is applied to meat in a rigid pack, the gas will be absorbed by the muscle and fat tissue until equilibrium is attained. At equilibrium, the partial pressure of CO_2 will be less than that of the original gas mixture, and the total gas pressure will also be less than at which the gas mixture was initially applied. Similar considerations apply in flexible packaging systems. If CO_2 alone is added, the pack will collapse around the meat as gas is absorbed unless CO_2 is added in excess of the quantity required to saturate the meat at atmospheric pressure. When mixtures of gases are used, the less soluble nitrogen and unrespired components of the gas mixture maintain a volume of gas at atmospheric pressure around the meat that is less than the volume added initially.

The solubility of CO_2 in muscle tissue of pH 5.5 at 0°C is approximately 960 ml per kg of tissue at STP. As the temperature increases, the solubility decreases by 19 ml per kg for each °C rise. As tissue pH increases, the solubility decreases by 360 ml per kg for each pH unit. With raw meat, CO_2 at ~ 1.5 L kg^{-1} meat is required to saturate the product without the package collapsing tightly around the contents. The necessary initial large gas volume can result in pouches at first overfilling the cartons in which they are contained. However, the gas dissolves sufficiently rapidly for the pack volume to fall to its final value during overnight storage.

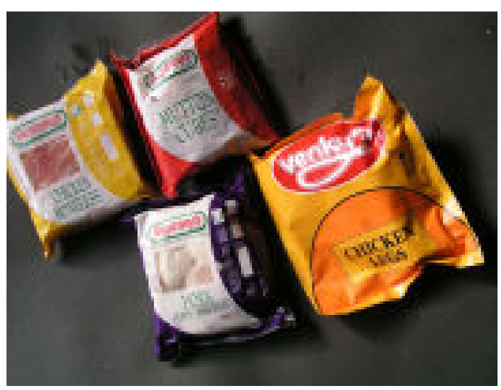
It has been reported that wholesale primal pork loins stored in 100% CO_2 at 0°C had a shelf life of approximately 3 months. Red meat colour is not adversely affected by high CO_2 atmosphere if oxygen is rigorously excluded from the package. Trials have also demonstrated that it is suitable for the prolonged storage of pork, poultry, venison, offal, fish, cooked meats, blanched vegetables and complete meals.

Beef needs a high oxygen content to maintain a bright red colour which is desired by the consumer. Chicken in comparison needs little oxygen and reduced amount of carbon dioxide. Pork with its high fat content needs less oxygen and some nitrogen for glow. The replacement of air already in the pack by a mixture of 70 percent oxygen, 20 percent carbon dioxide and 10 percent nitrogen at 0°C slows bacterial growth so greatly that microbially caused discolouration, sliminess and aroma changes are eliminated. Beef and pork portions generally have a shelf life of seven to eight days. Higher oxygen concentration can result in accelerated development of rancidity. A mixture of 80 percent carbon dioxide is even better bacteriologically although some colour loss may occur. Bulk packs of fresh pork in 10 percent carbon dioxide had a microbiological storage life of 40 days at 4°C.

PACKAGING OF FROZEN MEATS

Frozen meat is stored and displayed between -10 and -30°C, at which temperatures microbiological growth is arrested. Therefore, the changes in meat influenced by packaging are those associated with appearance, i.e., colour and the absence of frost inside the package.

If a bright red colour is required, it must be produced by oxygenation of the meat surface before freezing followed by packaging in a material, which is relatively permeable to oxygen. It has been claimed that ionomer film will keep the bright red



colour for at least a year if the meat is stored in the dark at -20°C. However, when exposed to light, the red colour begins to darken after about a week. This is caused by light activated oxidation of the pigment in the meat surface and is inevitable in meat, which has been frozen in the bright red state and subsequently exposed to light. When frozen meat and meat products are stored without an adequate moisture vapor barrier an opaque dehydrated surface known as freezer burn is formed. Freezer burn is caused by the sublimation of ice on the surface of the product when the water vapor pressure of the ice is higher than the vapour pressure in the environmental air. The key to avoiding freezer burn and lessening oxidative deterioration during frozen storage is to eliminate or reduce the headspace in the package which should also serve as an effective barrier to oxygen and water vapour. Freezer burn can occur even when using a packaging material, which is an excellent barrier to moisture vapor if the package headspace has not been essentially eliminated. Oxidative changes are even more effectively reduced through exclusion of air by means of vacuum packaging. Because there is no space between the meat and the packaging material, frost cannot develop to mask the attractive appearance.

Frozen, restructured meat products have traditionally been packaged in bags, pouches, trays, overwraps and plastic-coated paperboard, with polyolefins being the most common material used. They must, of course, contain appropriate plasticizers so that their mechanical properties are not impaired at sub-zero temperatures. Vacuum skin packaging is also used for frozen, restructured meat products. Typically, a heat-softened ionomer film is draped over the product which is supported on a lower web of the same material. Air is withdrawn from between the two webs and the webs heat sealed together. This results in a package that is sealed skin tight to the edge of the product, regardless of its contour or size. There are no empty spaces for moisture condensation to occur, freezer burn is virtually eliminated during frozen storage.

CURED AND COOKED MEATS

During storage, cured meats deteriorate in the first instance because of discoloration, secondly because of oxidative rancidity in the fat, and thirdly on account of microbial changes. Although the pigment of cured meat (nitrosylmyoglobin or nitrosylhemochrome) is stable in the absence of oxygen or under vacuum, its oxidation to metmyoglobin is very rapid when oxygen is present. The rate of nitrosylmyoglobin oxidation increases directly with increasing oxygen tension unlike myoglobin itself where the rate of oxidation is maximal at 4 mm Hg oxygen partial pressure. The most common and effective antioxidants used are ascorbate or erythrobate which are either incorporated into the curing brine or sprayed onto the surface of the product after maturing.

Nitrosylmyoglobin and nitrosylhemochrome are much more susceptible to light than myoglobin; cured meats fade in 1 hour under retail display lighting conditions. Since light accelerates oxidative changes only in the presence of oxygen, vacuum or inert gas packaging can eliminate the effect. Holding vacuum packaged meats in the dark for 1-2 days before exposing them to display lights allows residual surface oxygen to be depleted by microorganisms and tissue activity, thus reducing subsequent colour deterioration.

Smoke, traditionally produced by the slow combustion of sawdust derived from hard woods, inhibits microbial growth, retards fat oxidation and imparts flavour to cured meats. However, these days smoke essences are sometimes used instead of actual smoke, and they contribute only flavour to cured meats.

Cured hams undergo a different type of spoilage from that of fresh or smoked hams, due primarily to the fact that curing solutions pumped into hams contain sugars which are fermented by the natural flora of the ham and also by those organisms such as lactobacilli pumped into the product in the curing solution.

THERMO-PROCESSED MEATS

Thermal processing at above 100°C, usually accomplished under pressure, is done to prepare commercially sterile meat products.

1. Short-term storage: Meat products like patties, sausages, nuggets, meat balls, etc, can be packaged in pouches made up of polyethylene, polypropylene, PVDC, rubber hydrochloride, etc, for short term storage lasting for 10-12 days at 4°C.

2. Long-term Storage: Meat products like corned beef, corned pork, meat gravies, meat soups, liver sausages, chicken curry, boneless chicken, etc., are hermetically sealed and cooked to make commercially sterile for long term storage at room temperature. Two types of containers are suited for this purpose.

a. **Metal cans:** Canned meat products are shelf stable for a number of years at room temperature. Tinplate cans have maintained their lead in this field. These are coated on the inner side with sulphur-resistant lacquer. Shallow drawn aluminum cans with internal lacquer have been successfully used for certain meat products.

b. **Retort pouches:** Thermoprocessed meat in retort pouches are shelf stable for a minimum period of one year. Composite film especially film/foil/film laminates are used in making the retort pouches as follows:

   i) Outer plastic film made up of polyester, polyamide or oriented polypropylene provides support and physical strength to the composite.

   ii) Middle layer of aluminum foil contributes excellent barrier properties.

   iii) Inner layer consisting of polypropylene provides head sealability.

PACKAGING OF DEHYDRATED MEATS

Dehydration is a successful means of preserving many meats with proper packaging. There is a marked susceptibility of dehydrated meats to oxidation resulting in rancid odour.

Packaging Materials

1. Tinplate cans
2. Metal / foil / plastic film laminates compressed bars of dehydrated minced meat with inner cellophane and outer paper/Aluminium foil/PE laminate wrap are reported to be shelf-stable for one year.

Flexible pouches most suitable for vacuum and modified atmosphere packaging consist of polyester / PE / Aluminium foil / PE or cellophane / PE / Aluminium foil / PE laminates.

POULTRY AND EGGS

Poultry

Raw poultry meat is a perishable commodity of relatively high pH (5.7 - 6.7), which readily supports the growth of microorganisms when stored under chill or ambient conditions. The shelf life of such meat depends on the combined effects of certain intrinsic and extrinsic factors, including the numbers and types of spoilage organisms present initially, the storage temperature, muscle pH and type (red or white), as well as the kind of packaging material used and the gaseous environment of the product.

The vacuum packaging of poultry carcasses, cuts and other manufactured products can extend shelf life provided that the product is stable under chill conditions. During storage at 1°C in either O_2 permeable film or vacuum packs, extension in shelf life from 16 to 23 days (pH 6.1 - 6.3) was observed for the vacuum packaged products. The maximum usable CO_2 concentration was 25% since above this, the meat became discoloured; even at 15%, a loss of bloom was sometimes noted.

While the number and the type of microorganisms found on stored poultry are important factors when determining the shelf life, the real determinant is the sensory quality of the raw and cooked product. One study which evaluated the quality of raw and cooked poultry that had been stored under MA and refrigeration for up to 5 weeks, found that MAP (80% CO_2) poultry would be quite acceptable to consumers for up to 4-

6 weeks depending on the temperature of storage. It was noted that commercial poultry processors may not get a longer shelf-life because of difficulties in controlling the packaging process and temperature under production conditions.

In a study of broiler carcasses packaged under vacuum in film of low O_2 permeability, or under CO_2 in gas-impermeable packages, shelf life was found to be a function of storage temperature, packaging and O_2 availability. Putrid spoilage in gas-impermeable packages after 7 weeks storage at 3°C or 14 weeks storage at -1.5°C was attributed to enterobacteria. In vacuum packages with oxygen transmission rates of 30-40 ml m^{-2} day^{-1}, putrid odors were detected after 2 weeks storage at 3°C and 3 weeks storage at -1.5°C.

Packaging of Dressed and Cut-up Poultry

By nature, poultry fat is unsaturated and is very prone to the development of oxidative rancidity. Dressed poultry has a shelf life of 5-7 days during refrigerated storage. Packaging of poultry meat should be undertaken immediately after the dressing operations are over. Unpacked refrigerated storage may result in surface dehydration, whereas frozen storage may give rise to freezer burn, characterized by surface discoloration, tough texture and diminished juiciness as well as flavour.

Packaging Materials and Techniques

Over-wraps: Packaging of dressed whole birds, halves or cut up parts for retailing and early use can be done in plastic films such as polyethylene, polypropylene, PVDC, rubber hydro-chloride or Nylon-6 films of 38 to 50 µm. Polyethylene is the most widely used packaging material in our country because of its low cost and easy availability. These thermoplastic film sheets can be fabricated into bags. Each dressed eviscerated bird is inserted into a bag. Giblet of individual bird is wrapped in waxed paper or parchment paper and placed into the body cavity before bagging. The problem of body fluid accumulation is avoided by putting an absorbent pad or blotter on the back of each bird to soak up the liquid. The bag can now be heat-sealed or twist-tied or clipped shut.

Tray with over-wraps: The common packages for retail dressed small whole fryers, broilers, roasting chicken or even cut up parts can be placed in polystyrene foam trays over-wrapped with a transparent plastic film. A blotter underneath absorbs the excessive meat juice accumulation. Chickens thus wrapped have a shelf life of 7 days at 4°C in refrigerator.

Shrink Film Over-wraps: Many thermoplastic films such as polyethylene, polypropylene, polyvinylidene can be biaxcially-oriented to stay stretched at ambient temperatures. Dressed birds are over-wrapped with such films and passed through hot air tunnel or dipped in water tub maintained at 90°C for few seconds to effect shrinkage of the film.

V*acuum Packaging:* The ideal materials are Polyester/Polyethylene(PE), Polyamide/Polyethylene, PVDC co-polymer film, Nylon/EVA.

Modified Atmosphere Packaging: In this technique, the atmosphere surrounding the perishable commodity is modified. The manipulation of package atmosphere is done by flushing carbon dioxide, nitro-gen and oxygen alone or in combination. Studies have shown that a mixture of 60% nitrogen and 40% carbon-dioxide or 50% nitrogen and 50% carbon dioxide is ideal for modified atmosphere packaging of chicken meat.

Bulk Packaging: Plastic crates have become popular as bulk containers due to their toughness, light weight, dent resistance and ease of stacking and handling.

Packaging of Mechanically Deboned Poultry Meat (MDPM)

To stabilize the colour, to check the lipid oxidation, to inhibit microbial deterioration and to maintain the texture, vacuum packaging can be useful. Modified atmosphere packaging (MAP) can be done by providing 20-30% carbon dioxide, 0-10% oxygen and 70-75% nitrogen.

Eggs

Infertile eggs are used almost exclusively for human consumption. The pores in the shell permit gaseous diffusion as well as moisture loss and the entry route for microorganisms which might infect the egg. The factors associated with the loss of shell egg quality are time, temperature and humidity. During the storage of shell eggs, the pH of albumen increases at a temperature-dependent rate from about 7.6 to a maximum value of about 9.7, the rise in pH of albumen causes a breakdown in the gel structure of the thick white.

Several methods of altering the environmental conditions around eggs have been used to prolong their shelf life, the major one being refrigeration. Coating of the shell with mineral oil has also come

into common usage to increase the shelf life by reducing the rate of CO_2 and moisture loss. Spray oiling has come into usage for the shells of eggs, light mineral oils of food quality normally being used. It is essential that the treatment be applied to the eggshell within a few hours, since weight loss during the first few days can be significant. Clearly, the rate of CO_2 loss at any particular temperature will be a function of the partial pressure of CO_2 in the external environment. Thus the attempts to extend the shelf life of shell eggs have involved storing the eggs in an atmosphere containing CO_2 in an impermeable package. A comparative study evaluating the quality and shelf life of fresh shell eggs stored at room temperature with four different treatments (not packaged; packaged in air; packaged with 15% CO_2; and oil coated) concluded that controlled

atmosphere was the most efficient method of preserving egg quality at room temperature for a period of 7 weeks. Although such procedures increase the storage life of eggs, the economics and success of spray oiling have prevented such procedures from becoming generally adopted.

Packaging of Shell Eggs

1. Moulded pulp filler flats or plastic filler flats each containing 30 eggs are used.
2. Paperboard cartons with dividers.
3. Folded paperboard cartons with shrink film overwrap of PE, PVC or PVDC.
4. Expanded polystyrene foam egg cartons or trays provide excellent cushioning and strength besides being light weight
5. Bulk packaging, under Indian conditions, it is advisable to keep 210 eggs per carton (7 trays of eggs each) during shipment. For export purposes, all white paperboard shipping cartons each containing 360 eggs are used.

SEAFOOD

Spoilage of flesh foods such as fish and shellfish results from changes brought about by chemical reactions such as oxidation reactions due to the inherent enzymes, and the metabolic activities of microorganisms. The chemical composition and microbial flora and seafood vary considerably between species, different fishing grounds and seasons.

Both salt water and fresh water fish contain comparatively high levels of proteins (about 18%) and other nitrogenous constituents. Non-fatty fish such as cod and haddock have a lipid content of less than 1% in contrast to fatty fish such as herring and mackerel which can have lipid contents of up to 30%. The spoilage of salt and fresh water fish appears to occur in essentially the same manner.

It is generally accepted that the internal flesh of healthy, live fish is sterile, microorganisms that exist on fresh fish are generally found in the gills, the outer slime, and the intestines. The post mortem changes leading to spoilage depend principally on the chemical composition of the fish, its microbial flora and subsequent handling, processing and storage.

Immediately after post mortem, a whole series of tissue enzyme reactions begin the process of autolysis (basically self digestion of the fish muscle) which leads eventually to spoilage. The autolytic enzyme reactions predominate for 4-6 days at 0°C after which the products of bacterial activity become increasingly evident with the appearance of undesirable odors and flavours. The rate of the autolytic changes are determined by many factors, the most important being temperature, pH, availability of O_2 and the physiological condition of the fish before death.

The third type of spoilage is chemical spoilage, primarily oxidation of the fatty compounds leading to the development of rancid flavours. Because seafood has a much higher content of polyunsaturated fat than meat, it is more prone to the development of oxidative rancid flavours. The rate of rancidity development is closely related to the temperature of storage and the reactions can still occur at freezer temperatures as low as -30°C. Some substances such as salt and some processes such as drying and smoking can aggravate the oxidation problem, and therefore frozen smoked fish has a shorter shelf life than unsmoked fish of the same species.

Shellfish are divided into two main groups; crustaceans which include shrimp Lobster, crabs and crayfish, and mollusks which includes oysters, clams, squid and scallops. The microbial flora of shellfish reflects the waters from which they are caught, contaminants from the deck and handlers, and the quality of the washing waters used. Mollusks differ from crustacean material with a lower total quantity of nitrogen in their flesh. Because the carbohydrate is largely in the form of glycogen, the spoilage of molluscan shellfish is largely fermentative. This results in a progressive fall in tissue pH as spoilage develops, from pH 5.9-6.2 in fresh mollusks to less than about pH 5.5 in spoiled mollusks.

Modified Atmosphere Packaging

The normal spoilage bacteria, which cause off-odours and flavours, are inhibited and microorganisms not usually involved in aerobic spoilage eventually predominate. These are microorganisms such as *Streptococci* and *Lactobacilli,* which are less affected by the elevated CO_2 atmosphere and which grow more slowly than the normal aerobic spoilage bacteria. Because the microorganisms which predominate under MAP also cause less noticeable and less offensive organoleptic changes, the net result is a significant extension of shelf life under MAP at refrigeration temperatures.

However, there are significant differences in the application of MAP to meats, including poultry, and to seafoods. Because seafoods contain much lower levels of myoglobin than do meats, higher levels of CO_2 can be used before discoloration becomes a problem. Vacuum and modified atmosphere packaging including N_2 and CO_2 flushing suppress the normal spoilage flora and thereby extend the shelf life of seafoods. Whereas, the presence of CO_2 does not lead to an increase in growth of C. *botulinum*, replacing air with nitrogen produces anaerobic conditions and an increased susceptibility to the growth of C. *botulinum* in advance of spoilage signals due to spoilage microflora. Vacuum

packaging in high barrier films produces the same growth conditions as replacing air with nitrogen. However, if an oxygen-permeable film is used for vacuum packaging, distinct spoilage signals will be produced if the pack is held at abuse temperatures because of the ingress of oxygen into the package.

Effective gas compositions vary

according to fish species, with low oxygen concentrations being used with fatty fish which are susceptible to oxidation rancidity. Generally, gas mixtures for non-fatty fish would be 30% O_2, 40% CO_2 and 30% N_2, and for smoked and fatty fish 40% CO_2 and 60% N_2. Problems caused by too high a CO_2 include taint, an acid flavour to certain species of fish, and clouding of the eyes.

It is evident from the published literature that MAP can extend the shelf life of a variety of fish and fish products. However, MAP is not equally effective for extending the shelf life of all fish products. Although some claims have been made of a shelf life of up to 3-4 weeks for the refrigerated storage of MAP fish. General target shelf lives of these products are in the range of 10-14 days, but may reach 18-20 days if the temperature is controlled very tightly.

High temperature abuse (21-27°C) for periods of 12-24 hours is a major concern since MAP fish generally do not become overtly spoiled under these conditions yet may be toxic, whereas fish held at the same temperatures under similar aerobic conditions begin to become putrid before toxin production occurs.

Safety Aspects

The only effective way to assure the safety of refrigerated vacuum packaged or MAP fish products would be to either (a) keep the product below 3°C at all times; (b) heat the product sufficiently to destroy spores of all strains, or (c) heat the product sufficiently to inactivate the nonproteolytic spores and then keep the product well below 4°C. The latter two points may be effective form a theoretical standpoint, but in practice, it may be difficult in a fish processing environment to avoid post-processing contamination with spores of *C. botulinum.* Inactivation of botulinum toxins by heating the food prior to consumption requires an internal temperature of 80°C for 10 min or 86°C for 1 min, such temperatures are not being achieved in a standard 700 W microwave oven in 5 min.

BIBLIOGRAPHY

Bell RG and Garout AM (1994). The effective product life of vacuum-packaged beef imported into Saudi Arabia by sea, as assessed by chemical, microbiological and organoleptic criteria. Meat Sci, 36(3): 381-396.

Bell RG, Penney N, Gilbert KV, Moor-head SM and Scott SM (1996). The chilled storage life and retail display performance of vacuum and carbon dioxide packed hot deboned beef striploins. Meat Sci, 42(4): 371-386.

Blickstad E and Molin G (1983). Carbon-dioxide as a controller of the spoilage flora of pork, with special reference to temperature and sodium chloride, J Food Protect, 46: 756.

Bonilauric P, Liuzzo G, Merialdi G, Bentley S, Poeta A, Granelli F and Dottori M (2004). Growth of *Listeria monocytogenes* on *vacuum*-packaged horsemeat for human consumption, Meat Sci, 68(4): 671-674.

Brody AL (1989). Modified atmosphere/ vacuum packaging of meat. In: Controlled/Modified Atmosphere/ Vacuum Packaging of Foods, ed:

Brody AL. Food and Nutrition Press Inc, Trumbull, Connecticut, pp 17-37.

Buys EM (2004). Colour changes and consumer acceptability of bulk packaged pork retail cuts stored under O_2, CO_2 and N_2. Meat Sci, 68(4): 641-647.

Buys EM, Nortje GL, Jooste PJ and Holy AV (2000). Combined effect of modified atmosphere bulk packaging, dietary vitamin E supplementation and microbiological contamination on colour stability of Musculus gluteus medius. Meat Sci, 55(4): 403-411.

Wang FS, Jiang YN and Lin CW (1995). Lipid and cholesterol oxidation in Chinese-style sausage using vacuum and modified atmosphere packaging. Meat Sci, 40(1): 93-101.

Fernández FE, Odériz VML and Rodríguez RMA (2002). Sensory characteristics of Galician chorizo sausage packed under vacuum and under modified atmospheres. Meat Sci, 62(1): 67-71.

Esteban GM, Ansorena D and Astiasaran I (2004). Comparison of modified atmosphere packaging and vacuum packaging for long period storage of dry-cured ham: effects on colour, texture and microbiological quality. Meat Sci, 67(1): 57-63.

Gatellier P, Hamelin C, Durand Y and Renerre M (2001) Effect of a dietary vitamin E supplementation on colour stability and lipid oxidation of air- and modified atmosphere-packaged beef. Meat Sci, 59(2): 133-140.

Genigeorgis CA (1985). Microbial and safety implications of the use of modified atmosphere to extend the storage life of fresh meat & fish. Int J Food Microbiol, 1: 237-251.

Gill CO (1988). The solubility of carbondioxide in meat. Meat Sci, 22: 65.

Gill CO, Brit (1990). Controlled Atmosphere packaging of chilled meat. Food Control, 1: 74.

Gill CO, Harrison CL, and Penney N (1990). The storage life of chicken carcasses packed under carbon dioxide. Int J Food Micro, 11: 151.

Grandison AS and Jennings A (1993). Extension of the shelf life of fresh minced chicken meat by electron beam irradiation combined with modified atmosphere packaging. Food Control, 4(2): 83-88.

Grau FH (1983). Microbial growth on fat and lean surfaces of vacuum packaged chilled beef, J Food Sci. 48: 326,

Harte BR (1987). Packaging of restructured meats. In: Advance in Meat Research, Vol 3, eds: Pearosn AM and Dutson TR. Elsevier Applied Science Publishers, Essex, England, pp 433-468.

Hintlian CB and Hotchkiss JH (1986). The safety of modified atmosphere: A review. Food Technol, 40(12): 70.

Hobbs G (1983). Microbial spoilage of fish. In: Food Microbiology: Advances and Propects, eds: Roberts TA and Skinner FA. Academic Press, London, England, pp 217.

Hotchkiss JH, Baker RC and Qureshi RA (1985). Elevated carbondioxide atmospheres for packaging poultry. II. Effects of chicken quarters & bulk packages. Poultry Sci, 64:333 .

Insausti K, Beriain MJ, Purroy A, Alberti P, Gorraiz C and Alzueta MJ (2000). Shelf life of beef from local Spanish cattle breeds stored under modified atmosphere. Meat Sci, 57(3): 273-281.

Insausti K, Beriain MJ, Purroy A, Alberti P, Lizaso L and Hernandez B (1999). Colour stability of beef from different Spanish native cattle breeds stored under vacuum and modified atmosphere. Meat Sci, 53(4): 241-249.

Jackson TC, Acuff GR, Vanderzant C, Sharp TR and Savell JW (1992). Identification and evaluation of volatile compounds of vacuum and modified atmosphere packaged beef strip loins. Meat Sci, 31(2): 175-190.

Jay JM (1986). Modern Food Microbiology, 3rd Edn, Van Nostrand Company, New York, pp 205-238.

Jayasingh P, Cornforth DP, Carpenter CE and Whittier D (2001). Evaluation of carbon monoxide treatment in modified atmosphere packaging or vacuum packaging to increase color stability of fresh beef. Meat Sci, 59(3): 317-324.

Jeremiah LE, Gibson LL and Argnosa GC (1995). The influence of controlled atmosphere and vacuum packaging upon chilled pork keeping quality. Meat Sci, 40(1): 79-92.

Johnson BY (1974). Chilled vacuum packed beef. CIRSO (Austrilia) Food Res Quart, 34: 14.

Jones JM, Mead CG, Griffiths NM and Adams BW (1982). Influence of packaging on microbiological, chemical and sensory changes in chill-stored turkey portions. Brit Poult Sci, 23: 25.

Kerry JP, O'Sullivan MG, Buckley DJ, Lynch PB and Morrissey PA (2000). The effects of dietary-tocopheryl acetate supplementation and modified atmosphere packaging (MAP) on the quality of lamb patties. Meat Sci, 56(1): 61-66.

Keun-Taik Lee and Chan-Suk Yoon (2001). Quality changes and shelf life of imported vacuum-packaged beef chuck during storage at 0°C. Meat Sci, 59(1): 71-77.

Lanari MC, Schaefer DM and Scheller KK (1995). Dietary vitamin E supplementation and discoloration of pork bone and muscle following modified atmosphere packaging. Meat Sci, 41(3): 237-250.

Liserre AM, Landgraf M, Destro MT and Franco BDGM (2002). Inhibition of Listeria monocytogenes by a bacteriocinogenic Lactobacillus sake strain in modified atmosphere-packaged Brazilian sausage. Meat Sci, 61(4): 449-455.

Lundquist BR (1987). Protective packaging of meat and meat products. In: The Science for Meat and Meat Products, 3rd edition, eds: Price JR and Schweigert BS. Food & Nutrition Press, West Port, Connecti-cut, pp 487-505.

Luño M, Beltrán JA and Roncalés P (1998). Shelf-life extension and colour stabilisation of beef packaged in a low O_2 atmosphere containing CO: Loin steaks and ground meat. Meat Sci, 48(1-2): 75-84.

Luño M, Roncales P, Djenane D and Beltran JA (2000). Beef shelf life in low

O_2 and high CO_2 atmospheres containing different low CO concentrations. Meat Sci, 55(4): 413-419.

Mead GC (1983). Effect of packaging and gaseous environment on the microbiology, and shelf life of processed poultry products. In: Food Microbiology: Advances and Prospects, eds: Roberts TA and Skinner RA, pp. 203.

Nam KC and Ahn DU (2003). Combination of aerobic and vacuum packaging to control lipid oxidation and off-odor volatiles of irradiated raw turkey breast. Meat Sci, 63(3): 389-395.

Nannerup LD, Jakobsen M, Frans van den Berg, Jensen JS, Møller JKS and Bertelsen G (2004). Optimizing colour quality of modified atmosphere packed sliced meat products by control of critical packaging parameters. Meat Sci, 68(4): 577-585.

Nottingham PM (1982). Microbiology of carcass meats. In: Meat Microbiology, ed: Brown MH. Applied Science Publisher Ltd, London, pp 13-65.

Ogrydziak DM and Brown WD (1982). Temperature effects in modified atomophere storage of sea foods. Food Technol, 36(5): 86.

Pexara ES, Metaxopoulos J and Drosinos EH (2002). Evaluation of shelf life of cured, cooked, sliced turkey fillets and cooked pork sausages—'piroski'—stored under vacuum and modified atmospheres at +4°C and +10 °C. Meat Sci, 62(1): 33-43.

Post LS, Lee DA, Solberg M, Furganang J, Specchio and Graham C (1985). Development of Botulinal toxin and sensory deterioration during storage of vacuum and modified atmosphere packaged fish fillets. J Food Sci, 50: 990.

Sahoo J and Anjaneyulu ASR (1997). Effect of natural antioxidants and vacuum packaging on the quality of buffalo meat nuggets during refrigerated storage. Meat Sci, 47(3-4): 223-230.

Seideman SC and Durland PR (1984). Factors associated with fresh meat color: A review. J Food Qual, 6: 211.

Seideman SC and Druland PR (1983). Vacuum packaging of fresh beef: A review. J Food Qual, 6: 29.

Seyfert M, Hunt MC, Mancini RA, Hachmeister KA, Kropf DH and Unruh JA (2004). Accelerated chilling and modified atmosphere packaging affect colour and colour stability of injection-enhanced beef round muscles. Meat Sci, 68(2): 209-219.

Sheridan JJ, Doherty AM, Allen P, McDowell DA, Blair IS and Harrin D (1997). The effect of vacuum and modified atmosphere packaging on the shelf-life of lamb primals, stored at different temperatures. Meat Sci, 45(1): 107-117.

Smiddy M, Fitzgerald M, Kerry JP, Papkovsky DB, O' Sullivan CK and Guilbault GG (2002). Use of oxygen sensors to non-destructively measure the oxygen content in modified atmosphere and vacuum packed beef: impact of oxygen content on lipid oxidation. Meat Sci, 61(3): 285-290.

Sørheim O, Erlandsen T, Nissen H, Lea P and Høyem T (1997). Effects of modified atmosphere storage on colour and microbiological shelf life of normal and pale, soft and exudative pork. Meat Sci, 47(1-2): 147-155.

Sørheim O, Kropf DH, Hunt MC, Karwoski MT and Warren KE (1996). Effects of modified gas atmosphere packaging on pork loin colour, display life and drip loss. Meat Sci, 43(2): 203-212.

Sørheim O, Ofstad R and Per Lea (2004). Effects of carbon dioxide on yield, texture and microstructure of cooked ground beef Meat Sci, 67(2): 231-236.

53. Stadelman WJ (1986). Preservation of quality in shell eggs. In: Egg Science and Technology, 3rd Edn, eds: Stadelman WJ and Cotterill OJ. Avi Publishing Co. Inc., Westport, Connecticut, pp 63-73.

Stubbs RL, Morgan JB, Ray FK and Dolezal HG (2002). Effect of supplemental vitamin E on the color and case-life of top loin steaks and ground chuck patties in modified atmosphere case-ready retail packaging systems. Meat Sci, 61(1): 1-5.

Taylor AA (1985). Packaging fresh meat. In: Developments in Meat science–3, ed: Lawrie RA. Elesevier Applied Science Publishers Ltd., Essex, England, pp 89-113.

Taylor AA, Down NR and Shaw BG (1990). A comparison of modified atmosphere and vacuum skin packing for the storage of red meats. Int J Food Sci Tchnol, 25: 98.

Walters CL (1975). Meat color: the importance of haem chemistry. In: Meat, eds: Cole DJA and Lawrie RA. Avi Publishing Co. Inc., Westport, Connectcut, pp 385.

Watts BM (1954). Oxidative rancidity and discoloration in meat. Adv Food Res, 5: 1.

Young LL, Reviere RD and Cole AB (1988). MAP of fresh red meat. Food Technol, 42 (9): 65.