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Packaging Options for Case-ready Chilled Meats Part II - Modified-atmosphere Packaging

The Information Brochure entitled "Packaging Options for Case-ready Chilled Meats – Part I" outlines the progression of retail presentation of fresh meat from traditional naked bulk trays, through stretch-wrapped foam trays to a range of vacuum-packaging-based options. These options allow for the presentation of meat in vacuum-packed meal units under conditions that physically protect the product from contamination and moisture loss whilst significantly extending the shelf life of the product.

The above brochure explains the vacuum packaging options and how meat cuts can be presented in an environment which is purposely maintained at a low oxygen level to inhibit bacterial growth. However, the colour pigment, myoglobin, remains in the purplish non-oxygenated state (reduced myoglobin). Alternatively, just prior to retail presentation the meat can be 'bloomed' in the presence of oxygen, converting the pigment to the attractive bright red colour of oxymyoglobin.

The environment can be controlled more accurately, with a wider range of options, by creating a modified-gas atmosphere in the headspace of the pack around the meat cuts. Replacement of the natural atmosphere of air (which contains approximately 21% oxygen, 78% nitrogen and 0.03% carbon dioxide) with other gas mixtures is called modified-atmosphere packaging (MAP.)

Case-ready MAP combines some of the packaging options of vacuum packaged case-ready packaging with the enhancing effects that a range of gas mixtures has on shelf life and visual presentation. The choice of packaging option and gas mixture is determined by the requirements of shelf life and presentation.

Modified-atmosphere gas mixtures

Modified-atmosphere packaging of meat uses mixtures of three gases: oxygen, carbon dioxide and nitrogen. Depending on the mixture, these gases have different effects on the growth of bacteria on the meat surface and the state of the colour pigment, myoglobin. The two main gas compositions are: high oxygen, moderate carbon dioxide for short storage life of 5-12 days; and very low oxygen, high carbon dioxide for extended storage life of 6 weeks.

Oxygen

The presence of oxygen significantly effects the growth rate of some bacteria. Aerobic spoilage bacteria, such as pseudomonads, only grow on meat surfaces in the presence of oxygen and will cause spoilage when numbers reach 1 x 107 cfu/cm^2. The absence of oxygen from the meat surface inhibits the growth of these bacteria. Anaerobic and facultative anaerobic bacteria (that grow in the absence of oxygen) predominate on the meat surface when oxygen is not present. These bacteria grow slowly at low temperatures and may cause spoilage after 10-15 weeks storage at 0°C, e.g. vacuum-packaged meat. Growth of aerobic spoilage bacteria in the presence of oxygen is significantly faster, even at low temperatures, and may cause spoilage after 5-7 days.

Oxygen plays an important role in the colour of fresh meat. In the absence of oxygen, (or at very low-levels) as in vacuum-packaged meat and in the centre of meat muscle groups, the colour pigment, myoglobin, remains in the reduced form. This pigment is a purplish colour and, when exposed to oxygen, is readily converted to the bright red oxymyoglobin form. When a vacuum package of fresh meat is opened or a muscle group is cut through, the exposed surface 'blooms' to bright red within several minutes.

Over a period of time, in the presence of oxygen, the pigment will irreversibly convert to the metmyoglobin form, which is an unattractive brownish colour. The rate of conversion to metmyoglobin is dependent on temperature and the level of oxygen present, and the inherent nature of the muscle type. The fastest rate of metmyoglobin development occurs at a level around 0.3-2% oxygen. As the oxygen content increases, the rate of conversion decreases until, at levels in which oxygen predominates, this irreversible reaction is very slow.

For effective low-oxygen MAP, oxygen levels below 500 ppm must be maintained.

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In air, oxygen penetrates only about 5 mm below the surface of meat. As the concentration of oxygen at the meat surface increases, so does the depth of penetration. Increased oxygen penetration gives increased depth of oxymyoglobin and improved bright red colour. Maximum red colour development occurs at oxygen levels above 50%. Consequently, high-level-oxygen environments present red meat in an attractive bright red condition.

Carbon dioxide

Aerobic spoilage bacteria not only require oxygen for growth but are strongly inhibited by carbon dioxide at elevated levels. Carbon dioxide does not totally inhibit the growth of all microorganisms. In fact, a gas atmosphere of carbon dioxide, with the absence of oxygen, may select for the growth of lactic acid bacteria. In a high carbon dioxide atmosphere, lactic acid bacteria become dominant at the competitive expense of aerobic spoilage bacteria. In this case, it is only after extended storage that spoilage occurs.

Carbon dioxide has a minimal effect on meat colour. By maintaining the carbon dioxide level in a gas mixture at around 20-30% with high oxygen levels of 70-80%, the bright red meat colour can be maintained, with the growth rate of aerobic spoilage bacteria being reduced to below that which would occur in air.

Carbon dioxide is highly soluble and dissolves into the water phase of meat at a ratio of approximately 1:1 gas to meat (depending on temperature – the lower the temperature, the greater the solubility), thereby reducing the volume of the headspace and concentrating the residual oxygen within 48 hours. A large volume of gas must be added to the pack to overcome this reduction and to maintain an adequate headspace within the package for carbon dioxide to work effectively.

Nitrogen

Nitrogen is an inert or unreactive gas that has no effect on bacterial growth or the colour of meat.

Nitrogen is not highly soluble and is not absorbed into the meat in any significant quantity. In MAP systems, only sufficient nitrogen is used as a filler gas to maintain a suitable headspace to prevent the packs collapsing and distorting when carbon dioxide is absorbed into the meat.

Choice of gas mixture

The proportion of each gas in the mixture affects bacterial spoilage and shelf life, myoglobin pigment form and display colour, and gas absorption and headspace during storage.

It is essential to choose the correct gas mixture to match the packaging materials, the product, and the requirements of retailers and consumers. The correct choice requires the involvement of processors, packers, packaging suppliers, gas suppliers, retailers and consumers to ensure a successful outcome.

Packaging styles used in case-ready MAP systems

Modified-atmosphere packaging requires the maintenance of a headspace within the package throughout the packing, storage and display of the product. Small 'family meal' meat products require a supporting tray to hold the product, due to the possibility of excessive weep or drip and poor shape, which are likely to be unattractive to the consumer.

Two styles of packaging are available using pre-formed rigid or semi-rigid trays to support the product. One involves the sealing of a film directly to the tray holding the product and is generally known as a lidded pack. The second involves placing the entire product and supporting tray inside a preformed bag and sealing it, generally known as flow wrapped.

Conventional foam trays cannot be used in low-oxygen packs, as the foam material from which the tray is produced contains many small bubbles of air, which will introduce oxygen to the package.

Lidded packs

Lidded packs usually consist of a deep profile barrier tray with a barrier shrink-film sealed to the upper rim. Shrink film is used to give a smooth, taut appearance that is visually attractive. The tray profile needs to be sufficiently deep to fully contain the product beneath the rim of the tray, with adequate headspace to contain a modified atmosphere over the entire, exposed product surface. There are two main types of packs: high-oxygen, moderate carbon dioxide (e.g. 80% oxygen, 20% carbon dioxide) packs of 'bloomed' bright red meat; and very low oxygen (<0.1%), carbon dioxide, nitrogen (e.g. approximately 40% carbon dioxide, with the remainder nitrogen) packs of purplish-coloured product. Gas containing almost 100% carbon dioxide cannot be used for semi-rigid packs, as absorption of carbon dioxide is likely to cause package collapse.

The minimum volume (millilitres) of the tray for high-oxygen MAP case-ready packed products is 2 times the weight (grams) of the product. This allows for a volume of gas approximately equal to the volume of product. i.e. for 500 grams of meat, 500 millilitres of gas is required. Overall tray volume for this example must be 1 litre.

Packs containing moderate levels of carbon dioxide (i.e. approximately 20% of the gas atmosphere) have limitations owing to absorption of some of the carbon dioxide into the water phase in the meat. In these packs, the high levels of oxygen will maintain the meat pigment in its attractive bright red form; however the carbon dioxide concentration in the headspace is reduced to < 20%. This can result in the aerobic spoilage bacteria, as well as other types of spoilage organisms, growing slowly on the meat, causing microbiological spoilage in 7-12 days. If a higher carbon dioxide level was used, the pack may distort.

Any surface that is in contact with the tray or top film will not be in the modified atmosphere and is likely to discolour. Contact of the lower surfaces of the product with the tray is minimised by dimpling the surface of the tray bottom. This allows gas circulation below the product, ensuring that the maximum surface possible is in contact with the modified-atmosphere gas, maximising the shelf life extension effect of carbon dioxide and the colour enhancement effect of oxygen.

The trays used are an integral part of the modified-atmosphere package so must be prepared from materials that have high oxygen- and carbon dioxide-barrier properties. The trays can be rigid or semi-rigid. Alternatively they can be of foam plastic construction with a high barrier, inner layer bonded to the foam material. The choice of the style of tray to be used is determined by the requirements of the market-place and the availability and cost of equipment and packaging materials.

Films used for the top surface of the pack must also effect a high barrier to gas.

With very low-oxygen packs, peelable MAP films can be used in a similar way to films that are used for peelable vacuum-skin packaging. When the barrier outer layer of the film is in place, the product can be held in the very low oxygen atmosphere to maximise shelf life prior to retail display. At the point of display the outer film is peeled away exposing the permeable layers. Over the next 20 minutes air permeates through the film and the oxygen converts the reduced myoglobin to the bright red, oxymyoglobin. As a result, the product develops a natural bright red bloom ready for display. Peelable films that have microscopic perforations or pores in the inner permeable layer to allow accelerated oxygen transfer to the meat surface are available.

Rigid-cover packs

A similar effect has been obtained by sealing the product into a semi-rigid barrier tray containing a very low oxygen, carbon dioxide, nitrogen atmosphere: firstly, with a flexible permeable film covering the product, and secondly, with a barrier rigid-plastic cover or dome. The rigid dome maintains a low-oxygen environment within the package during storage but removal prior to display allows the product, on exposure to air, to bloom. The use of a dome allows adequate headspace to be achieved without a deep profile tray. At retail presentation the package appears similar to conventional stretch film packaging, without the large headspace associated with modified-atmosphere packs. The packaging system 'Flavaloc' uses this style of package.

An advantage of the single MAP process is that retail-ready packs can be individually selected and prepared for display.

Long shelf life

The lidded and rigid-cover packs allow for short shelf life (5-12 days) as a high-oxygen package, or moderate shelf life (3-6 weeks depending on carbon dioxide levels) as a very low-oxygen package.

Additional storage life can be achieved by maintaining the oxygen level at extremely low concentrations throughout the storage period. The addition of a sachet that chemically absorbs oxygen and releases carbon dioxide can almost completely eliminate all oxygen in a conventional low-oxygen (high-carbon dioxide) package. At packaging, the residual oxygen level is less than 500 ppm, which may be further reduced after activation of the sachet by moisture. Release of carbon dioxide from the sachet compensates for the absorption of carbon dioxide by the meat during the early part of storage.

It is possible to prepare sachets to meet the requirements of most packaging situations, depending on the size and weight of the pack. One limitation to the use of sachets is the cost of individual units, which is inversely related to the number produced. Sachets can be prepared incorporating absorbent materials that will absorb any free exudate, or weep, released by the product.

Long storage lives of fresh meat can also be obtained with peelable-film technology systems utilising chemical sachets that scavenge oxygen and release carbon dioxide. The packaging system Trifresh uses this technology, with greater than 6 weeks storage life at 0°C and 2 to 3 days retail display commercially achievable.

Flow-wrapped packs

Flow wrapping is the formation of a barrier-film envelope entirely enclosing the package, including both the product and its supporting tray. This requires different equipment from that required for lidded packaging as the requisite seals are only within the structure of the barrier envelope or bag. Since the modified atmosphere is maintained within a bag, the tray does not have to be of material impermeable to gas. In fact, conventional foam trays inside a barrier, shrinkable bag produce an attractive and technically suitable package for these case-ready, high-oxygen MAP products. Five to 10 days shelf life can be obtained using an atmosphere of 80% oxygen and 20% carbon dioxide.

Flow-wrapped packs, even with rigid plastic trays, are not suitable for low-oxygen packaging. For effective low-oxygen MAP, oxygen levels below 500 ppm must be maintained. Owing to the non-uniform configuration of the meat and packaging, it is impossible to ensure that all pockets of air inside the impermeable bag are extracted and replaced by carbon dioxide. Any residual air contains 20% oxygen and, when dispersed through the final package, will prevent achievement of the necessary very low levels of oxygen. For high-oxygen packs, this is not a problem, as any small amounts of residual oxygen present will have little effect on the overall gas composition.

Packaging operations

The successful implementation of MAP case-ready technology relies on a combination of the selection and integrity of the packaging materials and the control of the packaging process.

Selection of packaging materials

In a MAP package it is essential that the selected gases be maintained at the recommended levels within the package for maximum performance. The permeability of carbon dioxide through a packaging film is approximately 3-4 times that of oxygen. The use of very low permeability films is essential to maintain these gases at the required levels. Films should be selected primarily for their oxygen-barrier properties, followed by optical properties including gloss, clarity, antifog capability, seal integrity and machineability.

Film integrity

Barrier films used for MAP case-ready packaging must have a permeability of no greater than 10 cubic centimeters of oxygen per square metre of film per 24 hours at 25°C, 760 mm mercury air pressure and 75% relative humidity. At refrigerated temperatures, permeability will be significantly less. A further reduction in permeability is obtained if the film is shrunk after sealing. During shrinkage the film thickens, making it more impermeable.

Tray integrity

As the tray is an integral part of a lidded package, it is as important to maintain impermeability in the tray as it is in the case of cover film. As the tray provides stacking strength during storage it must be robust enough to avoid distortion and damage. During the tray formation process, the plastic becomes thinner at the corners, increasing permeability in these areas. Trays must be specifically produced for modified packaging purposes to ensure adequate impermeability at all points and under all conditions of production, storage and distribution.

The total package permeability to oxygen should be limited to a maximum of 0.05 cubic centimetres per tray per 24 hours, at 25°C and 760 mm mercury air pressure. Carbon dioxide permeability of the same film will be 0.15 cubic centimeters per tray per 24 hours at 25°C and 760 mm mercury air pressure. Consequently it is important to consider the gas mixture composition and the need to prevent transfer of these two gases.

Evaluation of trays for permeability should be done as a total package under production conditions and can generally only be carried out by packaging specialists, such as Food Science Australia's Sydney Laboratory and some suppliers.

Process control

The packaging technology chosen is only as effective as the control applied to the overall packaging process. An effective quality assurance program is essential to ensure that the following issues are addressed and controlled:

- Product hygiene prior to, and during, packaging
- Temperature control from slaughter to consumer
- Handling procedures
- Stock control, both in the processing and retailers cold rooms.

It cannot be stressed strongly enough that the success of modified-atmosphere packaging of meat and meat products is critically dependent on the control of product hygiene and temperature throughout the life of the product from carcase to consumption. A HACCP based quality assurance program should be implemented.

To ensure effective management from slaughter to the consumer it is essential that the following points should be considered before committing to any case-ready packaging technology option:

- Product and production capabilities
- Market intelligence
- Experienced suppliers of both packaging equipment and materials
- Reliability of processors supplying carcase or vacuum packaged meat to the retail packaging process
- Capability of cold chain operators to maintain recommended temperatures for meat chilling and transportation.
- The retailer's ability to display the product effectively.

Case-ready packaging technology can only be successfully implemented if the points outlined in this brochure are addressed.

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