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Modified-atmosphere Packaging of Chilled Primal Cuts & Carcasses

Modified-atmosphere packaging (MAP), sometimes called controlled-atmosphere packaging (CAP) or gas flushing, involves creating a specific atmosphere around a food product. This atmosphere controls chemical, enzymatic or microbiological reactions and therefore reduces or eliminates the main processes of deterioration in the product. This results in the extension of storage life.

The atmosphere is generally contained within the packaging material of the individual food item. It may, however, be contained within the material of an outer pack containing several individual items or even within the confines of an individual shipping container. For gas-flushed chilled primals and carcasses the gas environment is contained within the packaging film of the one or more cuts or carcasses.

Why gas flush primals and carcasses?

In Australia vacuum packaging is widely accepted as the standard method of extending the storage life of chilled meat. Although very effective on beef it does not give adequate extension of storage life to sheep meats to allow sea freight to some remote markets. The vacuum-packaging process is also unsuitable for very large items, such as whole lamb carcasses, and products with high levels of exposed bone. Modified-atmosphere packaging, using an atmosphere that consists almost entirely of carbon dioxide, has been established as a viable alternative. Although not widely used to date, the commercial application of this technology to lamb carcasses and cuts has been successfully carried out since the early 1990s.

How does CO₂ gas flushing work?

The spoilage bacteria commonly found on meat, pseudomonads, not only require oxygen for growth and are retarded without oxygen, but are inhibited by carbon dioxide at levels >20%. *Brochothrix thermosphacta* does not require oxygen for growth and requires 60-70% carbon dioxide to begin retarding growth. Carbon dioxide does not, however, completely inhibit the growth of all microorganisms. In fact, carbon dioxide and

an absence of oxygen may promote the growth of lactic acid bacteria. In an atmosphere of almost 100% carbon dioxide, lactic acid bacteria are selected at the competitive expense of other spoilage bacteria. It is only after extended storage that spoilage occurs. It was found that with lamb carcasses packed commercially in carbon dioxide with oxygen levels of less than 0.2%, lactic acid bacteria predominated at 10 weeks storage.

Of equal commercial importance is the retail shelf life of products that have been held in a high carbon dioxide atmosphere for an extended period. The longer a product is held in an atmosphere of carbon dioxide, the shorter the retail shelf life on opening. For example, although lamb carcasses can be stored for 16 weeks, the shelf life in retail display is short. The optimum result is four days retail life after 12 weeks modified-atmosphere storage.

Carbon dioxide is highly soluble and dissolves in the meat tissue, enhancing the inhibitory effect against spoilage bacteria. The meat will absorb approximately 1.5 times its volume (depending on fat to meat ratio) of carbon dioxide. Allowing for filling of any cavities in the product, such as a lamb carcass chest cavity, and provision of a head space in the pack, 2 to 2.5 times the product volume of carbon dioxide needs to be flushed into the pack, independent of the product packed. For lamb carcasses packaged in pairs, 2.5 times the volume has been established as ideal. For example, two 14 kg lamb carcasses require 70 litres of gas. This initially leaves the pack highly inflated. During the first 48 hours of storage, absorption of carbon dioxide reduces the headspace and leaves the pack slightly slack. Insufficient gas will create packs with a secondary vacuum and little residual carbon dioxide. This places the product and the packaging film under stress, resulting in excess drip, as well as reducing the inhibitory effect on bacterial growth.

It must be stressed that the establishment of a modified atmosphere within suitable packaging can significantly extend shelf life, but it is imperative that three factors be maintained:

- The gas atmosphere in the headspace of the bag must be correct, i.e. the oxygen level must be less than 0.1%.



- The hygiene of the processing area and carcasses must be at the highest level.
- The temperature of carcasses should be as near to 0°C as possible and chilling systems throughout the cold chain must be 0°C ± 0.5°C.

The processor should implement a HACCP system in order to control and monitor these and other factors outlined in this brochure.

How effective is the modified-atmosphere packaging of beef?

The extension of storage life for beef primals packaged in 100% carbon dioxide has not been as significant as for other species. Beef muscle contains a higher content of the colour pigment myoglobin which, in the presence of oxygen, oxidizes to metmyoglobin, causing 'browning' of the meat. This can occur at oxygen levels as low as 0.3%. It is difficult under commercial conditions to create and maintain carbon dioxide atmospheres sufficiently low in oxygen to prevent this surface discolouration from occurring.

Since beef cuts are generally not bone-in and are of a shape that can easily be vacuum packed, there is very little advantage in modified-atmosphere packaging as an alternative to vacuum packaging for single primals.

Modified-atmosphere packaging does not necessarily achieve lower levels of residual oxygen than vacuum packaging, so little difference (due to discolouration) in storage life could be expected. The difficulty in obtaining a head space around a bulky, beef primal in excess of 1.5 times its weight makes cartoning impractical until carbon dioxide absorption has occurred. The limited additional storage life obtained, when set against these problems, does not warrant the expense of modified-atmosphere packaging. The 12 weeks currently obtainable with vacuum-packed beef is generally adequate.

However, recent trials have indicated that MAP, using high levels of carbon dioxide, will have applications for retail-ready consumer portions of beef, since the bloomed colour is retained longer.

How effective is the modified-atmosphere packaging of sheep meats?

Modified-atmosphere packaging has been used successfully in Australia, albeit on a small scale, to sea freight chilled lamb carcasses to the Middle East since the early 1990s. In this commercial application the lambs are packed in reversed pairs interlocked with the hind legs of each carcass fitted into the chest cavity of the other.

After proper packing, storage and shipping it has been found that the carcasses are visually and microbiologically acceptable. In the absence of oxygen, oxymyoglobin at the carcass surface reverts to myoglobin, giving the carcass a dull look. However, on opening the packs and hanging the carcasses for only 20 minutes, the carcasses re-bloom close to their original red colour as the myoglobin is converted back to oxymyoglobin. When compared with a conventionally packaged carcass they may either appear slightly paler or have a slightly 'fiery' appearance

if the fat has been stained by excessive weep. Experience has shown the product to be very acceptable visually after 12 weeks, and sometimes for up to 16 weeks.

During storage, ageing takes place and the muscle fibres within the meat break down owing to natural enzymic activity, giving a tenderising effect. Even after 4 weeks this effect is quite dramatic, giving extremely tender product. However after 16 weeks the product, even if microbiologically sound, has been found to have lost sufficient muscle fibre to adversely affect texture and palatability. This change in palatability is noted as a pulpy texture and loss of 'bite'.

Commercial experience has shown that, using this packaging technique, carcasses can be reliably stored without problem for up to 12 weeks, and have a retail shelf life of 4 days. The product has acceptable colour, odour and retail shelf life and has improved texture. Storage beyond 12 weeks has been successfully achieved but is not commercially recommended.

How is the lamb carcass gas-flushing process carried out?

Selection of carcasses for this process is very important. To optimise the use of container space and packaging, carcasses must be neck strung and within a limited size range. Carcass length is the critical parameter and carton design should take into account the average and maximum lengths of carcasses within the weight range desired by the market. Longer-legged lambs from late-season or with merino influence may create a problem unless optimum container utilisation is sacrificed by using long cartons. Attempts have been made to use over-length carcasses by band-sawing the shanks. The danger with this is, however, the high possibility of contaminating the carcasses prior to packing.

To achieve maximum storage life, carcasses should be processed as soon as possible after slaughter and not beyond 48 hours. It is essential that the carcasses be adequately chilled. Ideally packing will occur the day after slaughter with deep muscle temperatures at 0° - 1°C. If overnight chilling cannot achieve 1°C, then packing should be delayed a further day to ensure that the carcasses are at this temperature.

For cost-effective use of packaging materials during MAP of lamb carcasses, the carcasses are packaged in pairs. Two freshly slaughtered and chilled carcasses are interlocked head to toe so that the hind legs of each carcass fit into the chest cavity of the opposing carcass. Protective material is placed over the rim of each anal cavity to prevent punctures, and the pair is wrapped in an absorbent wrap. Plastic hoods are placed over each end to protect the neck and legs from damaging the outer bag and the whole unit is placed inside a very low permeability bag. This is the outer barrier bag used to contain the modified atmosphere. Oxygen permeability of the film should be less than 10 cubic centimetres of oxygen per square metre of film per 24 hours at 25°C, 760 mm mercury air pressure and 75% relative humidity. Foil laminate bags have been used in New Zealand but lack of visibility inside the pack during flushing, and excessive cost, make them less desirable.

The bagged carcasses are then fully evacuated of air and gas flushed with carbon dioxide to produce an atmosphere with a

target oxygen level of less than 0.1% (1000 ppm) and a maximum oxygen level of 0.15% (1500 ppm). To ensure that this low level is achieved, it is necessary to establish a strict specification for the carbon dioxide gas supplied. The carbon dioxide used must be of food grade, have a maximum oxygen content of 200 ppm and have very low hydrocarbon content.

The flushed and sealed pack is cartoned, if gas flushing has not been carried out in the carton, and finally labelled and possibly strapped ready for storage at -1 to 0°C.

Two types of machine are available for flushing and sealing: the snorkel-type machine and the chamber-type machine. The snorkel type machine evacuates and flushes the bag containing the carcasses by extending a probe into the anal cavity of the upper carcass and alternately applying vacuum and gas. To achieve an oxygen level as low as 0.1%, three evacuation and flushing cycles are necessary.

The chamber machine evacuates and flushes the entire chamber in which the bagged carcasses are placed. As the bag is not collapsed onto the carcasses, evacuation is more efficient and, to achieve 0.1% oxygen, only one cycle is required.

With a snorkel machine gas flushing occurs with the bagged carcasses already in their carton to minimise handling and to give them support during the flushing process. With a chamber machine, restrictions in chamber volume require that the carcasses are cartoned after gas flushing.

Both machine types have advantages and disadvantages. From a commercial viewpoint, the chamber machine is considerably more expensive than the snorkel machine but has a greater throughput as it requires only one cycle to achieve 0.1% oxygen. Carbon dioxide usage is similar in both machines as, although the chamber machine requires only one cycle against the snorkel machine's three cycles, it must evacuate and flush the entire chamber, not just the bag. From a quality-control viewpoint, the snorkel machine has the disadvantage that the bag is repeatedly collapsed onto the carcass during evacuation and the film becomes stressed and may puncture. An advantage with this type of machine is that the pack, not being enclosed in a chamber, can be seen during its entire flushing and sealing process so that any problems that occur can be observed.

Consideration should also be given to the method of holding the bag during sealing as the presence of wrinkles along the seal can cause leakers. Obviously the machine chosen should be capable of handling the bag size required for carcasses or cuts. Evaluations of both machine types by the CSIRO Meat Research Laboratory (now Food Science Australia) have shown that under similar production conditions the leaker rate and operator dependency are less with the use of a chamber-type machine. However, the leaker rate is low enough with both machines to ensure commercial acceptability.

Quality control of carbon dioxide-flushed carcasses must be of the highest standard to achieve the required shelf life. Those parameters necessary for good vacuum packaging must also be observed for this packaging process. These include:

- raw-material quality;
- personal hygiene;
- plant sanitation;

- temperature control; and
- product and package handling.

Some specific quality checks are required. Regular evaluation of oxygen content in the atmosphere is necessary. Most oxygen evaluations are generally carried out immediately after sealing the bag but some evaluations during storage will give valuable information on possible leakage rates. Evaluation can be done non-destructively by piercing the bag with a sampling needle through a resealable, rubber septum. A sample is drawn off automatically through a sampling pump and feed tube direct to the oxygen analyser. Once confidence is gained with this packaging system a sampling level of 1 in 10 will give adequate assurance of operator and machine performance. Sampling for oxygen content must be supported with strict visual assessment.

Leakers can be detected at the point of packing (with experience) but are more likely to be detected if product is visually checked 48 hours after packing, before the carton is finally strapped. Lidding and strapping after 48 hours allows the carbon dioxide to be absorbed into the carcass, reducing pack volume. Unfortunately this is not always possible, particularly as product throughputs increase. Storage space limitations may necessitate lidding and strapping immediately after packing. This is feasible but produces a very tight fit in the carton and, consequently, stress on the barrier bag.

The flush volume of gas should be checked regularly to ensure an adequate volume is used to maintain a headspace and prevent a secondary vacuum. This will ensure that the necessary carbon dioxide atmosphere is maintained. Gas volumes are checked by flushing and sealing an empty bag and pushing it into the bottom of the carton so that it takes the shape of the carton. By calculating the volume of the carton filled, a reasonably accurate determination of the volume of gas dispensed can be made.

The use of large volumes of carbon dioxide can freeze the delivery line, restricting gas flow. To minimise this problem, it is recommended that three or more gas cylinders be connected through a manifold and a heater unit be installed in-line to maintain the gas above its freezing point.

Difficulties experienced in obtaining a suitably low level of oxygen while gas flushing can be reduced by including, inside the MAP package, a sachet containing chemicals that react in the presence of moisture to scavenge oxygen and release carbon dioxide. Sachets that include an absorbant pad, which soaks up weep, are available for bulk packs, such as lamb carcasses. This moisture then activates the enclosed chemicals. The resulting chemical reaction will use up approximately 120 millilitres of oxygen and release approximately 7 litres of carbon dioxide. Use of these sachets not only reduces the residual oxygen level in the final pack but also allows a lower level of carbon dioxide to be flushed into the pack prior to sealing. This allows the packs to initially be less inflated while still avoiding a secondary vacuum from carbon dioxide absorption by the meat. The results are reduced difficulties in lidding highly inflated packs and a lower incidence of leakers from stressed packaging film and seals.

Can cuts from sheep, lamb and other species be modified-atmosphere packaged?

Bone-in and boneless sheep and lamb cuts can be effectively packaged in 100% carbon dioxide-modified-atmosphere packaging. A number of options have been successfully tried including:

- MAP of individual cuts using methods very similar to those described for lamb carcasses. Bone-in cuts will require the use of bone protection material to prevent puncturing of the impermeable film. Any weep is absorbed by a soaker pad placed beneath the cut rather than an entire blanket wrap. Several carbon dioxide-gas-flushed packaged cuts are placed in a carton prior to strapping and storage.
- Master packaging of pre-wrapped cuts in a 100% carbon dioxide-modified atmosphere. Primal cuts are pre-packaged by wrapping in a permeable IW stretch film or by vacuuming in a permeable bag. The permeability of the film or bag must be adequate to allow rapid penetration of carbon dioxide through the film or bag to the product. The pre-packaged cuts are then placed into an impermeable bag in a carton for gas flushing with 100% carbon dioxide. A chamber machine is the most suitable gas-flushing machine for bulk cuts. The chamber machine can handle a standard 27.2 kg meat carton.

After gas flushing, the carbon dioxide passes through the permeable film creating a suitably low oxygen/high carbon dioxide atmosphere at the meat surface, limiting microbial spoilage. When the master pack is opened, the carbon dioxide disperses and oxygen permeates the film back to the meat surface, which re-blooms to an attractive red 'fresh meat' colour.

- 100% carbon dioxide master packaging of 100% carbon dioxide-MAP primal cuts. It has been shown that cuts can be individually 100% carbon dioxide-modified-atmosphere packaged using bags made from impermeable film and then further packaged in a master pack using 100% modified-atmosphere packaging. It is expected that this option, while technically feasible, is unlikely to be commercially used except in circumstances demanding the extremes of shelf-life extension.

Care in choice of gas, handling and storage as required for lamb carcasses applies equally to cuts. With the additional handling and resultant contamination that occurs with the preparation of cuts from carcasses, the storage life and retail shelf life of MAP sheep cuts is understandably shorter than that of sheep carcasses packaged under the same conditions. It has been shown that primals packed commercially in carbon dioxide with oxygen levels of less than 0.2% can be stored for 10 weeks, and have a retail shelf life after opening of 3 days.

Consumer portions of lamb can also be successfully packaged in retail-ready trays using high levels of carbon dioxide to give a storage life of 6 weeks (refer to the brochure 'Packaging Options for Case Ready Meats').

Pork cuts can be packaged in a 100%-carbon dioxide atmosphere to achieve an extended storage life. Pork, however, exhibits a higher incidence of high-pH meat on which carbon dioxide is less effective in inhibiting bacterial growth. This

results in MAP being less effective on pork than on beef and lamb in extending storage life. Non-bacterial enzymic activity in pork during storage can cause flavour changes, limiting storage life. Pork primals, packaged under good conditions in a carbon dioxide atmosphere containing less than 0.2% oxygen, can be stored for 10 weeks. Those parameters discussed in relation to limiting the storage-life extension of lamb also apply to chilled pork cuts.

What opportunity is there for using other gas mixtures?

As the purpose of gas flushing primal cuts and carcasses is only to extend shelf life and not to enhance retail display, the only relevant gas is that most suitable for shelf life extension. While other gases and gas mixtures have application in gas flushing of retail ready meats and other food commodities, only a 100%-carbon dioxide atmosphere has a commercial application for primal cuts and carcasses.

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