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Meat Technology Update

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Modified atmosphere packaging of meat

Increasingly, red meat for retail display is being prepared and packaged centrally rather than at retail stores. Centralised packaging is growing in popularity because it requires less labour, equipment and space. It also reduces the chances of further cross-contamination.

Consumers regard bright red meat as fresh and will often make choices between packs of meat on this basis alone. This affects the marketability because any discoloured meat must be trimmed or sold at discount prices. Therefore, with any distribution system that involves centralised packaging, the appearance must be maintained.

Figure. 1. Packages of beef mince 3 days after purchase; overwrap above, MAP beneath. Evidence of discolouration near surface of overwrap pack.

Technical basis for MAP

The oxygen in air gives fresh meat its bright red appealing colour. Meat blooms whether its surfaces are exposed directly to air or over-wrapped on trays under oxygen-permeable film. The presence of oxygen leads to eventual browning of the meat surface and to growth of spoilage bacteria. Both of these make the meat unacceptable to consumers after several days, even when it is held near 0°C.

Vacuum-packaging of beef and lamb in barrier films excludes oxygen from the surface of the meat. This greatly extends the storage life of the meat, particularly when it is stored at –1 to 0°C. However the bright red bloom that is so appealing to retail customers does not occur when oxygen is excluded. Therefore, although the shelf-life extension provides the opportunity for much wider distribution of the meat from a central location, vacuum packs of purple beef or lamb continue to meet with opposition from retail customers.

The storage life extension provided by vacuum-packaging is only partly due to the exclusion of oxygen; it is also due to carbon dioxide (CO_2) that is generated in the meat tissue.

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The knowledge that CO_2 inhibits bacterial spoilage of meat and that oxygen is needed to give the bloom that appeals to retail customers, has led to the development of modified atmosphere packaging (MAP) where relative proportions of gases in the packs are varied to achieve desired outcomes.

The principal pigment of fresh meat is myoglobin, which can exist in three main forms. Deoxymyoglobin is the deoxygenated form and is responsible for the purple colour of freshly cut meat or meat stored in the absence of oxygen, such as with vacuum packaged meat. When exposed to oxygen, deoxymyoglobin is rapidly transformed into oxymyoglobin. This form of myoglobin is responsible for the attractive bright red colour of meat typically associated with freshness by consumers (Figure 1). The third form, metmyoglobin, is brown and is irreversibly formed through the oxidation of myoglobin. Consumers relate the presence of this brown colour to the loss of freshness and are reluctant to purchase that particular product. Final meat colour is determined by the relative proportions of the three forms of myoglobin present at the surface of the meat

The main gases used in MAP are oxygen, carbon dioxide and nitrogen. Oxygen and carbon dioxide are of most significance in MAP meat and the relative proportions of each of them affect changes in meat colour and microbiological quality.

When exposed to O_2, fresh meat will exhibit the bright red colour characterised by oxymyoglobin formation. However, low concentrations of O_2 – around 0.5 to 1% - lead to rapid onset of irreversible browning. These conditions must be avoided by either keeping the O_2 at much higher levels or by excluding it.

The role of CO_2 is primarily to inhibit the growth and metabolism of microorganisms. CO_2 selectively inhibits the growth of gram-negative spoilage bacteria, and, in doing so, may allow other bacteria such as lactic acid bacteria to predominate. The lactic acid bacteria cause spoilage only after extended periods.

Nitrogen is used as an inert gas filler. It provides no benefit to the product in terms of bactericidal or bacteriostatic effects but helps maintain the structural integrity of the package when carbon dioxide is absorbed into the meat. The use of nitrogen has no direct effect on meat colour.

An important consideration with the use of CO_2 in MAP is that it is highly soluble in muscle and fat tissue. It will dissolve into the meat in an approximate 1:1 ratio (1 litre CO_2 per kg of meat). The solubility of CO_2 is temperature dependent and increases at lower temperatures. Headspace calculations must take the solubility of CO_2 into account when planning the packaging parameters. When using a CO_2-rich mixture in packs, the ratio of the total package volume (in litres) to the meat weight (in kilograms) is dependent on the gas mix composition and could be up to 3:1 for mixtures in which CO_2 predominate.

In practice, with packs containing high O_2 and moderate CO_2, a compromise between that ideal and a tolerable pack size means ratios are usually somewhat lower. A minimum of 20% CO_2 throughout the storage period should be aimed for as explained later. The fact that CO_2 can be either generated from meat as mentioned earlier, or absorbed into it, means that the concentration of CO_2 in packs can vary depending on such factors as its initial concentration in the mixture and the storage temperature.

Packaging options

Three main types of packaging approaches exist for modifying the environment in retail packs of fresh meat:

- Vacuum / vacuum skin packaging;
- high O_2 MAP;
- low O_2 MAP.

The three approaches differ in their preservative capabilities and their applicability to the centralised packaging of retail meat.

The term MAP is usually reserved for procedures where air that surrounds the meat is replaced with gas mixtures that differ in composition from air. Vacuum-packaging is the most common method of modifying the internal environment of a package, however it has not been considered in detail here because it does not fit within this meaning of MAP.

Vacuum / vacuum-skin packaging

During conventional vacuum packaging, product is placed in a package of low O_2 permeability, the air is evacuated and the package is sealed without replacement with another gas mixture. Over time, an environment containing elevated levels of CO_2 will develop as the meat product and contaminating microorganisms consume residual O_2 and produce CO_2. The meat is purple in appearance however and therefore unappealing to many consumers. However, a range of beef, pork and lamb products in heavily printed and decorated bags, that are vacuum packed and put straight on the retail shelf have met with good consumer acceptance.

Vacuum-skin barrier packs are an alternative to conventional vacuum packaging for retail portions. A further enhancement of this approach is to use special peelable films. In these systems, air is evacuated and packs are sealed using an O_2-permeable film overlain with a peelable O_2-impermeable film to maintain the oxygen-free environment of the pack. Prior to retail display, the outer impermeable film is removed and the meat blooms on exposure to air.

High O_2 MAP

The concept of packing fresh red meat under high concentrations of O_2 to retard metmyoglobin (browning) formation has been recognised for many decades. High concentrations of O_2 are used to increase the amount of oxymyoglobin at and beneath the surface of the meat tissue and a bright red colour. This high O_2 concentration does not inhibit the growth of aerobic spoilage organisms. The growth rate of the aerobic spoilage organisms can be reduced by the addition of moderate amounts of CO_2 to the gas mixtures. When the CO_2 content of a gas mixture exceeds 20%, the rate of growth of the microbial population is approximately halved. Therefore, an atmosphere of around 80% O_2 and at least 20% CO_2 is beneficial for both microbiological quality and meat colour. In practice atmospheric mixtures of 60-80% O_2 and 20-40% CO_2 are commonly used.

The use of high O_2 MAP is suitable for products that are to be held for short periods of time and in which a bright red colour is most desirable throughout the display life. Temperature control is critical to the success of this application. Poor control will lead to growth of spoilage organisms and premature browning of the meat.

Low O_2 MAP

Low O_2 MAP is aimed at exploiting fully the inhibitory effects of CO_2 on spoilage bacteria and is used on products that are to be transported long distances or stored for several weeks. Products may be gassed with CO_2 alone although the water and fat solubility characteristics of CO_2 often require the addition of N_2 to prevent the pack collapsing. Gas mixtures used in this type of MAP will often contain greater than 65% CO_2 with the residual as nitrogen.

Despite the obvious drawback of the purple meat colour, it is possible to use this technology in the centralised packaging of retail meat cuts. The retail cuts can be placed in pre-formed plastic trays and after air has been replaced with the gas mixture, a dual-layer film is applied to seal the pack. The dual layer film consists of a peelable O_2 impermeable film that when removed after the packs of product have been stored, exposes an O_2 permeable film that allows the meat to 'bloom'. This process allows retail meat cuts to be stored for much longer periods of time prior to display than high O_2 MAP and thereby lends itself for centralised production systems. However there are reservations about this system because it can take some hours for the meat to bloom sufficiently to put on retail display.

Master packaging is a system that also enables centralised packaging of fresh beef cuts. In this technique, several conventional retail packs wrapped in gas-permeable film, are placed in a large high-barrier bag and typically filled with a high CO_2 atmosphere. At the retail level, the outer bag is opened and packs removed to allow the meat to bloom. Extended storage and retail display-life have been achieved using this system and it is being used more widely.

Meat Types

There are considerable differences between the storage life and display life of meat from different species. Beef, lamb and pork have differing susceptibility to chemical and microbial spoilage. Packaging systems offer various possibilities depending on the particular conditions that are chosen, but all depend on changing the atmosphere within which the meat is packaged.

Beef

Consumer preference for the bright-red colour in fresh beef is a major factor in determining the way beef is packaged. As a consequence, the use of vacuum packaging in retail marketing is limited.

Whilst vacuum packaging currently dominates the meat distribution system, the use of MAP for fresh retail-ready beef continues to increase rapidly throughout the world with the US predicting that by 2003, 50% of ground beef sold in the US will be sold in case ready format. MAP for retail incorporates high levels of O_2 and CO_2 to achieve acceptable colour and shelf-life. High O_2 MAP mixtures of 60-80% O_2 and 20-40% CO_2 are commonly used and a display life of 5-8 days can be achieved. High O_2 MAP systems are therefore useful for centralised production facilities supplying directly to local markets.

The use of low O_2 MAP for beef is not recommended, as the meat will discolour at low O_2 concentrations. However, MAP systems that employ oxygen-free gas mixtures of 50-90% CO_2 and 10-50% N_2 and double layer peelable film can provide extended storage and shelf life. Storage of up to 40 days followed by up to 4 days retail display can be achieved using this approach.

Lamb

As with beef, consumers prefer lamb to have a bright red colour during retail display and for this reason MAP systems that use low levels of O_2 are not used for retail packs.

Vacuum packaging and flushing using CO_2 enables packaged lamb to have a fresh/chilled storage life of up to 16 weeks at –1 to 0°C, with acceptable display life. This compares with a maximum of 8-10 weeks with conventional vacuum-packaging.

High O_2 systems remain the first choice for the MAP of consumer cuts of lamb. However, growth of certain spoilage bacteria (e.g. *B. thermosphacta*, *S. putrefaciens* and psychotrophic Enterobacteriaceae) at the high pH of some lamb meat (= 5.8) limits its display life. The use of MAP systems for lamb cuts at the retail level has consequently met with limited success to date.

Pork

Unlike beef and lamb the colour of pork is relatively insensitive to oxidative deterioration at low O_2 concentrations. Therefore low O_2 MAP can be used with pork. It should not, however, be used with pork of pale, soft, exudative (PSE) quality as the low residual O_2 concentrations cause the meat colour to rapidly deteriorate.

Low O_2 MAP is used extensively for bulk packaging of pork primal cuts. Storage life of over 12 weeks at 0°C is possible when using high CO_2 MAP systems. This storage life is much greater than vacuum-packaged pork, which will typically spoil within 8 weeks by lactic acid bacteria.

As with beef, high O_2 MAP is used for the retail display of consumer cuts of pork. Provided the skin and excess fat is removed from the product, storage times equivalent to high O_2 MAP beef are possible.

Safety of MAP

Concerns have been expressed that the increase in shelf-life of low-O_2 MAP meats through inhibition of spoilage bacteria may provide sufficient time for human pathogens to grow to dangerous levels while the food still remains attractive to the consumer. *Clostridium botulinum* is of most concern because of the severity of illness it causes and because of its ability to grow at high levels of CO_2 and in the absence of O_2. Some strains of *C. botulinum* are known to produce toxins at temperatures below 4°C. Whilst there is a potential risk, problems can be avoided by ensuring that extended storage of the packs routinely occurs at or near 0°C. Pathogens that are able to multiply at chill temperatures such as *Listeria monocytogenes* and *Yersinia enterocolitica* are also of concern in MAP meat products. Both of these organisms are capable of slow growth at temperatures as low as 0°C, but are inhibited significantly by high levels of CO_2. Above 8°C, other pathogens capable of tolerating high levels of CO_2 such as *Salmonella* spp. and enterohaemorrhagic *Escherichia coli* (EHEC) may pose a risk to the consumer. However, as with other chilled meats, under no circumstances should MAP product be held at more then 5°C. Temperature abuse is the most important extrinsic factor influencing the storage life of fresh meat, whatever the packaging system.

MAP of fresh meats is generally considered less hazardous than MAP of ready-to-eat foods because cooking (if correctly carried out) will kill all vegetative pathogens. However, microbiological contamination is a concern and MAP is not a substitute for poor hygiene and the greatest of care should be taken when producing MAP fresh meats.

Any packaging technology is only effective if high standards of hygiene and temperature control are maintained.

Where to from here?

Exciting times await those who are able to harness the potential of MAP technology. Future developments will centre on active, smart or intelligent packaging such as O_2 scavenging from package atmospheres, CO_2 control by generation or absorption, controlled release of antimicrobial preservatives, and time-temperature integrator tags. Customer resistance to environmentally unfriendly packaging systems and demands for biodegradable packaging is likely to increase. The correct balance between storage / shelf life and the environment must be achieved.

The drive towards centralised production, packaging and distribution of case-ready meats will inevitably lead to further developments in MAP. It is important however to remember that the effectiveness of MAP fresh meat is reduced if meat of poor microbiological quality is used. Consideration must be given to the type of meat, the deteriorative processes to which the meat is subject, the initial microbiological quality of the product, and the temperature history that the product might experience during packaging, storage and distribution. Knowledge of all aspects of MAP is essential and when used effectively can give storage and retail display lives for chilled fresh meat that just 20 years ago seemed impossible.

Further Information

An information advisory package covering packaging can be obtained from MLA by contacting Matt Bishop on (02) 9463 9233.

For more information, contact one of the Meat Industry Services staff listed below.

Food Science Australia Meat Industry Services Section

The Meat Industry Services (MIS) Section of Food Science Australia is an initiative supported by Meat and Livestock Australia (MLA) and the Australian Meat Processor Corporation (AMPC) to facilitate market access for, and support world-class practices in, Australia's meat industry.

Need additional information help, information or advice?

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