MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

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Shelf life of Australian chilled, vacuum-packed lamb

Meat Technology Update 6/09 reported on recent investigations into the reported extension of shelf life of vacuum-packed beef beyond the traditional expected shelf life of 12 weeks. That MTU showed that chilled, vacuum-packaged Australian boneless beef can have a storage life of at least 20 weeks under optimal temperature conditions.

MTU 6/09 also showed that whether all vacuum-packed product will achieve this shelf life is dependent upon the initial quality of the meat (pH, colour and microbiological quality), adequate vacuum packing and temperature control through the supply chain. It then identified those meat-quality attributes and microbiological controls required to achieve this extended shelf life.

This Meat Technology Update investigates the limitations to shelf-life extension of lamb cuts stored chilled under vacuum packaging, and identifies the meat-quality attributes and packing practices, handling practices and storage conditions required to maximise chilled, vacuum-packed shelf life.

Executive overview

The process guidelines for Australian exporters of vacuum-packaged beef—to help them achieve storage lives of 10 to 12 weeks at 0°C, developed from studies undertaken over 25 years ago—have also been successfully applied to lamb cuts by many Australian processors. The application of these guidelines has allowed lamb processors to achieve storage lives of six to eight weeks at 0°C. Recent commercial evidence has indicated that shelf lives in excess of this can be successfully achieved, but are not necessarily understood, or accepted, by key markets.

Australian sheep and lamb processors export vacuum-packed lamb shoulders to a number of countries where they are sliced, packed in overwrap trays and distributed to various supermarket outlets for sale. The shelf-life for the overwrap trays is determined based on the Aerobic Plate Count (APC), using an incubation temperature of 35°C, of small surface pieces from the whole shoulders immediately prior to slicing. However, the microbiological flora of vacuum-packed meat is expected to consist mainly of Lactic Acid Bacteria (LAB) which are unlikely to result in product spoilage, even at high levels. Consequently the determination of shelf life using APC is not likely to reflect the wholesomeness of the product.

A research team at the South Australian Research and Development Institute (SARDI) has recently reported on its finding from two MLA projects investigating the shelf-life evaluation of sliced lamb shoulders. These projects investigated the relationship between microbiological status and sensory attributes of the slices of lamb after extended storage. Both projects demonstrated that there was no relationship between the sensory scores and the microbiological levels of the sliced lamb shoulders.

Figure 1: Lamb shoulder being prepared during the trial

Despite microbiological levels of sliced product from the short-aged and longer-aged shoulders reaching over 5 and 7.5 $\log_{10}$ cfu/g after four days of storage, no relationship between microbiology and sensory attributes could be established. Consequently, there may be opportunities to work further with customers to modify existing shelf-life protocols without negatively affecting consumer acceptance.

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Vacuum-packaged primal cuts

It is common to store and distribute chilled lamb as boneless primal cuts (1–5 kg) vacuum-packaged in bags made of plastic materials with low permeability to gases. Meat packed in this manner is easy to handle; its colour is preserved; and its storage life is greatly increased. Inside a vacuum package the residual oxygen is consumed by tissue and microbial activity, and carbon dioxide is produced. Provided packaging has been performed correctly, there is little head space within a vacuum package. While accurate gas analysis within a vacuum pack is difficult, the atmosphere in the head space most likely contains less than 1% oxygen, some 20–40% carbon dioxide, with the remainder being nitrogen.

Vacuum-packaged meat that is stored in low-permeability films is purple in colour since the meat pigment, myoglobin, is in the reduced form. When vacuum packs are opened, the purple colour should turn to red (return of the 'bloom') within around 30 minutes. Development of a brown colour during storage indicates that an excessive quantity of oxygen has been present during storage. This is caused either by the use of a film which is excessively permeable; or because the pack is a 'leaker', with oxygen being able to enter via a faulty bag seam or through a puncture; or because the meat tissue has been unable to consume the oxygen remaining in the pack after vacuum-packaging. One reason for this inability is the packaging of meat too long after slaughter. After several days, there is a decline in the activity of certain enzymes in the meat that assist the consumption of oxygen. By avoiding excessive intervals between slaughter and vacuum-packaging (the interval is now frequently less than 24 hours), and by carefully checking vacuum packs for evidence of leakers 24 hours after packaging, Australian processors have successfully prevented premature appearance of brown lamb in vacuum packs.

Maximum commercial storage life of vacuum-packaged primal cuts of red meats is obtained provided that:

1. meat is produced using good manufacturing practice, with low initial total counts of microorganisms that are able to grow at the storage temperature;
2. best practice is applied in handling, packing and storage of bagged and cartoned cuts;
3. packaging film is free of leaks and has a low permeability to gases; and
4. there is good control of temperature during the storage period.

When vacuum-packaged lamb spoils, it is largely due to aroma and flavour changes. Most usual is the development of an 'off' or atypical flavour in the cooked meat. When first detected this flavour is commonly described as cheesy, sour and acid, but later in storage also as bitter and liver-like. These changes are attributed to the accumulation of acidic end products resulting from the growth of lactic acid bacteria which comprise the main group of bacteria in vacuum-packed product. Sometimes other species of bacteria, including *Brochothrix thermosphacta*, are implicated in spoilage events.

Figure 2: Trial pack prepared for retail display under overwrap conditions

What we mean by shelf-life

Generally, food is considered to have reached the end of its shelf-life when it is no longer acceptable to the consumer. It may either be that the colour, flavour, texture, aroma or nutrient content have deteriorated to the point where the food is no longer acceptable; or it could be when a food-safety issue arises—where the food may make consumers ill. Whilst shelf-life is usually equated with spoilage—for fresh meat in particular—the end of retail shelf-life might be reached before spoilage, as such, is evident. For example, the loss of bloom of mince or slices during retail display, or exceeding a microbial count specified as an acceptable maximum by a retailer, may be the determinant of shelf-life; whereas spoilage—as defined by off-odour and slime—would be the point at which it is unacceptable for consumption.

The majority of Australian lamb sold in vacuum packs is opened, sliced or otherwise prepared for retail sale, and packed for retail display either by overwrapping or in a modified atmosphere. Where shelf life is determined by loss of attractive appearance—as is often the case with retail packs prepared from vacuum packs—that shelf life is set at the time of retail purchase rather than at the time of consumption. The shelf life guidelines for vacuum-packaged lamb given in this paper reflect the widespread retailer requirement for a period of retail display; however, it should be recognized that for food service and similar applications where a period of retail display is not required, the shelf life in vacuum packs will be longer.

While actual spoilage of vacuum-packaged lamb is usually microbial in origin, chemical factors also may be important in determining shelf life, particularly when it is defined in terms of appearance.

Consumer acceptance of meat

Appearance is one of the most important attributes by which consumers judge the quality of meat, therefore colour deterioration is one of the main factors that limits storage life—at least until the point of purchase. Meat must be packaged in a manner that retains its appearance, and presents it in an attractive way.

Many studies have shown that there is no direct relationship between colour and other important properties such as tenderness and juiciness. Once the consumer has purchased the meat, the other properties then become important (odour, flavour, tenderness, juiciness, etc.). The growth of micro-organisms, including aerobic spoilage bacteria once vacuum packs are opened, may result in changed odour and flavour that is ultimately identified by consumers as spoilage.

Ideally, packaging techniques for retail display and storage should maintain the appearance of meats, and delay microbial spoilage.

Meat colour

Myoglobin, a coloured pigment similar to haemoglobin of blood, gives lean meat its colour. The greater the concentration of myoglobin, the darker is the colour of the meat.

Figure 3: Trial packs under retail display

Myoglobin is the oxygen-carrying protein of muscle, and can exist in a number of forms which vary in colour. For example, in the absence of oxygen—as in vacuum packs—it is in the reduced form which is purple, but in the presence of oxygen it forms oxymyoglobin, which is bright red.

The conversion of myoglobin to oxymyoglobin is rapid and reversible. When the muscle is first cut, or has been stored in vacuum packs then exposed to air, it rapidly takes up oxygen and changes from purple to bright red. This is termed blooming and occurs within half an hour in air at 0–5°C. When oxygen is excluded by vacuum packaging, the colour reverts to purple. In the continued presence of oxygen, both myoglobin and oxymyoglobin become oxidized to metmyoglobin which is brown. The reaction proceeds slowly (at least 2–3 days in air at 0–5°C before any metmyoglobin is evident), but it is not readily reversible.

Meat colour is affected by the species, sex and age of the animal. The meat from older animals has more myoglobin than does that from young animals. Within a particular carcase, different muscles contain varying concentrations of myoglobin, and so vary in colour. Stress prior to slaughtering also plays a significant role, as it affects the final pH of the meat which, in turn, affects colour. Meat with a high final pH will frequently be darker and drier than normal.

Retail display following vacuum-packaged storage of primals

Figure 4: A retail pack of sliced lamb

Vacuum-packaged primal cuts are broken down to consumer cuts prior to sale. The longer the period of prior storage in the vacuum pack, the shorter is the display life of the consumer portions. The end of acceptable display life is normally evidenced by the development of an unacceptable amount of metmyoglobin browning. Longer display life can be achieved by the use of modified-atmosphere packaging, but its advantage becomes less as the period of prior vacuum-packaged storage increases.

Meat spoilage

In air, aerobic bacteria predominate on meat. If nitrogen-containing compounds (i.e. amino acids) are used by these bacteria, the end products of microbial growth will include malodorous amines (ammonia, putrescine and cadaverine) and sulphur compounds. Together these cause 'off' odours and flavours that are typically described as putrid. These may become evident when bacterial numbers are as low as one million per cm^2. Because some of these compounds are volatile, spoilage is usually first noted as an off (putrid) odour which causes rejection, i.e. the meat is unacceptable. This can normally only happen in vacuum packs if air has leaked into the packs.

If bacteria use glycogen or other carbohydrates from the meat, rather than the amino acids, the end products are organic acids, especially lactic and acetic acids. Under these circumstances spoilage is due to the accumulation of these acids, and since these compounds do not have a strong odour at the concentrations likely to be produced, spoilage may be noted first as a flavour change (souring). If there is any evidence of spoilage in meat from vacuum packs, it is more likely to be because of flavour—souring—than odour.

Microbial contamination

The muscle tissue of healthy animals contains very few micro-organisms. During processing, the surface of the carcase is commonly contaminated with micro-organisms which come mainly from the skin or fleece. These organisms originate from the environment of the animal (soil, etc.) and its gastrointestinal tract (faecal contamination). Other possible sources of contamination include the equipment used in dressing (e.g. knives), and the hands and clothes of the workers. While some micro-organisms of human origin may reach the meat, the bulk of the contamination comes from the animals themselves.

The intention of the meat industry is to produce meat with as low numbers of microbes as reasonably possible, in order to maximise shelf-life and minimise the occurrence of organisms associated

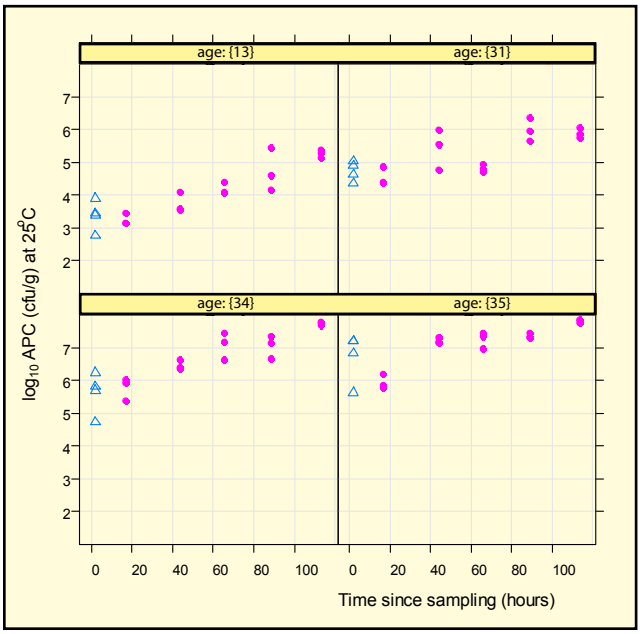

Figure 5: Aerobic Plate Counts, incubated at 25°C over time (in hours between sample collection/slicing and microbiological testing) for the four different ages of lamb shoulders—dots indicate slices; triangles indicate pieces.

with food-borne illness. That the industry is successful in doing so, is confirmed by scientific studies. National surveys of the microbiological status of Australian lamb were undertaken in 1993, 1998, and 2004; the results have been published in peer-reviewed scientific publications. In 2004, chilled sheep carcases from 20 abattoirs were found to have an average total viable count of just 190 organisms per cm^2.

Growth of bacteria on meat

Any contaminating bacteria are largely confined to the surfaces of the meat where oxygen is readily available. Meat is a good source of the nutrients needed by bacteria for growth—proteins, phospholipids, fatty acids and carbohydrate (notably glycogen) and other soluble non-protein substances.

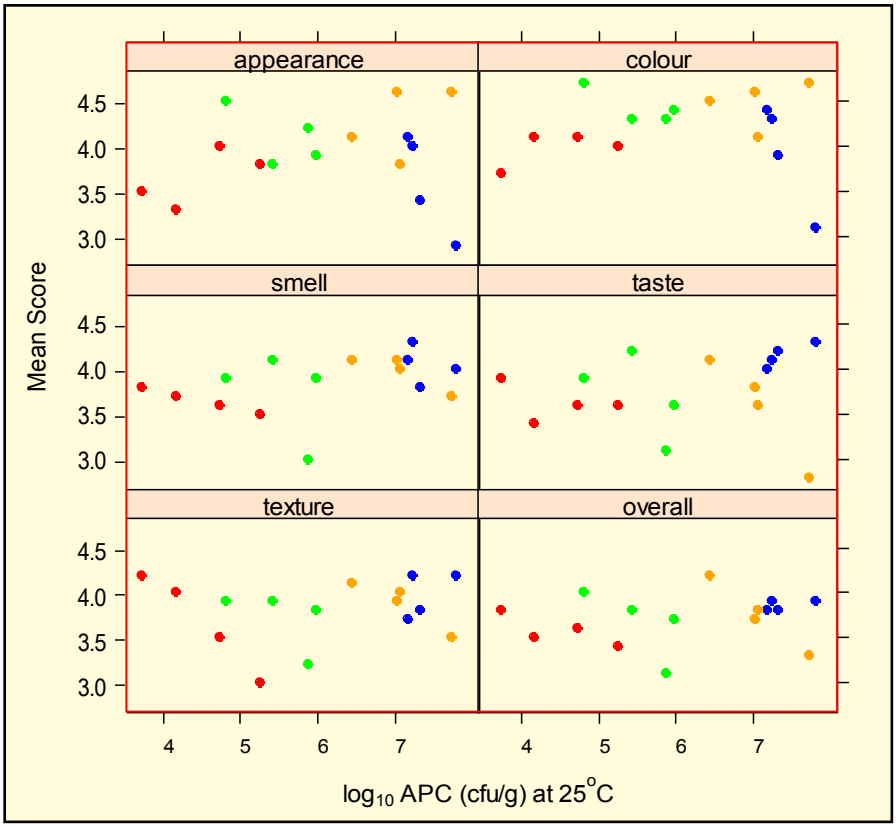

Figure 6: Scatter plot of the sensory scores versus $\log_{10}$ APC (at 25°C)—the different coloured points indicate different product ages. (red = 13 days aged; green = 31 days aged; yellow = 34 days aged; blue = 35 days aged)

Figure 7: A retail display of lamb portions

Environmental factors play a major role in controlling the growth of micro-organisms on meats.

Temperature—Growth rates at 0–1°C are only about half those at 5°C, and are further reduced as temperature falls. A storage temperature as low as is practical should be used for vacuum-packaged meat. About –1°C is optimal, provided that temperature control is such that freezing of the packs is avoided.

Gas atmosphere—The growth of many common spoilage organisms, particularly the aerobic bacteria, is inhibited by the presence of carbon dioxide and/or by the absence of oxygen, i.e. by manipulation of the redox potential. This is the basis of the effectiveness of vacuum packaging in preventing spoilage and prolonging storage life of meat.

pH—Whilst most micro-organisms can grow over the range of pH values of muscle (5.4–7.0), this factor becomes important in combination with other factors. For example, if lean red meat is placed in an environment where oxygen is no longer available, the composition of the flora which develops is greatly dependent upon muscle pH. In the context of vacuum packaging, some bacteria—that are inhibited in vacuum packs when the pH of the meat is normal for lamb (5.5–5.7)—can grow to spoilage levels at higher pH. By excluding meat from carcases where the pH of the LD muscle is excessively high, Australian meat processors of vacuum-packaged meat have eliminated spoilage problems attributed in the past to these bacteria.

Investigating microbiological growth during retail display of sliced, vacuum-packaged lamb

The objective of the first SARDI project was to investigate the changes that occur during the storage of vacuum-packed boneless lamb shoulders prior to slicing and holding in retail-style overwrapped trays. The microbiological and organoleptic properties of sliced lamb shoulders—that had been vacuum packed for between 13 and 35 days before being sliced and stored at 3.5 +/- 1°C for up to four days—were assessed. The relationship between microbiology and sensory attributes were determined.

On each assessment day during the trial, the sliced product was sampled for microbiological analysis. Microbiological tests consisted of Aerobic Plate Count (APC) and LAB incubated at 25°C for 96 hours.

Raw and cooked slices were subjected to an untrained Japanese sensory panel. The panel assessed the cooked product for taste and texture; and the raw product for appearance, colour and smell—rating them on a 1–5 point scale, where 5 = good; 1 = not good.

As expected, LAB were the predominant bacterial group on the sliced product over the storage trial, irrespective of time. The microbial growth over the four days was 0.4–0.5 $\log_{10}$ cfu/g per day (figure 5), which was consistent for APC and LAB. Also, as expected, the length of time that whole lamb shoulders were vacuum packed had a significant effect on the starting levels of the sliced product—13-day-aged lamb shoulders started with approximately 3 $\log_{10}$ cfu/g; while 35-day-aged lamb shoulders started with approximately 6 $\log_{10}$ cfu/g.

For appearance, colour, smell and taste, the sensory panel indicated that there were significant differences between the four different product ages; however, these differences were not consistent—which indicated that factors other than ageing may have impacted on the sensory profile.

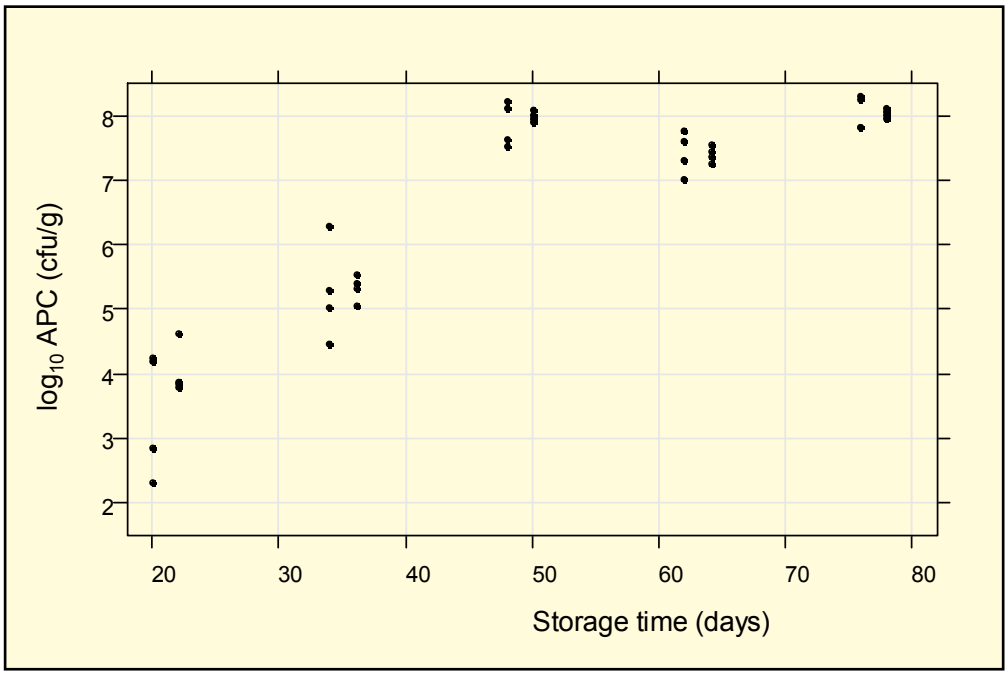

Figure 8: Aerobic Plate Counts for surface pieces collected directly after opening vacuum-packed lamb shoulders

While appearance and colour scores were affected by the order of evaluation (on the 5-point scale, the last product assessed scored on average 0.4 units lower than the first), they were unaffected by how long sliced product had been stored (figure 6). In contrast, smell, taste and overall impression of the four different product ages were unaffected by the order in which they were evaluated, but their score did reduce by an average 0.5 over the storage trial.

Investigating extended vacuum-packaged storage of lamb

The objective of the second SARDI project was to assess the microbiological and organoleptic properties of vacuum-packed lamb shoulders that had been stored for periods of up to 78 days. In particular, the relationships between microbiology and sensory attributes were investigated.

Vacuum-packed lamb shoulders were stored at –1 to 0°C for up to 78 days. Microbiological and sensory evaluations were made at days 22, 36, 50, 64, and 78 days, post vacuum packing. For each evaluation, lamb shoulders were removed from cold storage two days prior to the sensory session and on the day of the sensory session. These shoulders were sliced and packed in overwrap trays. Packs sliced two days prior to sensory evaluation were stored in the chiller during the day and under lights in a commercial display cabinet at night.

Meat surfaces were sampled from whole shoulders directly after opening the vacuum packs at each slicing occasion; and slices of retail product were sampled immediately prior to sensory evaluation from product exposed to zero and two days retail storage. All samples were microbiologically evaluated for APC and LAB. Levels of APC and LAB increased steadily up until 50 days of storage, by which time the stationary phase of 7–8 $\log_{10}$ cfu per g were reached (figure 8). Levels of APC and LAB on sliced product reflected those of vacuum-packed meat. Product freshly sliced exhibited an average of 0.8 to 1.9 $\log_{10}$ cfu/g less APC and LAB than product that had been displayed for two days.

At each sensory session an untrained panel of Japanese consumers evaluated the product for appearance, colour, smell, taste, texture and overall impression, scoring them on a 1–5 scale (5 = good; 1 = not good). No differences in sensory attributes were detected by the panel across the storage period— 22-day-aged product scored on average the same as 78-day-aged product. The only factor which had a significant effect on the sensory scores was the retail display time of sliced product, with product displayed for 2 days scoring lower on average—approximately ¼ score lower for appearance and colour, and approximately ½ score lower for the smell, taste and overall impression.

When sensory attributes were compared to microbiological levels no relationship could be found. That is, the consumer panel could not perceive difference in appearance, colour, smell, taste or texture in lamb with different levels of APC or LAB; however, consumers could perceive differences between freshly cut product and product that had been sliced and displayed for two days, though the observed differences were not related to the storage time of the product and hence the levels of APC and LAB.

Conclusions

From the data collected in these studies, it is clear that there is no relationship between the sensory scores and the microbiological levels of sliced lamb shoulders. Determination of shelf life is unlikely to be achieved through Aerobic Plate Counts, so the establishment of an APC limit is not useful. Organoleptic assessment is a more useful determinant of shelf life, particularly when supported by microbiological assessment of specific bacteria including *Brochothrix*. Consequently, there may be opportunities to work further with customers to modify existing shelf-life protocols, without negatively affecting consumer acceptance.

References

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Vacuum Packing Primal Cuts 2000, *MLA Advisory Package – Packaging.*

The experimental work described in this document is summarized from MLA reports:

- A.MFS.0185 Shelf-life evaluation of sliced lamb shoulders (August 2009); and
- A.MFS.0196 Extended shelf-life evaluation of sliced lamb shoulders (January 2010)

The information contained herein is an outline only and should not be relied upon in place of professional advice on any specific matter.

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