

Meat technology update

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Shelf life of Australian chilled, vacuum-packed, boneless beef

Extensive commercial evidence and recent scientific studies indicate that chilled, vacuum-packaged Australian boneless beef can have a storage life of at least 20 weeks under optimal temperature conditions.

Whether all vacuum-packed product will achieve this shelf life is dependent upon the initial quality of the meat (pH, colour, microbiological quality), adequate vacuum packing and temperature control through the supply chain.

The scientific studies and commercial observations suggest that shelf life may extend beyond 20 weeks, particularly if the primals are used in food service. The primals may also be suitable for retail display beyond 20 weeks, depending upon market expectations for the appearance of product.

Executive overview

Studies undertaken over 25 years ago led to process guidelines for Australian exporters of vacuum-packaged beef to help them achieve storage lives of 10 to 12 weeks at 0°C. Since then, cumulative commercial evidence, supported by recent scientific studies, indicates that a rather longer shelf life—20 weeks or more—is now regularly achieved. This paper provides information on the principle of vacuum-packaging, shelf life and consumer acceptance of meat, and suggests some reasons why the shelf-life extension has occurred. For those readers who seek a more detailed understanding of the science of vacuum packaging, the paper also discusses meat colour, meat spoilage and the role of bacteria, and describes the recent Australian scientific study of vacuum-packaged beef that supports the industry observations.

Certain factors that have particular influence on the shelf life of chilled, vacuum-packaged boneless beef are now widely recognized; the most notable are microbiological status of the meat when it is vacuum-packaged, its pH level, the integrity of the package, and the temperature history at which the packs are stored. Careful control of these and other factors by processors and distributors have resulted in consistent superior quality after storage times that were unattainable in the past. A study conducted in 2008 by Food Science Australia on vacuum packs of beef destined for United States markets



Long storage life of vacuum packs reflects vigilant attention to detail. In the case of these beef striploins, dividers in cartons minimise the risk of physical damage to vacuum packs during transport and storage

found that the microbiological count at the time of packaging the primals was generally very low. When the test packs were stored at the recommended temperature for transport and storage (minus 0.5 ± 0.5°C), even after 20 weeks the total viable count on many primals was very low, around 1000 cfu/cm². Most of the bacteria were lactic acid bacteria (LAB) that do not contribute to early loss of meat quality. By producing lactic acid and competing with spoilage bacteria, LAB are widely regarded as beneficial. As assessed by a trained meat panel, the confinement odour, the odour noted on first opening the vacuum packs, was highly satisfactory throughout the period of study. At 20 weeks the colour of the beef bloomed to a bright colour and after three days under retail conditions the meat still had a very satisfactory colour. While retail display life would trend shorter beyond 20 weeks, it could be concluded from the study findings that shelf life of the vacuum packs may extend beyond 20 weeks, particularly in food service where storage temperatures are not similar to retail displays.



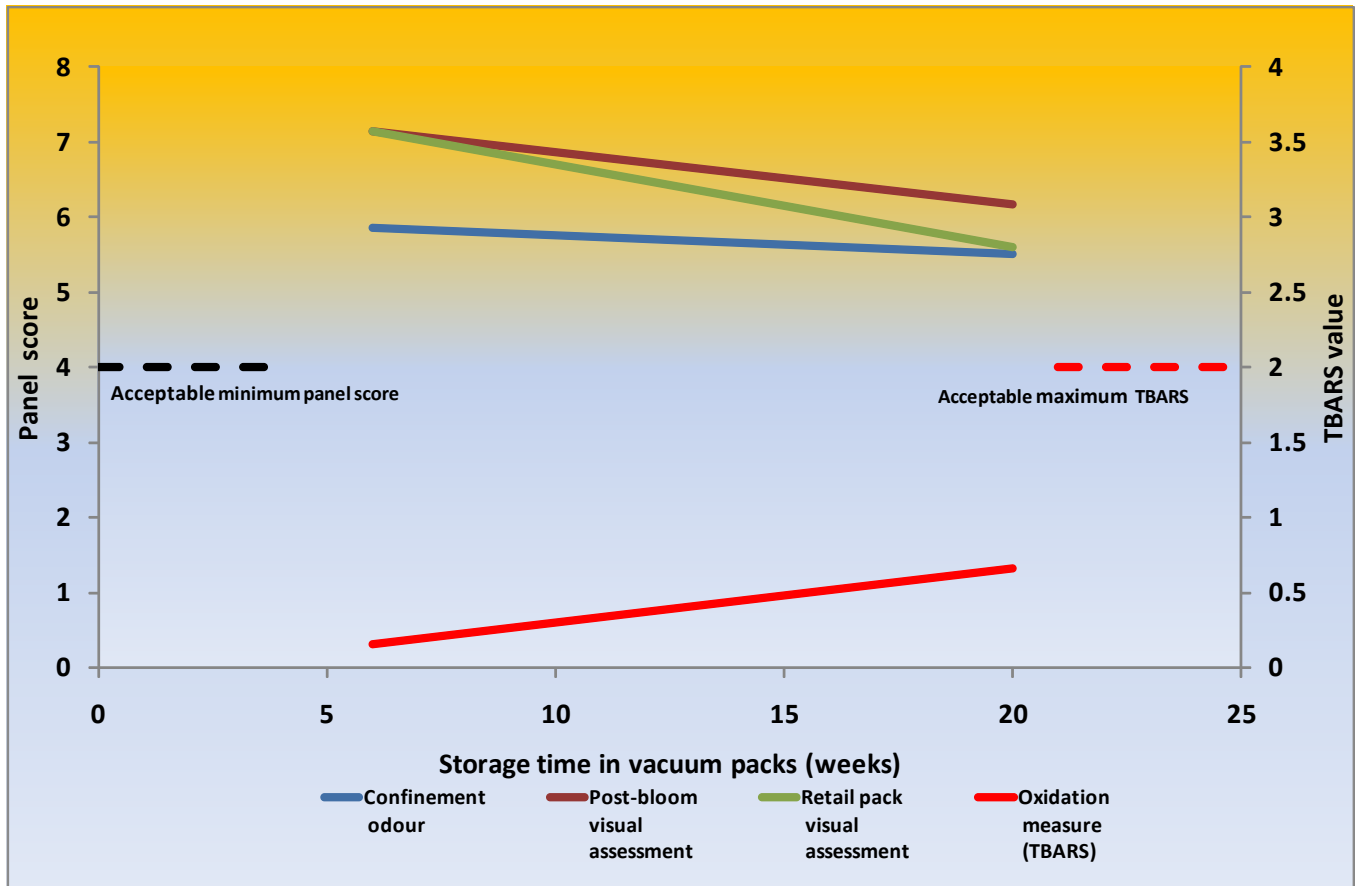


Figure 1: Assessment of vacuum-packaged primals stored for up to 20 weeks. Sensory panel scores plotted for confinement odour (blue line), and visual assessments (brown, green lines), also chemical measure of oxidation (TBARS; red line). The broken horizontal lines indicate the limits of acceptability for the panel scores (black) and TBARS (Red).

Vacuum-packaged primal cuts

It is common to store and distribute chilled beef as primal cuts (2–9 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



Vacuum-packed half striploin and cube roll after 20 weeks of ageing

atmosphere in the head space most likely contains less than 1% oxygen, some 20–40% carbon dioxide, with the remainder being nitrogen.

Vacuum-packaged beef that is stored in low-permeability films is purple in colour since the meat pigment myoglobin is in the reduced form. When vacuum packs of beef 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



Tight packs of vacuum-packaged beef. Meat is purple in colour

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 beef too long a period 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-coloured beef 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 micro-organisms that are able to grow at the storage temperature;
2. packaging film is free of leaks and has a low permeability to gases; and
3. there is good control of temperature during the storage period.

When vacuum-packaged beef 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.

What we mean by shelf life

Generally, food is considered to be past 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 (ground beef) or steaks 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 beef 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 beef 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 beef 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 and, 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 ones 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.

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 beef 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 bulls and older cattle has more myoglobin than does that from young cattle. Within a particular carcass, 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 dark.

Retail display following vacuum-packaged storage of primals

Vacuum-packaged primal cuts are prepared to smaller 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 beef 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 carcass is commonly contaminated with micro-organisms which come mainly from the hide. 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 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 beef were undertaken in 1993, 1998, and 2004; the results have been published in peer-reviewed scientific publications. In 2004, chilled beef carcasses from 27 abattoirs were found to have an average total viable count of just 21 organisms per cm^2 . 96.9% of the carcasses had counts of less than 1,000 per cm^2 . Although no clear evidence is available, it is likely that the regular attainment of such low numbers of bacteria on carcasses from which beef is vacuum-packaged is an important contributing factor in long storage life.

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.

Three environmental factors play a major role in controlling the growth of microorganisms on meats in vacuum packs.

Temperature: Growth rates at 0 to 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 minus 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 ones, 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.

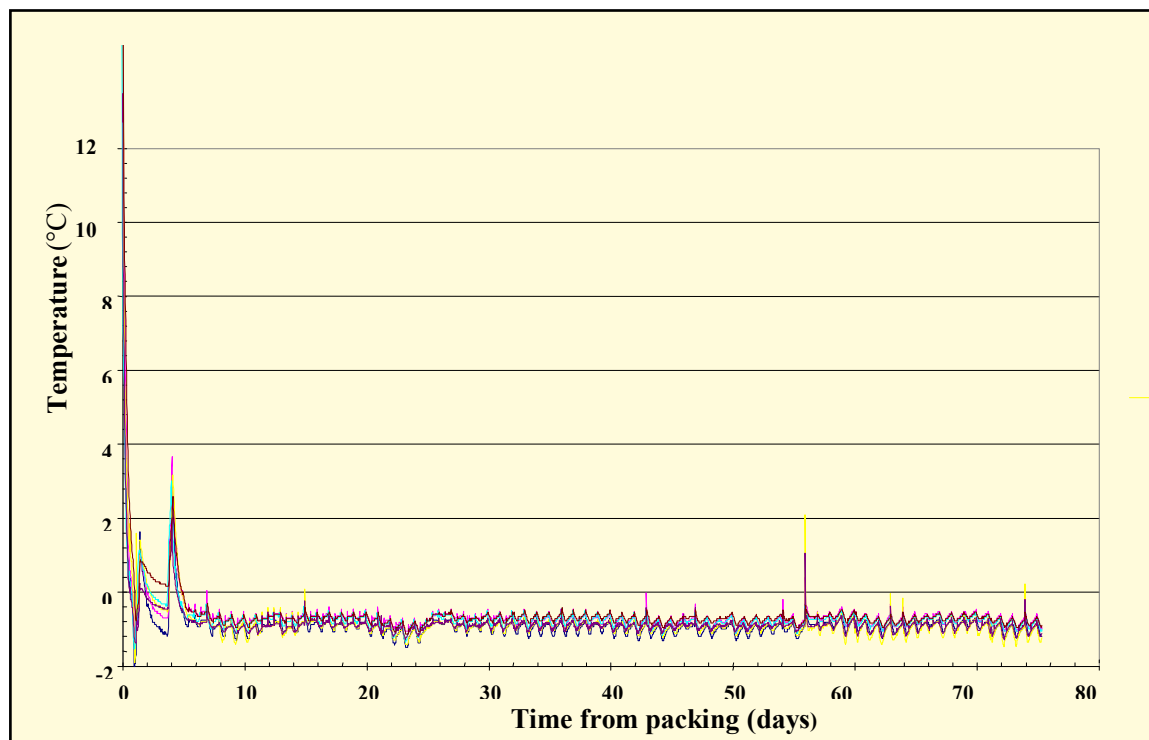


Figure 2: Temperature histories for six test samples stored at Food Science Australia.

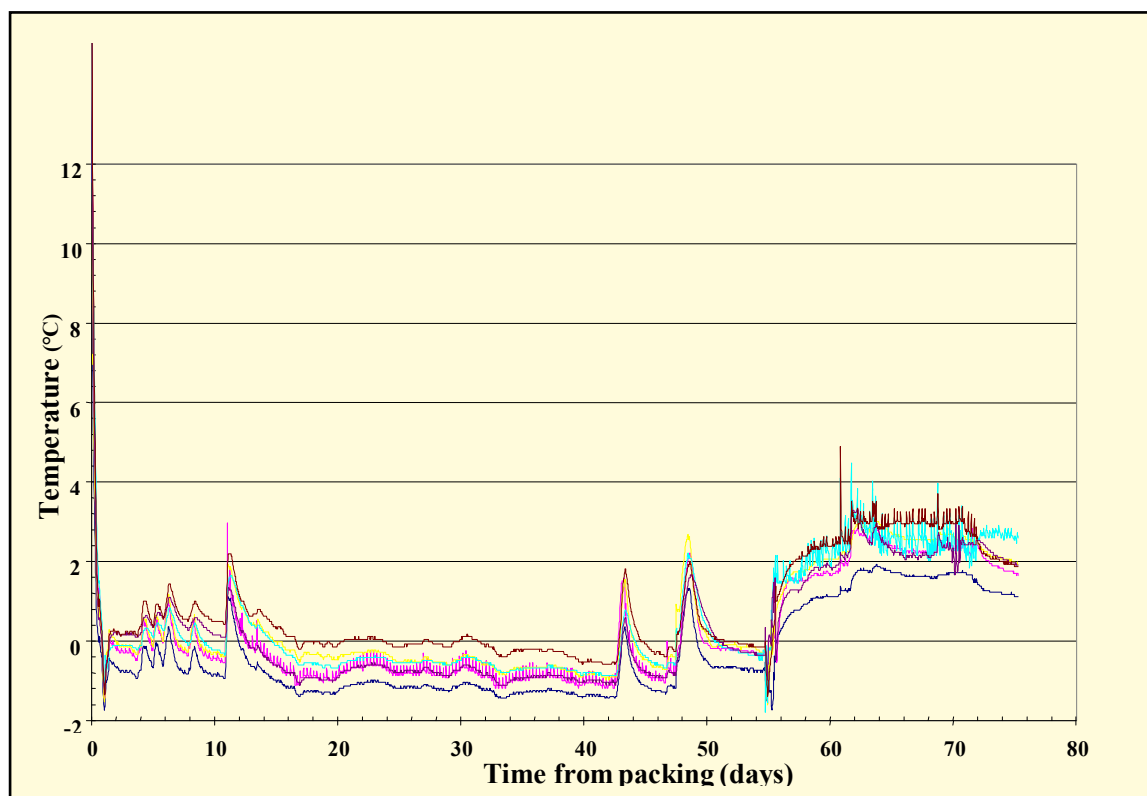


Figure 3: Temperature histories for test samples shipped to, and stored at, US destination.

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 (5.4–5.7) can grow to spoilage levels at higher pH. By excluding meat from carcasses where the pH of the LD muscle is 6.0 or higher, Australian meat processors of vacuum-packaged meat have eliminated spoilage problems attributed in the past to these bacteria.

Shelf-life study, 2008

A study was conducted in 2008 by Food Science Australia in Brisbane on beef primals destined for United States markets. The study was designed to provide contemporary scientific data on the sensory and microbiological attributes of beef vacuum-packaged commercially by Australian processors. Each of four export-registered slaughter and boning establishments in Australia supplied vacuum-packaged striploins and cube rolls for storage and assessment at the Brisbane research laboratory of Food Science Australia. Three of the establishments also shipped vacuum packs of the two primals through normal commercial channels to a destination in the United States.

Samples were stored at Food Science Australia (FSA) under optimal conditions. The temperature of the test primals only rarely (and very briefly) departed from the range minus 1.2°C to minus 0.5°C. Figure 2 shows the history for the first 11 weeks of storage.

The samples sent to the USA were transported under commercial conditions (minus 1.5°C to minus 0.5°C) and then stored at 2°C to 3°C

—normal US commercial conditions (Figure 3). The figure displays the short excursions from the target conditions during the loading and unloading of the shipping containers, and up to the time of transfer of the test samples to the US destination at 11 weeks.

The product was examined by a trained meat panel; the panel assessed packs for appearance, odour, and appearance of steaks after retail display. The quality of primals was also assessed by microbiological and chemical testing.

Throughout the storage period, the microbiological count (total viable count) on primals was often very low, less than around 1000 cfu/cm². Most of the colonies were lactic acid bacteria. Enterobacteriaceae and *Brochothrix thermosphacta* (bacteria known to contribute in the past to loss of quality of vacuum-packaged meat) were only infrequently detected in samples, even after 20 weeks storage.

The sensory and analytical results for striploins and cube rolls from the four establishments were similar, so results for both primals from all establishments were combined, allowing trends in the data to be calculated.

Throughout the 20-week period of the study, the confinement odour, the odour noticed on first opening the vacuum packs (and an early indication of product spoilage), was assessed as highly satisfactory for all packs (see Figure 1, Page 2). On average, a slight deterioration was noted through the study, but product was still very satisfactory at 20 weeks.

The visual acceptability (colour) of the primals was considered to be highly satisfactory throughout the study period (Figure 1, Page 2). At 20 weeks, the primals were still considered to have very satisfactory post-bloom colour.



Half striploin and cube roll after blooming, 20 weeks of ageing in vacuum packs

The visual appearance after 3 days under retail conditions was considered to be very satisfactory, even in product held for 20 weeks prior to simulated retail packing.

The measured oxidative change (measured as TBARS) is a non-specific test for oxidative products, and at the least, indicates chemical change in the product. The results (Figure 1) are shown for product once it was cut and stored under retail conditions (3°C, under fluorescent light) for three days. Consumer surveys indicate that people may start to detect an off-flavour in cooked meat at TBARS values between 0.6 and 2.0 (Greene and Cumuze 1981). At TBARS values of 2.0, off-flavours are definitely detectable, and the meat is considered to be unacceptable.



Cube roll steaks prepared from primals aged for 20 weeks, after three days of display in overwrap packs



Striploin steaks in retail trays, after 20 weeks storage of primals in vacuum packs

This study demonstrates that Australian vacuum-packed boneless primals (striploin and cube roll) may achieve at least 20 weeks shelf life when held under optimal temperature conditions. Whether all vacuum-packed product will achieve this shelf life is dependent upon the initial quality of the meat (pH, colour), microbiological quality, adequate vacuum packing and temperature control through the supply chain. The results suggest that shelf life may extend beyond 20 weeks, particularly if the primals are used in food service, and they may also be suitable for retail display, depending upon market expectations for the appearance of product. The study supports the commercial observations.

Acknowledgement

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A.F. Egan, I. J. Eustace and B. J. Shay (1988) Meat packaging-maintaining the quality and prolonging the storage life of chilled beef, pork and lamb. *Meat 88: Proceedings of Industry Day*, p.68-75

B. E. Greene and T.H. Cumuze (1981). Relationship between TBA numbers and inexperienced panelists' assessments of oxidized flavor in cooked beef. *Journal of Food Science*, 47, 52-54,58.

The experimental work described in this document is summarized from an MLA report, A.MFS.0132 Investigation of the storage life of vacuum packaged beef (2009)

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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