MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

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Shelf-life testing: methods for determining the claimable life of meat products.

In setting a shelf-life, both food safety and consumer acceptance must be considered. Food safety is always considered first when establishing 'use by' dates, but consumer acceptance of sensory attributes often governs 'best-before' dates. Update 3/03, June 2003 discussed the situations where date labelling of meat products is required. This Update considers approaches for shelf-life estimation.

Generally, food is considered to be past its shelf-life when it is no longer acceptable to the consumer. It could 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 product may make consumers ill.

Whilst shelf-life is usually equated with spoilage, for fresh meat in particular., the end of shelf-life might be reached before spoilage, as such, is evident. For example, the loss of bloom of mince or steaks, or reaching a microbial count specified as an acceptable maximum by a retailer, may be the determinant of retail shelf-life; whereas spoilage, as defined by off-odour and slime, would be the point at which it is unacceptable for consumption.

The Food Standards Code of Food Standards Australia New Zealand, FSANZ, includes a standard that prescribes a date-marking system for packaged food intended for retail sale or catering purposes.

Retailers usually print a 'use by' date on steaks, roasts and other packaged fresh meats. Under normal circumstances of hygienic handling and storage at 4°C or colder, spoilage bacteria, rather than pathogens, grow on uncooked meat and meat products; and since these meats will be cooked by the consumer before they are consumed, these products could therefore have a 'best before' date, rather than a 'use by' one. On the other hand, for ready-to-eat (RTE) meat products, the shelf-life may be influenced by the growth of pathogens (e.g. *Listeria*), even at the recommended storage temperature, and the date must be a 'use by' one.

The reason for spoilage may be different for uncooked products compared with RTE ones. This needs to be taken into account when deciding how to determine and validate a claimed shelf-life. Determining the shelf-life of an RTE meat product may well involve microbiological assessment including (probably) testing for *Listeria monocytogenes*. Determining the shelf-life of T-bone steaks on the other hand, will probably be based on assessment of colour stability and maybe odour during retail and home storage, and perhaps accompanied by some microbiological testing against specifications set by retailers.

Processors must date-mark any pre-labelled packages of fresh or processed meat. In addition, meat processors are being asked by retailers to provide dates for larger packs of meat—such as vacuum packs that will eventually be either sold intact or sliced and prepared as smaller retail packs. Here, shelf-life of the large pack should take into account that retailers will expect a display life of two, perhaps three, days from the retail packs prepared from it.

Increasingly, meat processors are being asked to show that their claimed shelf-lives for products have been validated. This Update discusses how the validation might be demonstrated.

General approaches to shelf-life estimation

The term 'shelf-life' is variously used for the:

- point of retail display at which consumers decline to purchase; or
- time to when the product no longer has an acceptable eating experience for the consumer; or
- time to when consumption is no longer safe.

A shelf-life determination involves an experimental study of the deterioration of the food, culminating in identification of the point that marks the end of its shelf-life. It is important that you are clear about the shelf life that you wish to specify.

There are several established approaches for the gathering of shelf-life data on food products:

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- estimating shelf-life based on published data;
- utilising known distribution times for similar products on the market;
- using consumer complaints as the basis for determining whether a problem is occurring;
- accelerated shelf-life testing; or
- assessing changes that occur in trial packs under simulated commercial storage.

Relatively little information on the shelf-life of specific products is published. Many shelf-life data are proprietary and, therefore, not available. Estimates from the published literature, some of which are summarised in Meat Update information sheet 'Storage life of meat', September 2002, are rather old and may not relate closely enough to current processing and packaging systems, or to current retailer or consumer expectations. The exception to this generalisation is that the food safety literature can often be used in circumstances where shelf-life is determined by an unacceptable safety risk.

Neither the utilisation of known distribution times, nor the consumer complaint approach, can be validated satisfactorily; and accelerated testing has little application to meat products—probably being limited to shelf-stable long-life products such as beef jerky.

The most direct and common way to determine shelf-life is to carry out storage trials under controlled conditions that reflect those that the meat normally encounters during the usual course of distribution, retail display, and storage by the consumer. Selection of an appropriate, reliable approach to simulating quality loss that will occur during commercial distribution and storage is an important first step when using this approach.

Select conditions that you anticipate will cover most situations, but not necessarily conditions of significant abuse. For example, if the package carries the statement 'keep refrigerated', it is unrealistic and inappropriate to undertake trials at 0°C. A more realistice temperature would be 4°C—if a period of storage in the home is likely. Take into consideration the fact that both chilled and frozen meats will be subjected to temperature fluctuations, particularly during summer months. It is often advsable to determine the shelf-life at two temperatures—the recommended storage temperature and the maximum temperature expected under normal transport and storage conditions.

Of the categories of food spoilage that can occur—physical, chemical, and microbiological—the two principal spoilage mechanisms that affect shelf-life of meat are microbial growth and oxidation of myoglobin (browning) or lipids (rancidity).

Estimating shelf-life

Before shelf-life testing can be carried out, it is important to establish which quality characteristics are important to the purchaser, or consumer, for the product under assessment. This may vary between products. Establishing the criteria of importance and defining the acceptable standards are policy matters for manufacturers and retailers to resolve. As mentioned earlier, variable quality characteristics to consider include:

- safety;
- meat colour;
- overall appearance;
- odour;
- flavour;
- texture.

Food safety shelf-life is limited by the presence of unacceptable numbers of pathogens on a meat or meat product, and is a function of the initial level of contamination by the pathogens in question, along with time and temperature. It is common, however, to regard food safety as being compromised if the food has been subjected to conditions that permit growth of pathogens—if the pathogens happened to be present.

Note that it is important not to rely on shelf-life evaluation to establish the microbiological safety of the product. In this respect, the question that needs to be addressed is: "Will the product formulation and storage conditions control growth of pathogens during the designated shelf-life—if they were present?" In this circumstance a HACCP analysis is necessary to identify which, if any, pathogens are relevant, and challenge testing may be required, particularly in the case of RTE meats. Such testing involves deliberate inoculation of the product with the pathogens that have been identified in HACCP, or with indicator bacteria that are known to behave similarly in the product to the pathogens.

In uncooked meats, and mostly with RTE meats, it will not be the presence of pathogens that dictate shelf-life.

Measures of shelf-life

In fresh meats that are stored in air, pseudomonads will dominate the total population of bacteria, so a standard plate count is a good guide to the onset of spoilage.

For vacuum-packed meat, however, total count is not a good index. As vacuum-packed meat is stored in the absence of oxygen, growth of pseudomonads, as strict aerobes, is restricted. Instead, after storage, the bacterial population will consist mainly of lactic acid bacteria.

Consumer acceptability of meat and meat products, particularly frozen ones, can be affected by factors that are not microbiological. They include:

- meat colour and appearance;
- rancidity caused by chemical oxidation of fats at low temperature;
- changes in texture caused by extended enzymic activity or product drying during storage, e.g. freezer burn;
- texture, flavour and odour changes caused by other chemical reactions occurring in the product during storage e.g. toughening from protein denaturation or colour and flavour changes from non-enzymic browning reactions.

Browning of meat is due to oxidation of the meat pigment myoglobin. Low pH meat—5.5 and lower—seems to be more susceptible to colour deterioration. Development of browning can be followed instrumentally using a colour meter. If previous experience has told you what the causal products of odour and flavour spoilage are, they can be tested for using appropriate chemical analyses, e.g. gas chromatography combined with mass spectrophotometry.

Instrumental techniques are only useful if there is a good knowledge of the relationship between the levels of specific chemicals and consumer perceptions of spoilage of your product. If that knowledge is not available, information on the deterioration of quality has to be obtained by the use of taste panels using either trained technicians or untrained consumers.

Some specific examples

Raw meats - fresh

Pathogen growth is most conveniently estimated in raw meats by predictive microbiology using a model such as that developed in Australia by the University of Tasmania and Meat & Livestock Australia.

Table 1: Suggested attributes to assess when estimating shelf-life of range of products

Retail meat package	Quality attribute	Nature of spoilage	End of shelf-life	Approach to estimating shelf-life
Fresh meat on over-wrapped tray	Good pink-red 'bloom'; odour of fresh meat.	Off-odours; off-flavours; stickiness; slime from bacteria; discolouration.	Loss of bloom; brown discolouration; microbiological specification exceeded.	Colour meter; colour panel; counts of total bacteria.
Fresh/MAP - high oxygen	Good pink-red 'bloom'; odour of fresh meat.	Off-odours; off-flavours; slime from bacteria; discolouration.	Loss of bloom; brown discolouration; microbiological specification exceeded.	Colour meter; colour panel; counts of total bacteria; counts of specific bacteria.
Vacuum pack	Purple meat colour; tight pack; normal confinement odour.	Sour; dairy off-odour; off-flavour; greening from microbial activity; browning.	Unacceptable, persistent confinement odour; meat discoloured (brown, grey, green) in intact pack.	Colour meter; colour panel odour/taste panel; counts of specific bacteria.
VP/ over-wrapped	Good pink-red bloom; odour of fresh meat; minimal drip.	Off-odour; off-flavour (incl. sour, dairy odour); browning.	Loss of bloom; brown; sour odour, flavour; microbiological specification exceeded.	Colour meter; colour panel; odour/taste panel; counts of total bacteria; counts of specific bacteria.
VP/ MAP – high O_2	Good pink-red bloom; odour of fresh meat; minimal drip.	Off-odour; off-flavour (incl. sour, dairy odour); browning.	Loss of bloom; brown; sour odour, flavour.	Colour meter; colour panel; odour/taste panel; counts of total bacteria; counts of specific bacteria.
Sliced corned beef, cooked – vacuum pack	Pink; odour of corned beef.	Souring; slime; off-odour after pack opened; pathogen growth (e.g. Listeria).	Loss of pink colour; souring; microbiological specification exceeded.	Colour meter; colour panel; taste panel; counts of total bacteria; counts of specific bacteria; challenge test specific pathogen(s).
Frozen ground beef	Pink-red.	Rancidity; freezer burn	Rancid odour, flavour when cooked; surface desiccation; sponginess.	Taste panel.
Frozen lamb chops	Pink-red.	Rancidity; freezer burn.	Rancid odour, flavour when cooked.	Taste panel.

The criteria specified in the Export Control (Meat and Meat Products) Orders 2005 are appropriate for determining what would be deemed unacceptable temperature abuse that would compromise shelf-life.

In fresh meats that are stored in air e.g. in over-wrapped trays, as the numbers of pseudomonad bacteria reach around 100 million per cm^2, they produce a putrid odour and slime forms on the meat surface. The pseudomonads will dominate the total population of bacteria, so a total count is a good guide to the onset of spoilage.

High microbial populations may not necessarily impair sensory characteristics, but a pre-determined level of micro-organisms, together with factors such as sensory attributes, is often used to indicate that the end of life has been reached. Total counts in excess of 1 million per cm^2 of product surface—or per gram of mince or other comminuted product—is often taken to indicate that spoilage is imminent, and are often regarded as the end of acceptable shelf life.

Raw meats in vacuum packs

Lactic acid bacteria grow slowly on vacuum-packed meat at chill temperatures—to 10–100 million per gram after about 6 weeks storage. They will stay around this level for the rest of the life of the product. Signs of spoilage will not be evident until several weeks after the maximum population of bacteria is reached. When spoilage eventually becomes evident, it will be due to cheesy or sour milk odours and flavours, rather than the putrid odours caused by pseudomonads in air.

For vacuum-packaged fresh meat of normal pH, a total bacterial count is NOT a useful indication of the microbiological quality of the product. If the total count is made up of mostly lactic acid bacteria, counts of more than 10 million per gram do not indicate incipient spoilage or any processing or storage problem. Only total counts in excess of 100 million per cm^2 would indicate the end of the product's shelf life.

If meat in vacuum packs has a pH greater than 5.9, off odours may be detected when the bacterial count is just over one million per cm^2 if:

- the storage temperature is 5-10°C; or
- there are traces of oxygen in the pack due to using a packaging film with a high oxygen transmission rate.

In such vacuum-packed meat there may be an increased growth of spoilage bacteria such as *Brochothrix thermosphacta*, *Shewanella putrefaciens*, and psychrotrophic enterobacteria. These bacteria will cause souring and off-odours. Selective counts of these organisms can be useful in identifying the limitations to storage life of such product.

Cooked perishable meats

Cooking will normally destroy vegetative micro-organisms with only spores surviving. Post-processing contamination, however, will eventually lead to spoilage at the contaminated surfaces. Most commonly, spoilage of cured meats is caused by growth of lactic acid bacteria and normally becomes evident some time after the lactic bacteria reach their peak numbers. Green surface discolouration is caused by peroxide oxidation that is attributable to certain strains of these bacteria.

As stated earlier, determining the shelf-life of an RTE meat product may also involve challenge testing for *Listeria monocytogenes*.

Panel assessments

Sensory techniques supported by statistical methods are frequently used to determine the time at which a product achieves the limit of acceptability. The determination of consumer acceptability is most reliably done by means of panels of 100 or more untrained tasters, an exercise that is usually cost-prohibitive for establishing shelf-life. To minimise the cost and time involved other approaches are:

1. an experienced sensory scientist determines the limit for acceptability of a given attribute and then uses a trained panel to measure the intensity of this attribute during storage;
2. the acceptability assessed by a trained panel is correlated to that of untrained consumers.
3. an increasing number of untrained consumers are used to assess the deterioration during storage, concentrating the testing more heavily on samples that are close to the end of their shelf-life.

The first is the easiest to perform, but does not give any information on consumer perceptions.

The following techniques may be used for panelling.

- Difference tests—Paired comparisons and triangle tests are useful to compare stored product with fresh product. However, errors can occur because new fresh samples are used at each testing during the storage. This technique also has the drawback in that it says nothing about acceptability—just whether it differs from the fresh control. It can be used to compare a revised process or new packaging film with an existing one.
- Hedonic scoring—Consumers are asked to rate the acceptability of the product on some predetermined scale. Common scales include terms like: like very much, like a little, neither like or dislike, dislike a little and dislike very much. The limitation to this technique is that the acceptability can go up or down due to changes within the storage, and panellists respond differently to these changes, e.g. rancidity, moisture loss.
- Quantitative descriptive analysis (QDA)—QDA is based on the ability of panellists to reliably describe their perceptions of a product's attributes. This requires screening of panellists and the development of a suitable sensory language. Sensory attributes are scored and give good information on which attributes change during storage; however results still have to be related to consumer acceptability.

Sensory assessments by panels should normally be designed and interpreted by a specialist. Here are some suggested general procedures for shelf-life testing.

1. Develop a testing protocol consisting of: the specific objective; detailed test design—which covers product, packaging and storage specifications; and panelling procedures; and includes the number of samples required.
2. Identify the key quality indicator/s from any previous studies or published literature. Any information on known distribution time or turnover time of the product would be useful here.
3. Establish the sampling frequency and duration of the testing based on experience from previous studies or published data. If the interval of sampling is too long, the risk of under- or over-estimating shelf-life increases. Determination of the end of the experiment must be based on some preset criterion such as minimum required commercial shelf-life, or some specific organoleptic criterion of unacceptability.
4. All testing should be based on one common sample, if possible, to ensure consistency between panellists. There are a number of publications covering detailed procedures for effective sampling, taste panelling and analysis of data. It is important that specialist knowledge be obtained to ensure that the sampling and panelling will give meaningful results.
5. Prepare a report of the outcomes and recommendations, along with the details of design and application of the experiment. This report is the validation of the chosen shelf life of the product and is an important document to support your HACCP-based meat safety plan.

Further reading

Bin Fu & Theodore P. Labuza (1997). Shelf-Life Testing: Procedures and Prediction Methods. In Erikson and Hung (Eds) *Quality in frozen Foods*. (pp. 377–415). Chapman & Hall, New York.

FSANZ User Guide to Standard 1.2.5 – Date marking of packaged food.

Steele R. (Ed.) (2004). *Understanding and measuring the shelf-life of food*. CRC Press, Boca Raton USA ISBN 1 85573 732 9.

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