INVESTIGATION OF TEMPERATURE MINIMA FOR THE STORAGE OF CHILLED MEAT

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SUMMARY

Details of investigations to establish the temporal stability of chilled primal cuts of beef and lamb and their quality after extended storage are reported. Meat cuts were either wrapped in polyethylene or vacuum-packaged in bags which provided a good oxygen barrier. Packs were held in brine or closed cartons in a room maintained at -2.2 to -2.6°C. They were examined at intervals for evidence of freezing. Some packs were opened after storage and the meat was assessed for appearance, odour, flavour and microbiological quality.

Whereas those cuts wrapped in polyethylene all froze within 2 to 3 days, the majority of those in vacuum packs remained not frozen for at least 4 weeks. Of 28 packs held in brine, 19 (68%) were still not frozen after 3 months and only one pack froze in the ensuing 9 months. Chilled meat removed from vacuum packs after extended storage was generally of very good quality. Growth of the bacterial flora was very slow.

It is concluded that the temporal stability of supercooled meat is very good if a constant temperature is maintained.

INTRODUCTION

Work at the Meat Research Laboratory and elsewhere has shown that the temperature at which chilled meat is stored should be as low as possible to maximise storage life. It is known that at 0°C growth rates of spoilage bacteria on meat are only about half those at 5°C and are further reduced as the temperature falls. Although psychrotrophic species of Gram-negative bacteria can still grow at -5°C or lower if the growth medium is not frozen ,growth is very slow (Partmann 1975).

If procedures could be developed such that storage of chilled meat at sub-zero (Celsius) temperatures was commercially practicable (i.e. freezing was avoided) the storage life of chilled beef and lamb would be significantly increased compared with the life at the temperatures near 0°C which are currently employed.

However in practice the crystallisation of ice in fresh meat tissue begins at -1.1°C (Calvelo, 1981) and around -1°C has been accepted as the minimum practicable storage temperature for chilled meat. 0°C has been widely adopted as the storage temperature for vacuum-packaged chilled meat cuts.

Crystallisation of ice and other materials, including a number of metals, is normally preceded by supercooling during which they can be cooled to several degrees below their equilibrium freezing temperature before crystallisation commences. Meat has been observed not to begin to freeze until temperatures as low as -6.5°C are reached (Menegalli and Calvelo 1979; Partmann 1972). Galovkin et al. (1970) reported that they were able to hold quarters of beef for up to 12 days at -2 or -3°C without freezing.

This paper reports preliminary investigations to establish the temporal stability of chilled primal cuts of beef and lamb held at -2 to -3°C.

EXPERIMENTAL METHODS

Primal cuts of meat used in the investigations included: knuckles, rumps, silversides, topsides and cube rolls of beef and short loins, legs, racks and shoulders of lamb. All primals were boned out from the carcasses 24 h after slaughter. They were either wrapped in polyethylene or vacuum-packaged. Those primal cuts to be vacuum-packaged were placed in 'W' gauge Barrier Bags (W.R. Grace, Melbourne). The packs were evacuated and sealed using a chamber vacuum-packaging machine (Supervac GK 170 KN/B/G) then heat shrunk by a one second immersion in water held at 90°C.

Some packaged cuts were stored in a room maintained at 0 to 1°C. However most were stored in a room which was maintained between -2 and -3°C. Packs were held either in closed cartons on the shelves or stored in containers filled with approximately 30 litres of brine (NaCl 6.5% w/v) to further reduce temperature fluctuation. The temperature of the brine equilibrated to the mean temperature of the room before the meat was immersed.

Temperatures were measured with copper-constantan thermocouples connected to a Digitrend 235 data logger (Doric Scientific). Regular checks of the accuracy of the equipment was carried out using a calibrated mercury thermometer.

Initially the room was set to operate at -2.6°C ± 1C. A mechanical failure resulted in the temperatures of the brines and carton interiors rising to -1.6°C and -1.0°C respectively for around five days. Thereafter the mean temperature fell to -2.2°C. Due to an inability to effect small adjustments to the temperature controller, subsequent work was carried out at this temperature.

The cuts were examined at intervals to determine whether freezing had occurred.

Freezing was deemed to have occurred if the surfaces were no longer soft or if exudate was frozen. Once freezing commenced, the meat tissue quickly became quite firm and was therefore readily distinguishable from non-frozen tissue.

When non-frozen packs were removed from storage they were assessed by a trained laboratory panel of four for appearance, and after the packs were opened the odour was assessed. Steaks were cut from the beef topsides and the lamb loins were cut into chops. The steaks and chops were placed on polystyrene trays, overwrapped with PVC film and arranged in a forced-air bunker style retail display cabinet illuminated with aquarium fluorescent tubes (Sylvannia) located to give a light intensity of 1000 lux at the meat surface. The packs were assessed for appearance within 3 h of placement in the cabinet and thereafter at daily intervals.

On some occasions the packs were assessed for presence of 'off' odours after 3 days display. Chops and steaks

were cooked and the meat assessed for 'off' odours and 'off' flavours.

Microbiological assessment

For microbiological assessments tissue samples (2 x 5 cm) were taken and placed in sterile polyethylene bags. Peptone solution (0.1%) was added and the samples were treated with a Colworth Stomacher. Appropriate dilutions were spreadplated on pre-dried plates of tryptone soya agar (Oxoid) supplemented with 0.2% (w/v) yeast extract and 0.2% glucose (TSYG agar); streptomycin thallous acetate, actidione agar (STAA agar; Gardner 1966); peptone (0.8%, w/v; Oxoid) agar (P A agar; Grau 1983) and MRS (de Man, Rogosa, Sharpe) agar (Oxoid). Plates were incubated for 3 days at 24°C after which the numbers of *Brocothrix thermosphacta*, lactic acid bacteria and Gram-negative bacteria were enumerated.

RESULTS

The results summarised in Table 1 are compiled from a total of nine trials. Although the meat in some packs stored in brine and in cartons froze promptly, the majority remained not frozen for at least 4 weeks. In contrast all cuts which were placed in the room either not wrapped or loosely wrapped froze within 2-3 days.

Of the 28 vacuum packs stored in brine, five (18%) froze within two weeks (four within three days). Of the others 19 (68%) were still not frozen after three months. Four packs were opened for microbiological analysis after three months. Of the remaining 15, only one froze during storage for a further nine months.

Of the 47 primal packs stored in cartons 24 (51%) froze within two weeks. Three of the other 23 were opened for microbiological analysis after eight weeks. Ten packs (21%) remained not frozen after three months and all but two of these remained not frozen after one year.

None of the 16 packs of lamb primals were frozen when they were removed from cartons after 10 weeks' storage.

Meat from vacuum packs that were opened after extended storage was generally considered to be of very good quality. Topsides opened after 15 weeks quickly recovered an excellent red appearance (bloom). The confinement odour was assessed as slight, typical of that from meat aged in a vacuum pack at 0°C for 4-6 weeks. There was no evidence of any off or putrid odour. Steaks retained a good colour during retail display for three days. The cooked meat was considered to have an excellent flavour.

TABLE 1: Number of vacuum packs of beef which did not freeze during storage at -2.5°C*

	Storage time (weeks)						
	0	1	2	4	8	12	52
Brine	28	24	23	23	19	19[1]	14
Carton	47	33	23	18	17[2]	10	8

[1] After 12 weeks 4 packs removed for testing
[2] After 8 weeks 3 packs removed for testing
* Temperature varied during storage - see above.

Three topsides opened after storage at -2.2 to -2.6°C for one year had confinement odours typical of vacuum-packaged meat held at 0°C for approximately 12 weeks. Except for slight brown areas, the meat surfaces regained a bright red colour. Steaks sliced from the primals had a good odour and initially displayed a fresh red colour. However the appearance deteriorated rapidly. Within 24 h the meat surfaces were very brown.

Although no putrid or sour odours were present, when the meat was cooked it was found to have a strong liver-like flavour. The odour and flavour of the lamb loins after 10 weeks' storage was considered to be very acceptable with only one pack of chops having a slightly stale flavour.

The microbiological data indicate that growth of psychrotrophic bacteria on meat in vacuum packs does occur at a temperature below -2°C. However results are variable. For instance, for nine packs of beef on which the initial bacterial counts were 100 to 1000 per cm, counts after storage of the packs for 1 year ranged from less than 1000 per cm up to more than 100 million per cm.

Growth was slow however. Counts for packs tested after 7 weeks' storage were less than 1000 per cm and for four of five packs tested after storage for 14 weeks the total counts were 2000 per cm or less. Lactic acid bacteria dominated the flora. Generally organisms of *Brochothrix thermosphacta* and members of the Enterobacteriaceae were only minor components.

The vacuum-packaged primal cuts of lamb which were stored for 10 weeks at -2.2°C had total bacterial counts which ranged from 3 million to 11 million per cm. Lactic acid bacteria and *Brochothrix thermosphacta* were present in approximately equal numbers. Fewer than 1000 Gram-negative bacteria per cm were present.

DISCUSSION

The findings reported above indicate that it is possible to store meat at a temperature at least one degree C below the equilibrium freezing point for an extended period without freezing occurring.

Crystallisation of ice in meat includes two successive processes - nucleation and growth - both of which are dependent on prior supercooling of the tissue as its temperature falls. The mechanism of nucleation is not well understood. However it is well known that many particulate substances, including introduced ice crystals, are able to catalyse nucleation of ice. In our investigations meat which was not wrapped or loosely wrapped froze rapidly. Frequently the appearance of ice crystals on the underside of the plastic overwrap above the meat surface preceded freezing of the meat. It is likely that these crystals initiated the freezing.

The resistance of the vacuum-packaged meat to freezing can be partly attributed to the absence of opportunity for pure water ice to form on the surfaces of the meat or the packaging. The chance of nucleation was therefore diminished. In addition components of the plastic film used to vacuum-package the meat may have inhibited nucleation. A number of materials are known

which can inhibit nucleation or effectively lower the temperature at which nucleators become effective. The best known inhibitors are the so-called antifreeze peptides (AFP) found in the blood of Polar fish species. In the manufacture of plastic films it is common to add 20% or more by weight of plasticisers to lower the crystalline melting temperatures and glass-transition temperatures of the polymers (Oswin 1975). These plasticisers may well contribute to inhibition of nucleation in meat held in close contact with the film.

There is a strong suggestion that constancy of temperature is important in maximising the temporal stability of supercooled meat. There was a lower incidence of frozen packs of primals stored in brines (temperature fluctuation 0.1°C) than in cartons (temperature fluctuation 0.25°C between adjacent packs near centres of cartons). Fluctuations in the room air temperature sometimes exceeded 1°C. Temperatures adjacent to the interior walls of the cartons may have dropped sufficiently for nucleation to occur in many of the packs. Better refrigeration control equipment than was available for these investigations and close-stacking of cartons would permit improved maintenance of temperature.

From the limited microbiological data it is evident that growth of bacteria can occur on supercooled vacuum-packaged meat. However the growth is slow. After extended supercooled storage organisms known to contribute to spoilage of vacuum-packaged meat at 0°C - *Brochothrix thermosphacta, Enterobacteriaceae* and other Gram-negative bacteria - either were not detected or were present in very low numbers. The rapid loss of bloom and the bitter and liver-like flavours detected in the topside steaks after one year's storage were probably due to chemical changes in the meat caused by enzymatic activity (B.J. Shay, A.F. Egan, unpublished). Consequently it can be said that bacterial activity contributed very little to quality deterioration of the beef, even after this period.

CONCLUSIONS

We have demonstrated that long-term storage of chilled meat below its equilibrium freezing point is possible if it is vacuum-packaged. Maintenance of a constant storage temperature appears to be very important in the prevention of nucleation and freezing of the meat.

Premature nucleation, leading to freezing of a proportion of vacuum packs, must be avoided before storage of chilled meat at -2 to -3°C becomes a commercial reality. A greater understanding of the ways to avoid nucleation is necessary.

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REFERENCES

Calvelo, A. (1981). *In*: Developments in Meat Science - 2. Lawrie, R.A. Ed., Applied Science Publishers Ltd. London, New Jersey, 125.

Gardner, G.A. (1966). *Journal of Applied Bacteriology* **29**:455.

Golovkin, N., Tohernyshev, V. and Nebrevtchina, E. (1970). *Mjasnata Industria CCCP* **10**:38.

Grau, F.H. (1983). *Journal of Food Science* **48**:326.

Menegalli, F. and Calvelo, A. (1979). *Meat Science* **3**:179.

Oswin, C.R. (1975). Plastic Films and Packaging. Applied Science Publishers, London.

Partmann, W. (1972). *Bulletin of the International Institute of Refrigeration* Annexe 1972-**2**:77.

Partmann, W. (1975). *In:* Water Relations of Foods. Ducksworth, R.B. Ed., Academic Press, London, New York, San Francisco, 505.