STORAGE LIFE OF VACUUM- AND CARBON DIOXIDE-PACKED NEW ZEALAND CHILLED LAMB IMPORTED INTO SAUDI ARABIA

A.M. GAROUT[1], A.A. AL-RASHED[1] AND R.G. BELL[2].

1 Saudi Arabian Standards Organization, P.O. Box 3437, Riyadh, Saudi Arabia.
2 Meat Industry Research Institute, P.O. Box 617, Hamilton, New Zealand

SUMMARY
Transport and storage trials were conducted to determine the commercial storage life of vacuum- and CO_2-packaged lamb imported from New Zealand. With both packaging systems, storage life was terminated by the onset of putrid spoilage. Air-freighted vacuum-packed lamb had a storage life of 39 days while sea-freighted CO_2-packed lamb had a storage life of 92 days at mean trial temperatures of 2.3°C and -0.1°C, respectively.

INTRODUCTION

Elevated concentrations of carbon dioxide inhibit the growth of a wide range of micro-organisms (Enfors & Molin, 1980). In anaerobic systems the inhibitory effects of CO_2 on both the lactobacilli and enterobacteria components of anoxic meat microfloras increase with increasing CO_2 concentration (Gill & Penney, 1988). Research results (Gill & Penney 1986) and commercial claims (Warburton, 1988) suggest that the storage life of chilled meat can be significantly increased over that achieved by vacuum packaging through the use of a 100% CO_2 packaging atmosphere.

Vacuum-packaged lamb imported into Saudi Arabia is traded commercially on the basis that it has a chilled storage life of between 4 and 5 weeks. However, storage lives for chilled lamb, under optimum conditions, of 8 and 16 weeks are said to be commercially attainable with vacuum- and CO_2-packaging, respectively (Gill, 1988).

To resolve this apparent discrepancy between claimed and commercially attained storage lives of vacuum-packed lamb, and in anticipation of the commercial introduction of CO_2 packaging, the Saudi Arabian Standards Organization is conducting transport and storage trials to determine the commercial storage life of vacuum- and CO_2-packaged lamb imported from New Zealand. The case histories of the first vacuum-packed and CO_2-packed chilled lamb trials are reported.

MATERIALS AND METHODS

Between November 1988 and April 1989, transport and storage trials were conducted on a consignment of vacuum-packed lamb loins and on a consignment of CO_2-packaged lamb carcasses imported from New Zealand by air and sea, respectively.

1) Cold Chain

For each trial, the entire cold chain from the New Zealand point-of-production to the termination of the storage trials in Saudi Arabia was monitored by means of MIRINZ/DELPHI temperature loggers (Delphi Electronics, Auckland, New Zealand). To monitor the 20 carton consignment of lamb loins, a temperature logger was placed into the each of six cartons of the vacuum-packed product when the chilled carcasses were cut and packed 24hr after slaughter. For the whole carcasses, loggers were secured in the body cavities on the cooling floor at the slaughter facility. After chilling, the carcasses were packaged in pairs under CO_2 using the CAPTECH SYSTEM (UEB Packaging, Auckland, New Zealand) so that 10 of the 30 cartons used in the trial contained temperature loggers. In both trials the temperature loggers remained in place recording temperature every 30 minutes with an accuracy of ± 0.25°C until the cuts or carcasses were removed from storage for evaluation.

2) Microbiological Examination

In both trials five carcasses were

sampled for microbiological quality immediately before cutting and/or packaging. A second sampling of five carcasses or five loins was carried out on arrival at the coolstore in Riyadh. Thereafter, groups of three carcasses or loins were sampled upon removal from chill storage. Loins were rinse sampled while composite swab samples, from 5 cm^2 sites on the brisket, flap and leg were obtained from carcasses. Serial dilutions of both types of sample were prepared in 0.1% peptone and spread onto plate count agar. After incubation at 25°C for 72 hr, a differential count based on colonial appearance was made. From a single plate, one for each carcass or loin examined, ten representative colonies were selected in numerical proportion to their relative abundance in the spoilage microflora. These colonies were subcultured and identified to genus level using the 7-test identification procedure of Newton et al. (1978).

3) Chemical analysis

Vacuum-packed loins or loins taken from CO_2-packaged carcasses were subjected to chemical analysis. Seven cuts or carcasses were sampled on arrival at the coolstore, and thereafter, groups of five were sampled. The following analyses were performed on lean "rib-eye" (Longissimus dorsi) muscle tissue or on the overlying subcutaneous fat: i) pH of minced lean muscle by direct use of a glass electrode, ii) Total Volatile Nitrogen (TVN) in lean muscle, by steam distillation (SASO, 1977b) and iii) Free Fatty Acids (FFA) in fat by titration of a cold 40/60 petroleum ether fat extract against NaOH (SASO, 1977a)

4) Sensory Evaluation

On arrival at the Riyadh coolstore, 32 vacuum-packed loins and the legs from 16 CO_2-packaged carcasses were frozen to serve as controls. To assess loins at each sampling, eight chilled vacuum-packed loins and four thawed controls were each placed into Tuflex bags (Trigon, Hamilton, NZ) and cooked to an internal temperature of at least 70°C by immersion in boiling water for 80 minutes. Aroma, texture, flavour and overall acceptability were assessed on a 7-point hedonic scale by a 60-80 member "in-house" panel. To assess whole carcasses at each sampling, one thawed control and a leg from each of two chilled carcasses were lightly salted, wrapped in cooking foil and roasted in a 175°C oven to an internal temperature of 70°C before being uncovered and browned for 15 minutes. The roast meat was assessed by a 9-member experienced panel to identify spoilage conditions on a 3-point scale were: 1= no spoilage evident, 2= incipient spoilage and 3= overt spoilage. A small "take home" panel of 13 families provided an indication of consumer acceptability of the chilled and frozen product.

RESULTS

1) Cold Chain

The cold chain for the importation of vacuum-packed lamb loins by air freight consisted of three phases: in-plant production, transportation and storage on arrival (Fig.1). Transportation included road transfer to the exporting airport, transient storage, preparation and passage as air cargo, "point-of-entry" inspection and finally road transfer to the destination coolstore. During the five day transportation phase, the average maximum, minimum and mean temperatures recorded by four temperature loggers were 5.8 $\pm$ 2.5°C, - 0.9 $\pm$ 0.3°C and 1.8 $\pm$ 0.9°C, respectively. Over the whole trial (from packaging to the detection of spoilage, 44 days after packaging) the average maximum, minimum and mean temperatures were 14.9 $\pm$ 2.1°C, -0.9 $\pm$ 0.3°C and 2.3 $\pm$ 0.2°C, respectively.

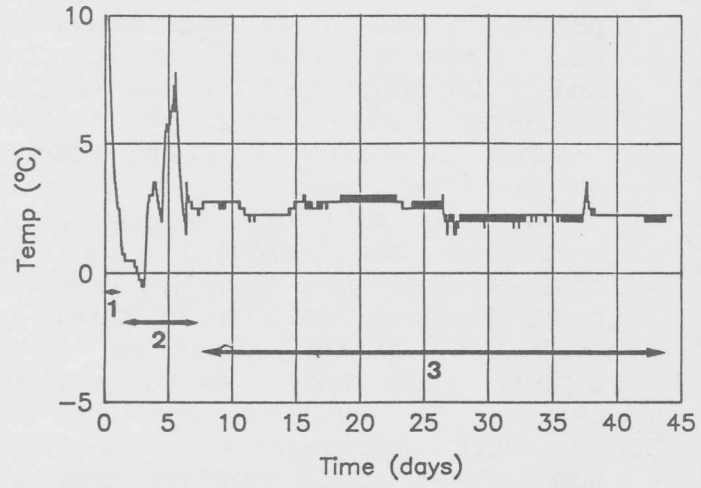


Figure 1. Temperature record for vacuum-packed lamb loins imported from New Zealand by air: (1) Production phase, (2) Transportation phase and (3) Storage phase. Loins were packaged on day 0, one day after slaughter.

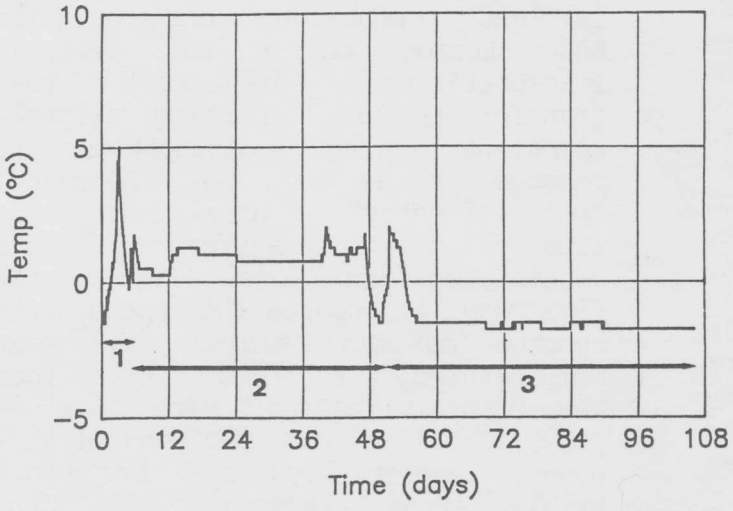


Figure 2. Temperature record for CO_2-packed lamb carcasses imported from New Zealand by sea: (1) Production phase, (2) Transportation phase and (3) Storage phase. Carcasses were packaged on day 3, three days after slaughter.

For sea-freighted CO_2-packaged lamb carcasses (Fig.2), in-plant preparation included prepack chilling; Captech packaging under CO_2 on day 3 and re-equilibration after packaging to subzero temperatures prior to dispatch. The transportation phase started with the packaged carcasses being transferred by road on day 5 to a second meat plant where, on the next day, the cartons of carcasses were stowed, as the top tier, in an integral refrigerated container, operating at an inlet temperature of -1.0°C. The container was landed at Dammam on day 39 and arrived by rail at the Riyadh Dry Port on day 44. Point-of-entry inspection was completed on day 50 when the cartons of carcasses were conveyed by refrigerated truck to a transfer coolstore. After sorting, the carcasses were received at the destination coolstore on day 51. The average maximum, minimum and mean temperatures recorded by the loggers during the 46 day transportation phase were 2.7 ± 0.8°C, - 1.2 + 0.4°C and 1.0 ± 0.2°C, respectively. Over the whole trial period from the cooling floor to the detection of spoilage on day 106 the average maximum, minimum and mean temperatures were 20.4 ± 1.3°C, - 1.75 + 0.0°C and -0.1 ± 0.3°C, respectively.

2) Microbiological Examination. Gram-positive cocci dominated the initial contaminating microflora on the carcasses prior to cutting and/or packaging. The initial microflora was between 10^3 and 10^4 cells/cm^2. The rate of development of spoilage lactobacilli-dominated microflora at chill temperatures was significantly slower under CO_2 than under vacuum (Fig.3). When overt

spoilage became evident on days 106 (CO_2) and 45 (vacuum), the microfloras were numerically similar. At spoilage, the microflora on vacuum-packed lamb contained between 10 and 30% of either enterobacteria or Brochothrix thermosphacta in addition to the lactobacilli. At spoilage of CO_2-packaged lamb (day 106), the microflora appeared to be composed entirely of lactobacilli. However, anaerobic incubation at 25°C for 72 hr of a duplicate set of dilution plates prepared on day 113, i.e. seven days after the initial detection of spoilage, found that enterobacteria represented approximately 1% of the microflora.

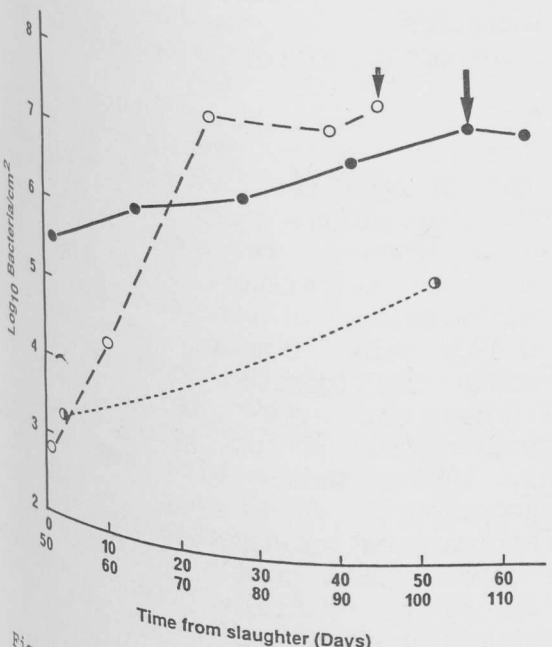


Figure 3. Spoilage microflora development at chill temperatures on vacuum-packed lamb loins (Open symbols 0 to 60 days) and on CO_2-packed lamb carcasses (Half solid symbols 0 to 60 days, solid symbols 50-110 days), arrows indicate first detection of spoilage.

3) Chemical Analysis

The Longissimus dorsi muscles had a high ultimate pH. Their pH values remained essentially unchanged during storage, with trial means of 6.1 ± 0.2 and 6.4 ± 0.2 for vacuum- and CO_2-packaging, respectively. Total Volatile Nitrogen increased at a similar rate in both packaging systems up to the onset of overt spoilage, albeit the curve for lamb packaged under CO_2 is displaced by approximately 50 days compared to the curve for vacuum-packed lamb (Fig.4). The FFA content of subcutaneous fat however, increased more rapidly under vacuum than under CO_2. Concentrations of FFA were also displaced by approximately 50 days for the CO_2-packaged product. Similar concentrations of FFA occurred in vacuum- and CO_2-packaging, for a short period, after approximately 40 and 90 day's storage, respectively.

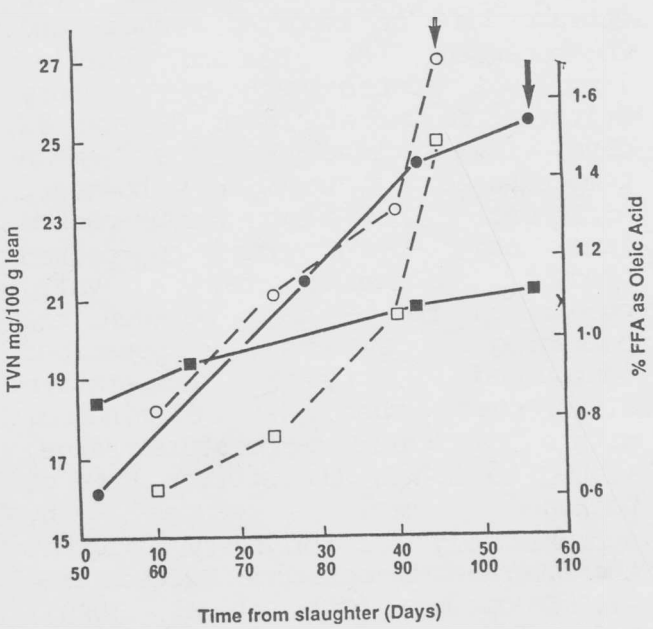


Figure 4. Changes in Total Volatile Nitrogen (circles) and Free Fatty Acids (squares) during chill temperature storage of lamb under vacuum (open symbols) and CO_2 (solid symbols), arrows indicate first detection of spoilage.

4) Sensory Evaluation

Unlike the vacuum-packaged lamb, CO_2-packaged product had virtually no confinement odour before the onset of overt spoilage. The visual appearance of both products remained acceptable throughout the trials. The taste-panels found the sensory attributes of vacuum- and CO_2-packaged meat to be acceptable only up to the 39th and 92nd days after slaughter, respectively. The subsequent sampling; on days 45 and 106, respectively, found that overt putrid spoilage had rendered the meat olfactorily unacceptable.

While the onset of overt spoilage was unequivocal there were appreciable differences of opinion concerning the acceptability of the chilled and frozen products by both the "in-house" and "take-home" panels.

DISCUSSION

Under the trial conditions the storage life of imported vacuum- and CO_2-packaged New Zealand chilled lamb was determined by sensory criteria to be at least 39 and 92 days, respectively. The mean temperatures were, however, different; 2.3°C for vacuum-packed lamb and -0.1°C for CO_2-packed product. In order for a valid comparison to be made between the packaging systems aberations introduced by temperature differences must be eliminated. Within the chill temperature range, -2.0°C to 5.0°C, the storage life of packaged meat reduces by approximately 10% for every 1°C that the average temperature exceeds the -1.5°C optimum (Gill et al, 1989). Under the the trial conditions, a storage life of at least 34 and 95 days for vacuum- and CO_2-packaging, respectively, would be predicted from those claimed under optimum conditions (Gill, 1988). Conversely, based on trial results, if the meat had been held at -1.5°C, the storage life of the vacuum- and CO_2-packaged lamb can be predicted to be 62 and 108 days, respectively. The long sample interval and calculation based on the last acceptable sampling rather than from the onset of incipient spoilage make these estimates conservative, particularly in the case of CO_2-packaging. From the limited data available and allowing a commercial tolerance of 1.5°C above the optimum transportation/storage temperature storage lives of at least 53 and 92 days would be expected for vacuum- and CO_2-packaged chilled lamb imported by air and sea respectively. Under Saudi Arabian summer conditions, shorter storage lives could be expected if loss of temperature control at inspection and transfer points was sufficient to serious to produce significant increases in the overall transportation/storage temperatures.

The temperature that determines the rate of spoilage development is not that of the refrigeration equipment but that at the meat surface. There will, however, be some fluctuation in the temperature of the air delivered by a refrigeration unit, ±0.5°C being commonly achieved in modern refrigerated containers and trucks, but ±2.0°C being usual in chilled storage facilities, (Gill et al, 1989). Today, with the notable exception of air freight, refrigerated transporatation can be regarded as mobile storage and failure to maintain product at its optimum temperature rests not with the equipment but with the operators. Nowhere, is this more apparent than in the widely held belief that the uncalibrated temperature gauge measuring the operating temperature of the refrigeration equipment actually records product temperature.

In this trial, overt spoilage was delayed by approximately 50 days in packaging under CO_2 rather than vacuum. This extension of storage life afforded by CO_2-packaging is also evident in the microbiological and chemical data. As observed previously (Gill & Penney, 1988) the

CO_2 atmosphere retarded the growth of the spoilage microflora especially those organisms of high spoilage potential such as the enterobacteria. The 50-day temporal displacement of the onset of spoilage is particularly obvious in the data relating to breakdown of protein, shown in figure 4. The wide sampling interval and inherent variation between samples precludes reasonable extrapolation of this data to define incipient spoilage in terms of TVN content. However, it appears reasonable to conclude that TVN contents in excess of 25 mg/100g are associated with putrifying meat. The release of FFA as a result of fat hydrolysis was also slower under CO_2 than under vacuum, where the rate of FFA accumulation increased markedly with the onset of spoilage (Fig.4). The potent spoilage bacteria, the enterobacteria and B.thermosphacta, may play a role in both fat hydrolysis and protein breakdown. In CO_2-packs as opposed to vacuum-packs, growth of these organisms was suppressed and, at spoilage, there was no accelerated FFA and TVN accumulation. As only putrid spoilage was detected by the sensory panel, fat degradation, even in the vacuum-packs, probably had not advanced sufficiently for the accumulated products of fat decomposition to cause rejection of the meat.

Unspoiled meat can be judged unacceptable by consumers for a wide variety of reasons unrelated to its freshness. Saudi panelists generally found the aroma and taste of the chilled lamb less acceptable than panelists of other nationalities. As the acceptability ratings did not change significantly over the trial periods, this likely reflects a local preference rather than indicating adverse effects of prolonged storage at chill temperature.

CONCLUSIONS

Given similar chill temperature holding conditions, the storage life of CO_2-packaged lamb will be approximately 50 days longer than that attained using vacuum-packaging. Storage life in both packaging systems will be terminated by the onset of putrid spoilage, resulting principally from the growth of psychrotrophic enterobacteria.

The actual storage lives of vacuum- and CO_2-packaged lamb attained are determined principally by the average temperature maintained during production, transportation and storage. The results obtained in individual trials are, therefore, unique. For regulatory purposes, further trials must be conducted to establish statistically reliable bases from which realistic storage lives for chilled lamb packaged under vacuum and CO_2 can be promulgated.

REFERENCES

Enfors, S.O. & Molin, G. (1980): Effect of high concentrations of carbon dioxide on growth rate of Pseudomonas fragi, Bacillus cereus and Streptococcus cremoris. J. Appl. Bacteriol. 48: 409-416.

Gill, C.O. (1988): Packaging meat under carbon dioxide: The Captech System, Meat 88. Proc. Ind. Day, 34th Int Cong. Meat Sci. Technol, Brisbane, Australia. pp. 76-77.

Gill, C.O. & Penney, N. (1986): Packaging of chilled red meats for shipment to remote markets. Proc. IIR, Conf. Meat Chilling 86, Bristol, UK.

Gill, C.O. & Penney, N. (1988): The effect of the initial gas volume to meat weight ratio on the storage life of chilled beef packaged under carbon dioxide. Meat Science 22: 53-63.

Gill, C.O., Phillips, D.M. & Harrison, J.C.L. (1989): Product temperature criteria for shipment of chilled meats to distant

markets. Proc. Symp Transportation, Handling and Storing of Food Products in the Kingdom. Riyadh, Saudi Arabia.

Newton, K.G., Harrison, J.C.L. & Wauters A.M. (1978):
Sources of psychrotrophic bacteria on meat at the abattoir. J. Appl. Bacteriol, 45: 75-82.

Saudi Arabian Standards Organization (1977a):
Physical and chemical methods for testing edible vegetable oils and fats. Saudi Standard 30.

Saudi Arabian Standards Organization (1977b):
Methods for physical and chemical analysis of meat and meat products. Saudi Standard 44.

Warburton, D.J. (1988):
The Captech Process, Proc. 25th Meat Industry Research Conf. Hamilton, New Zealand pp 186-190.

Figure 1. Temperature record for vacuum-packed lamb loins imported from New Zealand by air: (1) Production phase, (2) Transportation phase and (3) Storage phase. Loins were packaged on day 0, one day after slaughter.

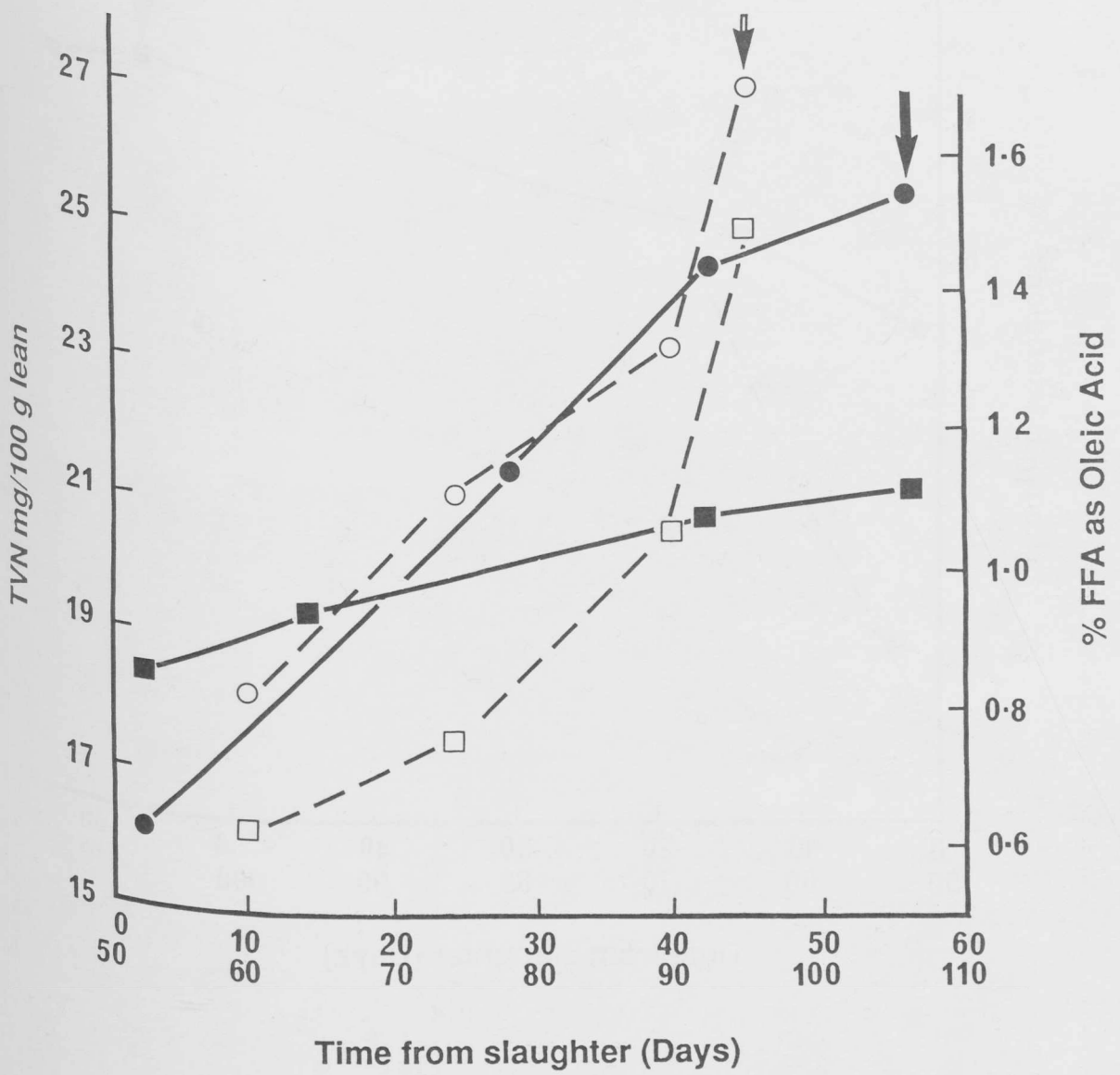
Figure 2. Temperature record for CO_2-packed lamb carcasses imported from New Zealand by sea: (1) Production phase, (2) Transportation phase and (3) Storage phase. Carcasses were packaged on day 3, three days after slaughter.

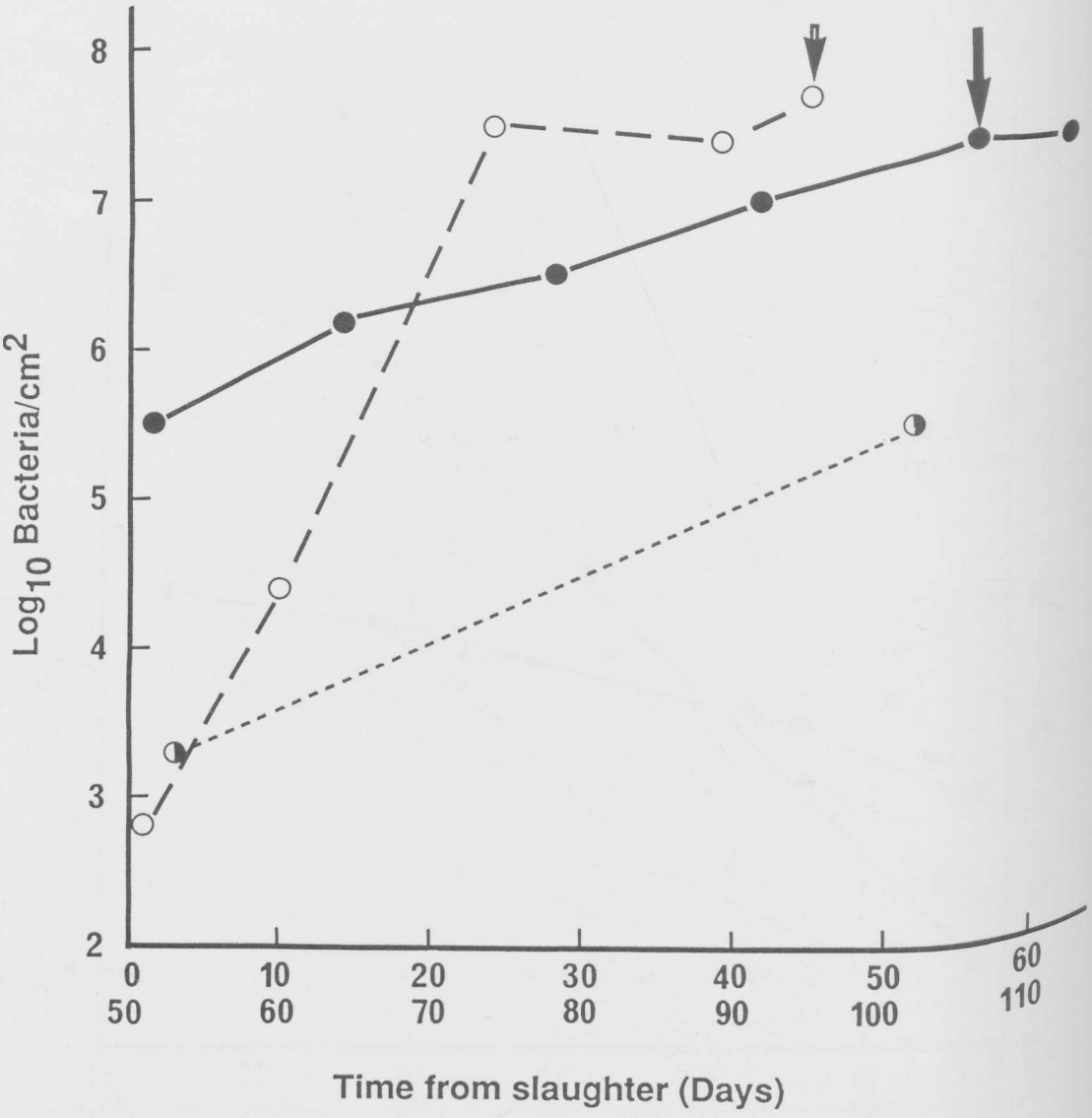
Figure 3. Spoilage microflora development at chill temperatures on vacuum-packed lamb loins (Open symbols 0 to 60 days) and on CO_2-packed lamb carcasses (Half solid symbols 0 to 60 days, solid symbols 50-110 days), arrows indicate first detection of spoilage.

Figure 4. Changes in Total Volatile Nitrogen (circles) and Free Fatty Acids (squares) during chill temperature storage of lamb under vacuum (open symbols) and CO_2 (solid symbols), arrows indicate first detection of spoilage.

10
5
0
−5
Temp (°C)
0
12
24
36
48
60
72
84
96
108
Time (days)
1
2
3

10
5
0
−5
Temp (°C)
0
5
10
15
20
25
30
35
40
45
Time (days)
1
2
3


TVN mg/100 g lean
27
25
23
21
19
17
15
% FFA as Oleic Acid
1·6
1 4
1 2
1·0
0·8
0·6
0
50
10
60
20
70
30
80
40
90
50
100
60
110
Time from slaughter (Days)


8
7
6
5
4
3
2
Log10 Bacteria/cm2
0
50
10
60
20
70
30
80
40
90
50
100
60
110
Time from slaughter (Days)