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Effect of temperature control in supply chains on quality of frozen manufacturing beef

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EXECUTIVE SUMMARY

There were three components to this project:

a. A supply chain survey;
b. Simulation of cold chain breaks; and
c. Implication of cold chain breaks for product quality.

This report documents the results of a survey of frozen meat temperatures during shipping to the United States and the effect of cold chain breaks on product quality. Part B, simulation of cold chain breaks was undertaken at Food Science Australia's North Ryde Laboratories and will be the subject of a separate report.

Under the temperature survey, temperature loggers were inserted to record the surface temperatures of cartons of manufacturing beef during transport from Australian meat processing plants to a cold store in Philadelphia on the east coast of the United States. Temperatures were logged in a range of positions in a 6 m (20 ft) container and a 12 m (40 ft) container.

Both shipping containers experienced significant periods during which no refrigeration was applied. There were three off-power periods, the longest of which was 13.5 hours, with the 20 ft container and one period of just over 10 hours for the 40 ft container. During these off-power periods, meat surface temperatures of cartons on the outside of the load rose by about 8 degrees Celsius to between -13 and -8.6°C. Meat surface temperatures within the load did not change.

While on power, temperature control with both containers was very good.

The survey, which was a snapshot of the temperature conditions under which Australian frozen meat is shipped, did reveal some practices that may be considered less than ideal:

a. An off-power period of 12.5 hours occurred with the 20 ft container on board the ship during the voyage.
b. Cartons were loaded too close to the doors thereby restricting air flow, resulting in higher meat surface temperatures at the door end of the container.
c. The container doors were not closed immediately after loading, resulting in higher meat temperatures at the beginning of the trip, which took up to 12 days to reach the carriage temperature of -20°C.

The majority of frozen manufacturing meat is exported in shipping containers, but there has been some trade as palletised cargo in the refrigerated hold of 'conventional' ships. However this trade is currently suspended.

In both shipping methods, frozen product may be the cold chain may be broken for brief periods. Containers may be off-power during transport to and from the wharf and pallets of frozen cartons are exposed to ambient conditions on the wharf while loading and unloading the ships.

In order to assess the effect of these practices on quality parameters of frozen manufacturing beef, quite extreme cases of un-refrigerated conditions were simulated and the meat analysed. One set of six cartons was held at a constant -20°C, another set was allowed to warm in a similar manner to a container off-power for two days and a third set exposed to an ambient temperature of 25°C for five hours. The meat was stored at -20°C for four weeks prior to the first abuse, returned to -20°C for four weeks

(to simulate the voyage to the U.S.), subjected to a second temperature abuse, then stored at -20°C for a further four weeks.

At the end of the 12 weeks storage period, the 18 cartons were ground using a similar procedure to that followed by the commercial grinders. Samples were taken and analysed for fat content, anti-oxidants and products of lipid oxidation.

There were no differences in the amounts of α- tocopherol and β-carotene in either of the abused groups compared with the control, indicating that they had not been destroyed by accepting the free radicals of lipid oxidation.

Measurement of TBARS, peroxides and head space analysis for hexanal showed no differences between abused groups and the product stored at a constant -20°C. A taste panel could not detect any significant difference between treatment groups.

These results indicate that frozen manufacturing beef exported by either refrigerated shipping container or ‘conventional’ shipping is not affected by short periods of exposure to ambient conditions or container off-power periods when stored for three months.

EFFECT OF SHIPPING PRACTICE ON QUALITY OF FROZEN MANUFACTURING BEEF

(a) - Supply Chain Survey

1.0 INTRODUCTION

Frozen manufacturing meat, purchased from Australian plants is exported to the United States in refrigerated containers and, when operating, by conventional shipping. There is concern regarding the integrity of the cold chain when the cartons are exposed to ambient conditions during loading and unloading of conventional refrigerated vessels and when containers are off-power during transport to and from the port

2.1 PROJECT AIM

To survey the cold chain for frozen, cartoned manufacturing meat from packing in Australian plants to delivery to a cold store in the United States by:

- 20 foot container;
- 40 foot container; and
- Conventional shipping.

3.0 PROCEDURE

3.1 General

Plants from which the consignments of meat to be monitored were processed and packed for export were selected. Visits were made to the plants and cartons of manufacturing meat for the consignment were selected at the end of the processing line, prior to lidding for insertion of temperature loggers.

Two types of temperature loggers were used to measure meat surface temperatures and air temperatures. Dual-channel Tinytag Plus loggers (from Hastings Data Loggers) were used to monitor air temperatures and the corner temperature of cartons at the top of the load (Figure 1). Thermocron, iButton loggers (Figure 2), supplied by OnSolution Pty Ltd, were used to record the temperatures of the tops, sides and ends of cartons.

One sensor from the Tinytag was inserted through the plastic liner and against the corner surface of the meat and the other passed through the corner of the carton so that it was in the air approximately 25 mm outside the carton. The logger was placed inside a plastic bag between the liner and the fibreboard.

The iButton loggers were placed inside Ziplock plastic bags and taped to the surface of the liner in three positions in the cartons – the top surface, side surface and end surface between the liner and the fibreboard.

All temperature loggers were set to record at 10-minute intervals and each carton that contained loggers was clearly identified on at least three faces with brightly coloured labels.

On arrival at the cold store in the United States, the labelled cartons were separated from the load and stored until the data loggers could be removed by a US employee and returned to Australia for downloading the data. All loggers were calibrated prior to the trial and the downloaded data adjusted by the appropriate correction factor.

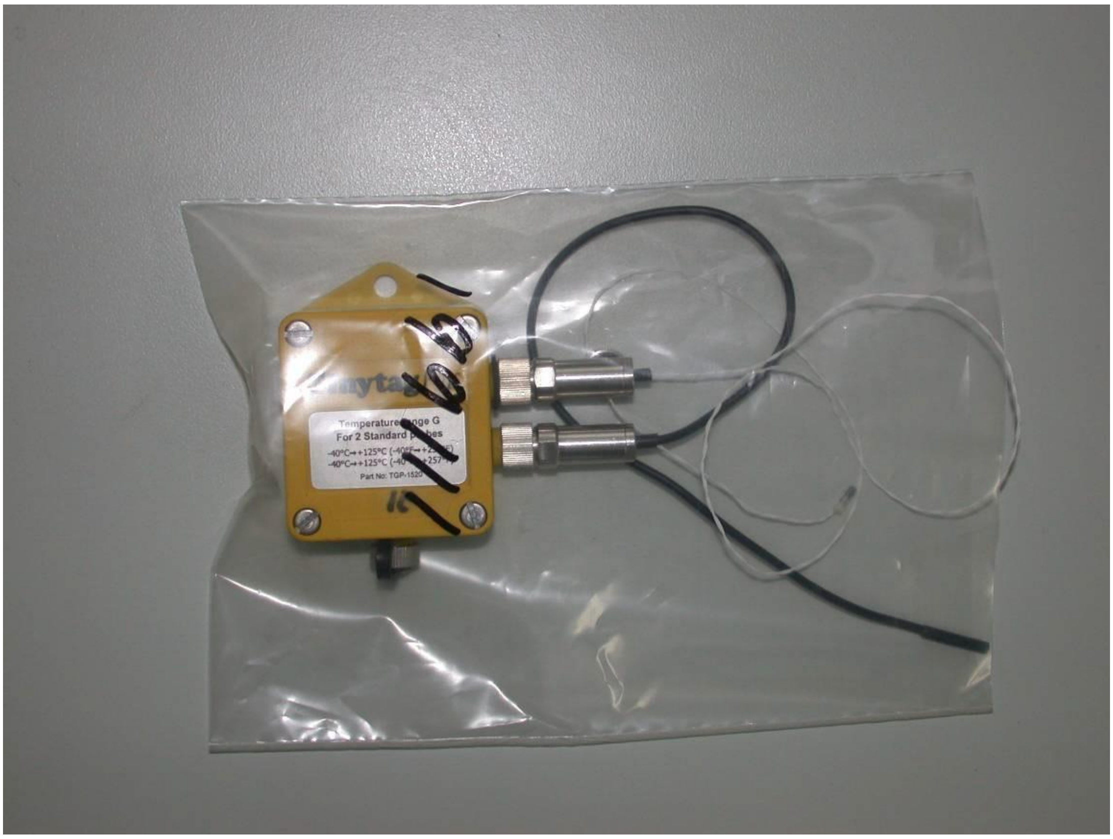

Figure 1: Tinytag logger to record corner surface and air temperatures

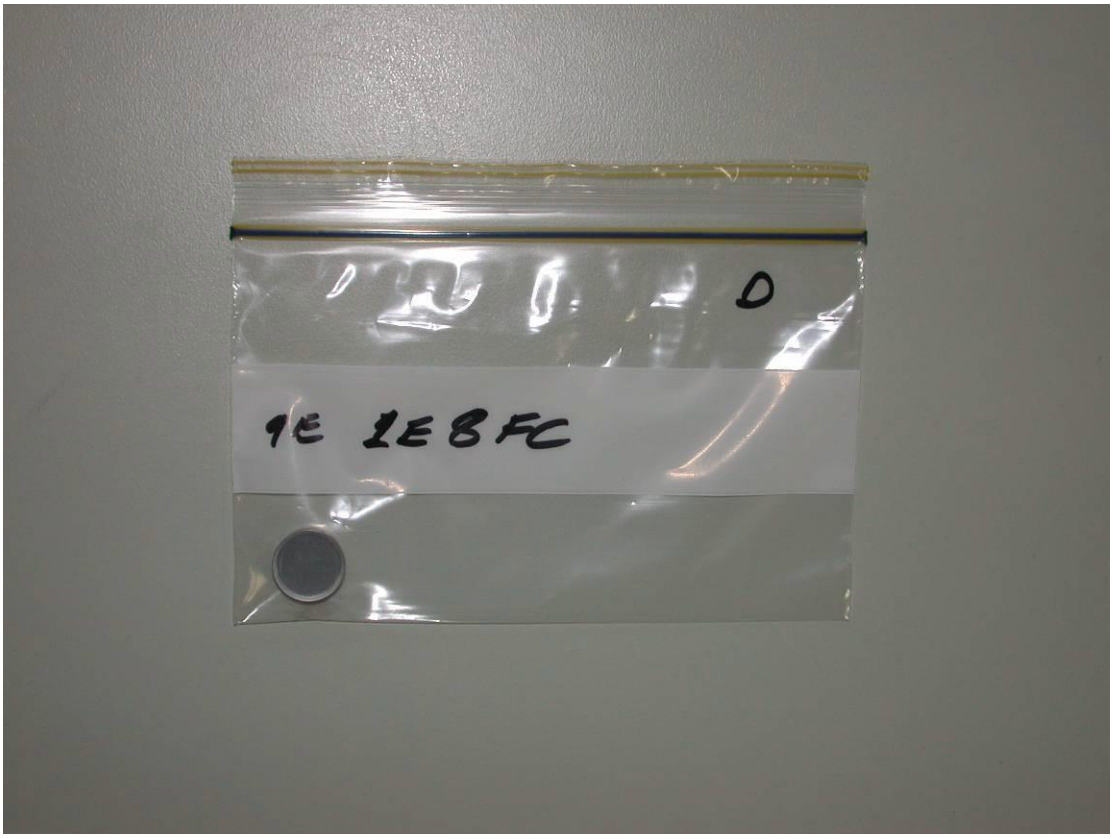

Figure 2: iButton logger used to record meat surface temperatures

3.2 20 ft Container

On Wednesday 14 June 2006, nine cartons of manufacturing beef labelled, A-F 90 CL, were selected and temperature loggers inserted as described above. Each carton was identified with a number 1 to 9. Cartons 1, 2 and 3 had the Tinytag logger plus three iButton loggers, while the remainder had just the three iButton loggers. After sealing, the cartons were placed on a stillage and then into a batch air blast freezer.

The cartons were loaded into the container on the morning of Monday 19 June. Cartons were stacked on their edges on the pallets as three layers each of 12 cartons. The pallets were mechanically loaded into the container as units, two pallets high. Four pallets only contained 30 cartons, rather than 36, in order to allow them to all fit into the container.

Prior to loading the container, the test cartons were placed into pallets to replace existing cartons as follows:

- Cartons 4 to 9 inclusive were placed on the top layer of bottom pallets, so that the tops and ends of the edge-stacked cartons with loggers were to the outside of all four sides of the pallet.
- Cartons 1 to 3 were placed at the top corners of top pallets so that the corner with the logger was to the top corner of the container. Carton 1 was located at the refrigeration end, carton 2 near the centre and carton 3 at the door end of the container.

The positions of the test cartons in the container are shown diagrammatically in Figure 3 and a photo of the loaded container in Figure 4.

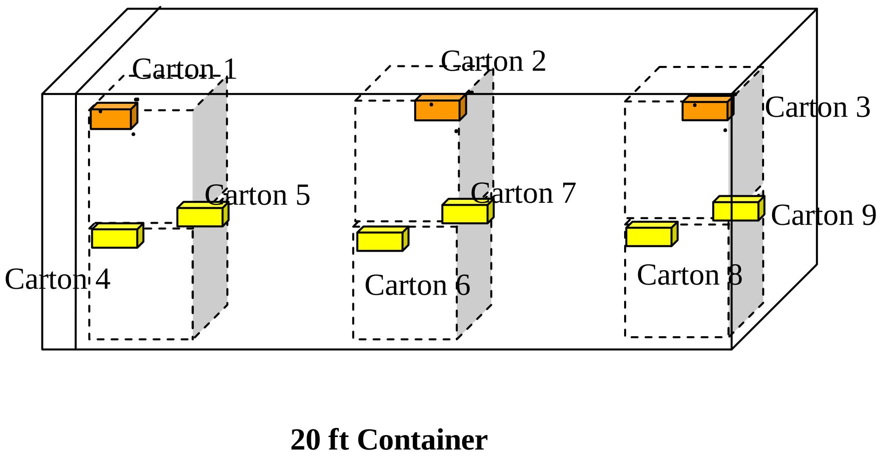

Figure 3: Location of test cartons in the 20 ft container

The trailer on which the container was loaded was equipped with a generator and the refrigeration was turned on at the commencement of loading. On completion of stuffing, the refrigeration controller was checked and adjusted to a return air set point of -20°C.

The container was transferred to a transport depot in Inverell where it was held on power until departing for Brisbane that afternoon at about 5.00 pm. The container arrived at the Port of Brisbane at 10.30 pm and was loaded onto the Maersk Dale in a position below deck.

Figure 4: 20 ft container on completion of loading

The container was discharged in Philadelphia on 21 July 2006 and transported to a cold store where it was unloaded and the test cartons put aside for retrieval of the loggers.

3.3 40 ft Container

Another plant was selected as the site from which to monitor a 12 m (40 ft) container. On Monday 4 September, 12 cartons of C-F 90 CL beef were selected from the processing line immediately prior to the lids being glued onto the cartons and loggers inserted as described above. The cartons were numbered 1 to 12 with cartons 1 to 4 being fitted with Tinytag loggers plus three iButton loggers. The remainder were fitted with just the three iButton loggers.

Following application of the lids, the cartons were placed as a group into the continuous air blast freezer. On emerging from the freezer on Wednesday 6 September, the test cartons were palletised and placed into the cold store.

The container was loaded on Friday 8 September. Cartons are palletised for storage as 6 per layer, flat stacked six layers high. The refrigerated container was suitable for a maximum of 1,000 cartons, therefore pallets were adjusted to 50 cartons each by the addition of two layers plus two cartons on top for 50 cartons per pallet.

Prior to commencing loading, the test cartons were inserted into pallets to replace existing cartons as follows:

- Cartons 5 to 12 were inserted into the fourth layer so that the ends and sides where loggers were located were to the outside of the pallet.
- Cartons 1 to 4 replaced one of the two cartons on top of the test pallets so that the corner of the carton with the sensor was near the top of the container when loaded.

- The pallets were identified with large labels, A, B, C and D, corresponding to test cartons 1 to 4 respectively.

Pallet A was loaded into the container first and located at the refrigeration end on the left. Pallets B and C were positioned at approximately ⅓ and ⅔ the length of the container and Pallet D was located at the door end, all on the same side.

The locations of the test cartons in the container are shown diagrammatically in Figure 5 and a photo of the fully loaded container in Figure 6.

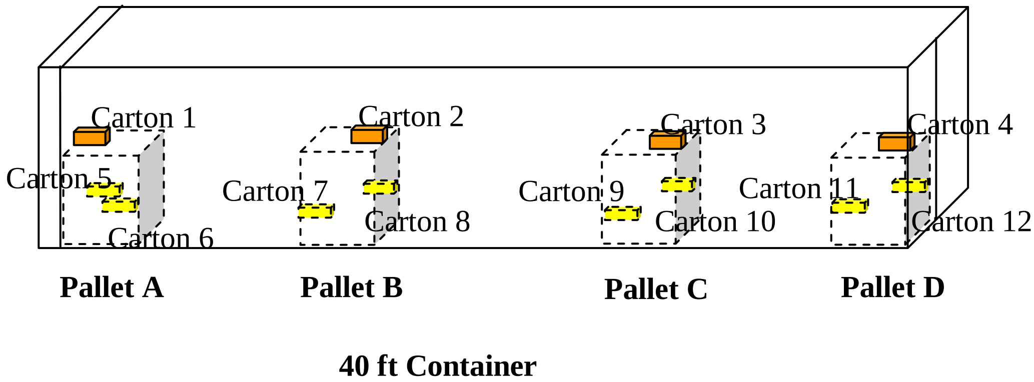

Figure 5: Location of cartons in 40 ft container

On completion of loading, the container was to be transported to the rail depot in Rockhampton. However due to congestion at the depot, the container could not be moved to allow the doors to be closed until over an hour after completion of loading.

The container was connected to power prior to commencement of loading and set to a return air temperature of -20°C. The power was disconnected prior to road transport to the rail yard where it was placed back on power and also transported by rail to the Port of Brisbane under power. It arrived in Brisbane at 16.48 on 9 September and was loaded onto the Maersk Dayton on 17 September in an internal position above deck. The ship arrived in Philadelphia on 11 October 2006. The container was transported to the cold store on 12 October where it was unloaded and the test cartons kept until the loggers were retrieved and returned to Australia. A summary of the movements of both containers is given in Table 1.

Figure 6: Fully loaded 40 ft container

Table 1: Timetable for operations (local times)

Operation	20 ft Container No. HLXU 372 690 9	40 ft Container No. CRXU 680 465 8
Loggers inserted	08:22, 14 June	10:50, 4 September
Cartons into freezer	08:37, 14 June	11:22, 4 September
Removed from cold store	10:00, 19 June	09:45, 8 September
Container loading complete	11:20, 19 June	11:45, 8 September
Depart for Brisbane	17:00, 19 June	03:45, 9 September
Arrive Port of Brisbane	22:50, 19 June	16:48, 9 September
Loaded on ship	00:29, 28 June	02:30, 17 September

Discharged Philadelphia	14:30, 21 July	17:26, 11 October
Unloaded at cold store	07:50, 26 July	07:00, 13 October

4.0 RESULTS

4.1 20ft Container

Meat surface temperatures measured at the corners of the cartons which were located at the top of the load are plotted in Figure 7. This shows that there were three significant periods when the container was off-power – during loading onto the ship in Brisbane, a 12.5 hour break during the voyage and 13.5 hours when discharged in Philadelphia. The plot also shows that, except for during the frequent defrosts, the surface temperatures were steady when under refrigeration. However there were differences between positions within the container. The temperature at the door end was consistently higher than at the mid point and the refrigeration end.

The longest off-power period was 13.5 hours from 10.30 am to midnight local time, after unloading in Philadelphia. The temperatures at the top corners and in the centre of the container are presented in Figure 6. This shows that, while the air rose to close to zero, the meat corner surface temperature rose by 7.8°C to -8.6°C at the door end. There was negligible change at any of the measured load centre temperatures. The maximum temperature in Philadelphia on that day was 32°C with 14 mm of rain falling in the afternoon.

Meat surface temperatures near the centre of the load (Figure 9) were steady for the entire journey at -19°C to -20°C. The initially very low temperatures at the plant were due to the test cartons remaining in a blast freezer from packing on Thursday to shipping on Monday morning.

This container had a very frequent defrost cycle of once every 12 hours 20 minutes for a period of 30 minutes. The air temperature around the load rose to -5°C to 0°C during each defrost (Figure 10) resulting in corner surface temperature rises of between 0.5 and 2.6 degrees. The air temperature at the door end was up to 3°C higher than at the mid point of the container with the differential getting slightly larger as the journey progressed.

Plots of temperatures recorded at the top, ends and side of the load are in the Appendix.

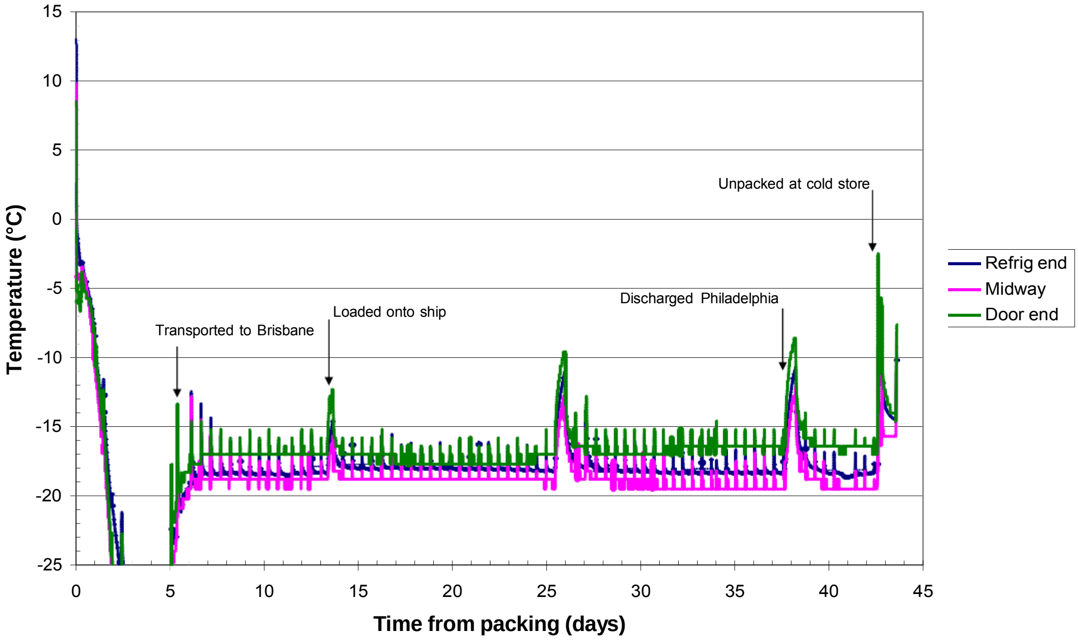

Figure 7: Meat surface temperatures at the top corners of 20 ft container

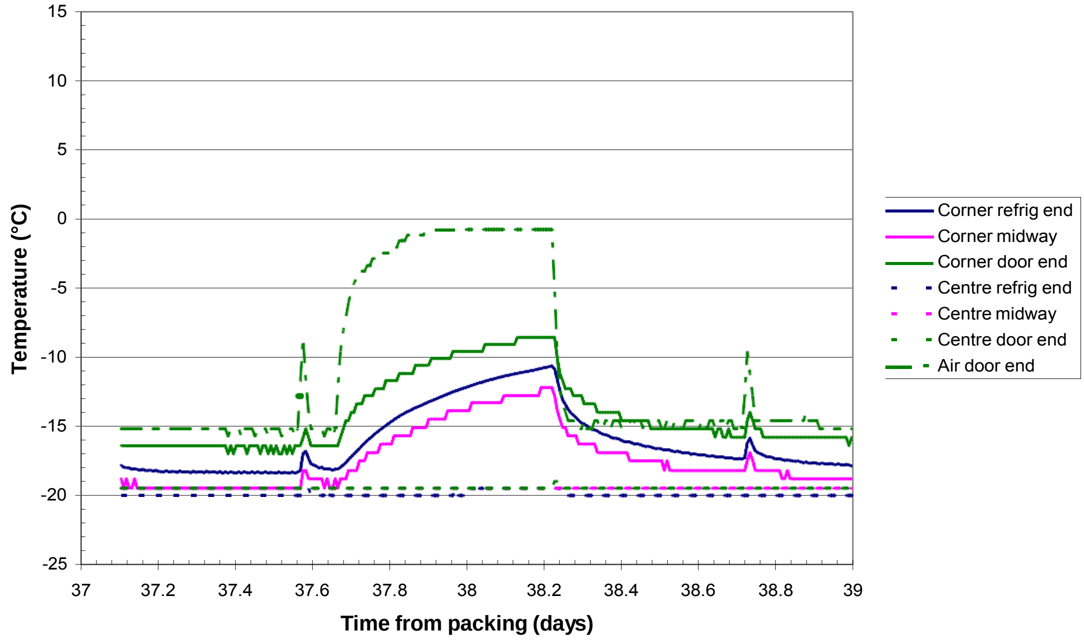

Figure 8: Meat surface temperatures during time off-power after discharge (20 ft)

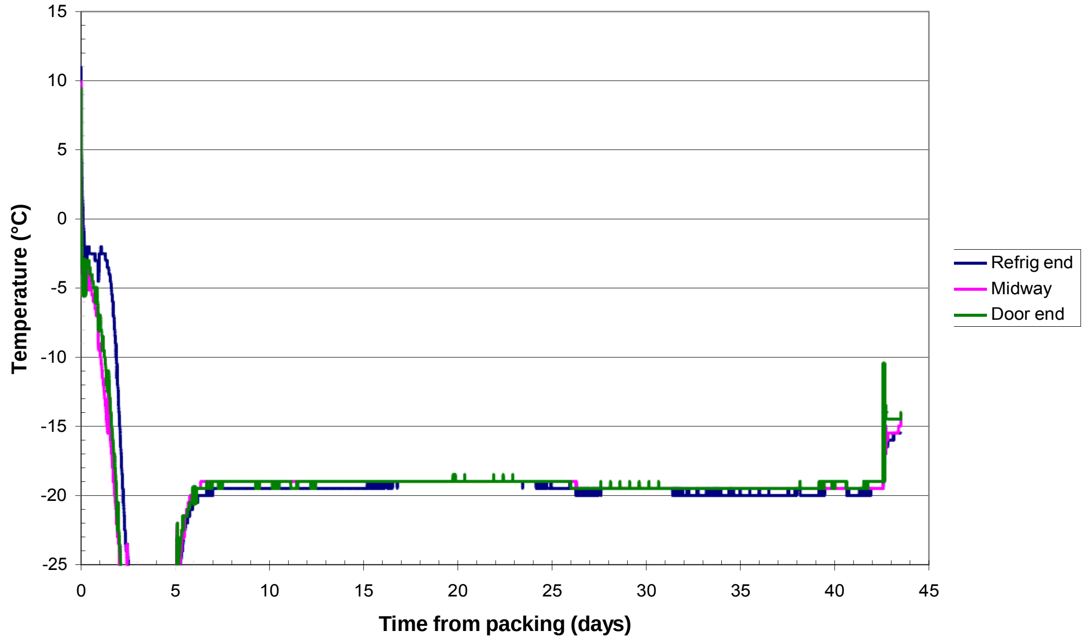

Figure 9: Meat surface temperatures at the centre of the container (20 ft)

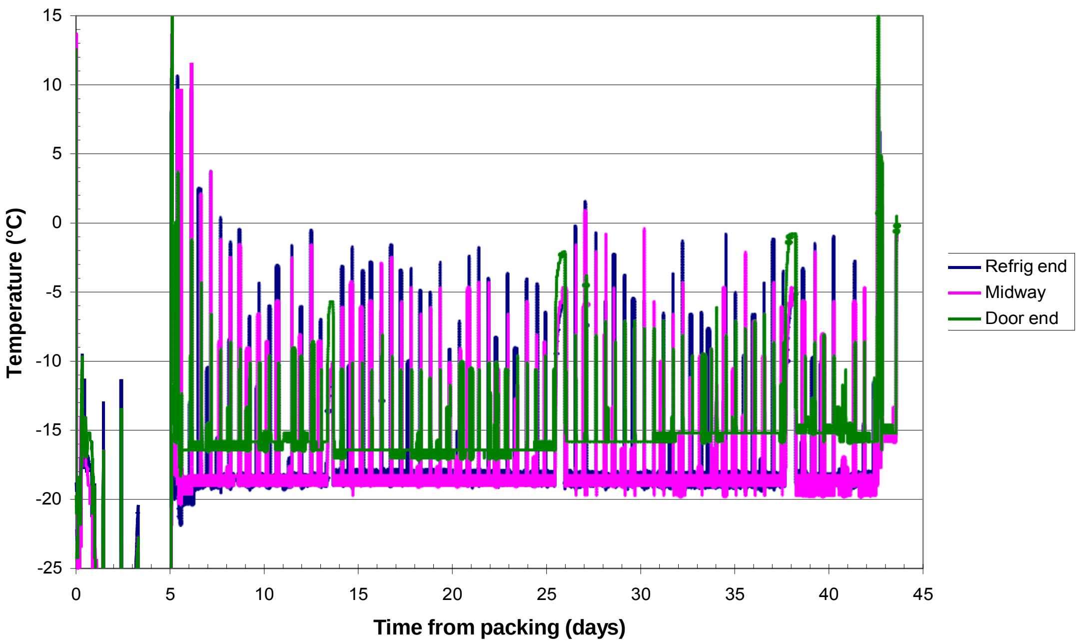

Figure 10: Air temperatures at the top corners of the container (20 ft)

4.2 40ft Container

Meat surface temperatures at the corners of the top cartons are shown in Figure 11. The only significant time when the container was off-power was for 10 hours 10 minutes during loading onto the ship in Brisbane. It was also evident that the temperature of the surfaces rose to above -5°C during loading and took several days to reach the carriage temperature. Once the corner surfaces had reached the carriage temperature, they remained near -20°C for the complete journey. However they did respond rapidly during defrosts (reaching -15 to -12°C) most likely due to there being only two cartons on the top layer.

During the 10 hour off-power period in Brisbane (Figure 12), the air temperature rose to -8.5°C, but corner surfaces did not rise above -11.5°C. There was no effect on temperatures near the centre of the load. The container was off-power from 5.30 pm to 3.30 am when the ambient temperature ranged from 15°C to 19°C with some light rain.

Meat surface temperatures near the centre of the load took 5 – 10 days to reach the carriage temperature (Figure 13), but once at that temperature remained steady for the remainder of the trip.

The air temperature in the container was quite high at loading due to the container not being directly connected to the loading dock, but once the doors were closed and power connected, the temperature reached the set point in about 6 hours. Air and meat surface temperatures were uniform at the different locations measured in the container.

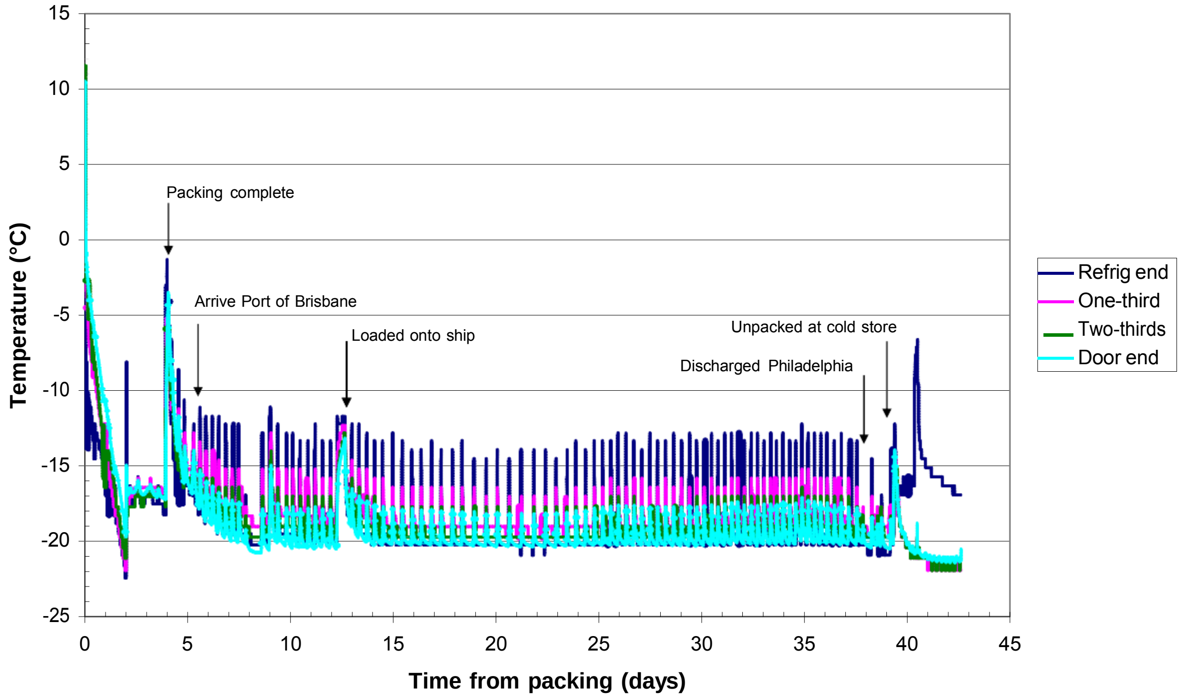

Figure 11: Meat surface temperature at the corner of container (40ft)

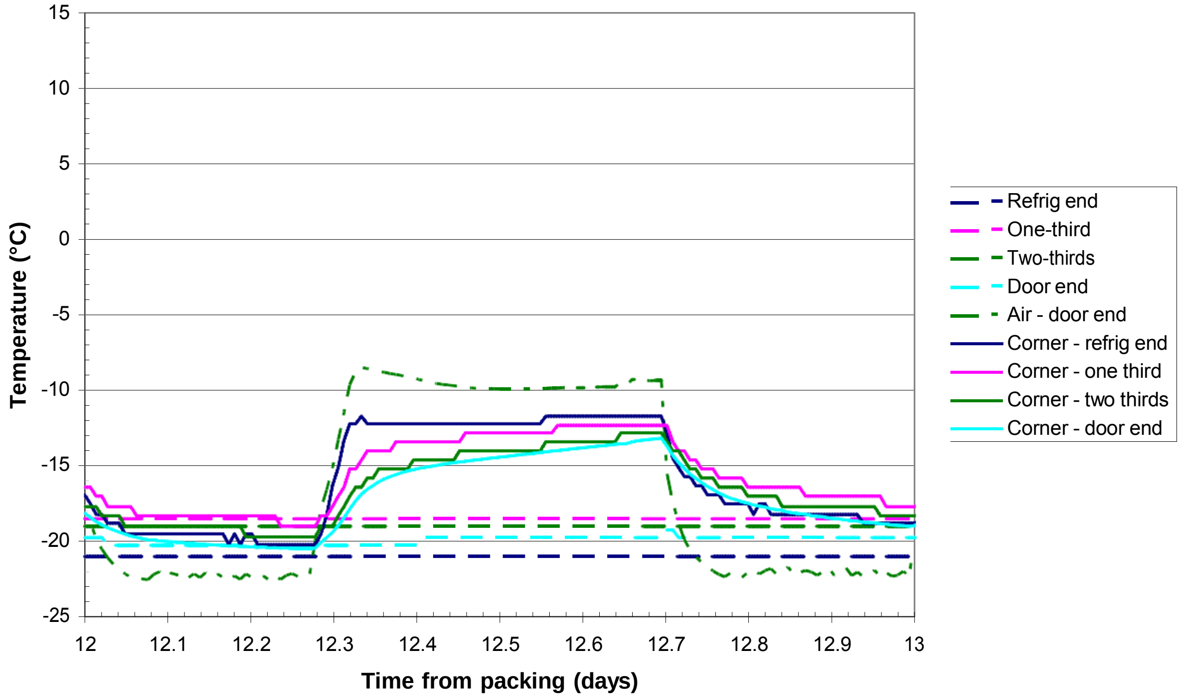

Figure 12: Meat surface temperatures during time off-power (40 ft)

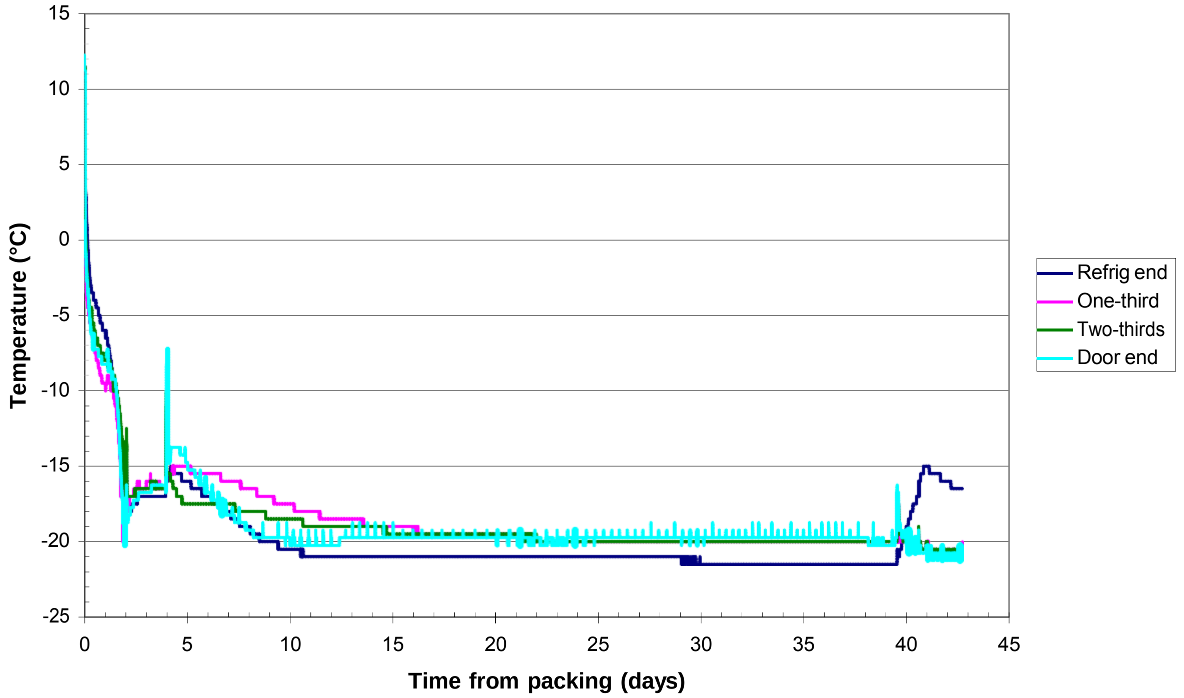

Figure 13: Meat surface temperatures at the centre of the container (40 ft)

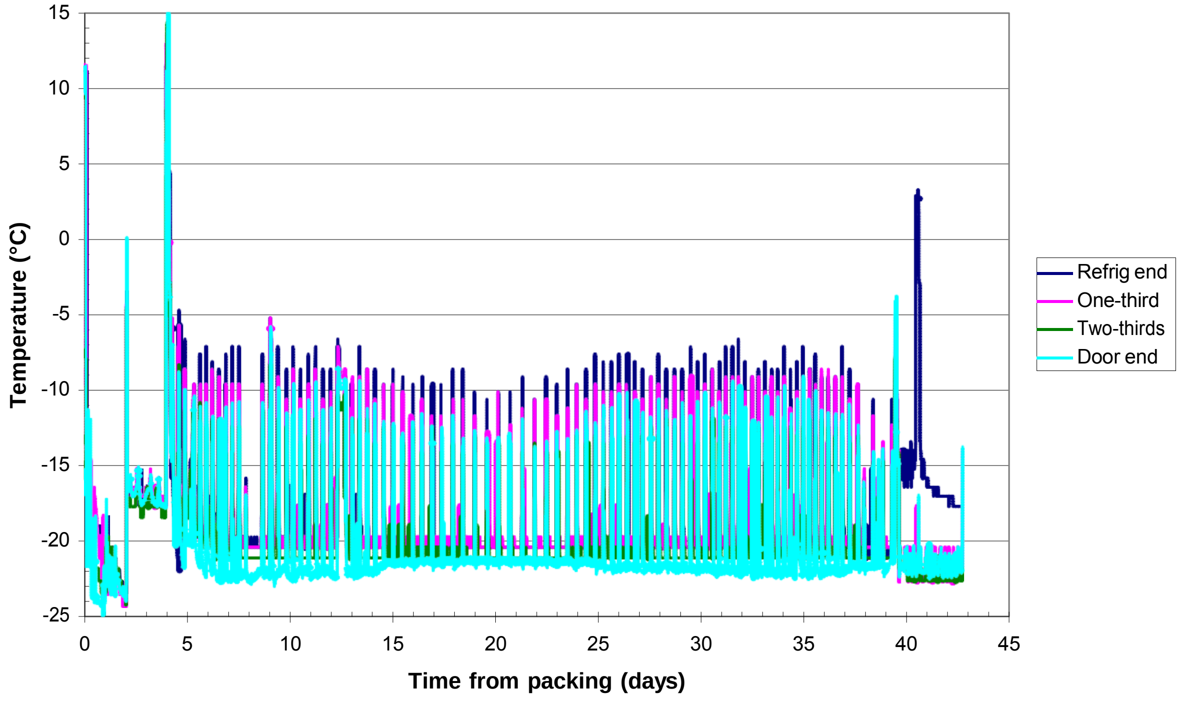

Figure14: Air temperatures at the top corners of the load (40 ft)

5.0 DISCUSSION

Although the 20 ft container was not off-power during transport to Brisbane as anticipated, there were still three significant off-power periods during the journey. One was during loading onto the ship and the other at unloading but one also occurred while on board ship for reasons that could not be determined. Temperature rises during the off-power periods only affected the surfaces of cartons on the outside of the load.

Air and meat surface temperatures were higher at the door end of the container than at other positions for the entire journey. This is most likely due to restriction of air flow because the cartons were loaded hard up against the door. The containers operate on the principle of an envelope of refrigerated air surrounding the load and if circulation is restricted by loading product hard up to the ceiling or the doors, some areas can be starved of air resulting in temperature rises. Therefore space should be available above the load and at the doors for free air movements.

There was only one off-power period with the 40 ft container and there appeared to be little effect of carton location on temperatures recorded. However the meat temperature was about three degrees above the carriage temperature at loadout and rose another two degrees during loading. The temperature rise was due to two main reasons. Firstly the facility did not allow the container to be sealed against the loading dock and secondly there was a delay of 80 minutes in closing the doors after loading due to congestion at the rail terminal which restricted transport options. Consequently cartons near the centre of the load took up to 12 days to reach the carriage temperature. However, they were still below -15°C at most sites.

6.1 CONCLUSIONS

This project was only able to provide a very brief snapshot of the temperature conditions under which Australian manufacturing beef is exported to the United States of America. However, several points could be made from the survey:

2. The container refrigeration maintained very good temperature control.
3. During periods when the containers were off-power, the majority of the load was unaffected by the air temperature rising to near 0°C.
4. Meat surface temperatures of cartons on the outside of the load rose to around -10°C during an off-power period of 13.5 hours.
5. Some less than ideal practices were revealed:
    a. An off-power period of 12.5 hours occurred with the 20 ft container on board the ship during the voyage.
    b. Cartons were loaded too close to the doors thereby restricting air flow, resulting in higher meat surface temperatures at the door end of the container.
    c. The container doors were not closed immediately after loading resulting in higher meat temperatures at the beginning of the trip, which took up to 12 days to reach the carriage temperature of -20°C.

EFFECT OF SHIPPING PRACTICE ON QUALITY OF FROZEN MANUFACTURING BEEF

(c) – Implications of cold chain breaks for product quality

7.0 INTRODUCTION

Cartoned manufacturing beef may be shipped from Australia to U.S. markets by refrigerated container or, at times, as 'conventional' refrigerated cargo in the hold of ships. During containerised transport, the refrigerated container may be off-power for some time during transport to and from the wharf, while with conventional shipping, pallets of frozen meat are exposed to ambient temperatures on the wharf awaiting loading into the hold of the ship.

A previous project (MLA Project SCT.012) assessed the effect, under a laboratory situation, of temperature abuse on 600 g samples of beef trim. There were minimal differences between abuse and control samples. The purpose of this work was to assess the effect of temperature abuse on whole cartons of beef.

8.0 PROJECT AIM

To determine the effect of temperature abuse, equivalent to the worst that might be experienced when pallets of cartoned beef are exposed to ambient temperatures during conventional shipping and when refrigerated containers are off-power, on the organoleptic properties of manufacturing beef.

9.1 PROCEDURE

Eighteen cartons of frozen manufacturing beef, labelled C-F 85 CL were purchased from an export meat processor and transported by a commercial refrigerated truck to the Cannon Hill Laboratory of Food Science Australia. The meat was all produced from grass-fed steers and the cartons were packed within a period of 20 minutes. The cartons were numbered and thermocouples were inserted into the meat by drilling a hole and inserting some water to freeze the sensor in place in the following positions:

- In a top corner of each carton, approximately 10 mm deep and approx. 10 mm from each face; and
- In the centre of two cartons on each of the three layers of the pallet at approximately half the depth of the cartons.

The thermocouples were connected to Grant Squirrel temperature loggers set to record at intervals of one hour. The cartons were palletised and placed into a freezer operating at -20°C.

9.1 Temperature abuse

The cartons were subjected to three different temperature regimes as follows:

- **Control** cartons (1 to 6) stored at a constant -20°C for 12 weeks;
- **Conventional (ambient) abuse** cartons (7 to 12) subjected to two periods of exposure to a high ambient temperature; and
- **Container off-power abuse** cartons (13 to 18) subjected to two periods of exposure to a temperature just above freezing.

The cartons were stored for four weeks prior to the first abuse.

The ambient abuse was achieved by moving six cartons (one layer) to a room controlled at 25°C until the average corner temperatures reached approximately -1.5°C (about 5 hours). On return to the freezer, the six cartons were stacked together and insulated to slow the rate of re-cooling. During the abuse period, the logger was set to record at 3-minute intervals.

The off-power abuse was achieved by moving another layer of six cartons to a room operating at 1°C and insulating them to give a slow temperature rise similar to that measured in a container when off-power. The cartons were returned to the -20°C freezer after 48 hours when the centre temperature reached -5°C. The cartons were allowed to cool rapidly in the freezer. The temperature logger was set to record at 15-minute intervals during the abuse period.

The temperature abuse regimes were repeated for the same cartons after a further storage period of four weeks. The cartons were then stored for another four weeks after which they were removed for grinding and sampling.

9.2 Grinding and sampling

Each carton was removed from the -20°C room to a 10°C environment approximately one hour prior to grinding. The cartons were then ground and sampled using the following procedure:

1. The thermocouples were removed from the meat and the carton and plastic liner stripped off and the block cut into shavings using a Rühle frozen block cutter.
2. The frozen shavings, collected in plastic tubs were first ground through a 16 mm plate using a Wolfking mixer grinder. The temperature after the initial grind was -2.0 to -2.5°C.
3. All the coarse ground meat from the carton was returned to the Wolfking hopper and thoroughly mixed, then ground through a 3.2 mm plate. The mince temperature after the second grind was about -1.2°C.
4. Samples were collected from the well-mixed final ground meat and frozen to -80°C for later analysis.
5. Some of the remaining ground meat was then used for manufacture of patties using a Formatic Retail patty machine from Deighton Manufacturing, Bradford England. The patties were then vacuum packed and frozen to -20°C for later sensory assessment.

9.3 Sample analysis

Each of the ground samples were analysed for fat and moisture content, vitamins (tocopherols, carotenes and retinol), TBARS and head-space analysis using the following procedures:

<u>Fat determination</u>

Fat content (% w/w) of minced beef trim was determined by oven drying at 104°C and applying the relationship between moisture and fat (Thornton *et al*, 1981).

<u>Anti-oxidant determination</u>

The contents of α-tocopherol, β-carotene and retinol were determined on hexane extracts of minced beef trim prepared using the method of Liu *et al* (1996). The concentrations of α-tocopherol, β-carotene and retinol in the extracts were determined by HPLC using the system for β-carotene (Yang *et al*, 1992) with α-tocopherol being detected with a fluorescence detector.

<u>Analysis of lipid oxidation</u>

The measurement of lipid oxidation products requires a number of measurements because a number of the main product categories are unstable with time and diminish as they are converted to further intermediary products. For this reason it is best to use a number of methods.

- TBARS

  Thiobarbituric acid reactive substances (TBARS) were determined on aqueous homogenates of minced products using the method of Witte *et al* (1970). Raw samples were left at 4°C for 24 hours prior to analysis. Cooked samples were prepared on raw samples that had been left at 4°C for 24 hours, cooked and then left a further 24 hours at 4°C prior to analysis.

- Peroxide value

  Peroxide values (PV) were determined on lipid extracts prepared from minced products with chloroform:methanol using the method of Shantha and Decker (1994) but using hydroperoxide as a standard (Zhen-Yue *et al* (1992).

- Head space analysis of volatiles

  Duplicate one gram portions of minced samples, from each carton, were placed into 10 mL amber headspace vials and sealed. The sealed vials were heated on a heating block at 70°C for 20 minutes and stored at 4°C over night. After approximately 20 h storage at 4°C, the vials were opened and 2 mL of saturated brine was added to each vial, resealed and transferred to the GC sample injection tray which was maintained at 4°C for analysis by solid phase micro-extraction (SPME) and Gas Chromatography with a flame ionisation detector. SPME operations were performed using a CombiPal autosampler. The following analytical conditions were used.

  SPME fibre – Carboxen/PDMS

  Equilibration - 70°C for 15 min

  Desorption time – 7 min

  GC Column: HP VOC, 60m x 0.32mm ID, 1.8 micron film

  GC Temperature program: held at 60°C for 2min, increased to 220°C at 6°C/min and held at the final temperature for a further 7 min.

  The procedure allows measurement of various volatile aldehydes that are produced from unsaturated fatty acids in lipids as a result of lipid oxidation. The major aldehyde observed was hexanal and this was therefore used to determine relative differences between storage times and treatments.

<u>Sensory evaluation of aroma in cooked samples</u>

A limited sensory evaluation of ‘meat’ and ‘other’ aroma was made on control samples and those samples that had been subjected to temperature abuse. At the completion of the storage trial all samples were frozen and kept at -80°C until they were required for sensory analysis. Samples were then thawed and brought to the boil in water (1:1, v/v) and simmered on low heat for a further 20 min. Samples were then maintained at 60°C for a maximum of 30 min until assessment was made by panellists.

A consumer panel of 13 untrained assessors was presented with a control and each of the abused samples at each of three sessions and they were asked to assess for ‘meat’ and ‘other’ aroma. Samples were presented as boiled minces under daylight conditions and they were asked to use a category scale where 1 = none and 9 = very strong.

10.0 RESULTS AND DISCUSSION

10.1 Temperature profiles of cartons

The temperature profiles of the three storage and abuse treatments are presented in Figures 15, 16 and 17. These record the temperatures from loading into the freezer at Food Science Australia with time zero being the time of packing in the plant boning room.

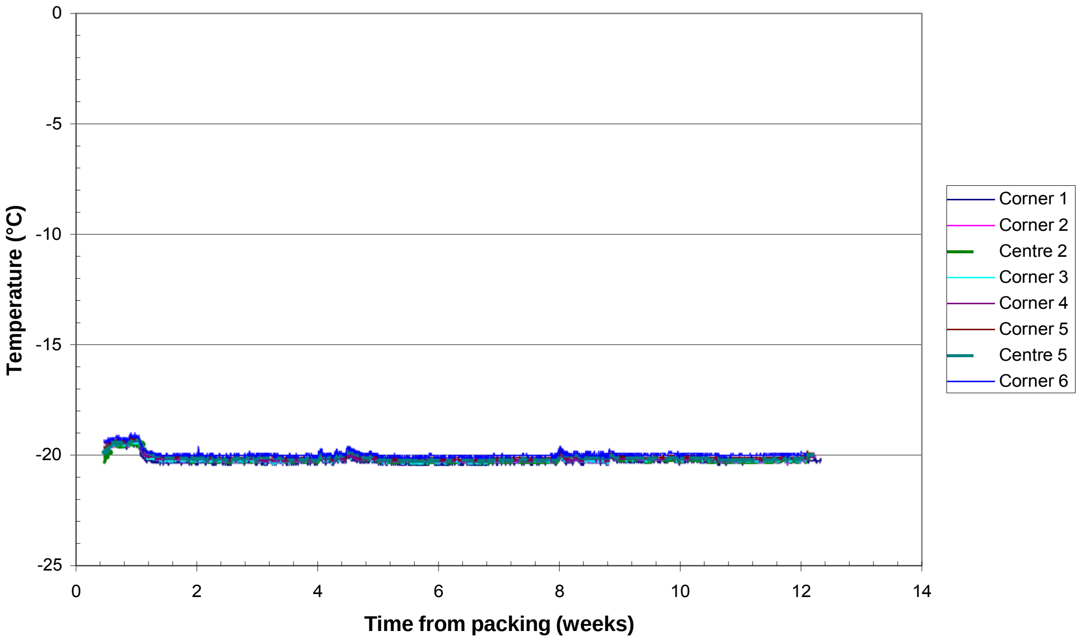

Figure 15: Temperatures of control cartons

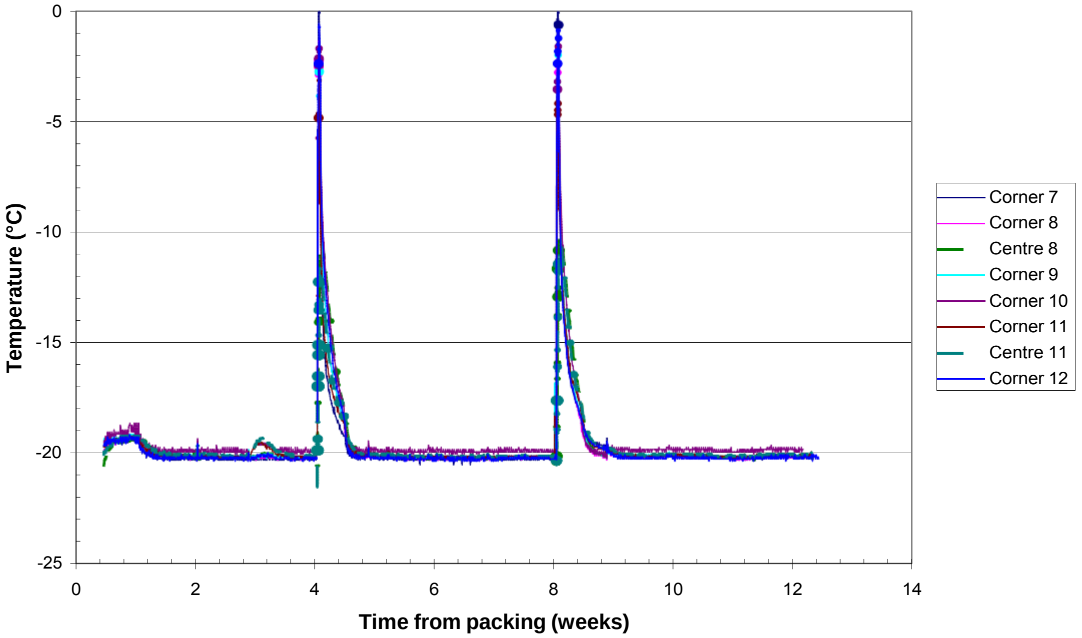

Figure 16: Temperatures of ambient abuse cartons

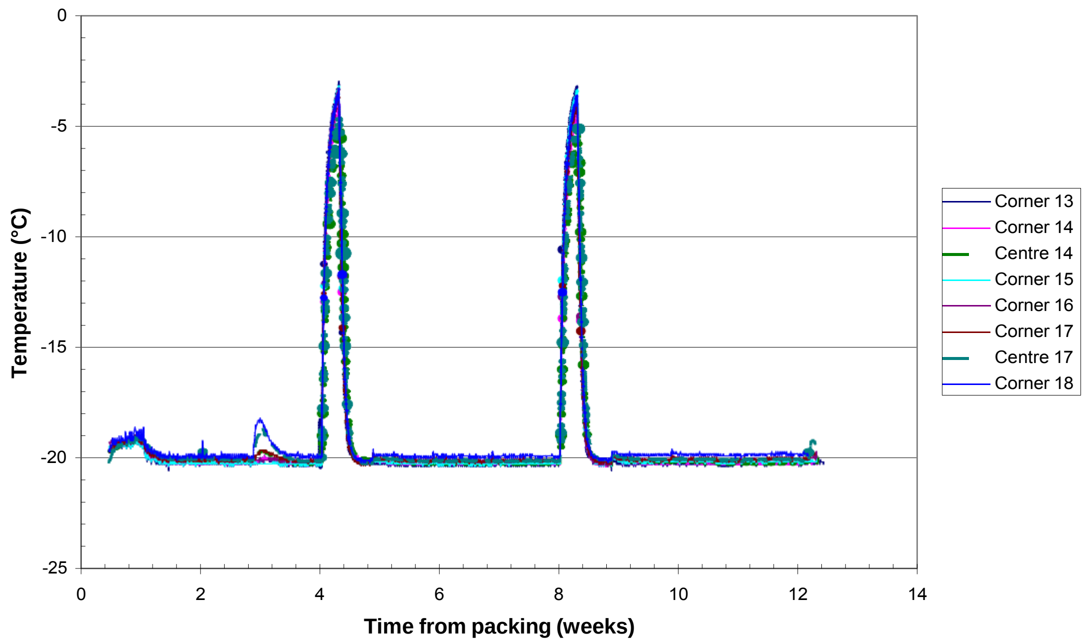

Figure 17: Temperatures of container off-power abuse cartons

The storage temperature remained very close to -20°C for the period of the trial except for a slight adjustment after about one week. There was also a brief rise of up to 1.5 degrees on the top layer of the pallet due to some sightly warmer cartons being stacked on top of the pallet.

Plots of typical meat temperatures during the abuse regimes are presented in Figures 18 and 19. During exposure to a high ambient temperature for a brief period, the centre temperatures of the cartons rose to about -10°C (Figure 18). In the case of longer exposure to a temperature just above freezing (+1°C), the centre temperatures rose to -5°C and the corners to about -3.5°C.

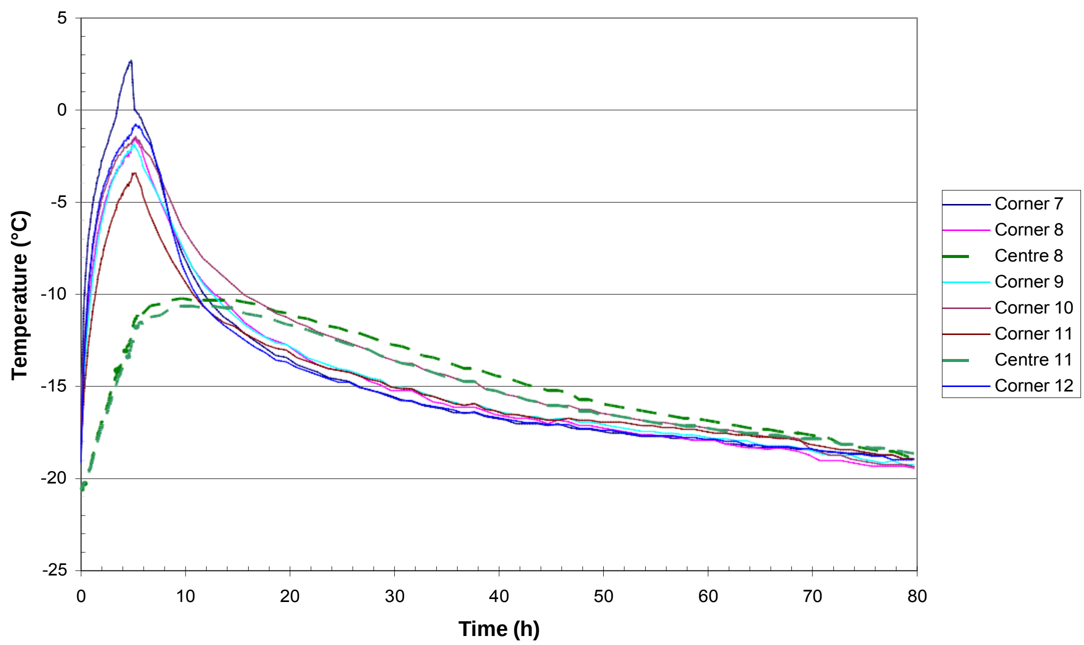

Figure 18: Temperatures during ambient abuse (25°C air)

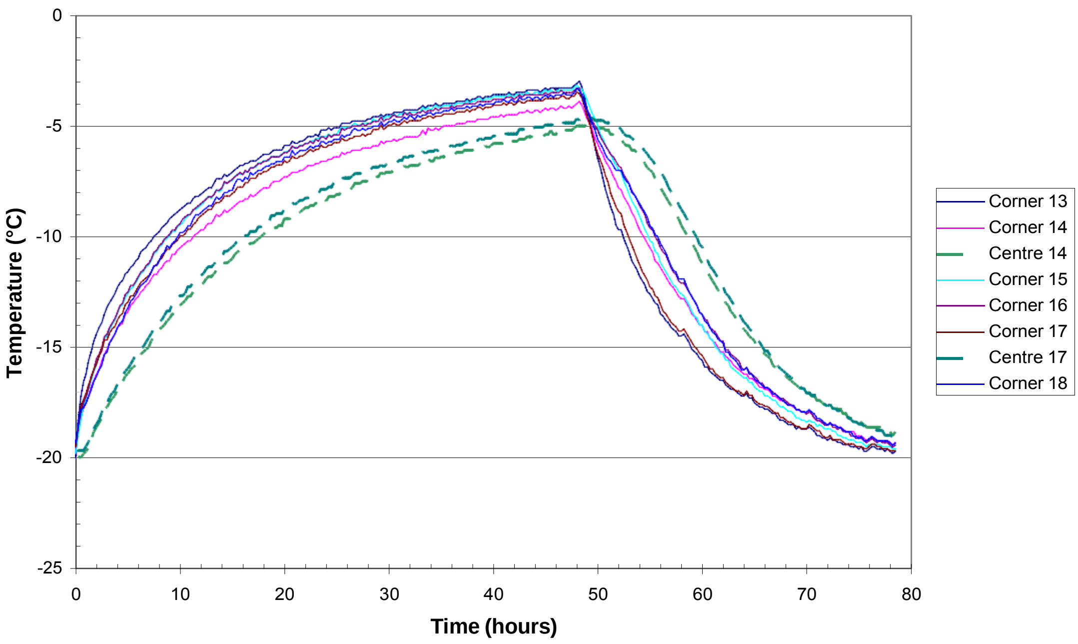

Figure 19: Temperatures during container off-power abuse (1°C)

10.2 Analyses of samples of ground beef

Fat content

The lean meat content (100 minus % fat) of samples from each carton and the mean for each group are presented in Table 21. Cartons were purchased as 85 CL and the overall average for the 18 cartons (83.1 % CL) was within 2% of that specification. However, the CL of individual cartons ranged from 77.4 (22.6% fat) to 87.8 (12.2% fat).

Table 2: Lean meat content of samples from test cartons

Carton No.	Chemical Lean (%)	Group Average (± SD)
Control		
1	83.5	
2	84.9	
3	81.1	84.1 ± 1.9
4	85.4	
5	86.6	
6	83.3	
Ambient abuse		
7	84.5	
8	82.5	
9	82.8	83.2 ± 3.4
10	77.4	
11	87.8	
12	84.4	
Off-power abuse		
13	84.5	
14	83.6	
15	84.2	83.0 ± 1.6
16	82.3	
17	80.0	
18	83.1	

Evaluation of lipid oxidation

Lipid oxidation can be prevented or reduced by the presence of anti-oxidant compounds which are themselves destroyed by accepting the free radicals. The disappearance of these anti-oxidants during storage can give an indication of the extent of lipid oxidation. In the work described here we found that there were essentially no differences in the amounts of α-tocopherol or β-carotene in either of the abused meat groups compared with the controls at the end of 3-months storage at -20°C (Fig. 20 and 21). There was a significant decrease ($P<0.05$) in retinol concentration with 'ambient temperature abuse' compared with the control (Fig. 22).

We also measured the fatty acid composition of the total lipids extracted from each of the storage groups. In particular, we found that there were no measurable changes in the percentages of the total poly-unsaturated fatty acids in any of the samples (Fig. 23). Poly-unsaturated fatty acids are most susceptible to oxidation, and when oxidised, they generate a range of other reaction products such as peroxides and aldehydes. However, because only a small loss through oxidation can lead to significant effects on flavour and aroma this method is not considered to be very sensitive for detecting lipid oxidation. It does however show that there are no major changes in fatty acid composition.

Three different methods were used to measure lipid oxidation at the end of storage. TBARS, peroxide value and hexanal content were determined. TBARS was determined on raw samples kept for 24 hours at 1°C and also on cooked samples after 24 hours storage at 1°C (Fig. 24). Although cooking resulted in higher values there were no significant differences between the treatment groups ($P>0.05$) indicating that temperature abuse as performed had not affected lipid oxidation.

Peroxide value is indicative of the presence of peroxides that are generated from oxidised lipids during the early phase of lipid oxidation. For this measurement it was necessary to extract the lipid from the meat prior to assay and therefore it is dependent upon the fat content of the meat. In this work there were only minor differences in the mean fatness of the samples and therefore the results have been expressed as meq peroxide/ kg meat. Although there were some differences between treatment groups, neither of the abused groups were higher than the control (Fig. 25), confirming that abuse treatments had not affected lipid oxidation.

The final method used involved the measurement of hexanal in the headspace above cooked samples. Hexanal is a volatile breakdown product of linoleic acid, one of the major poly-unsaturated fatty acids. Fig. 26 shows that there were no significant differences ($P>0.05$) in the hexanal content for any of the treatment groups again suggesting that the temperature abuse treatments used had not resulted in further lipid oxidation.

As a final assessment of the samples a sensory analysis of aroma was undertaken by a small group of untrained panellists. Panellists were asked to assess 'meat' and 'other' aromas of products presented as boiled minces. Control samples tended to have higher 'meat' aromas (more positive meat aromas) and lower 'other' aromas compared with the abused samples but the differences were not significant (Fig. 27).

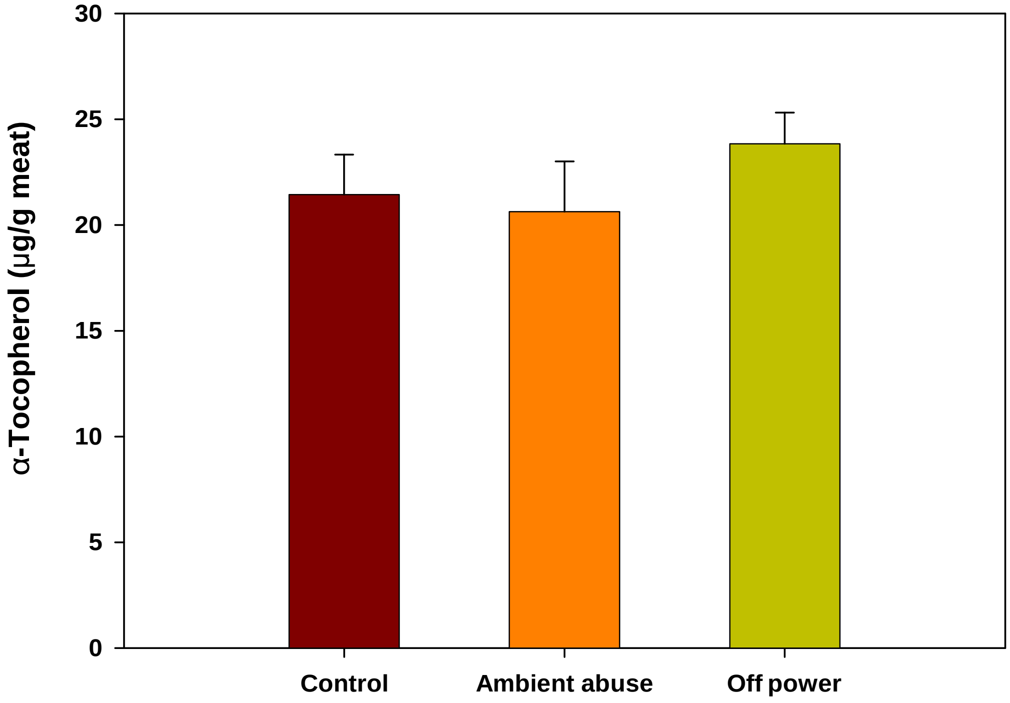

Figure 20: Content of α-tocopherol (means ± se, n=6) in meat after storage for 3 months under the conditions described in Methods

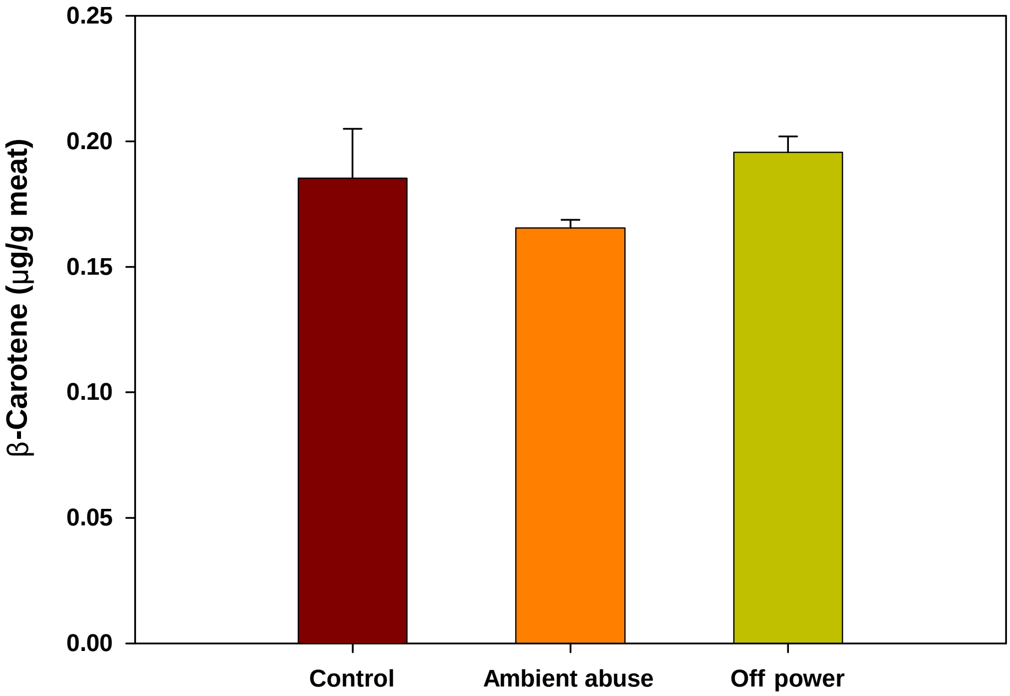

Figure: 21: Content of β-carotene (means ± se, n=6) in meat after storage for 3 months under the conditions described in Methods

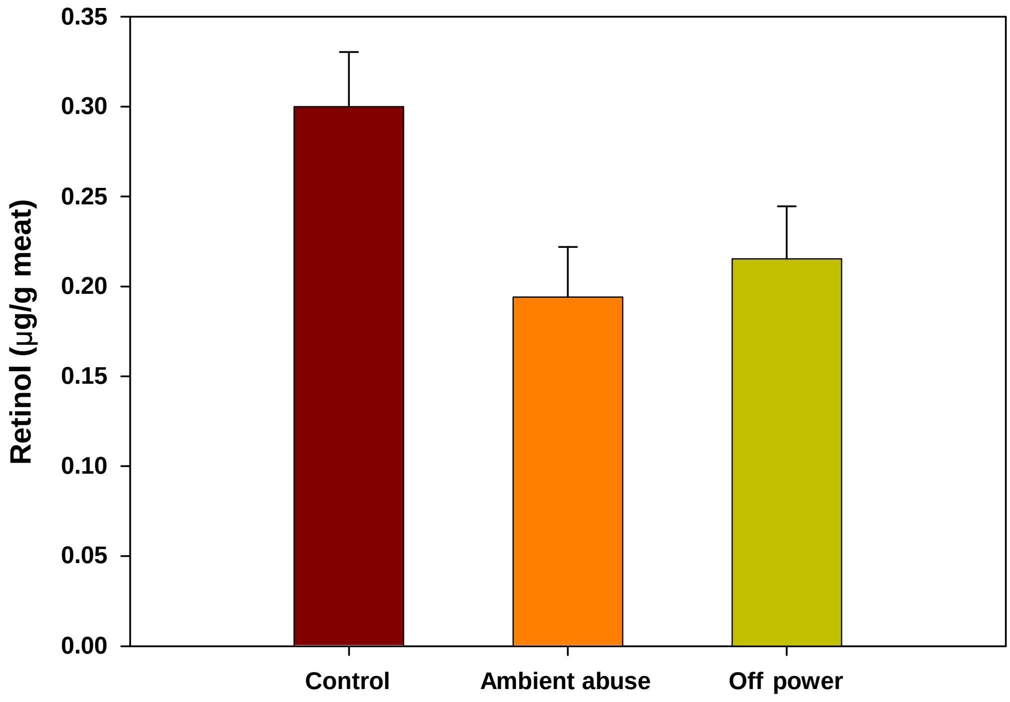

Figure: 22: Content of retinol in meat after storage for 3 months under the conditions described in Methods

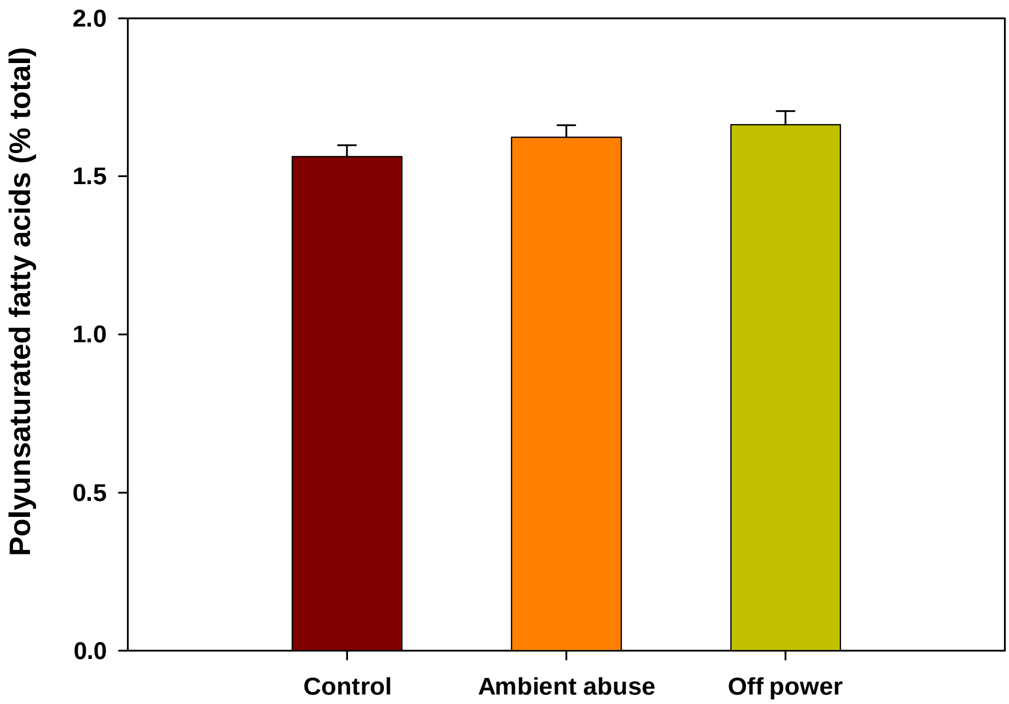

Figure: 23: Percentage of poly-unsaturates (means ± se, n=6) in meat after storage for 3 months under the conditions described in Methods

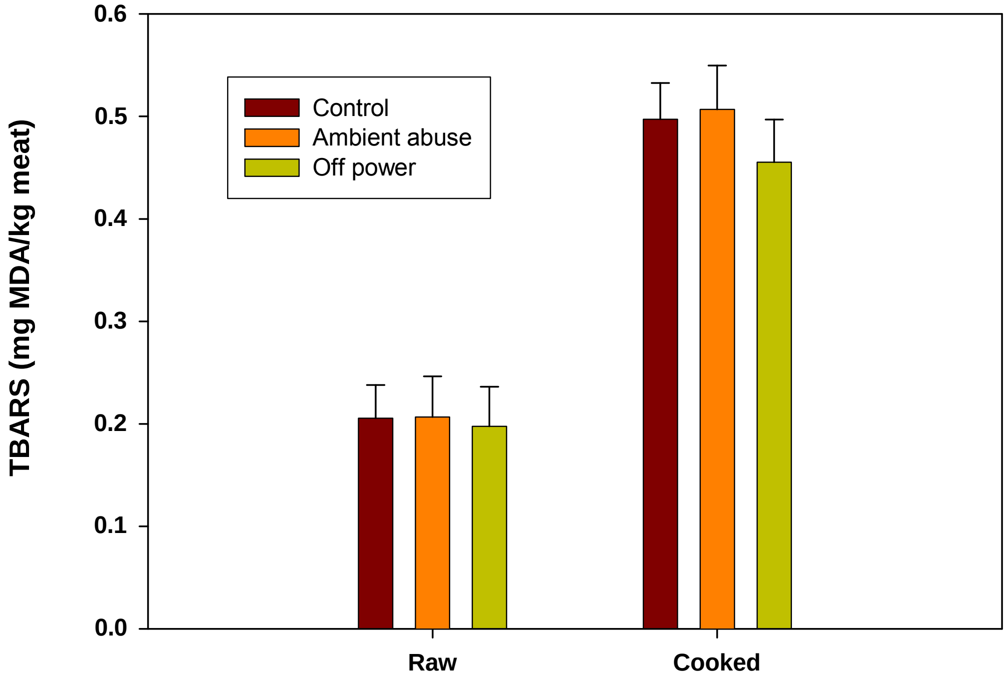

Figure: 24: Content of TBARS (means ± se, n=6) in raw and cooked meat after storage of raw meat for 3 months under the conditions described in Methods

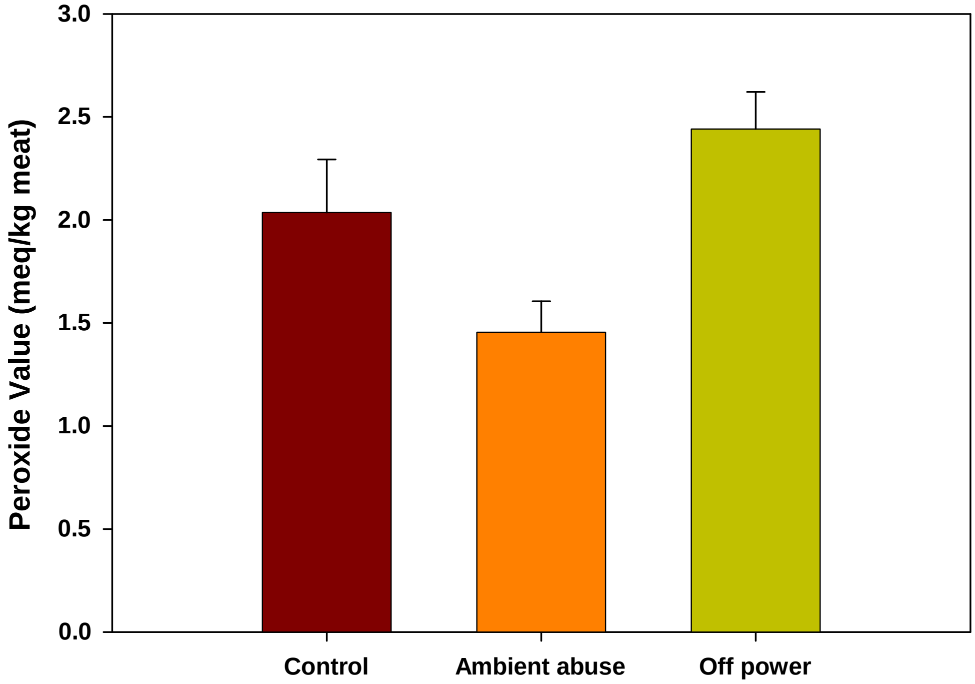

Figure: 25: Peroxide value (means ± se, n=6) in lipid extracts from raw meat after storage for 3 months under the conditions described in Methods

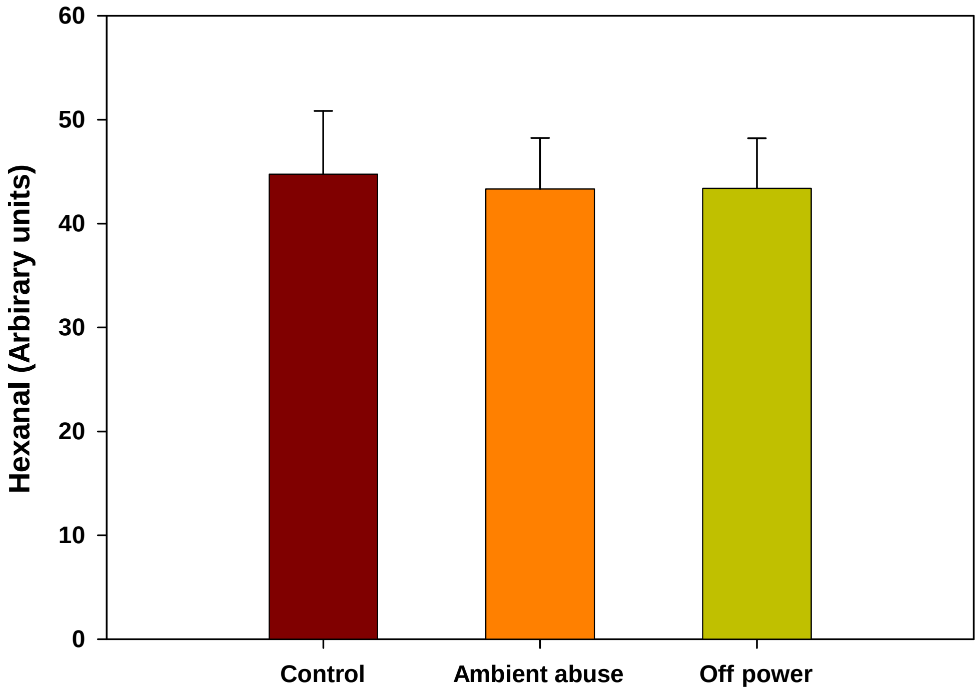

Figure: 26: Content of hexanal (means ± se, n=6) in headspace of cooked meat after storage of raw meat for 3 months under the conditions described in Methods

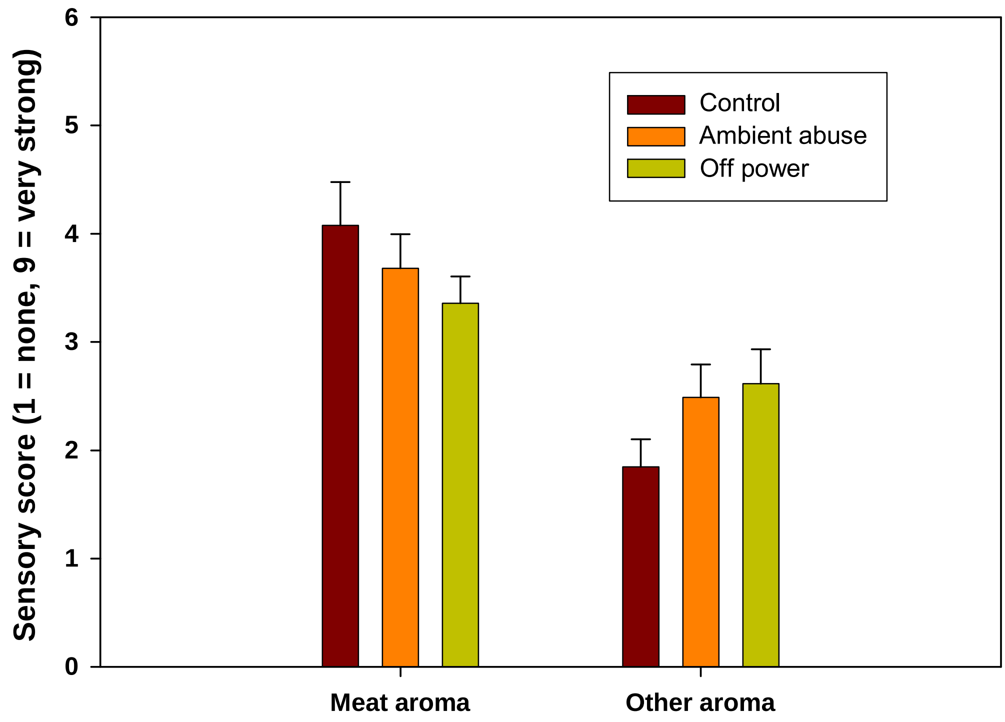

Figure: 27: Sensory scores (means ± se, n=6) of panellists for aroma in cooked meat following raw meat storage for 3 months under the conditions described in Methods

11.0 CONCLUSIONS

The temperature abuse treatments that the cartons of meat were subjected to did not appear to have any effect on any of the attributes measured to estimate lipid oxidation in the meat. Compared with the control meats the abused samples contained similar amounts of anti-oxidants α-tocopherol and β-carotene, had similar percentages of polyunsaturated fatty acids and on cooking, generated similar levels of an oxidation product, hexanal in the head space. Peroxide values and TBARS contents were not significantly different. It therefore seems unlikely that there would be any rancidity or associated quality problems with meat treated in this way.

12.0 REFERENCES

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Zhen-Yue J., Hunt, J V. and Wolff, S. (1992) Analytical Biochemistry **202**, 384-389.

13.0 APPENDIX – MEAT SURFACE TEMPERATURES ON THE TOPS, ENDS AND SIDES OF CONTAINERS

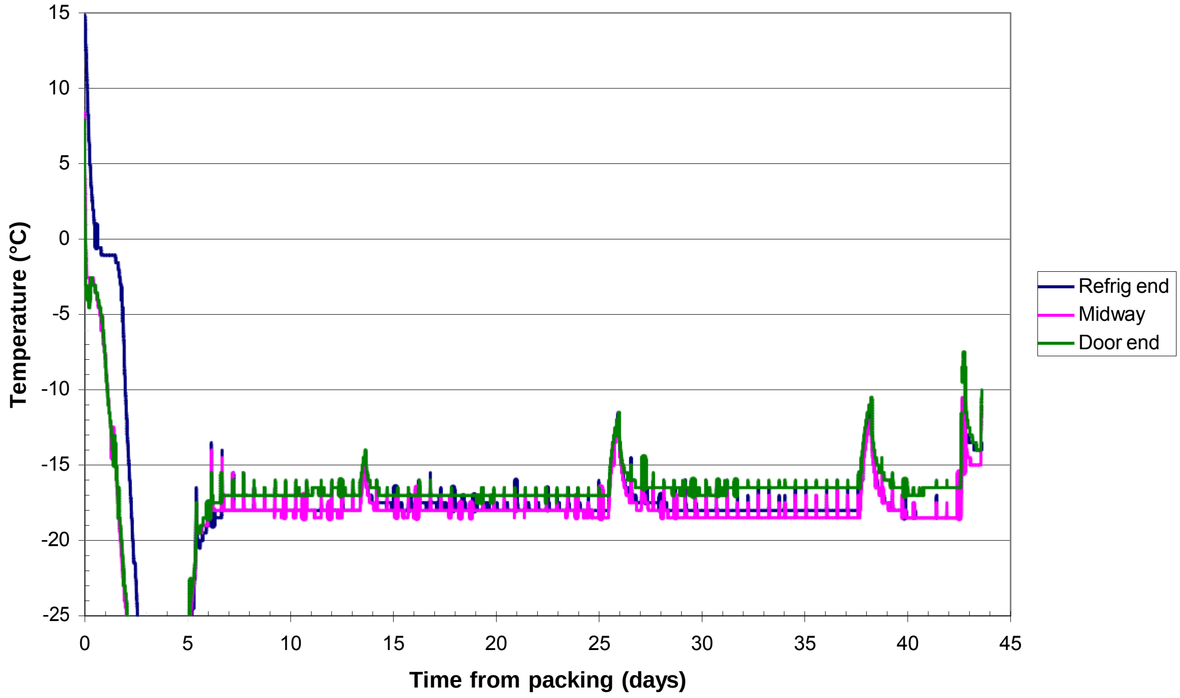

Figure A1: Meat surface temperatures on the top layer – 20 ft container

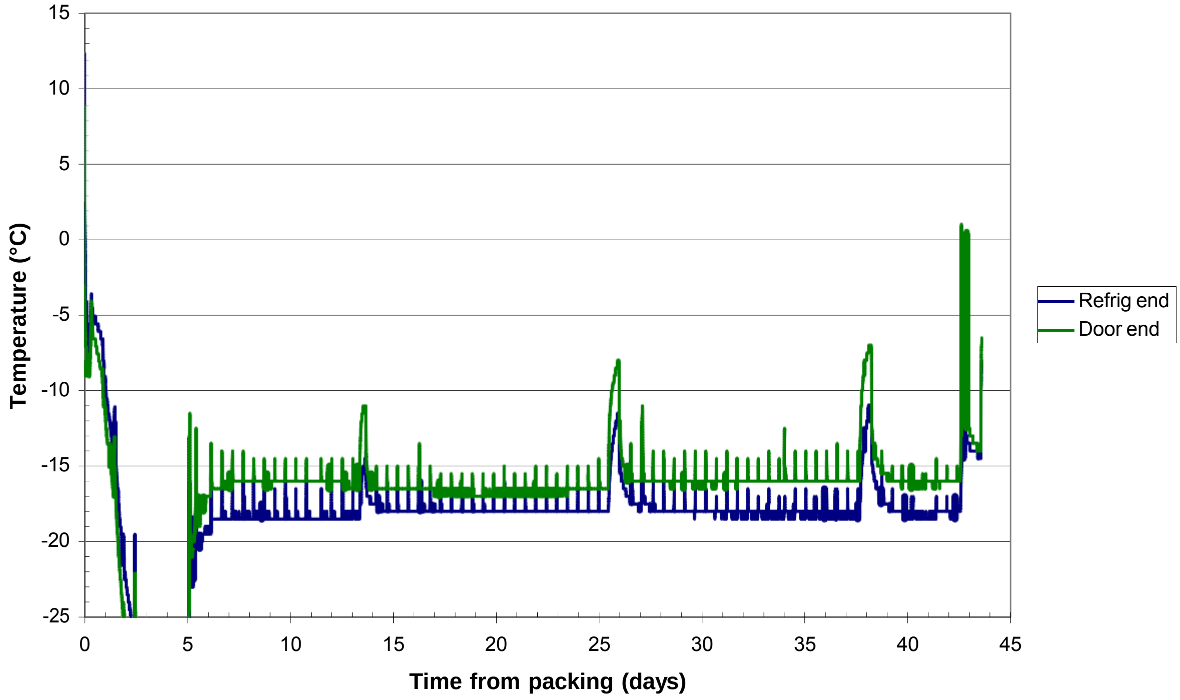

Figure A2: Meat surface temperatures at the ends – 20 ft container

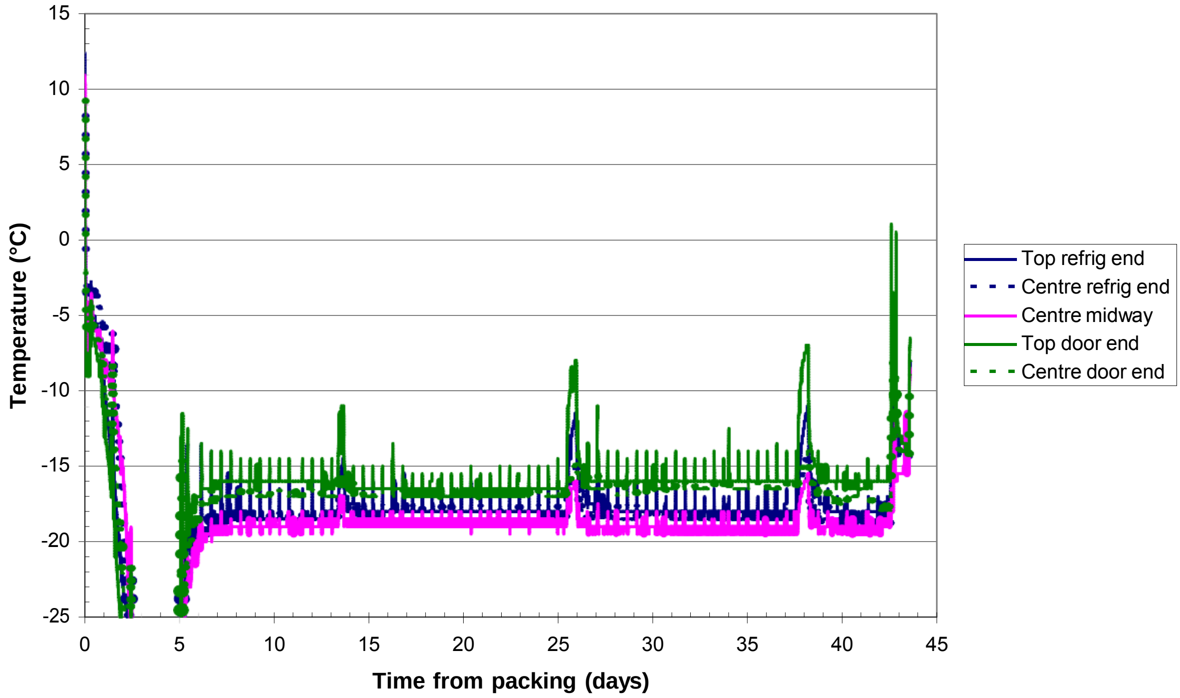

Figure A3: Meat surface temperatures at the side – 20 ft container

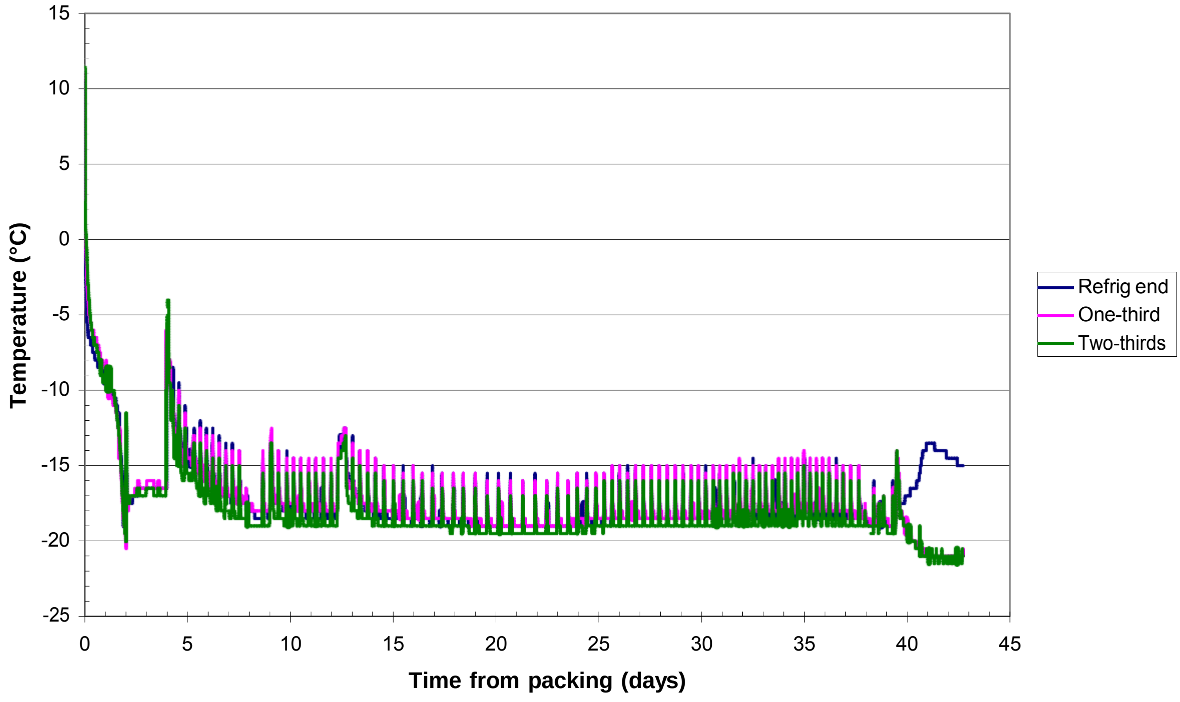

Figure A4: Meat surface temperatures at the top layer – 40 ft container

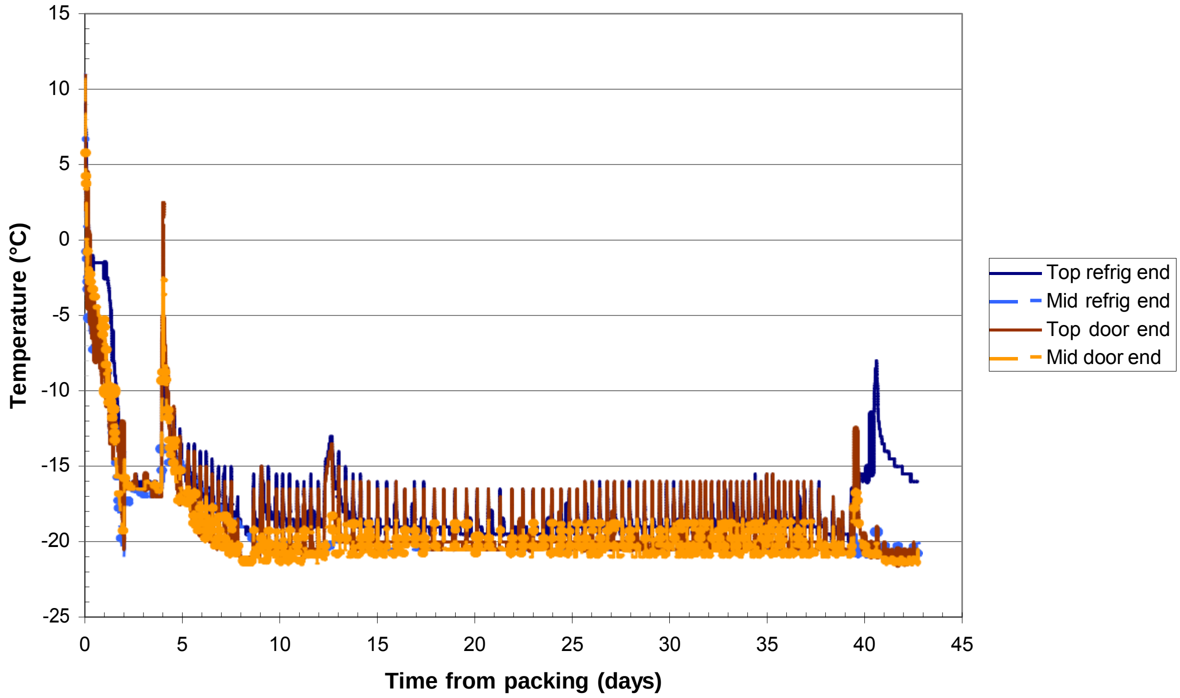

Figure A5: Meat surface temperatures at the ends – 40 ft container

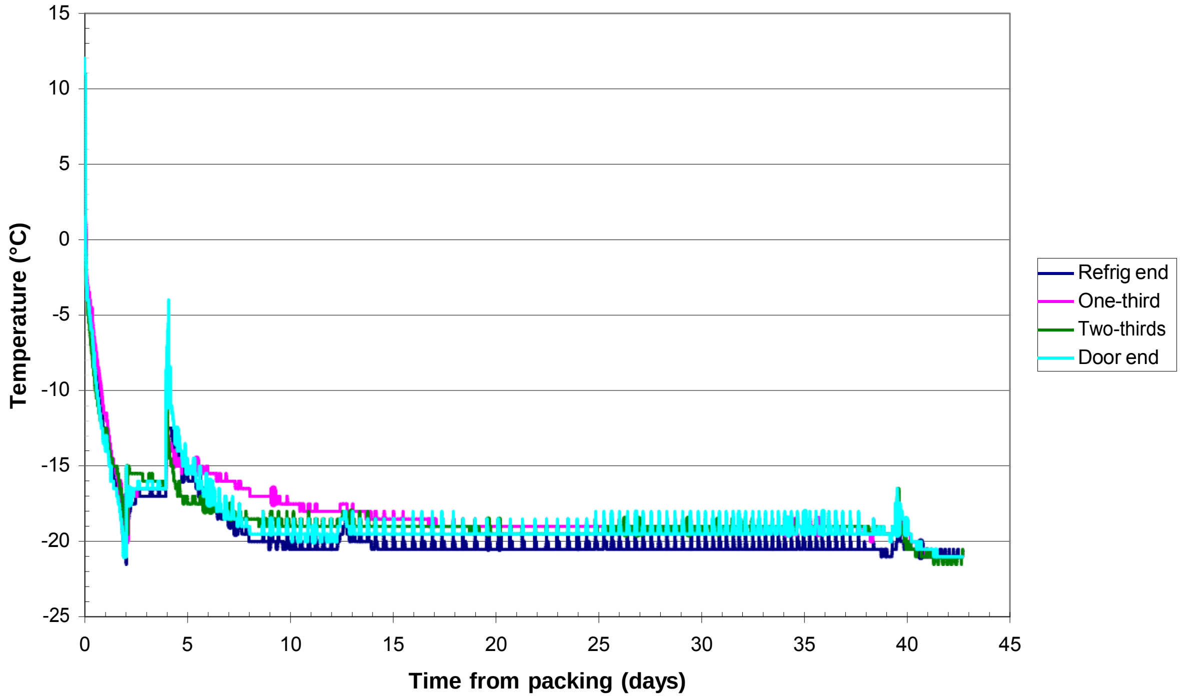

Figure A6: Meat surface temperatures on the side – 40 ft container