MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

1/07 – February 2007

Do breaks in the cold chain affect frozen beef quality?

- **After three months frozen storage, rancidity and other off flavours are not promoted by periods of temperature rise such as might occur:**
  - **while loading cartons of frozen beef into containers;**
  - **during road transport of shipping containers of product;**
  - **while loading pallets of product into refrigerated cargo holds of ships; or**
  - **as a result of some refrigeration incidents.**
- **There is likely to be little or no effect of the temperature rises even after longer periods of frozen storage—one year or longer—but this needs to be confirmed.**
- **Nevertheless, care should still be taken to ensure that frozen beef is maintained at –18°C or colder whenever possible.**

It is generally accepted that the colder the storage temperature, the longer the storage life of frozen meat. The common recommendation is that frozen meat be stored at –18°C (0°F), and cartons of frozen beef are normally frozen to –18 to –20°C and handled and transported at no warmer than –18°C. During handling and transport, however (and due to refrigeration incidents), cartons may be exposed to higher temperatures under situations such as:

- accumulation in marshalling areas in preparation for loading out;
- containers off power during transport to ports and loading on-board ships;
- pallets of cartons exposed to ambient temperatures when loading into the refrigerated holds of ships.

Do these brief cold-chain breaks have any effect on the quality of Australia's manufacturing beef? This update considers the likely impact of the breaks on meat temperature in unit (pallet) loads and in containers.

Loading containers

When removed from the cold store, the surfaces of frozen meat in cartons, particularly near corners, can rise quite quickly, depending on the ambient temperature and the temperature of the meat. For example, the surface temperature can increase from –15°C to –6°C in just over an hour—even at an air temperature of 10°C. At a temperature above 25°C, the surface can rise to –6°C in less than 30 minutes. Table 1 shows times for the surface to rise to –6°C and the centre to rise to –10°C for cartons exposed to various ambient temperatures.

Figure 1: Frozen beef may be subjected to brief temperature rises without affecting its quality.

If delays occur while loading containers or refrigerated ships, cartons should be returned to the cold store, otherwise some of the product will be at a temperature significantly above the container operating temperature. If this happens, it can take up to two weeks for the temperature of cartons within the load to reach the container set-point temperature.

Table 1: Time (h) for meat surface temperatures to rise to –6°C and carton centre temperatures to rise to –10°C at various ambient temperatures

Ambient temperature	Initial meat temperature			
	–15°C		–20°C	
	Surface	Centre	Surface	Centre
10	1.2 h	5.0 h	2.8 h	7.1 h
15	0.8	4.3	1.8	6.0
20	0.6	3.9	1.3	5.4
25	0.5	3.5	1.0	4.0
30	0.4	3.4	0.8	4.6
35	0.4	3.2	0.7	4.3

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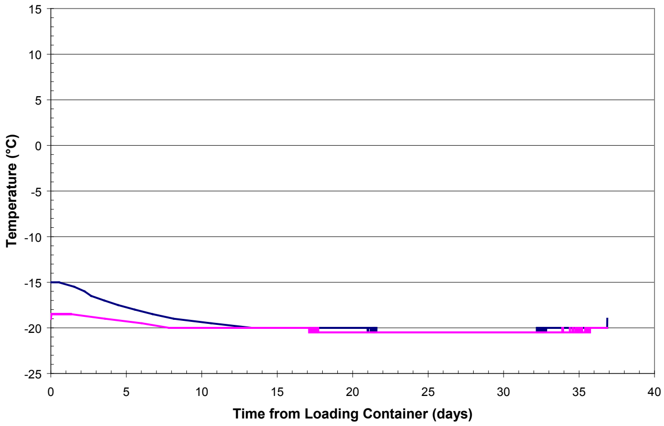

Figure 2: Product loaded into a container above the carriage temperature can take up to 2 weeks to cool.

Figure 2 shows an example of product at –15°C loaded into a container operating at –20°C. Cold stores should be operated at a temperature close to that at which the refrigerated containers will operate, as the container equipment is not designed to rapidly reduce product temperatures.

Refrigerated containers operate on the principle that an envelope of cold air surrounds the load and removes heat conducted through the container walls. If this air flow is obstructed, warm spots may occur in the container. The air flow may be obstructed by packing cartons hard against the ceiling and against the doors. Tests have shown that loading cartons above the load line so that they are against the ceiling or past the floor channels can result in the air temperature at the door end of the container being 3 to 4°C higher than in other positions in the container. Resulting meat surface temperatures in this region can be 2 to 3°C higher than in other parts of the container.

A range of methods is commonly used to load cartons into containers. These include manual loading, unit loading and a combination of the two. More efficient stowage can be achieved with cartons frozen in plate freezers as they can be stacked flat to form stable loads to the full height of the container. Stretch wrapping of unit loads aids stability and reduces the likelihood of cartons moving and impeding the flow of cold air. Such wrapping also reduces abrasion between cartons which can damage labels. Regardless of the method used to load a container, the carton and unit dimensions should be such that the container limits are not exceeded.

Product surface temperature can also rise if container doors are not closed immediately after loading. If the container refrigeration equipment is operated and the doors are left open to the outside, cold air will be expelled and warm, moist air will be drawn in. This moist air will condense on the coil leading to icing and inefficient refrigeration until after a defrost has occurred.

Container transport

When the container is transported from the meatworks or cold store to the port, it may be off power for a considerable time. Several off-power periods, each ranging from 1–2 hours to 10–15 hours, are not uncommon during a voyage from an Australian meatworks to a United States cold store. Most refrigerated containers are supplied with power while on rail transport in Australia, but generators are only supplied with trucks on some of the longer road journeys.

Studies have shown that for most breaks, such as during road transport and loading onto the ship, the majority of the product will be unaffected. Under most conditions, a container loaded with frozen cartoned meat may be off power for a very long time (in excess of three days) before any product commences to thaw and there is a risk of significant microbiological growth. The temperatures of cartons on the outside of the load, particularly at the top corners, will increase more rapidly than those near the centre as shown in Figure 3; however, those outside surfaces also return to the carriage temperature most rapidly. In the example in Figure 3, the time to return completely to the original temperature was similar to the time refrigeration was off.

Detailed recommendations on the times that containers may be off power under a range of conditions are given in an information sheet available on the Meat Update website (www.meatupdate.csiro.au).

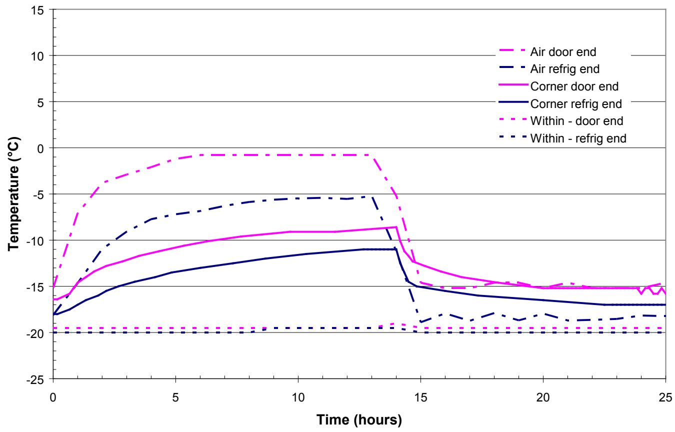

Figure 3: Air and meat surface temperatures in a container off power for 14 hours

Containers may also break down. Situations arise where containers are returned and unloaded because there has been a breakdown, and there may be an issue in determining if the product is wholesome or safe. The most vulnerable are likely to be those cartons or items that are closest to the walls of the container, especially those on the top. These should be kept separate from those from the internal part of the load. Even if temperature measurements or other tests show that the outer cartons have been affected, the inner cartons may well have remained frozen and be suitable for sale.

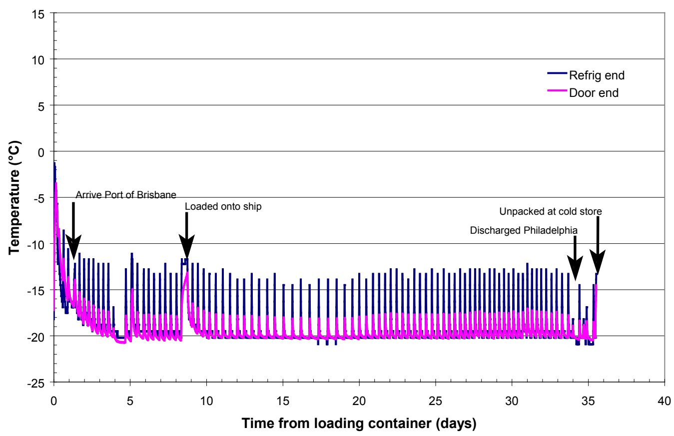

Figure 4: Meat surface temperatures at the top corners of a container

In well-packed containers, the air temperature is uniform throughout and within approximately 1°C of the set point; however, defrost intervals and temperatures vary significantly between containers. Intervals can range from once every 12 hours to once every two days. In containers set to –20°C, the air temperature during defrost can rise to between –12 and +10°C. These defrosts result in small regular increases in meat surface temperatures as shown in Figure 4. Internal product temperatures and cartons within the load are unaffected. While they are unlikely to affect the quality of the surface meat, the studies undertaken to date were not designed to provide the answer.

Effect of temperature rises on quality

As discussed above, due to interruptions to refrigeration, there will be some fluctuations in frozen-meat temperatures. Does this result in any loss of product quality? Quality deterioration of frozen beef is usually attributable to rancid off-flavours caused by lipid oxidation, although it can also be because of lower water-holding capacity in final products due to protein denaturation.

Assessment of lipid oxidation

Lipid oxidation will be prevented or reduced by the presence of anti-oxidant compounds naturally present in the meat such as α-tocopherol, and β-carotene, the amounts of which vary depending on, for example, whether the cattle have been grass- or grain-fed. Disappearance of these anti-oxidants during storage can be an indication of the extent of lipid oxidation.

The initial products of lipid oxidation are unstable and diminish with time as they are converted into further intermediary products. For this reason several methods should be used in tandem to assess lipid oxidation. These can include determination of thiobarbituric acid reactive substances (TBARS), peroxide value (PV) and head space analysis of volatiles. The latter method involves the measurement of various volatile aldehydes that are produced from unsaturated fatty acids as a result of lipid oxidation. The major aldehyde observed in the headspace above cooked samples is hexanal. Hexanal is a volatile breakdown product of linoleic acid, one of the major poly-unsaturated fatty acids in beef, and several other fatty acids.

Significant increases in values of TBARS, PV or hexanal can indicate that rancid flavours are likely to be detected by consumers.

Product subjected to temperature rises

In a recent trial, FSA scientists subjected cartons of frozen manufacturing beef to two forms of temperature rise such as could happen on trips from Australia to the United States in extreme cases of:

- containers of frozen cartons being off power for two days, and
- pallets of cartons held at an ambient temperature of 25°C for five hours.

The periods of temperature rise were each applied twice—to simulate extreme events both in Australia and the US. Centre (meat) temperatures of the cartons rose to –10°C after the 5-hour exposures and to –5°C after the two-day exposures. The product was assessed at three months.

Assessment of product

The beef was ground using procedures followed by major beef patty manufacturers and samples of the ground meat were analysed. There were essentially no differences in the amounts of either of the anti-oxidants, α-tocopherol or β-carotene, in the samples from the cartons subjected to temperature rises compared with cartons that had been stored at a constant –20°C for three months.

TBARS were determined on raw samples and on cooked samples. While cooking resulted in higher values, no significant differences were detected between treatment groups (Figure 5). The other methods of assessment of lipid oxidation produced similar results, with values for the treatments subjected to temperature rises being no higher than the control samples. Hexanal in the head space was similar for each treatment as shown in Figure 6.

These trials showed that it is unlikely that there would be any rancidity or associated quality problems with frozen cartoned manufacturing meat shipped from Australia using normal practices where breaks occur in the cold chain.

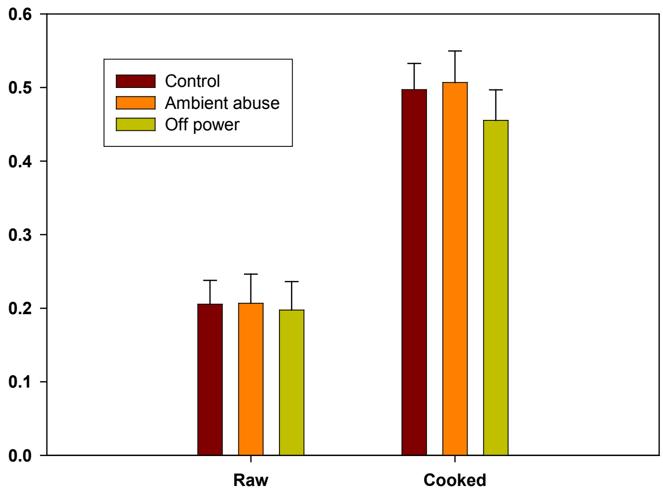

Figure 5: TBARS analysis of raw and cooked samples

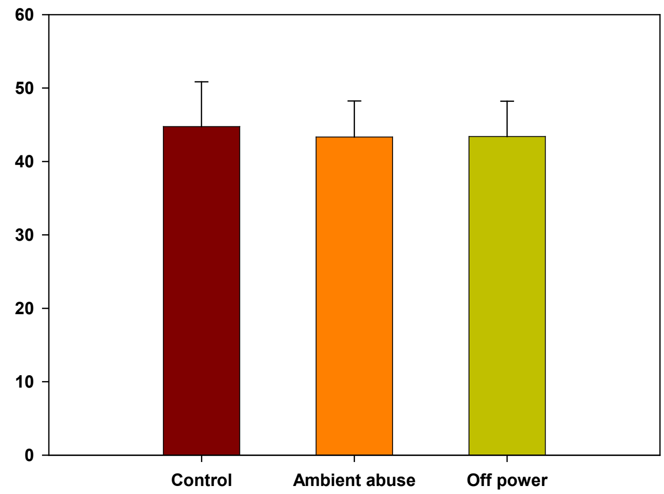

Figure 6: Results of head space analysis

Conclusion

Frozen beef that is tightly wrapped and sealed into cartons appears to be a robust product that is not affected by changes in temperature when stored for three months.

Further reading

Relationships between time away from active refrigeration and meat temperature for cartons in containerised and unit (pallet) loads.
Information sheet accessible on www.meatupdate.csiro.au

Australian exporters can contribute to the maintenance of optimum product temperatures by following simple procedures during on-site storage and while packing into containers.

- *Store frozen product at a temperature as close as possible to the container set-point temperature. (Product loaded at –15°C can take two weeks to equilibrate to –20°C.)*
- *Containers should seal against a refrigerated loadout area during loading.*
- *Don't pack containers above the load line or past the floor channels. Refrigerated containers rely on surrounding the load with an envelope of cold air to remove heat conducted through the walls and ceiling. If this air flow is obstructed by loading cartons hard to the ceiling or up against the doors, warm spots can occur.*
- *If there is any extended delay during loading, frozen cartons should be returned to the freezer store.*
- *Container doors should be closed immediately on completion of loading and during any extended delays.*

Contact us for additional information

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