MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

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The chilled, vacuum packed meat cold chain

The way to the production of good quality chilled meat is the systematic application of a number of essential elements including hygiene, temperature control, equipment and material selection, and quality assurance.

The advice contained in this Newsletter is relevant to both export and domestic operations for which long storage and/or transport times are required.

The optimum storage and transport temperature for chilled meat is the lowest possible temperature at which no freezing occurs. Since non-vacuum-packed meat commences to freeze at about –1.5°C, and vacuum-packed meat starts to freeze at about –2°C (depending on meat type and pH), the aim is to reduce the meat temperature to -1°C to 0°C as soon as possible after packaging. Ideally, no vacuum-packed product should be loaded out until the meat temperature is at or below 0°C.

Chilling

The time taken to cool product to 0°C in air depends on the temperature of the air, the rate of airflow past the product and the level of insulation provided by the package.

Rapid chilling without freezing the meat is desirable. To achieve this, there are three options:

1. Holding chiller

Chilling vacuum-packed meat in a holding chiller is the least costly method—and the least effective method. Unfortunately, cartons of heavy cuts may take more than three days to cool to 0°C, even when stacked with reasonable airflow over the carton surfaces. Block-stacked cartons can take a week to cool to 0°C.

To achieve the shortest time to cool:

- Chill carcases well before boning (beef deep butt temperature below 15°C and preferably close to 10°C, sheep meats below 7°C).
- Allow sufficient air gaps between cartons to give adequate airflow over the carton surfaces. Airflow over carton surfaces is increased by placing cartons on racks or stillages designed with a minimum 20–30 mm gap for free airflow. Alternatively, plastic ‘egg–crate’ dunnage or spacers can be placed between layers on a pallet—although this is not as effective. Even with gaps of 20–30 mm between the cartons, air movement within a pallet or stillage is reduced. Subsequently, air temperature between cartons in the centre of the

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stack can be 5°C higher than the temperature around those cartons on the edge of the stack.

- Never block-stack vacuum-packed meat on pallets until the product temperature at the centre of the carton is at or below 0°C.

2. Blast chiller

Blast chilling involves placing cartons on racks or stillages in a room with high air velocity similar to that of a blast freezer (3-5 m/s). A blast chiller with a fixed air temperature of from -1° to -2°C may take up to 36 hours for lidded product to cool to 0°C.

Still faster cooling is possible using more sophisticated air temperature control, such as cooling initially with very cold air (from -15° to -10°C). Then, as meat surface temperature approaches freezing point, the air temperature is raised to -1°C, or the meat is moved to another chiller operating at -1°C. In this way meat can be cooled to 0°C in less than 20 hours without freezing.

For optimum performance, air velocity over the cartons should be in excess of 2 m/s. Fans, carton placement and racking should be arranged so that large voids and restrictions that promote preferential airflows (and air bypassing other cartons) are eliminated, thus attaining even air distribution. The long axis of the cartons should be aligned with the direction of airflow to enhance the surface heat transfer through the top, bottom and sides.

Another way to reduce cooling time is to chill cartons before the lids are fitted. Unlidded cartons cool faster than lidded, strapped or glued cartons. (Time reduction for the surface of primals, for example, amounts to about 30%.) Chilling in unlidded cartons is only suitable for two-piece cartons where a cap-style lid can be fitted separately at a later time.

3. Uncartoned chilling

An alternative to the conventional approach of chilling after cartoning is pre-cooling vacuum-packed cuts prior to cartoning. Rapid chilling of vacuum-packed cuts reduces weep and improves shelf-life and meat colour.

Chilling cuts individually has two other sound, practical arguments. Even the heaviest cuts can be cooled to below 0°C within less than 24 hours and this enables packed cartons to bypass the holding chiller and be loaded directly into freight containers. It is easier to detect ‘slow-leakers’.

Vacuum-packed products can be chilled either by immersion in chilled water for several hours, or by chilling in air overnight. Trial data has shown that chilling vacuum-packed cuts in air for slightly longer periods than in ice/water is equally effective, except that initially the surface does not cool as rapidly. This is because the surface heat transfer coefficient in ice/water is about 10 times that in air but the thermal conductivity of the product is fixed (i.e. heat removal from the surface is 10 times faster in ice/water than in air but is limited by the rate of heat transfer from within the meat to the surface). For large cuts this reduces the benefits of immersion chilling compared to air chilling.

Holding

A holding chiller, assuming it is not to be used as an active chiller, ideally, should meet the following specifications:

- Air temperature: -1 $\pm$ 0.5°C;
- Air velocity: approximately 0.5 m/s to provide good air distribution;
- To reduce ingress of warm air, doors should not open directly to outside or to areas of high ambient temperature;
- A constant temperature should be maintained, since fluctuations in meat temperature promote weep.

At load-out meat should be as cool as possible without freezing the meat—ideally, -0.5°C $\pm$ 1°C.

Load-out, shipment and long-distance transport

The aim in stowing chilled meat into a refrigerated truck, trailer or container should be to use the circulating air stream to create a ‘jacket’ or ‘envelope’ around the stow. This allows heat leaking through the top, bottom and all sides of the container or compartment unit to be swept by the circulating air stream to the refrigeration unit, where it is pumped out of the truck or container. To achieve this envelope, product should be packed tightly enough to prevent air from short-circuiting between cartons, and the space around the product must be kept free for air circulation. In particular, the space above and below the stow must be kept free for air to circulate the full length of the compartment of the truck or container, and the gap between the back door and cartons must be kept open to allow the circulating air stream to sweep away heat leaking through the doors. If the unit is overpacked, the gap may be blocked when the doors are forced up against the stow.

In refrigerated containers, air returns to the refrigeration unit over the top of the stow. There must be sufficient gap between the top of the stow and the container’s ceiling (the ‘headspace’) to allow unimpeded flow of air from the door-end of the container back to the refrigeration unit. For guidance purposes, virtually all refrigerated containers are marked with a red ‘load-line’ near the top of each sidewall inside the container. This load-line indicates the maximum level to which product should be stowed without ‘starving’ parts of the stow of air.

It is also important to allow free air movement beneath the stow; no obstructions (such as timber dunnage) should be placed in floor side channels, and nothing should be allowed to drop between the channels into the T-sections of the truck’s compartment or the container’s floor. Similarly, with slip-sheets care must be taken to ensure the lips of the last two slip-sheets do not obstruct the free movement of air from floor to ceiling in the air gap just inside the doors.

Load-out

Refrigerated shipping containers and truck compartments are designed to maintain temperature—not to rapidly cool cargo to its carriage temperature.

A basic requirement for successful transport, therefore, is that the meat be loaded out at the correct temperature. If this is not done, the container refrigeration system will only reduce the temperature of the load slowly, particularly if the ambient temperature is high. Temperature reductions of from 1° to 2° C per week may be all that can be achieved for product at the centre of containers. Similarly most truck refrigeration systems can usually do little to reduce meat temperatures, and are intended only to absorb the heat that leaks into the refrigerated compartment.

To prevent excessive warming as trucks and containers are loaded, ideally, meat load-out docks should be cooled to below 10°C, and buffer-seals fitted to prevent the entry of ambient air.

On unrefrigerated loading docks, meat should not be left out during load-out because most docks operate well above the desired load temperature of 0°C; cartons should be transferred directly from the holding chiller to the container. During breaks, container and coolroom doors should be closed and during longer breaks, the refrigeration unit should also be operated. Load-out should be completed as quickly as possible—this means that product should be marshalled in the chillers in readiness for the load-out process.

The refrigerated container or truck compartment should only be prechilled to a temperature that can be maintained during loading just before load-out, with the refrigeration system being switched off during the load-out period but switched on again as soon as load-out has been completed. This means prechilling is only advisable if the load-out area is well chilled and properly buffer-sealed.

The container or truck refrigeration unit should not be run during the loading operation for several reasons:

- If the load-out area is well chilled and properly buffer-sealed there is no need to run the unit
- Provided loading takes place without delay, product temperatures will change little during load-out
- On unrefrigerated loading docks, the entry of warm air during loading will cause the refrigeration unit to ice up, reducing its efficiency in the important period immediately after container closure and sealing, and maybe initiating a premature defrost.

For the same reason, pre-cooling of container or truck refrigerated compartments before loading to temperatures lower than those that can be maintained during loading is not recommended. When the doors of a pre-cooled unit are opened, moisture condenses on walls and the floor of the container or truck. All such moisture must later be removed (as water vapour) by the circulating air stream, reducing the efficiency of operation of the refrigeration unit.

It is also important to make the stow secure. Cartons are designed to be stacked in columns (i.e. directly on top of each other so that the carton itself takes the load) and if cross-stacked or stacked partly off-centre may collapse. Prevent voids that might leave cartons loose. To prevent movement in transit, fit vertical packing (e.g. polystyrene foam or inflated dunnage bags) to fill any gaps left if the stow doesn't neatly fill the width or length of the truck or container. But be sure to leave a gap of approximately 50 mm between the end of the stow and the doors to allow air to sweep heat away from the inner surfaces of the doors.

Dunnage (vertical battens) to create spaces for air to flow through the load is not necessary provided meat is loaded out at recommended temperatures. Dunnage may, in fact, lead to excessively high temperatures at the door end.

Ideally, meat and offal should be stored and transported at from -1.5° to 0°C. Transport at temperatures greater than 0°C will reduce shelf-life and may produce excessive weep in the packs. Since some temperature variation (approximately 2°C) is inevitable between cartons at different locations in the container, the delivery air temperature should be set as close to the freezing point (generally -1.5°C) as possible.

Shipping containers and set-point temperatures

There are many models and makes of refrigerated containers in use, and some may be unsuitable for transporting some chilled produce to some markets. Thus, containers must be chosen to satisfy the requirements of the produce to be carried, appropriate to the length of voyage. It is the shipper's responsibility to provide all relevant details of the product to be carried so that the shipping company can supply a container suitable for the carriage of that produce. Because container insulation deteriorates with time, containers more than 12 years old may not be suitable for chilled meat.

All refrigerated containers keep produce cold by circulating cold air through the loadspace. Air is delivered into the loadspace at floor level and returns to the refrigeration unit by returning through the headspace, between the stow and the ceiling. This is known as 'bottom delivery' or 'bottom-to-top' air circulation.

When carrying chilled product, all modern containers control the temperature of the delivery air stream, which is the coldest part of the stow. This is termed 'delivery, or supply, air control'. The delivery air temperature is close to the 'set-point'. (These same containers control the temperature of the return air stream when set to low temperatures for the transport of frozen products; this is termed 'return air control'). The container's thermograph ('Partlow chart') usually records the return air, which is usually from 2° to 3°C warmer than the delivery air stream because it has collected heat from the container. Most modern containers are fitted with digital temperature readouts or data recorders, which indicate

delivery air temperature, return air temperature, or both.

Packers should specify the container set-point temperature and allow the shipping company to decide how the container should be ‘pre-tripped’ and adjusted to achieve this temperature. Normally one would expect to use a set-point of –1.5°C for chilled meat. Understand what temperature is recorded and discuss ‘pre-trip’ requirements and whether lower delivery temperatures (down to as low as -2°C) could be used without freezing some meat.

Packers should place one or two transportable temperature recorders, or battery-powered data loggers, in each container to provide an independent record of temperature. These are usually placed where the highest temperatures are expected: on top of the top carton stowed against either wall in the second tier of cartons from the door end. Such temperature records can help diagnose the reasons for a poor outturn.

Previous research by the Meat Research Corporation (MRC) found:

- While the container was operating, the highest product temperatures were at the top corners at the door end of the container. Increasing the ambient temperature from 20° to 40°C increased the spread of meat temperatures in the container by from 2° to 3°C. Meat temperatures were not affected by type of carton.
- Using an actual delivery air temperature of -1°C in an ambient temperature of 20°C, all cartons of meat were kept below +1°C (i.e. within 2°C of each other). At an ambient temperature of 40°C and a delivery air temperature of -1°C, 5% of the cartons were above +1°C but below +2°C.
- Actual meat temperatures depended on the accuracy of the ‘pre-trip’ calibration of the temperature controller and its stability with ambient temperature changes.
- In some containers, changes in the ambient temperature altered the temperature of the air delivered to the container. Between containers, there was a difference of 1°C in the mean temperature of chilled meat. This was due to a combination of differences in ‘pre-trip’ calibration and the ability of the control sensor to measure the true mean temperature of the air delivered to the container.
- When the power was turned off, product at the door-end top corners warmed fastest because these corners receive heat from the adjacent surfaces: the top, the side and the end. This was followed closely by product at the bottom corners.

Refrigerated trucks and trailers

As in the case of refrigerated containers, the refrigeration units fitted to trucks and trailers keep the load cool by circulating a stream of cool air through the loadspace. However, in trucks and trailers the air is delivered into the headspace and returns to the refrigeration unit beneath the load. This is known as ‘top delivery’ or ‘top-to-bottom’ airflow.

The top corners of the truck’s refrigerated compartment are most vulnerable to the external temperature because heat can pass through the three adjacent surfaces, i.e. the top, the end and the side. Product inside the compartment in these areas is therefore similarly vulnerable to undesirable temperature increases. The effect of this heat inflow is additional to that of ambient air entering the truck’s refrigerated compartment every time the doors are opened to make a delivery.

It is important to adequately address the following matters with regard to the truck’s refrigeration system:

- Ensure that the refrigeration system has sufficient capacity.
- Service the refrigeration system regularly.

- Ensure that the product load never impedes either the return or discharge airflows to and from the truck's refrigeration system.
- Check for leaks—door seals, cracks and drainage holes.

Operation of the truck's refrigeration unit should be monitored throughout the journey. Many refrigeration units have in-cab readout units, or large digital displays that can be read through the driver's rear vision mirror. Any problem detected early can then be rectified before the load warms excessively. Fitted temperature chart recorders or data loggers are desirable. As with containers, it is in the packer's interest to place his own temperature logger in each truck load, for an independent record of the operation of the truck's refrigeration unit, and maybe also to probe cartons as the truck is being loaded. Know what you are logging—the temperature at the air delivery is always lower than that at the air return.

For further information and for recommendations for domestic short-distance delivery, readers should refer to the first three references under Further Reading.

Further Reading

Australian Standard for Transportation of Meat for Human Consumption.

Meat & Livestock Australia Transport Information Kit, 1999.

'Transport & Distribution of Meat in Australia—Final Report'—A report of research conducted September 1996-September 1997 by Alliance Consulting & Management, Brisbane and Slack-Smith Consulting Pty Ltd, Sydney for the MRC.

AMT *Meat Technology Update No. 95/3*, 'Chilled Cartoned Meat in Shipping Containers.

CSIRO Meat Research Laboratory, 'Production of Chilled Meat for Export—Workshop Proceedings', 1991.

CSIRO *Final Report*, CS128, 'Optimisation of Chilling during the Processing, Containerised Transport and Storage of Meat', (Part B: Chilled Meat Containerisation).

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