MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

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Principles of Chilling

Carcase chilling is one of the most critical stages in the hygienic production of meat. The effectiveness of chilling will influence food safety, the ultimate shelf life of the product, carcase appearance, eating quality, weight loss and boneability.

Chilling carcases in air limits the growth of bacteria and can produce a reduction in their number through two main mechanisms:

- reduction of carcase surface temperature; and
- drying the surface tissue.

At lower temperatures the oxygen penetrates more deeply into the meat and the bright red oxymyoglobin layer thickens. If cooling of heavy, fat carcases is slow, then pale regions occur, particularly in deep muscles and these regions brown faster in retail display and release more weep.

Rapid reduction in temperature post-slaughter can toughen meat by the process of cold-shortening. This can be of major importance for the lighter beef carcases and lambs destined for the domestic market and electrical stimulation should be considered.

The minimisation of weight loss has both economic and aesthetic benefits for the meat processor. Provided the same average temperature is achieved, a lower evaporative weight loss is achieved by rapidly chilling carcases and sides than through slower chilling.

Refrigeration Equipment

Export and large domestic abattoirs invariably employ central refrigeration equipment using circulation of ammonia. Small and medium-sized domestic abattoirs may use plant which operates on a range of HCFC and HFC refrigerants now that CFC refrigerants are being phased out. Ammonia should be considered for all new systems. All systems have three common components: compressors, condensers and evaporators.

It is the design and arrangement of the evaporators that has the greatest influence on the product. An evaporator consists of rows of finned tubes (the coils) through which the refrigerant flows. Air passes over the fins and is circulated around the room. The air may be blown through the coil in a forced draught cooling (FDC) unit or drawn over the coil in an induced draught cooling (IDC) unit. Evaporators may be direct expansion, liquid recirculation or flooded systems. Direct expansion is the least efficient.

Rapid cooling can be achieved by operating evaporators at low refrigerant temperatures. However, this can result in a large quantity of moisture, taken from the carcase, condensing and even freezing on the coils, causing excessive

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product weight loss as well as the need for frequent defrost of the coils.
Minimal weight loss (and minimum condensation on the coil and a higher relative humidity in the room) can be attained by keeping the temperature differential between the air returning to the coil and the air exiting the coil as low as practical. Finned coil evaporator design is a complex subject with factors such as tube diameter, fin spacing, number of rows of coils, face area and coil depth, etc. all having an influence on performance. Best results are achieved by having a large face area, a shallow depth and an 'air on' to 'air off' temperature differential of 3.0°C to 3.5°C.

The use of modulating back pressure temperature regulation also aids in producing good temperature control and minimum weight loss by continuously adjusting the refrigerant flow to the load so that the evaporator operates at the highest possible suction condition as the load reduces.

The rate of carcase chilling is affected by two main factors over which we have control. They are air temperature and air velocity.

Air temperature

The temperature of the air over the carcase has the greatest effect on the carcase cooling rate. A suitable practical chilling cycle should have the air return temperature at near 10°C during loading in order to control condensation, then reducing rapidly to near 0°C within one to two hours of completion of loading. It should be held at this point until the majority of the heat has been extracted from the carcases (10 to 12 hours for beef) and the product surface temperature is below 7°C. If the product is intended for boning, the air temperature can then be allowed to rise in a controlled manner to 5°C or 6°C prior to loadout. This air temperature should ensure that the surface temperatures do not rise above 7°C. Primary chiller temperature control should be via the return air. Improved control is achieved by monitoring surface and deep butt temperatures. Air distribution should be such as to avoid 'warm spots'.

Figure 1 shows deep butt and surface temperatures of a beef side during this type of chilling cycle. It can be seen that it can take six to eight hours for the surfaces to reach 7°C. The deep meat temperature may still be at 25°C to 30°C; therefore loading out beef for the domestic market even after 12 hours' chilling is likely to result in surface temperatures rising above 7°C during transportation.

When chilling over the weekend, the air temperature should remain at 6°C or lower to ensure that surface temperatures are below 7°C. If beef carcases are to be boned, a brief reheat period may be included to soften the fat of heavy bodies.

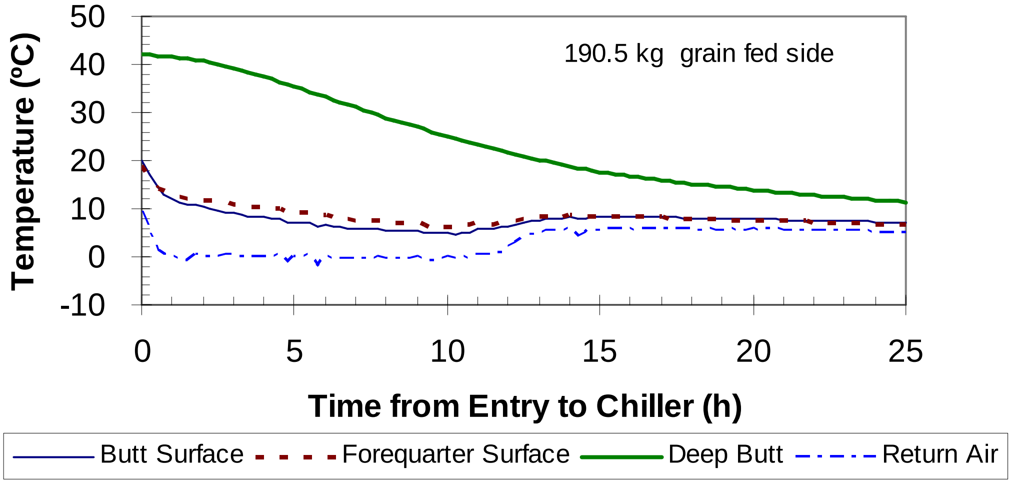

Figure 1: Typical current chilling cycle for beef sides

Air velocity

Air velocity has less effect than air temperature on cooling rate, although increases at low velocity bring substantial reductions in cooling times. Increasing the air velocity from 0.5 m/s to 2.0 m/s can reduce cooling time by 18%. A further increase to 3.0 m/s brings only an extra 6-8% reduction in cooling time. However, large increases in velocity consume additional power. This also produces heat which must be removed by the refrigeration system. Whilst air velocities above 1.0 m/s may not be justifiable, care needs to be taken to ensure that low air velocities do not produce dead spots in the chiller.

In the chilling cycle in Figure 1 (currently used by some plants), the air velocity should be relatively low during loading. There must be sufficient air circulation and evaporator temperature differential at the 10°C return air temperature during loading to prevent condensation. The peak heat and moisture load occurs when the last hot carcase has entered the chiller. Higher air velocities (1 to 2 m/s) should be used during active chilling and low (<0.5 m/s) during the hold period when the majority of the heat has been extracted. This will prevent excessive drying and weight loss, especially over weekends.

Control of air temperature and air velocity through fan speed control is best done using programmable logic controllers (PLC) which will provide flexibility in setting parameters to suit the type of carcase and the outcome required.

Monitoring the Process and Results

It is important that the chilling process be monitored on a regular basis. The minimum monitoring should be:

- continuous recording of chiller return air temperature;
- measurement of a selection of carcase deep butt temperatures at loadout and during cooling;
- measurement of a selection of carcase surface temperatures at loadout and during cooling;
- visual inspection, e.g. cleanliness, carcase spacing, condensation, carcase 'bloom'.

In its least sophisticated and outdated form, recording chiller temperature consists of the engine driver or night watchman reading a thermometer and recording the measurement on paper. The minimum that should be accepted today is continuous chart recording.

A more flexible system is to record temperatures using a data logger which can display in tabular and graph form on a computer. This has the benefit that the system can be accessed from remote locations, such as the engineer's residence. Then it is also possible to log on to the system from any location in the world which is serviced by the telephone network. These systems can also incorporate automatic telephone dialling to warn the engineer of equipment failures or high/low temperatures.

The temperature of the air returning to the coil after passing over the product will give the best indication of the average air temperature. The calibration of the sensor should be checked periodically as it may drift with time.

Chilling operations should also be regularly monitored by a walk-through inspection by supervisory staff. Some of the operational procedures to be monitored include:

Standard of cleanliness of the room. As a minimum, the floor should be hosed down between loads, but many plants are now moving towards a full washdown with foam detergent sanitiser each day. Evaporators should be cleaned periodically to remove any build-up or mould.

Condensation. Condensation from the overhead structure and the underside of cooling units and pipes can contaminate carcases and is a pet subject of Regulatory Authorities. Condensation in these areas is generally the result of poor design such as undersized refrigeration equipment, poor air distribution or chiller location. It can also be caused by incorrect operation, overloading the chiller and leaving doors open to moist slaughterfloor air for extended periods.

Carcase spacing. Supervisors should ensure that carcases are not touching during chilling. In the case of beef carcases, interleaving the sides is claimed to provide better air movement over the cavity. Contact between carcase surfaces not only provides moist areas for bacterial growth, but can detract from carcase appearance. For example, pig carcases that touch have patches of lighter colour.

Carcase appearance. An experienced eye can detect when carcase appearance or 'bloom' is not optimal. This could range from moist carcase surfaces due to inadequate chilling or carcases pushed together, to excessive drying caused by poor temperature or air velocity control.

Evaporators. All fans should be operational and blowing in the correct direction. Check for icing of evaporators, indicating that a defrost is required.

Additional temperature monitoring could include automatic logging of deep meat and surface temperatures during chilling. To be useful, a clean, deep meat probe would need to be consistently located each time. The probe would need to be fairly robust, so care should be taken to ensure that a minimal length of probe is exposed to the chiller air to minimise conduction errors. Surface temperatures could be measured by either a clean, lightweight probe just under the surface or an infrared sensor aimed at a carcase on the end of a rail.

The air velocity off the evaporator could also be measured periodically to ensure that there is no drop-off in performance due to blockage of the coil or build-up on fan blades.

Air velocities within the room should be checked at the time of commissioning the chiller. It is important to attain an even distribution of air throughout the chiller to eliminate dead spots. It is all too common to find chillers with excellent air velocities down the walls and along the floor but with poor flow through the carcases.

Where low air velocities (< 0.5 m/s) are to be measured, hot wire anemometers are the appropriate instrument; otherwise vane anemometers may be used. Excellent digital hot wire and vane anemometers with averaging facilities are available.

Conclusion

Control of air temperature to ensure that carcase surface temperature requirements are met is the most important aspect of carcase chilling. Achieving even air flow, at the optimum velocity, over all carcases is also important to provide adequate heat transfer and minimum weight loss.

Monitoring the process by correctly recording air temperature and measuring carcase temperatures at loadout is an important aspect of effective management of chilling.

Contact us for additional information

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