Results for today; Ideas for tomorrow

Meat Technology Update

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Evaporative weight losses during processing

Loss of product weight from various causes can have a significant effect on overall product yield. Some loss of weight during processing is inevitable. For instance, loss from surface drying during chilling is a necessary consequence of ensuring food safety and quality; however, processors do have some control over the factors that can influence weight loss during processing. For example, control can be applied to limit losses during carcase chilling and holding, freezing, storage in vacuum packs, and during retail display.

This newsletter discusses evaporative weight losses from chilled and frozen product and strategies that can be used to minimise these losses. Weight loss in the form of drip is discussed in Meat Technology Update 02/6.

Carcase chilling

Weight loss (shrink) during hot carcase chilling is affected by the type of equipment installed and the way the facility is operated. The chilling process has been widely investigated and conditions that minimise weight loss without compromising microbiological quality are well documented.

Beef carcase weight losses during conventional overnight chilling have been reported to vary from less than 1% to up to nearly 3%. When carcases are boned, excessive weight loss from fat carcases may not be reflected in loss of saleable meat. This is because the weight loss is restricted to surface tissues which may be trimmed of; but, for leaner carcases for manufacturing and carcase meat, a high weight loss would certainly result in economic losses.

Weight is lost by evaporation from the carcase surface at a high rate during the first 4–5 hours of chilling and at a reduced rate thereafter. Typically about 80% of the evaporative weight loss occurs in the first 8 hours of a 20-hour chilling program.

Air temperature, air velocity, relative humidity, carcase weight

and fatness all have effects on the weight loss.

Air temperature

The effect of chiller air temperature on evaporative weight loss is quite small. During a normal 18–20 hour chilling cycle, a lower air temperature results in a slightly increased weight loss. For example, in one study, reducing the air temperature from 5ºC to 0ºC increased weight loss for a 140 kg side by slightly less than 0.1%; however chilling at lower temperature decreased the chilling time, resulting in less overall weight loss.

Air velocity

When cooling for a set period, high air velocities increase weight loss. In one experiment, increasing air velocity over beef sides from 0.75 m/s to 3.0 m/s raised losses by 0.2% over 18 hours.

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Higher air velocities enable more rapid chilling, but the fan power requirements increase by the cube of the air velocity. In most practical situations increasing the air velocity above 1 m/s cannot be justified by the small increase in cooling rate.

As the surface temperature approaches the air temperature, the rate of cooling is determined mainly by the thermal conductivity of the meat and not the rate of transfer of heat from the meat surface to the air. Therefore a reduction in air velocity to less than 0.5 m/s after 8–10 hours of beef chilling will have little effect on the cooling rate but will have economic benefits by reducing weight loss and fan power consumption.

This is particularly important if the room is also required to operate as a storage chiller over weekends or longer periods.

Relative humidity

Relative humidity (RH) has a greater effect on weight loss than either air temperature or air velocity. Experimental work demonstrated that decreasing the humidity from 95% to 80% increased weight loss for beef sides by nearly 0.5% over an 18-hour chill. Therefore, for carcase chilling, the aim should be to keep the humidity as high as possible (above 90%) throughout the chilling cycle, particularly if carcases are held for extended periods.

The cause of low RH in a chiller is usually related to the original plant design and the manner in which it is operated. If the evaporator is undersized, it may be necessary to use a low evaporating temperature in order to achieve the desired rate of heat removal. This will create a large difference between the evaporator coil temperature and the temperature of the air. The larger the temperature difference, the more moisture will be drawn from the air in the form of condensation on the coil. Undersized evaporators are usually a result of attempts to minimise capital costs in the original chiller construction.

The design and surface area of the finned coil evaporator will have a major influence on the chiller RH and, as a result, on the evaporative weight loss. Design of the finned coil is a complex subject with factors such as tube diameter and configuration, coil depth, surface area, refrigerant flow path, fin spacing, all having some effect on performance. The combination of the depth of the coil and the face area is one of the most important considerations. A shallow coil of adequate surface area will provide the best performance with respect to minimising weight loss.

Best results are achieved with coolers that are designed for a 3.0 to 3.5ºC difference between the refrigerant evaporating temperature and the entering air temperature, and an air temperature reduction through the coil of 0.5 to 0.8ºC.

The heat load in the room will be much higher at the beginning of the chilling cycle. The peak load can be more than three times the average heat load; therefore, during the latter part of the chilling cycle, the evaporators will be oversized. It is useful then to have the facility to modulate the refrigerant suction temperature through back-pressure control so that the air cooler operates at the highest possible suction temperature for the load. This will minimise the temperature difference between the coil and the air, resulting in the highest RH.

Carcase weight

Under the same conditions, the percentage weight loss will be greater for lighter beef sides and small stock than for heavier carcases, due to the larger surface-to-weight ratio.

Fat cover

Fat cover can have a substantial effect on evaporative weight loss. A very lean side of beef with little or no fat cover can lose up to 1% more over an 18-hour chilling period than a side of similar weight with a thick, even fat cover.

Fast vs slow chilling

A British study in a commercial chiller in 1989 compared fast chilling of beef to achieve low weight loss, with slow chilling to avoid cold shortening. The results in Table 1 show that 0.3% lower weight loss was achieved with rapid chilling. Under experimental conditions weight losses of less than 0.5% have been achieved with rapid conventional chilling and cryogenic cooling.

Table 1: Fast chilling vs slow chilling

	Chiller Conditions	Weight Loss (%) after 24 hours
Slow	10 h at 10ºC, 0.9 m/s 4 h at 0ºC, 0.9 m/s 10 h at 0ºC 0.25 m/s	1.5
Fast	15 h at 5ºC to -5ºC, 0.9 m/s 9 h at 0ºC, 0.25 m/s	1.2

In summary, the conditions for chilling hot carcases that lead to the least weight loss are:

- chill as rapidly as possible for the first few hours using low air temperature (~0ºC) and high velocity (approx. 1 m/s);
- reduce the air velocity to below 0.5 m/s after 8 to 10 hours for beef;
- install evaporator coils with adequate surface area and shallow depth;
- utilise modulating back pressure control to ensure that the coil is at the highest possible temperature for the current load.

Spray chilling

Spray chilling of beef sides is used extensively in the United States and in some Australian plants. A major aim is the reduction of evaporative weight loss. A variety of spraying regimes have been used with longer periods of spraying resulting in less weight loss.

Australian regulations require that no carcase shall have gained weight after chilling. Spray chilling for the first 6 to 10 hours of a 20-hour chilling cycle will result in an average carcase weight loss of 0.2 to 0.4% with no sides gaining weight.

Slightly faster cooling rates have been reported with spray chilling for the surface and the thinner sections of beef carcases when compared with conventional chilling.
Researchers report that sides held for a further six days after overnight spray chilling lost less weight (3.2%) compared with conventional chilling (4.2%). Research also indicates that there is no significant difference between conventional and spray chilling in the quantity of weep in vacuum bags and the losses during retail display and cooking.

Chilled holding

Carcases and quarters are held on plants and in wholesale chillers for periods ranging from overnight and weekends to a week or more. When product is to be held for longer than a weekend, it should be in a room specially designed for this task. The parameters of low air velocity and stable temperature that minimise weight loss during holding are at odds with the requirements for rapid chilling of hot bodies. If the same room is to be used for both initial chilling and holding, it should be equipped with facilities to adjust air velocity to a lower level during holding. This can be done by use of speed controllers on the fans or by fitting two-speed fans to the evaporators.

Weight losses for beef sides of about 0.5% per day have been reported in a chiller with an air velocity of 0.5 m/s. Weight loss can be minimised by operating with low air velocities (<0.5 m/s) and small temperature differences between the coil and air temperature. If the room is to be used exclusively for holding carcases and quarters, sock chilling should be considered. Sock chilling utilises fabric ducts to distribute the air evenly through the room at very low velocity.

Carcase/quarter and carton freezing

The principles followed to minimise weight loss during chilling should also be followed when freezing carcases and quarters. Rapid freezing using a combination of high air velocity and low temperature results in lower weight loss than slower freezing. New Zealand trials on freezing lambs showed that rapid freezing using -34ºC and 3 m/s air velocity resulted in 0.66% weight loss for naked lambs whereas -18ºC and 1 m/s gave 0.88% loss. Wrapping the lambs in an impermeable film resulted in a weight loss of about half of that for the naked product.

Beef forequarters will lose more weight during freezing than hindquarters as their surface-to-volume ratio is higher. Hindquarters frozen naked at -20 to -30ºC and 0.8 to 3.0 m/s have been reported to lose 0.9% and forequarters 1.2%.

The conditions for freezing cartons are not as critical as for naked product because the meat is sealed in polyethylene; however, cartoned meat will lose approximately 0.05% in the form of frost inside the liner during air blast freezing.

Rapid freezing has been demonstrated to result in less drip when the meat is thawed than does slow freezing.

Frozen storage

Weight losses during frozen storage are highly dependent on the permeability of the packaging. For example, lambs in stockinet lose about 0.5% per month at -18ºC.. Adding a polyethylene wrap reduced this to less than 0.1% per month. Recent Cuban experiments at -18ºC and 0.5 m/s showed beef forequarters lost 1.25% per month if naked and 0.07% per month when wrapped in polyethylene. The integrity of the impermeable lining must be maintained to ensure the product is protected from desiccation.

Cold store temperature also affects the rate of weight loss. Investigations in cold stores in the UK demonstrated that stockinet wrapped lambs lost 0.85% per month at -10ºC and 0.4% per month at -20ºC.

During frozen storage, weight loss can still occur even from wrapped product and manifests itself as frost inside the liner. The Cuban work showed a weight loss of 0.18% per month for cartoned meat with polyethylene liners, which agrees fairly closely with some Australian data.

Fluctuating temperatures have been shown to increase weight losses during frozen storage. French experiments showed that losses when the temperature fluctuated by ±6ºC were three times those when the temperature was controlled to ±1ºC.

Weight loss during cold storage can be minimised by:

- utilising low air velocities (stores with older pipe coil evaporators produce less weight loss than forced air circulation units);
- using a large evaporator surface area so that the temperature difference through the evaporator is small;
- providing good temperature control to avoid product temperature fluctuations;
- ensuring that the integrity of impermeable product wrapping is maintained.

Storage at retail

Evaporative weight loss at retail stores during storage and retail display of unwrapped product is mainly influenced by the relative humidity of the air. In one study, delicatessen items could be displayed unwrapped for 4–6 hours at 85% RH before surface drying was noted, but only for about 100 minutes at 40% RH.

The percentage of weight lost by evaporation from the surface is dependent on the size of the item. Primal cuts will lose weight faster than whole carcases or quarters. Losses of 1 to 2% per day from cuts in butcher shop chill rooms can occur. Product prepared

for sale will lose weight even faster. In a conduction-plate-cooled display cabinet, unwrapped joints may lose up to 0.5% during six hours display; unwrapped steaks and chops up to 1%; and unwrapped mince up to 1.5%.

Table 2: Estimates of total evaporative losses (%) in cooling and distribution in the United Kingdom.

	Cooling	Storage	Transport	Shop			Total
				Carcase	Cut	Display	
Lamb – ideal refrigeration							
Days	0.5	3	0.25	1	1	0.25	6
Loss (%)	1.2	0.6	0.1	0.2	0.5	0.3	2.9
Lamb – typical refrigeration							
Days	0.5	3	0.25	1	1	0.25	6
Loss (%)	2.0	1.5	0.1	0.5	0.9	0.6	5.6
Beef – ideal refrigeration							
Days	1	3	0.25	3	1	0.25	8.5
Loss (%)	1.4	0.3	0.1	0.3	1.0	0.6	3.7
Beef – typical refrigeration							
Days	1	3	0.25	3	1	0.25	8.5
Loss (%)	2.5	0.6	0.1	0.9	1.5	1.5	7.1

Unwrapped meat displayed in a forced air cabinet could lose 50% more than in a cabinet with only a cold plate.

At retail level, the best means of minimising evaporative weight loss is to:

- keep the meat in large cuts as long as possible;
- cover sliced, diced or minced meat stored on trays in a chiller or display cabinets with plastic film to protect it from the air movement;
- limit the meat on display to what can be sold in a day, if possible.

Estimates have been made in the UK (Table 2) of the overall evaporative weight losses during cooling and distribution of chilled meat. This emphasises the importance of good refrigeration design and control at all stages of the production and distribution chain.

Further reading

James, S. J. & James, C. (2002) *Meat Refrigeration*, Cambridge:Woodhead.

For more information, contact one of the Meat Industry Services staff listed below.

Food Science Australia Meat Industry Services Section

The Meat Industry Services (MIS) Section of Food Science Australia is an initiative supported by Meat and Livestock Australia (MLA) and the Australian Meat Processor Corporation (AMPC) to facilitate market access for, and support world-class practices in, Australia 's meat industry.

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