MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

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Beef carcase chilling – opportunities for customising programs

- **Australian Meat Standard, AS 4696:2007, requires that carcase surfaces be reduced to 7°C within 24 hours.**
- **EC(MMP)Os require carcase and carcase parts to be cooled to 7°C under a program that meets the RI criteria.**
- **EC(MMP)Os are taken to comply with the Australian Meat Standard.**
- **It is possible to chill carcases and carcase parts and still produce product that is boneable, even after weekend chills.**
- **This Update provides information that will assist plants seeking approvals for alternative procedures.**

Meat processors can be in a situation where there are conflicting requirements for their carcase-chilling process. On the one hand they need to provide a safe product by chilling and holding at a temperature that controls the growth of major food pathogens; on the other hand, the fat of some products held at a low temperature becomes excessively hard, thus introducing workplace health and safety issues.

The Australian Standard has specific requirements for carcase chilling, but also makes allowance for validated alternative procedures to suit individual situations. The Export Control (Meat and Meat Products) Orders 2005 require companies to validate their chilling programs using RI criteria. Meat & Livestock Australia and the Australian Meat Processor Corporation and their predecessors have funded a range of research projects to help industry develop effective carcase-chilling procedures.

The issues

Most difficulties with carcase chilling relate to the heavier beef bodies, although fat mutton carcases can also cause problems, particularly in relation to hardness of the fat.

1. Achieving regulatory requirements

Control of the growth of the pathogenic micro-organisms *Salmonella* spp. and *Escherichia coli* is the main food-safety concern during the chilling of red-meat carcases. All processors of meat must comply with the Australian Standard for the Hygienic Production and Transporatation of Meat and Meat Products for Human Consumption (AS4696:2007). Export-registered establishments can meet the standard by complying with the Australian Government's Export Control (Meat and Meat Products) Orders:2005—the EC(MMP)Os.

For carcases, AS4696 requires that plants ensure that either:

- within 24 hours of stunning, the surface temperature of carcases, sides, quarters or bone-in major separated cuts must fall to 7°C or below; or
- for hot-boned carcases and carcase parts, they meet the refrigeration index (RI) criteria; or
- they achieve alternative temperature conditions that are specified in the approved arrangement.

The EC(MMP)Os require all carcase and carcase parts to be refrigerated to a temperature of no warmer than 7°C under a program that meets the RI criteria which are:

a. the RI average is to be no more than 1.5; and
b. 80% of RIs are to be no more than 2.0; and
c. no RI is to be more than 2.5.

Application can be made to AQIS to vary the approved arrangement to use an alternative procedure.

Many plants, both domestic and export-registered, operate with a chilling process in which carcases are chilled to, and held at, 7°C; however, a substantial number of plants, especially those boning heavy grain-fed cattle, find it difficult to operate to this standard.

They must therefore consider the option of a validated alternative procedure that uses different times and temperatures to meet the RI criteria.

2. Conforming with RI criteria

The whole cooling process, not just the initial carcase-chilling component, must meet the RI criteria—from entry of hot carcases into chillers to cooling of all boned meat to 7°C. Remember that operations that follow initial chilling, such as boning and cooling of boned meat, generate a component of the RI—this is typically in the range of 0.1 to 0.5.

There should be no difficulty in meeting the RI criteria when chilling carcases overnight. There may be difficulty, however,

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when carcases are held throughout weekends at elevated temperatures to avoid development of hard fat.

3. Hard fat

The hardness of beef fat depends mainly on its composition and temperature. The hardness of carcase fat at a given temperature will be determined mainly by its overall fatty acid composition. Saturated fatty acids such as palmitic and stearic acids have high melting points (65–70°C) and their presence contributes to hard fat; whereas, palmitoleic and oleic acids have low melting points (0–15°C) and confer softness. In cattle, grain feeding can result in elevated contents of stearic acid, but not always. In Australia, grain feeding generally leads to harder fat: the longer the time on grain, the harder the fat.

Fat can also become harder with time held chilled, largely due to molecular rearrangement of triglycerides. Therefore, carcases chilled for three days usually have harder fat at the same temperature than those chilled for 24 hours.

4. Bone taint

The superseded Export Meat Orders (1985) specified that the deep butt of beef sides should be reduced to 20°C or below within 20 hours of entry to the chiller. This requirement was based on evidence that the incidence of bone taint was greatly reduced when this was achieved. Although this is no longer a specific regulatory requirement, any chilling arrangement should consider the implications of cooling deep meat at a rate slower than this. The focus on control of surface-borne pathogens notwithstanding, the risk of bone taint probably limits how slowly heavier carcases can be chilled rather than RI.

Factors affecting the growth of *E. coli*

The main factors that affect the growth of these organisms during chilling are: the carcase surface temperature; and the availability of moisture at the surface—water activity (a_W). Availability of nutrients, pH and lactate concentration are other factors that can influence bacterial growth. On fat surfaces, however, where bacteria tend to grow faster than on lean, these change little during carcase chilling and so have only a small effect.

The combination of temperature and a_W is critical to controlling bacterial growth at chiller temperatures. Growth of *E. coli* is negligible when the temperature falls below 8°C, even under ideal conditions—hence the requirement to reduce meat surface temperatures to 7°C or below. At 0.993, the a_W of a moist meat surface is only slightly below that of free water and is pretty much optimal for bacterial growth. When the a_W is reduced, the minimum temperature at which pathogen growth can occur is higher for *E. coli* in broth media conditions— as shown

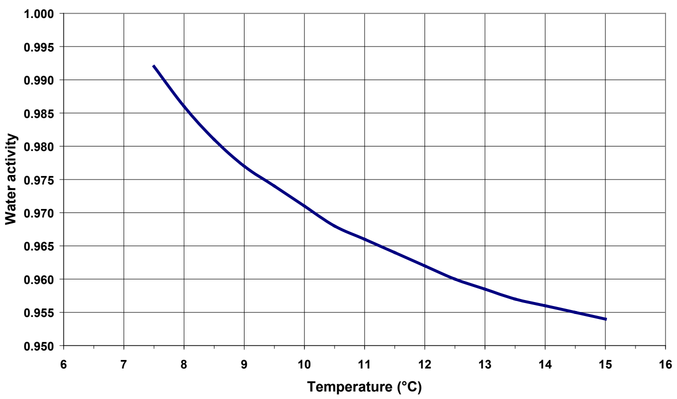

Figure 1: Minimum temperature for growth of E. coli *as affected by water activity*

in Figure 1. The line on the figure marks the boundary of conditions at which growth of *E. coli* can occur (above and to the right of the line).

The a_W varies depending on location on the carcase, initial moisture level and the stage in the chilling cycle. Figure 2 shows how the a_W at the brisket and butt change during carcase chilling.

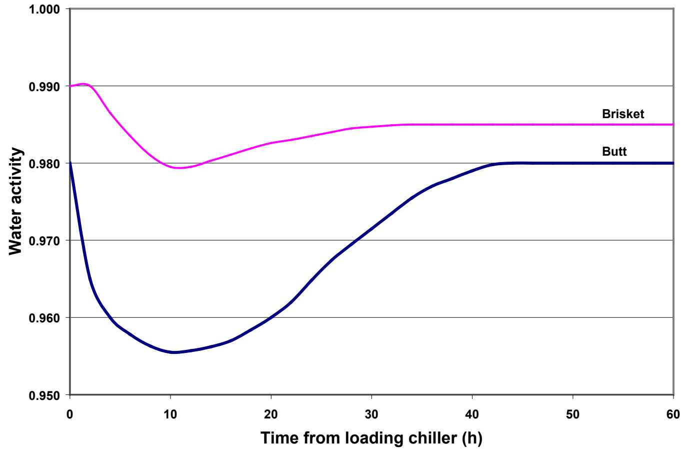

Figure 2: Pattern of water activity change during typical overnight and weekend chilling

Surfaces on thicker parts of the carcase (such as the butt and loin) are areas of low a_W; whereas, surfaces of thinner sections (such as the brisket and neck) have higher a_W as shown in Table 1.

Table 1: Water activity on beef sides after a weekend chill cycle

Site on carcase	Water activity
Butt	0.974
Loin	0.950
Flank	0.977
Brisket	0.989
Neck (inside)	0.984
Neck (outside)	0.982

Soon after commencement of the active chilling cycle, a_W falls to 0.96 or below at the butt and other drier sites, then rises slightly after 10 h before stabilising at about 0.98 by the end of a weekend chill. An a_W of 0.96 is quite inhibitory to *Salmonella* and *E. coli* at temperatures of 15°C or below, with almost complete inhibition at 12.5°C. Sites, such as the brisket, that are representative of moister areas fall to about 0.98 before equilibrating to about 0.985. At this a_W there is some inhibition. At 10°C, *Salmonella* generally will not grow, but some strains of *E. coli* can grow slowly.

Therefore growth of *E. coli* will not occur on areas such as the surface of the butt and loin once the temperature falls to 9–10°C, whereas slow growth is still possible on the neck and brisket. This fact makes the brisket, neck and similar surfaces the ones of microbiological concern, rather than the drier butt which may cool slightly more slowly.

When chilling enters the hold phase, the relative humidity of the circulating air rises to near 100%, contributing to the higher a_W values at the end of the weekend holding period.

There are excellent relationships between the relative humidity of the chiller air and surface a_W at specific carcase locations (Figure 3). This means that useful predictions of a_W can be made from RH. This is important because RH is simpler to monitor than a_W.

The initial drying of the surfaces is believed to have an inhibitory effect on bacterial growth and may even cause some death such that, during a normal overnight chill, there may be reduction of about 0.5 logs in *E. coli* numbers.

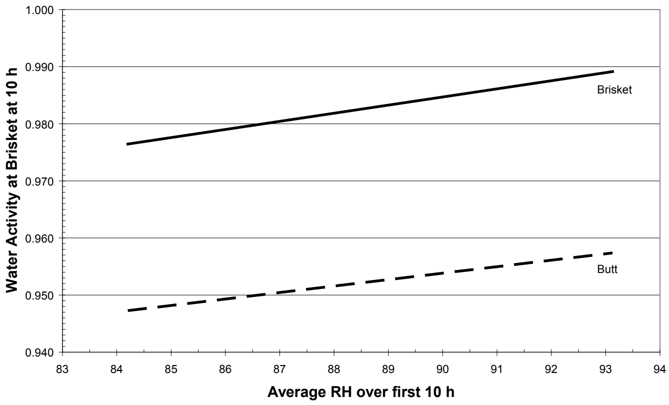

Figure 3: Typical relationships between average relative humidity for the first 10 h and water activity at the brisket and butt at 10 h.

Using the RI to design a chilling cycle

The effects of changes to a carcase-chilling cycle can be assessed at the computer before making any changes to the chiller controls. The RI allows the process to be modelled without placing any product at risk. Various temperature profiles for different portions of the chilling process can be developed on a spreadsheet and RIs for overall profiles calculated using the RI Calculator.

The rate of temperature reduction after the active chilling phase is initiated is dependent on the refrigerating capacity of the system. Some chillers are able to reach the air set-point temperature in a few hours; whereas, others may never reach it before the holding phase commences. Therefore, the initial chilling phase for the simulation must be taken from actual recorded temperatures for that chiller. It would be wise to select a slower cooling example from a full load of heavy sides.

The holding temperature for the desired period can then be added, along with a warming period if applicable, and the RI calculated. This approach is particularly useful when a special occasion (such as a long weekend) is encountered, and the process can be assessed beforehand to ensure that there is no risk of breaching the RI criteria.

While the current MLA Refrigeration Index calculator (Version 3) does not allow for water activity to be varied for calculations, the predictive equation underpinning the calculator can be enhanced to account for variable a_W. The ability to account for a_W would be useful not only in designing cycles, but also in circumstances where the impacts of refrigeration incidents in carcase chillers need to be assessed.

Alternative chilling profiles

In a modified chilling program, the initial loading and blast chilling phase will normally be unchanged. The main change will be to the holding phase for which there are three main options:

1. hold at a constant temperature above 7°C;
2. hold at 7°C and allow temperature to rise during the final stages; or
3. hold at 7°C and heat the chiller air at the end of the cycle (rewarming).

Establishments have their own individual beef carcase-chilling cycles, but most follow a similar pattern, with each cycle divided into different phases—normally: load, active chill, and hold. During the active chill phase, the air is circulated rapidly at 0–5°C; during the hold phase the air temperature is raised to 7–10°C and the air circulation is slowed to reduce evaporative weight loss.

There are often additions to these, such as: a period during which the temperature is raised from chill to hold in a stepwise manner (ramping up); and a warming phase at the end of the cycle. There is also the opportunity to incorporate slight variations for different classes of stock.

In a typical beef carcase-chilling cycle during which the product is chilled rapidly and held at 7°C or colder for 72 h over a normal weekend, the RI will be zero. An RI of zero, or close to, it can also be achieved by holding at a constant temperature above 7°C; for instance, a temperature of 9°C can result in an RI of zero. Even when holding at 10°C for a normal weekend, the RI may average 1.0 or less.

Carcase-chilling facilities on plants will have different capabilities, and there are often variations between chillers on the same plant. Therefore each situation should be assessed individually. The refrigeration index is a useful tool for plant personnel to fine tune their chilling cycles to achieve production aims while meeting food-safety standards.

Rise at end of cycle

When the chiller air temperature is allowed to drift up to (say) 11.5°C, there will be a slight softening of the fat allowing for easier boning. The particular chilling profile (blue line) shown in Figure 4 still results in an RI near zero at a_W 0.993. If the RI calculation could use an a_W of around 0.985 (a more likely a_W in many carcase chillers at this stage of the cycle), the temperature rise in Figure 4 could reach 15°C or higher over 25 h before an RI approaching 1.0 will be recorded.

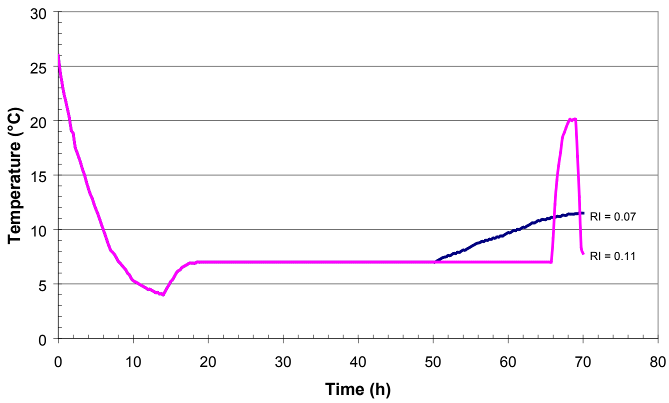

Figure 4: Brisket surface temperature when air temperature is allowed to rise towards end of chilling cycle

Rewarming

When boning heavy grain-fed beef, the gradual, slight rise in temperature may be inadequate. Many plants find that the surface needs to be warmed prior to boning. A heating cycle is achieved by methods such as:

- circulation of hot refrigerant gas through the evaporators;
- electric heating elements in front of the evaporators;
- steam coils in the evaporator air stream.

The air temperature can usually be more accurately controlled using the latter two methods. A typical brisket surface temperature profile during a cycle that includes a rewarming phase is shown in Figure 4 (red line). The RI from the start of chilling in this examples is 0.11.

Further information

Eustace, I and McPhail N (2004). Carcase chilling survey. Meat & Livestock Australia. Project PRMS 043B

Refrigeration index calculator package, version 3. Meat & Livestock Australia 2006.

Refrigeration index training kit. MINTRAC Ltd 2006.

Ross, T (1999). Predictive microbiology for the meat industry. Meat & Livestock Australia.

AQIS approval of alternative procedures

An AQIS Meat Notice to be distributed in 2007 will set out the protocol to be followed when an application for an alternative procedure is being made.

In order to validate an alternative procedure, there will probably need to be a trial, the design and execution of which will first have to be approved by AQIS.

If, for example, the application is to operate the carcase chillers such that the carcase surface is held at a temperature above 7°C overnight and on weekends, the chiller controls should be set to obtain the required temperature during the trial period. During that period the surface temperatures of at least 30 sides would be recorded using the procedure described in the MLA Refrigeration Index Training Manual. Weekend chills would be treated as a separate process to overnight chills. If distinctly different chilling programs are used for different classes of stock, then each should also be treated as a separate process. The temperature recording should be carried through the carton-chilling or freezing process.

The overall process RI would be calculated for each record using the MLA RI Calculator program and the results presented in tabular form, and summarised, so that it is easy to see whether the AQIS RI criteria are met.

When the trial is completed, a report setting out the results of the trial and independent validation findings (if necessary), is prepared and forwarded to AQIS.

Contact us for additional information

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