

# Literature for chiller validations

September 2004

This information sheet outlines a number of published studies that provide information that is relevant to various aspects of carcass chilling. Included are some case studies and literature to support temperature regimes that do not involve cooling meat to 7°C in 24 hours. Brief outlines of this literature explain how the studies are relevant and how they can be used to assist processors in validating their chilling programs. All of the listed publications are available by contacting Meat Industry Services staff as listed on the bottom of this information sheet.

## Case studies

The published studies described below have used microbial data and/or temperature profiles to monitor the hygiene of beef carcasses under specific chilling programs.

Gill and Bryant (1997) examined carcass chilling at two beef slaughtering plants in Canada. Spray chilling was used at both plants. Temperature histories during chilling were collected for deep leg, aitch bone pocket surface and other randomly selected surface sites of carcasses. Counts of total viable bacteria, coliforms and *E. coli* were obtained on swab samples taken from carcasses before and after chilling. At one plant, the counts – total, coliforms and *E. coli* – fell by less than 0.5 logs; at the other plant numbers of coliforms and *E. coli* were reduced by 2 log units (99%) and total counts by about 0.5 logs (60%). At the first plant, carcass surfaces mostly fell to less than 3°C but ranged from -4.3 to 9.8°C; at the other the minimum surface temperature was almost always less than 3°C. The investigation indicated that temperature data can be useful for monitoring the maintenance of SOPs.

McEvoy *et al.* (2004) tested carcasses at an Irish abattoir over a 12-month period for total viable counts, *E. coli*, coliforms and *Enterobacteriaceae*. Bacterial contamination on carcasses post-chilling was similar to or lower than on pre-chill carcasses. Numbers of *E. coli* at the brisket and inside round and of *Enterobacteriaceae* at the hock were reduced by 1.29, 2.13 and 1.55 log units respectively after chilling. The authors do not provide details of the carcass chilling conditions at the abattoir.

Chang *et al.* (2003) chilled pork carcasses for 18 to 24 hours in

a chiller at 1 to 4°C with air circulating at 0.45 to 0.9 m/s. Some carcasses were skin-on and others were skin-off. Once active chilling of the test carcasses began, the temperature of carcass surfaces fell from a temperature of 10°C to the holding temperature of 4°C within an hour. They found that levels of total viable bacteria (TVC), coliforms and *E. coli* fell significantly on both skin-on and skin-off carcasses during chilling. For skin-off carcasses, TVCs and numbers of coliforms and *E. coli* reduced by 1.2-1.7, 1.1-3.3, and 1.5-3.3 log units respectively.

A study supported by Meat & Livestock Australia (1998a) used naturally occurring microbial counts and also counts of a non-pathogenic, test microorganism inoculated onto test carcasses to assist in the comparison of a spray-chilling regime against the conventional chilling procedure. This case study was discussed in Meat Technology Update 4/04.

A further study determined the acceptable chilling cycles that adequately control growth of pathogenic organisms during weekend chilling at three plants (Meat & Livestock Australia, 1998b). A chilling pattern in which the air temperature was held at 8°C for much of the weekend, then raised to 9.5°C about 15 hours prior to boning, was recommended.

## Validation of chilling conditions higher than 7°C

When bacteria are transferred to a new environment – for instance from hides to a newly exposed carcass surface, they will undergo various physiological changes to ready them for growth in their new environment. If the transfer is abrupt – as is the case during slaughter and dressing, and again as the surface temperature falls rapidly in the chiller – the bacterial cells have to make these changes before any further growth can occur. Smith (1985) and the monograph prepared for MLA by Ross (1999) provide information on lag times for coliforms, *E. coli* and other bacteria. Ross (1999) introduces the concept of relative lag times or generation time equivalents; the ratio of lag time to generation time (generation time is inversely related to the growth rate of an organism). If the new environment is such that the rate of growth – once growth begins – will be slow, the lag time that precedes the commencement of growth will be long.

Sumner and Krist (2002) state that at 10°C the generation times of *E. coli*, *S. aureus* and *L. monocytogenes* are all greater than 5 h,

and suggest that warming chilled meat surfaces to 10°C for a few hours would not lead to detectable increases in pathogen numbers, particularly if a lag phase occurred.

Ross (1999) cites numerous papers from which he obtained information on the growth rates of bacteria in laboratory media and food systems including the paper of Smith (1985). Smith provides information on generation times for coliforms, *E. coli* and *Salmonella typhimurium* in blended raw meat tissue at various temperatures ranging from 8.2°C to 40°C. He generated equations relating the generation time and lag time of coliforms in blended meat to the temperature at which the meat was held. Smith stated that his calculations could be used to determine the length of time raw chilled meat may be held without increases in numbers of *Salmonella* or other organisms occurring. The equation did not take into account the effect of drying on the surface tissue of carcasses. Smith acknowledged this and stated that the drying could only lead to slower growth of the organisms present.

## Good manufacturing practice benchmarks

### Counts on carcasses

Studies of the quality of Australian beef and sheep meat have been conducted by the Australian industry, to determine the microbiological level on meat produced by current manufacturing practices. The first study was done in 1993/1994 by CSIRO/Food Science Australia (Vanderlinde *et al.*, 1998 and 1999), and a follow-up study was conducted in 1998 by Alliance Consulting (Phillips *et al.*, 2001a and 2001b). The results of these surveys can be used for comparison with your own chilling practices.

In addition, Sumner (1998) lists guidelines for microbiological levels for carcasses, as set by the Meat Standards Committee of ARMCANZ (Agricultural and Resource Management Council). These guidelines can be used for comparison against your own in-house data to assist you in setting your microbiological limits.

Category	TVC/cm <sup>2</sup> or /g	<i>E. coli</i> /cm <sup>2</sup> or /g
Excellent	<1,000	Not detected
Good	1,000 - 10,000	1-10
Acceptable	10,000 - 100,000	10-100
Marginal	100,000-1,000,000	100-1,000

### Counts on offal

There are a limited number of publications that have surveyed the microbial counts on various offal products after chilling. US researchers (Delmore *et al.*, 1999) evaluated the microbiological quality of various offal meats before and after cooling at several plants. Average *E. coli* counts after chilling were highest (3.0-3.4 log CFU/g) for flexor tendons, large intestine and cheek meat. There were significant differences in counts between plants and the authors suggested that there was a difference in processing and

chilling practices between the six beef processing plants. They also recommended areas where cooling practices could be improved.

Hanna *et al.* (1982) reported on the effects of refrigeration, freezing and thawing on the microbial flora and pH of livers, kidneys and hearts from beef, pork and lamb. Results indicated that if offal is promptly and properly refrigerated, no major increase in microbial count occurred over a 5-day period; but temperature abuse prior to freezing, did result in major increase in microbial counts.

Gill and Harrison (1985) compared the growth of *E. coli* on offals using direct microbial counts to that estimated using a temperature function integration technique (similar to predictive microbiology equations). The estimated and the directly determined values, generally agreed within one generation of each other.

## Setting critical limits

Critical limits can be derived from sources such as published data, regulatory standards and guidelines, and in-house experimentation; including some of the references mentioned already. Brown, (2000) briefly discusses the concept of targets (ie. the working limits), and establishing and setting critical limits.

## Predictive modeling programs

Predictive microbiology is a tool for evaluating the microbiological consequences of different food processing and handling procedures. Predictive microbiology models allow environmental factors that can be measured reliably (eg. temperature, pH, water activity) to become proxies for microbiological tests. The performance of predictive models has to be considered in terms of their applicability and accuracy.

Ross (1999) discusses the characteristics that useful predictive models need to have – particularly to reliably simulate real microbial growth on carcass and meat surfaces. He explains how several predictive food microbiology growth equations were validated as they relate to carcass and retail meat. Ross and his colleagues developed a model specifically for predicting the growth of *E. coli* on meat under Australian commercial practice. He discusses how it predicts the effects of temperature, pH, water activity and lactic acid concentration and how it compares with two other models that are widely available – the Pathogen Modelling Program (USDA), and Food Micro Model (UK).

There are some limitations of predictive microbiology that need to be considered. These include:

1. The models cannot be extrapolated outside the ranges (eg. T°C, a<sub>w</sub>) over which they were derived. Predictions outside the experimental ranges are usually not accurate and in some cases are nonsensical.
2. The models may predict faster growth rates than are observed. This makes them fail-safe but they may be overly conservative. The reason for this is the models are developed from results of tests mainly conducted in laboratory media. You should have evidence that the

model you select has been appropriately validated for meat surfaces.

In December 2003, FSIS issued Notice 50-03 that provides information about microbial pathogen computer modelling. The notice also contains guidance material about the role and limitations of modelling programs (<http://www.fsis.usda.gov/OPPDE/rdad/FSISNotices/50-03.htm>).

## References

Brown, M. (2000) *HACCP in the meat industry*. CRC Press, England. Pp: 182-185, 206-208.

Chang, V.P, Mills, E.W. and Cutter, C.N. (2003). *Reduction of bacteria on pork carcasses associated with chilling method*. *Journal of Food Protection*, 66: 1019-1024.

Delmore, R. J., Sofos, J. N., Belk, J. N., Lloyd, K. E., Bellinger, W. R. (1999) *Good manufacturing practices for improving the microbiological quality of beef variety meats*. *Dairy, Food and Environmental Sanitation*, 19: 42-52.

Gill, C.O. and Bryant, J. (1997) *Assessment of the hygienic performance of two beef carcass cooling processes from product temperature history data or enumeration of bacteria on carcass surfaces*. *Food Microbiology*, 14: 593-602.

Gill, C. O., Harrison, J. C. L. (1984) *Evaluation of the hygienic efficiency of offal cooling procedures*. *Food Microbiology* 2: 63-69.

Hanna, M. O., Smith, G. C., Savell, J. W., McKeith, F. K., Vanderzant, C. (1982) *Microbial flora of livers, kidneys and hearts from beef, pork and lamb: effects of refrigeration, freezing and thawing*. *Journal of Food Protection* 45: 63-73.

McEvoy, J.M, Sheridan, J.J, Blair, I.S and McDowell, D.A. (2004) *Microbial contamination on beef in relation to hygiene assessment based on criteria used in EU Decision 2001/471/EC*. *International Journal of Food Microbiology*, 92: 217-225.

Meat & Livestock Australia (1998a) *Safe beef carcase chilling*

*procedures – chilling strategies for export works – spray chilling*. MSQS.006.

Meat & Livestock Australia (1998b) *Weekend chilling strategies for export works*.

Phillips, D., Sumner, J., Alexander, J. F., Dutton, K, M. (2001a) *Microbiological quality of Australian beef*. *Journal of Food Protection*, 64: 692-696.

Phillips, D., Sumner, J., Alexander, J. F., Dutton, K, M. (2001b) *Microbiological quality of Australian sheep meat*. *Journal of Food Protection*, 64: 697-700.

Ross, T. (1999) *'Predictive Microbiology for the Meat Industry'*. Meat and Livestock Australia.

Note: Chapter 2, Literature review and data collation, Chapter 3, Model evaluation and collation, Chapter 4, Model development and in-plant evaluation of *Klebsiella oxytoca*, and Chapter 5, Quantifying and utilising lag times in predictive microbiology.

Smith, M. G. (1985) *The generation time, lag time, and minimum temperature of growth of coliform organisms on meat, and the implications for codes of practice in abattoirs*. *Journal of Hygiene*, 94: 289-300.

Sumner, J., Krist, K. (2002) *The use of predictive microbiology by the Australian meat industry*. *Journal of Food Protection* 73: 363-366.

Sumner, J. (1998) *Microbiological testing for the meat industry*. Meat & Livestock Australia, Sydney.

Vanderlinde, P. B., Shay, B., Murray, J. (1998) *Microbiological quality of Australian beef carcass meat and frozen bulk packed beef*. *Journal of Food Protection*, 61: 437-443.

Vanderlinde, P. B., Shay, B., Murray, J. (1999) *Microbiological status of Australian sheep meat*. *Journal of Food Protection*, 62: 380-385.

The information contained herein is an outline only and should not be relied on in place of professional advice on any specific matter.

**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.

**Need additional information help, information or advice? Contact one of the following**

#### BRISBANE:

Food Science Australia  
PO Box 3312  
TINGALPA DC Qld 4173

#### Ian Eustace

Ph. 07 3214 2117  
Fax. 07 3214 2103  
Mob. 0414 336 724  
[Ian.Eustace@csiro.au](mailto:Ian.Eustace@csiro.au)

#### Neil McPhail

Ph. 07 3214 2119  
Fax. 07 3214 2103  
Mob. 0414 336 907  
[Neil.McPhail@csiro.au](mailto:Neil.McPhail@csiro.au)

#### MELBOURNE:

Food Science Australia  
Private Bag 16  
WERRIBEE Vic. 3030

#### Jocelyn Midgley

Ph. 03 9731 3424  
Fax. 03 9731 3250  
Mob. 0414 647 231  
[Jocelyn.Midgley@csiro.au](mailto:Jocelyn.Midgley@csiro.au)

#### SYDNEY:

PO Box 181  
KURMOND  
NSW 2757

#### Bill Spooncer

Ph. 02 4567 7952  
Fax. 02 4567 8952  
Mob. 0414 648 387  
[Bill.Spooncer@csiro.au](mailto:Bill.Spooncer@csiro.au)

#### ADELAIDE:

PO Box 178  
FLAGSTAFF HILL  
SA 5159

#### Chris Sentance

Ph. 08 8370 7466  
Fax. 08 8370 7566  
Mob. 0419 944 022  
[chrisfss@ozemail.com.au](mailto:chrisfss@ozemail.com.au)