RECOMMENDATIONS FOR CHILLING AND HOLDING MEAT

By

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INTRODUCTION

Meat chilling has been the subject of investigation by engineers and scientists in many countries; hundreds of papers have been published in scientific and technical journals since Scott and Vickery (CSIRO Bulletin No. 129, 1939) carried out their pioneering studies fifty years ago. The recommendations they made for chilling carcasses and sides in the 24 hours following slaughter and in subsequent chilled storage are as valid today as they were then. Later work has greatly amplified our knowledge of practical operation of chillers and improved our understanding of the basic mechanisms involved. Bibliographies of relevant publications are available from several research Institutes, notably CSIRO Meat Research Lab. in Brisbane; British Meat Research Institute in Langford, Bristol; and MIRINZ in Hamilton, New Zealand.

Why then, in 1988, is it so difficult to give a satisfactory answer to a question asked time and time again:

What operating conditions must I use to optimise my chilling process?

We are unable to give a straight answer because, in a meatworks, the development of an optimum chilling procedure has to take into account a number of regulatory, economic and technical considerations. The optimum procedure would be complex and would require supervision and control at a level rarely available in meatworks. The following outline of factors affecting meat chilling is based on a paper given by the author to a CSIRO School for Meat Industry Engineers in 1973.

CONSIDERATIONS IN CHILLING

It is necessary to chill hot carcasses or sides and, if they are to be marketed as chilled meat, to maintain them cold (but not frozen) in order to limit or prevent growth of spoilage organisms.

In practice, different chilling procedures have been developed to suit local circumstances. For example, meat for local trade does not have to be stored for extended periods, so that less rigorous procedures may give sufficient storage life. For export meat, however, a long storage life is essential and the best procedure must be adopted. Chilling procedures vary from abattoir to abattoir as do chiller designs - it is not unusual to find in the one abattoir beef chillers of different design operating on different chilling cycles - the result of the uncertain state of knowledge which allows managers and engineers scope for original thinking in this vitally important area of meat works operation.

The choice of a chilling procedure to give best results in a given application must not only be capable of meeting requirements of regulatory authorities but must take into account several complex technical and economic considerations. These are grouped under four broad headings in Table 1. Most, if not all, are of economic significance in the final analysis - thus, product quality influences the price obtained for the meat, with heavy penalties incurred for serious quality defects.

TABLE 1: CONSIDERATIONS INVOLVED IN SELECTION OF CHILLING PROCEDURES.

REGULATIONS:	Chilling cycle must conform to regulations of Australia and/or importing country.
QUALITY:	Quality deterioration (spoilage by micro-organisms, surface wetting by condensation, loss of bloom and surface drying, toughening).
ECONOMIC:	Weight loss by evaporation and drip.
	Capital, operating and maintenance costs of chillers and refrigeration plant.
PRODUCTION:	Chilling cycle must suit production schedule.
	Chilled carcasses must by suitable for further processing (cutting, boning).

Table 2 tabulates the more important effects of the considerations of Table 1, also the physical and other factors which control them. The order in which they are listed is what the author believes to be the order of their importance to managers in the Australian meat industry. Production factors and refrigeration costs are listed last, not because they are of little importance, but because they are highly specific to a given application and therefore difficult to include in any general analysis. Knowledge and control of air temperature, velocity and relative humidity (R.H.) are fundamental to chilling procedures, influencing the rate of chilling and the temperature and wetness of the carcass surface.

TABLE 2: FACTORS IN CHILLING, THEIR EFFECTS AND CONTROL

Priority	Factor	Effect	Controlling Variables
1	Regulations	Over-riding	Orders set by Australia and importing country.
2	Evaporative weight loss	Direct loss of product	Air temp., R.H.& vel.; fat cover; chilling rate; time in chiller.
3	Drip	Direct loss of product	Temp. too low, causing meat to freeze.
4	Spoilage	Decreased storage life	Surface temp. & wetness; time in chiller.
5	Condensation	Decreased storage life	Air temp. & R.H.; surface temp.; operating cycle
6	Toughening, loss of bloom, surface drying	Loss of value	Chilling rate.
	Production	Throughput & effy.; working conditions	Time in chiller; final temp. of carcass surface
	Refrigeration costs	Plant economy	Refrig. capacity; rate & time of chilling; operating cycle

Many of the variables listed in Table 2 are under management control, although local factors such as poorly designed chillers, production requirements etc. may severely restrict the scope for altering conditions and effecting improvements.

The leading points of regulations applicable to meat chilling as at July 1988 are summarised in Table 3. In export abattoirs, inspection of meat processing is the responsibility of the Commonwealth Department of Primary Industry and Energy, who apply their own regulations and those of the country to which the meat is to be exported.

TABLE 3: REGULATIONS APPLICABLE TO MEAT CHILLING

Authority	Temperature/Time Requirements
DPI & E Aust. No. 250 of Export Meat Orders 2/1985	Meat temp. shall be reduced to not more than: a) 20°C within 20 hrs. for cattle, calves more than 40 kg and pigs more than 100 kg b) 20°C within 8 hrs. for sheep, lambs, goats and small calves and pigs. A max. temp. of the meat surface (10-12°C) is stipulated for chilled storage.
USDA	Accept DPI regulations, on basis of inspection of works by USDA vets.
EEC Third Country Directive	Carcasses must be chilled immediately; must be at 7°C or less before further processing.

It is noteworthy that chiller air temperature, velocity and R.H. have not been specified in any of the regulations in Table 3, only that the product shall be cooled to a given temperature in a given time (Australian DPI & E) or that the meat shall be at a given temperature before and during processing and storage (EEC Third Country Directive). The choice of chilling conditions to give these temperatures is thus left to chiller operators. Some of the design and operating variables involved in this choice are listed in Table 4.

TABLE 4: DESIGN AND OPERATING VARIABLES IN CARCASS CHILLING

Basic Variable	Affected By
Air Velocity	Fan characteristics; fan power; resistance to air flow in cooling units; location of units; type, number, size and spacing of carcasses.
Air Temperature	Heat transfer rating of cooling units; coil area; heat load; refrigeration capacity
Air RH	Coil area; heat load; refrigerant temp.

CHOICE OF CHILLING PROCEDURE.

In hot meat chillers, body heat is removed from carcasses straight off the slaughter floor. Air is the cooling medium and heat is transferred to the air by convection and evaporation at the surface of the carcass. Heat is transferred from the deeper layers of meat to the surface by conduction. Meat is a poor conductor of heat, so that in meat thicker than 2 or 3 cms, conduction eventually limits the rate of cooling. In the earlier stages of chilling, however, convection and evaporation are controlling; the rate at which they remove heat and water from the surface is affected by changes in the basic variables of air velocity, temperature and relative humidity (see Tables 2 and 4).

As an example, one possible answer to the question:

What operating conditions must I use to optimise my chilling process?

is as follows for beef sides.

Assumptions made include:

- chiller is of good design;
- cooling units have variable speed fans;
- capacity of refrigeration plant and chiller cooling units is adequate to allow air temperatures to be maintained at sub-zero levels early in the cycle;
- bodies electrically stimulated to prevent cold-shortening.

a) Sides to be Boned Next Day.

It is essential that the procedure gives meat temperatures that conform to the appropriate regulation. The temperature referred to in Table 3 is the deep butt temperature of the heaviest side in the slowest cooling zone of the chiller - the "worst-case" side. For sides that are to be boned the next day, there are good reasons for not cooling at a faster rate than the regulations require.

Heavier sides cool more slowly, so are loaded first and hung in parts of the chiller that receive a good flow of air - for example, on outside rails close to the cooling units. Sides are spaced so that they do not touch, allowing unimpeded flow of air over all surfaces of every side. A flow of high velocity (say 3 m/s), low temperature (say minus 6°C) air during the first few hours gives cold dry surfaces on which the growth of spoilage organisms is inhibited. Conditions must be such that the thin meat of lighter sides does not freeze. After a given time at this fast rate of cooling, air velocity is decreased to 0.2 m/s and temperature increased progressively to 7°C. This allows the heat remaining in the deep meat - still at close to slaughter temperature - to move under the slow transfer mechanism of conduction to the cold layers at the surface. Ideally, 24 hours after slaughter, the deep butt temperature in the "worst-case" side should be 20°C and the surface temperature about 10°C. Surface fat on such a side will be soft and present no problems in the boning room; the average temperature of meat packed into cartons will be much below 20°C, in fact, closer to 10°C.

The use of an initial fast rate of cooling followed by a slower rate not only minimises growth of spoilage organisms, it also reduces weight loss (shrink) by as much as 0.7% (from 2.3 to 1.6% based on hot/wet to cold/dry weights).

b) Sides to be Boned 3 or 4 Days After Slaughter.

For sides to be stored for several days before boning or being sold bone-in, a rate of cooling faster than for sides to be boned next day is desirable. In the early stages, a low temperature/high velocity airflow is used, as in case a) above, but in the later stages velocity is decreased to 0.2 m/s and temperature increased progressively to only 2 or 3°C. Under these conditions, at 24 hours after slaughter surface fat on the "worst-case" side will be set hard at 5°C or below and deep butt temperature will be below 20°C; shrink loss will be about 1.6%.

The 0.2 m/s, 2°C airflow is maintained until early in the morning on which the sides are to be boned; by now the sides are at about 3°C throughout and the surface fat is rock hard. Shrink loss will have continued at about 0.2% per day, provided the R.H. of the airflow is kept at about 95% - higher values encourage the growth of spoilage organisms, lower values give rise to greater shrink losses.

About 4 hours before boning is to commence, air temperature is increased to 20°C and velocity to 2 to 3 m/s, so that when sides enter the boning room, the temperature of the surface fat has increased to 10 to 15 °C. Although the fat is warm and soft, heat has penetrated only about 1 cm and the deep meat remains at 3°C.

CONCLUSIONS

The considerations involved in the design and operation of carcass chillers are many and varied; chilling procedures required to give the best result in any given application are complex and involve a level of control and supervision rarely found in meatworks. In this paper, an attempt has been made to list and explain the significance of the major considerations. A beef side chilling procedure is given as an example of how chiller conditions can be manipulated to meet DPI & E regulations while achieving low shrink, high meat quality and boneable carcasses.

"Spray-chilling", used in North American meat works, is being promoted in Australia. Water is sprayed at intervals over sides in the hot meat chiller, replacing water lost from the body by evaporation. A paper in March 1988 International Journal of Refrigeraiton describes the cooling of pig bodies using cold air at 0°C and 100% R.H. produced by direct contact cooling with ice-water. Both these methods are capable of greatly reducing shrink losses, but they maintain carcass surfaces in a fully wetted condition throughout chilling and storage. Spoilage organisms will grow more rapidly and there is some doubt as to the long term storage quality of the product. "Hot-boning" is seen by many as the future solution which will eliminate short-comings of conventional chill-boning processing. There are, however, formidable hygiene problems in a boning room handling hot meat and in cooling the product after it has been packed in cartons and hot boning is not in regular use in any Australian abattoir, as far as is known.

Development of the optimum chilling procedure requires the combination of knowledge and skills at both practical and theoretical levels. The cost and effort involved would, it is believed, be justified by increased yield of meat and improved quality control.