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Options for Hot Boning

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Summary

There is a risk that pathogenic bacteria can grow on hot-boned meat as the boneless meat cools in cartons to 8°C. If the cooling rate is fast enough, the risk of growth can be limited to less than 1 $\log_{10}$ (10 times) increase. The cooling rates required to limit microbial growth to this extent are not usually practical for meat boned straight off the slaughter floor and packed at 30–35°C. If meat is packed in shallow cartons and cooled in a plate freezer or air-blast freezer operating at a low air temperature (<–35°C) and high air velocity (>3 m/s), it should be possible to limit the growth of mesophilic bacteria on meat packed at 30–35°C to 1 $\log_{10}$ increase. If conventional packing and freezing techniques are used, carcasses should be cooled to 33–35°C. before hot boning starts and meat packed at about 25–27°C.

If cooling rates which could allow more than 1 $\log_{10}$ increase in mesophilic bacteria on hot-boned meat are used, the growth can be compensated for by reduced contamination on carcass and boneless meat. Contamination on hot-boned meat can be reduced by applying carcass decontamination or by controlling livestock procurement, as well as slaughtering, dressing and boning procedures which affect meat hygiene.

By controlling the initial contamination on hot-boned meat and the cooling rate of the boneless meat, it is possible to produce frozen or chilled hot-boned meat of equivalent microbial quality to conventionally cold-boned meat.

Introduction

In Australia, hot boning usually means boning carcasses that have a deep-butt temperature of more than 20°C. This definition arises from the Export Meat Orders (EMOs) which clearly state that carcasses that have not been cooled to 20°C can only be boned if the boning room has an approved hot-boning program.

The EMOs also specify the time allowed to cool hot-boned meat to 8°C. The time allowed depends on the temperature of meat at the time of packing and decreases as the meat temperature increases. Under these conditions, it is not possible to hot bone meat straight off the slaughter floor using conventional packing and air-blast freezing techniques. This is because meat boned straight off the slaughter-floor would be packed at a temperature of 30–35°C (Anderson et al. 1984) and could not be cooled to 8°C within the time allowed unless unconventional techniques are used.

Hot-boning programs have been developed to allow for cooling carcasses before boning starts. If carcasses are cooled to 30–35°C deep-butt temperature, meat can be packed at less than 27°C (Spooncer 1992). Meat packing at this temperature in conventional cartons can be cooled to 8°C in air-blast freezers within the time allowed.

The EMOs are under review. The new regulations allow for hot-boning programs to be approved in cases where the requirement to cool meat to 8°C within a specified time is not applied. In those cases, the overall production procedures, including cooling rates, can be taken into account. If the production procedures are controlled and it can be shown that meat produced under the controlled procedures is of suitable microbiological quality, the hot-boning program can be approved.

Microbiology of Hot-boned Meat

A disadvantage of hot-boned meat is that there is a risk that the meat can support the growth of pathogenic bacteria as it cools. In conventional boning, microbial growth on carcasses is controlled by a combination of drying and cooling the carcass surface. When the meat is boned and packed, moist meat surfaces will be contaminated and provide an opportunity for microbial growth. The surface temperature of boneless meat from chilled carcasses is usually less than 15°C for beef and less than 10°C for mutton. At these temperatures, the growth of pathogenic bacteria is slow and the meat should cool to 8°C within a few hours of boning. At 8°C and below, the growth of pathogenic bacteria is negligible.

In the case of hot-boned meat the boneless meat surfaces could be 20–35°C at the time of packing. At these temperatures, pathogenic bacteria can grow quickly.

There are two approaches to preparing hot-boned meat of equivalent microbiological quality to conventionally boned meat. One is to cool hot-boned meat quickly after it is boned, to control the microbial growth; the other is to minimise contamination on carcass and boneless meat. This can be achieved through selection and handling of livestock; hygienic slaughtering, dressing and boning practices; and decontamination of carcass meat.

Cooling Rates for Hot-boned Meat

The growth of mesophilic bacteria on hot-boned meat in a carton as the meat cools to 8°C has been studied by Smith (1978). From this work, the amount of growth that can be expected on hot-boned meat as it cools can be predicted. If hot-boned meat is cooled to 8°C within the times shown in Table 1, the growth of mesophilic organisms on the meat will be restricted to less than 1 $\log_{10}$ increase. Table 1 also shows the overall cooling rate that must be achieved in a freezer or chiller to cool meat to 8°C within the nominated times. The cooling rates allow for a 30-minute delay between packing and placing the meat under refrigeration.

The cooling rates shown in Table 1 have been the basis of hot-boning programs in Australian boning rooms between 1986–1993. Meat packers and regulatory authorities can be confident that there will be no more than 1 $\log_{10}$ increase in pathogenic bacteria at the centre of cartons cooled within the times listed in Table 1.

Achieving Cooling Rates

If microbial growth on hot-boned meat is controlled by applying the cooling rates shown in Table 1, there are options for selection of initial carcass-chilling period and initial packing temperature, depending on the cooling rate that can be achieved. Boning rooms can manipulate cooling conditions to achieve a rapid cooling rate and thereby take advantage of applying the maximum initial packing temperature. The factors

Table 1: Cooling rates required to limit the growth of mesophilic bacteria on moist meat in cartons to no more than 1 $\log_{10}$ (10 times) increase.

Initial packing temperature (°C)	Maximum time to cool meat to 8°C (min)	Required cooling rate (°C/h)
35	417	4.19
34	432	3.88
33	448	3.59
32	465	3.45
31	483	3.05
30	502	2.79
29	521	2.57
28	542	2.34
27	565	2.13
26	589	1.93
25	615	1.74
24	643	1.57
23	675	1.39
22	709	1.24
21	748	1.09
20	793	0.94

which affect cooling and which can be manipulated to some extent are:

- freezer type;
- freezer air temperature;
- carton style, size and fibreboard;
- packing style;
- freezer air velocity.

Freezer type

Plate freezers can cool cartoned meat more rapidly than air-blast freezers, and are a good option for cooling hot-boned meat.

Measurements of the cooling rate of hot-boned meat in a plate freezer have shown that bulk-packed meat in a 165 mm deep carton cooled to 8°C at an average rate of 2.45°C/hr when the plate temperature was –30°C. Similar cartons of meat cooled in an automatic air-blast freezer with an air temperature of –30°C cooled to 8°C at an average rate of 1.58°C/h. This means that the meat placed in the plate freezer at an initial temperature of 28°C would cool to 8°C within the time required to limit the growth of mesophilic bacteria to a 1 $\log_{10}$ increase. Meat cooled in the air-blast freezer would have to be packed at an initial temperature of 24°C.

Plate freezers are not commonly available in the Australian meat industry and the freezing option is usually between automatic air-blast freezers (AABF) and batch blast freezers. In theory, a batch blast freezer has an advantage over an automatic blast freezer because cartons can be placed on racks or stillages so that the sides of the cartons do not touch, and meat can cool through each side of the carton.

In an automatic blast freezer, the cartons are pressed together on the shelves and this reduces the surface area of carton available for cooling. The cooling rate of cartons with the short sides pressed together is up to 10% slower than cartons with all sides exposed; and, if the long sides are pressed together, the cooling rate is up to 15% slower (Lovett & Herbert 1978).

In practice, automatic blast-freezers often perform better than batch freezers. It is hard to get uniform air circulation in a batch freezer, and cartons in dead spots or areas of low air movement will cool slowly. There may be areas of high and low air circulation in an automatic blast freezer, but, as the cartons are conveyed through the freezer, they should all experience the same average cooling conditions.

The construction of stillages and shelves in freezers has an effect on cooling rates. Freezers with corrugated shelves can have a 10% advantage in cooling rate over freezers with flat shelves.

Freezer air temperature

Obviously, the air temperature in a blast-freezer will affect cooling rates. In tests on one freezer, bulk meat packed in 165 mm cartons cooled to 8°C at a rate of 1.58°C/h when the air temperature was -30°C and 1.43°C/h when the air temperature was -25°C. The air velocity was 3 m/s. At cooling rates of 1.58°C/h and 1.43°C/h, meat could be packed at initial temperatures of 24°C and 23°C respectively.

In another test, bulk meat in 150 mm cartons cooled to 8°C at a rate of 1.25°C/h at -17°C; 1.31°C/h at -20°C. and 1.52°C/h at -23°C. The air velocity was 2.5 m/s. At cooling rates of 1.25°C/h and 1.31°C/h, the initial packing temperature should be 22°C; and at 1.52°C/h the initial packing temperature should be 23°C.

In general terms, if the air temperature in a blast freezer is reduced by 5°C, it should be possible to increase the initial temperature at packing by 1°C and still cool the meat to 8°C within the time required to restrict the growth of mesophilic bacteria to 1 $\log_{10}$ increase.

Carton size and style

The cooling rate of bulk meat packed in cartons of different depth is shown in Tables 2 and 3. These tables also show the initial packing temperature appropriate for the measured cooling rates.

Carton style also affects cooling rates, depending on the surface area of the carton that has a double layer of fibreboard. A box-and-cap style carton should provide a faster cooling rate than a box-and-lid style. Cooling rates in box-and-lid cartons are more rapid than overlap-slotted containers.

Table 2: Cooling rate to 8°C in different size cartons of bulk meat in a freezer at –30°C and air velocity 3 m/s

	150 mm Carton	165 mm Carton
Cooling rate (°C/h)	1.87	1.58
Appropriate initial temperature (°C)	25	24

Table 3: Cooling rate to 8°C in different size cartons of bulk meat in a freezer at –20°C and air velocity 2.5 m/s

	105 mm Carton	135 mm Carton	150 mm Carton
Cooling rate (°C/h)	2.05	1.52	1.31
Appropriate initial temperature (°C)	26	23	22

Different types of fibreboard have different thermal properties and will affect cooling rates. The time taken to cool meat in solid fibreboard cartons is about 25% less than in B-flute cartons; and the cooling time in E-flute cartons is about 15% less than in B-flute.

Solid fibreboard cartons are more expensive than corrugated board and are not often used. E-flute cartons have less strength than B-flute cartons but should be satisfactory for frozen bulk-packed product.

Packing style

The way in which meat is packed into cartons can have a major impact on cooling rates. Solid packs such as bulk-packed and layer-packed meats have uniform cooling rates, as long as the top surface of the meat makes good contact with the carton (i.e. no air gap between the meat and carton).

The cooling rate of individually wrapped (IW) meat may be faster or slower than bulk meat. Air spaces in cartons of IW-packed meat will slow down cooling rates. However, the amount of meat in IW cartons and, therefore, the total heat load is usually less than in bulk-packed meat. As a result of the lower heat load, individually wrapped cuts may cool more quickly than bulk-packed meat, as long as the cuts make good contact with the top and bottom of the cartons.

If cuts do not make good contact with the top and bottom of the carton, for example in the case of IW bone-in mutton legs, the cooling rate may be slow, despite the low heat load in the carton.

In a trial with an automatic air-blast-freezer operating at –28°C, and air velocity at 3 m/s, IW knuckles and silversides in 175 mm cartons cooled at a rate of 2.11°C/h – which would suit an initial packing temperature of 26°C. Bulk-packed boneless beef in the same freezer cooled to 8°C at 1.65°C/h – which would suit a packing temperature of 24°C.

Air velocity

The average air velocity in blast freezers is usually 2–3.5 m/s. Change of air velocities over this range has only a small effect on cooling rates. Within individual freezers, there could be a wide variation in air velocities at different points and this could account for variations in freezing rates of cartons in a freezer.

Examples of cooling options

Table 4 shows cooling rates for hot-boned meat that have been measured under different conditions. The rates apply to solid packs (bulk packed or layer packed). The appropriate initial temperatures at the time of packing which correspond to the cooling rates are also shown.

Chilled Meat

To control the microbial growth on vacuum-packed chilled meat, the same cooling rates used to control microbial growth in frozen meat should be applied.

Tests have been conducted on cooling vacuum-packed cuts placed in part cartons with lids off, and with cuts placed one layer deep in open crates.

Vacuum-packed cuts placed in part cartons (approximately 12 kg per carton) with no lid on the carton and cooled in a chiller at –2.5°C and air velocity 0.3-0.5 m/s over the meat, cooled to 8°C at 1.67°C/h.

Vacuum-packed cuts placed one layer deep in open plastic crates (similar to bread carter's trays) and cooled in a chiller at –2°C and air velocity 1 m/s, cooled to 8°C at 2.21°C/h.

Vacuum-packed product can be cooled in chillers at similar rates to those achieved when cooling meat in blast freezers, as long as the product is exposed to chiller air.

Carcass Temperature

The cooling rates achieved for hot-boned meat determine the appropriate temperature for boneless meat at the time of packing. To achieve a particular packing temperature, carcasses may have to be cooled before boning starts. When meat is exposed during boning, evaporative cooling occurs at the surface and the temperature may drop several degrees. Therefore, there is a difference between carcass temperature and boneless-meat temperature.

If meat is boned straight off the slaughter floor, the carcass deep-butt temperature will be about 40–42°C. By the time the meat is boned and packed, the surface temperature of most meat will be 32°C or less, and the internal tissues less than 35°C (Anderson et al. 1984). Meat boned straight off the slaughter floor should be cooled from a packing temperature of 32–35°C to 8°C within 417 to 465 minutes to limit the potential growth

Table 4: Examples of cooling rates of hot-boned meat between the time of packing and 8°C under different cooling conditions.

Freezer type	Freezer temp. (°C)	Air velocity	Carton depth (mm)	Carton type	Cooling rate °C/h	Approp. initial temp.
Plate	–30	-	165	Box+cap B-flute	2.45	28°C
AABF	–30	3 m/s	165	Box+cap B-flute	1.58	24°C
AABF	–30	3 m/s	150	Box+cap B-flute	1.87	25°C
Batch	–35	3 m/s	125	Box+cap E-flute	2.5	28°C
Batch	–20	2.5 m/s	105	Box+cap B-flute	2.05	26°C
Batch	–20	2.5 m/s	150	Box+cap B-flute	1.31	22°C

of mesophilic bacteria to 1 $\log_{10}$ increase. The appropriate cooling rate in the freezer would be 3.45°C/h to 4.19°C/h, allowing 30 minutes between packing and placing cartons in the freezer.

The difference between carcass temperature and boneless-meat temperature depends on boning conditions and the type of meat. In general, the difference between deep-butt temperature and boneless-meat temperature is in the range 4–8°C. This means that in a boning room which is packing meat in 160 mm cartons and cooling meat in a freezer at –30°C; carcasses should be cooled to about 30–33°C in order to pack meat at an initial temperature of 25°C.

Options for Hot Boning

Hot boning of beef straight off the slaughter floor is not practical with typical packing and freezing conditions, if it is intended to control the growth of mesophilic bacteria on the meat to a 1 $\log_{10}$ increase. Under typical conditions, the meat should be packed at about 25°C which means cooling carcasses to about 33°C before boning commences. This amount of cooling takes several hours and would nullify many of the benefits of hot-boning; however, such a hot-boning plan could offer the flexibility of same-day boning.

The same boning conditions are more practical for mutton since mutton carcasses can be cooled to 33°C in about 1–2 hours.

With modified conditions, such as cartons of reduced depth (100–125 mm) made out of E-flute fibreboard, low air temperature (<-35°C) and a freezer with uniform and high air velocity (>3 m/s), hot boning of beef off the slaughter floor or after a short carcass-chilling period may be possible. Similarly, hot boning of beef off the slaughter floor could be feasible if the boneless meat can be cooled in a plate freezer.

If cooling rates for hot-boned meat are slower than what is required to limit the growth of mesophilic bacteria to 1 $\log_{10}$ increase, it is possible to compensate for the potential growth of bacteria on the boneless meat by reducing the initial contamination on the meat by carcass decontamination or improved hygiene.

Carcass decontamination

Decontamination can be achieved by applying hot water to a carcass. A 1 $\log_{10}$ reduction in bacteria on a carcass surface can be achieved by applying water at 66°C for 20 seconds or at 82°C for 10 seconds (Davey 1987). Decontamination can also be achieved by application of warm solutions of organic acid. A 1.5% solution of acetic acid at 55°C applied for 10 seconds will achieve a 1.3 $\log_{10}$ reduction in bacteria on meat (Eustace et al. 1980).

Decontaminated meat may not be suitable for hot boning straight off the slaughter floor since the carcasses would be wet. Wet carcasses are difficult to hot bone and a drying period before boning may be necessary.

Improved hygiene

Control of hygiene in livestock handling, slaughtering, dressing and boning can reduce the risk of contamination of carcass and boneless meat with pathogenic organisms. If initial contamination of carcass meat is controlled, it is possible to produce hot-boned frozen meat with acceptable microbiological quality even if the hot boned meat is cooled at a rate which would allow more than 1 $\log_{10}$ increase of bacteria on the meat.

The hygiene procedures which can influence the microbial quality of hot-boned meat have not been quantified, but could include drawing stock from a limited area, killing only clean stock, killing stock within a restricted time from receival, sourcing stock direct from farms, in addition to performing hygienic dressing and boning procedures consistently.

If the procedures which could affect the microbial quality of hot-boned meat are documented, and are performed consistently according to a quality-assurance program, it would be possible to demonstrate that meat of acceptable quality can be produced under the conditions specified in the quality-assurance program. In this case, a hot-boning program which does not include the cooling rates required to limit growth of mesophilic bacteria on hot-boned meat to 1 $\log_{10}$ increase could be approved.

Conclusion

For meat boned straight off the slaughter floor, the cooling rates required to limit bacterial growth on meat to less than 1 $\log_{10}$ increase cannot be achieved with conventional packing and freezing techniques. To comply with required cooling rates, carcasses should be cooled to a deep-butt temperature of about 30–35°C and boneless meat packed at temperature of about 24–28°C.

Meat boned straight off the slaughter floor has an initial packing temperature of about 30–35°C and this meat should cool to 8°C in 502–417 minutes to limit microbial growth to 1 $\log_{10}$ increase. This type of cooling rate could be achieved in small cartons cooled in a plate freezer, or a blast-freezer operating at unusually low air temperature (<–35°C) and high air velocity (<3 m/s).

References

Anderson, J., Buhot, J.W., Herbert, L.S. & Larnach, W.K. (1984). The investigation of methods of cooling and freezing hot boned beef. Meat Research Report 12/84. CSIRO Division of Food Research, Cannon Hill, Qld.

Davey, K. R. (1987) The decontamination of sides of beef using hot water in a novel cabinet - A summary of laboratory studies. Meat Research Record A/87, CSIRO Division of Food Research, Cannon Hill Qld.

Smith, M.G. (1978) The microbiology of hot-boned meat. In Advances in Meat Technology, CSIRO Division of Food Research, Cannon Hill, Qld.

Lovett D.A. & Herbert L.S. (1978) Design methods of carton freezers. Meat Research Report 12/78, CSIRO Division of Food Research, Cannon Hill Qld.

Eustace I.S., Bill B.A., Gibbons R.A. & Powell V.H. (1980). Vacuum packaged lamb carcasses. Extension of storage life by treatment with acetic acid solution prior to packaging. Meat Research Report 8/80, CSIRO Division of Food Research, Cannon Hill Qld.