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THE HYGIENIC ADEQUACY OF THE BEEF CARCASS COOLING PROCESS

R.J. JONES

Meat Industry Research Institute of New Zealand, Hamilton, New Zealand

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INTRODUCTION

An acceptable meat processing practice will produce product that is both safe and has a storage life compatible with commercial expectations. The achievement of these objectives is heavily dependent on minimizing both bacterial contamination of the product (an inevitable occurrence in the manufacturing environment) and the subsequent growth of contaminating organisms (Grau, 1987).

In a moist, rich environment, such as fresh meat, bacterial growth can be controlled by manipulating two growth factors: time and temperature. To be effective, this control must focus on the part of the product prone to bacterial contamination (i.e., the meat surface), and the effectiveness of such control can be assessed using bacterial enumeration methods such as plate counting. However, such traditional process control methods can be time consuming, costly and inaccurate. This makes an alternative method of process assurance, that minimizes these disadvantages, attractive. Such a method is temperature function integration (TFI) (Olley, 1978), which predicts the potential of a process to allow bacterial growth by integrating the process's time-temperature history with an appropriate bacterial growth model (Gill *et al.*, 1988; Lowry, 1988). This concept has been developed further by producing hardware and software that will monitor a process's time-temperature history, perform the integration and generate a numerical value known as the process hygiene index (PHI) (Jones, 1990). This value reflects the potential for bacterial growth - the higher the PHI, the greater the potential for growth.

TFI has the potential to be a convenient and effective quality assurance tool. However, it is useful only if standards that describe acceptable processes are available for reference. In New Zealand, TFI has been used to propose guidelines for the beef carcass cooling process based on a process that operates comfortably within accepted levels of "good manufacturing practice" (GMP) (Gill *et al.*, 1991). PHI-based standards for sheep processing have also been proposed (Jones, 1993) but are conceptually different to those of Gill because they are based on minimal but acceptable processing practice requirements. In other words, the standards are based on a commercial process that produces marginal, but acceptable, product. This paper will suggest a similar processing standard for beef carcass cooling from slaughter to when the carcass temperature drops below 7 °C, at which point the growth of mesophyllic organisms of public health importance is unlikely to be significant (Nottingham, 1982).

MATERIALS AND METHODS

Cooling process description

A commercial beef chiller was evaluated using electronic temperature loggers (Delphi™; Trutest, Auckland). The monitored chiller produced meat destined for freezing, and its performance was considered acceptable because it met the currently accepted convention: in having the capability to cool carcasses to a deep leg temperature below 7 °C within 48 hours. However, the chilling operation was also marginal because the time to cool to a deep temperature of 7 °C tended to be close to the 48-hour limit specified by NZMAF (1991).

After slaughter, carcasses were split and the sides placed in the chiller, which had been equilibrated to 4°C. Ten sides, representative of grades and weights, were chosen per load and were placed at positions in the chiller to give a representative sample of overall chiller performance. The time between sticking and chiller entry was less than one hour. A Delphi™ temperature logger was then attached to each of the ten selected sides (described later) within 10 minutes of the side entering the chiller.

Chiller loading took between 1.5 and four hours. The doors were then closed and sides left to cool, either over the weekend (52 to 60 hours) or overnight (12 to 16 hours) at constant refrigeration with an air temperature set-point of 4°C. Eleven chiller runs were tested.

Use of data loggers and software

The Delphi™ temperature logger is a microprocessor-controlled recorder contained within a 160x100x20mm case and connected to a thermistor encased within a 100mm teflon probe. Before use, the logger was connected to an IBM-compatible personal computer (PC) through an interface (Trutest, Auckland) and, using the MIRINZ AP1 program, programmed to collect temperature data every 1.875 minutes. The logger, once running, was suspended from a selected side by means of a skewer, and the probe was held against the carcass surface by means of a stainless steel disc of 40mm diameter. This disc was pinned, using a plastic staple, to the surface of the side at a site within the aitch-bone pocket. This site had previously been determined to be the slowest cooling site on a beef carcass, and thus afforded the greatest opportunity for bacterial growth (Gill *et al.*, 1991). The logger probe was inserted into a cone-shaped retaining slot within and running across the diameter of the disc between the two retaining pin holes. The assembly was designed to hold the stainless steel disc against the tissue surface so that the logger probe would accurately measure the surface temperature. Plastic was chosen for the pin because relative to other materials it does not conduct heat from deep tissue to the disc; therefore, the monitored temperature was a true reflection of the meat surface temperature.

Process assessment

At the completion of the cooling period, the logger was removed from the carcass. Data were collected and a PHI value was generated using the MIRINZ AP1 computer program. Although 110 carcasses were monitored, due to technical difficulties only 103 usable time-temperature histories were obtained.

A PHI for the process was automatically calculated from each set of data, using a triphasic *E.coli* growth model derived from a wild-type strain growing aerobically in half-strength Brain Heart Infusion broth (Gill *et al.*, 1991). The model used is an extension of that used by Lowry *et al.* (1988) to determine potential *E.coli* proliferation in thawing meat.

RESULTS AND DISCUSSION

Over all of the eleven tested chiller runs, the highest PHI value calculated was 18.6 (Table 1). This represents the maximum PHI value associated with acceptable carcasses produced during the monitored runs.

Assessment of the runs overall revealed a large variation in PHI values, which ranged between 5.4 and 18.6 (Figure 1). It is likely that such variation is common in normal commercial practice, reflecting both carcass weight and grade as well as position within the chiller (Gill *et al.*, 1991). This illustrates the desirability of operating to a "target" PHI value sufficiently below the maximum value allowable (that is to say, the industry standard), to ensure that the range of PHI values produced for each run does not exceed that standard. To accommodate this variation of PHI values obtained within a chiller, the process can be conveniently described in terms of a three-class sampling plan in which the 80th percentile is used as the "target". With such a sampling plan, a specified number of values are allowed to fall between this target value (m) and the maximum acceptable PHI (M). For the studied process the 80th percentile was found to be 14.1 (Figure 1). For simplicity, the (M) and (m) values can be rounded to 19 and 14 respectively.

In order that these guidelines can be used in a three-class sampling plan, a (c) value, the proportion of samples allowed to fall between (M) and (m), is required. It is appropriate to derive (c) from the most marginal run. This was Run 2 (Table 1), which yielded the highest PHI and the highest mean PHI. For this run, six out of ten (60%) PHI values were greater than (m). An appropriate guideline would therefore specify a maximum of 60% of values falling between (M) and (m). A (c) value of 60% might appear lenient; however, a reasonably large (c) value is necessary to accommodate the PHI values obtained in the assessed, acceptable process. In summary, suitable three-class process guidelines for a beef side cooling process that produces frozen product can be in the form: M=19, m=14, c=60% and n not less than five monitored carcasses per run.

The above guidelines are less stringent than those proposed by Gill *et al.* (1991). Consequently, a cooling process deemed unacceptable, because it did not meet standards based on a process that comfortably met GMP requirements, could be found acceptable by guidelines developed from minimum processing requirements.

The above guidelines have been developed for a process that produces meat destined for freezing. They would also assure the hygienic adequacy of a cooling process that produces beef destined for chilled storage. However, from a commercial perspective they might not be compatible with the required chilled product storage life because at chill temperature cold-tolerant organisms, including those responsible for spoilage, continue to grow. This growth, plus that which had occurred during the cooling process, may be sufficient to cause spoilage before the product reached its market. Generally speaking, the growth of mesophyllic bacteria of public health importance is similar to that of other bacteria, including spoilage bacteria, in that a positive correlation between temperature and growth rate exists (i.e., the growth rate increases with temperature). Producers of chilled beef may therefore need to process to a more stringent set of `in-house' PHI guidelines than those used for frozen product. Processing to a lower PHI "target" for meat destined for chilled distribution than that appropriate for frozen product will assure that the cooling process allows less general bacterial growth, resulting in a longer chill storage life before sufficient bacterial growth occurs to cause spoilage.

Although the above process assurance guidelines will assure the hygienic adequacy of the beef carcass cooling process, they will not assure the quality of the product. Satisfying the guidelines will only ensure that the cooling process does not allow an unacceptable amount of bacterial growth to occur on the product. Product quality considerations, such as the numbers, types and acceptability of bacteria composing the meat flora, can only be assessed using appropriate product quality assurance systems.

CONCLUSIONS

A beef chiller, operating marginally by established processing standards but nevertheless producing acceptable product destined for freezing, generated a maximum PHI value of 18.6 and an 80th percentile PHI value of 14.1. For any one run, the maximum number of PHI values falling between these figures was 60%. Therefore, the minimum standard for a hygienically acceptable beef side cooling process can be described in PHI terms as a three-class sampling plan in which: M=19; m=14; c=60% and n=not less than five logged carcasses per chiller.

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Table 1. Process hygiene indices calculated for cooling of beef sides.

Run #	Process Hygiene Index Maximum	Mean	Minimum
1	16.9	12.1	7.9
2*	18.6	15.1	11.2
3	18.3	11.4	6.5
4	16.0	12.9	6.8
5	16.4	11.3	6.6
6	16.3	12.8	8.3
7	13.1	10.5	5.6
8	10.8	9.2	8.1
9	13.8	8.0	5.4
10	15.6	10.0	6.2
11	11.8	8.1	5.4

* Run 2 contained the highest PHI and the highest mean PHI. Run 2 PHI values were as follows: 11.2, 11.3, 13.1, 13.4, 15.9, 16.4, 17.2, 17.2, 18.6.