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THE EFFICIENCY OF STORAGE DURING THE TRANSPORTATION OF HANGING BEEF BY RAIL OR ROAD

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INTRODUCTION

Much chilled beef is distributed as hanging sides or quarters of carcasses. Such product can be in transit for several days. It is obviously desirable to minimize the loss of storage life during the transportation of product, to ensure that the remaining storage life is adequate for the convenient fabrication and retail distribution of the meat.

The storage life of carcass portions stored in air will end when the *pseudomonas*-dominated spoilage flora attains numbers of about 10^8CFU/cm^2, and putrid odours become evident (Gill and Newton, 1978). The rate at which the spoilage flora increases is largely determined by the temperature history experienced by the contaminated meat surfaces (Pooni and Mead, 1984). The maximum storage life for chilled meat is then obtained when the surfaces are maintained at -1°C, the minimum temperature at which non-packaged meat can be maintained indefinitely without the meat freezing (Gill, 1986). There is at present little information on how well that ideal temperature is approximated in commercial practice. Therefore, temperature histories were collected from commercial processes for the transportation of hanging beef by rail and road, and those histories were evaluated using a temperature function integration technique (McMeekin *et al.*, 1988).

MATERIALS AND METHODS

The transportation of hanging beef, from three slaughtering plants in western North America to eastern North American markets, was examined. The sides are cooled overnight at all three plants. The sides are first sprayed with water while exposed to air at about 1°C, and are then exposed to air of about -3°C when spraying is stopped. Most hanging beef is loaded to transport within a few hours of leaving the chiller. At one plant, beef sides are loaded to refrigerated railway wagons. At the other two, the sides are divided into fore and hind quarters that are loaded to refrigerated road trailers.

Temperature histories were collected using MIRINZ/Delphi temperature data loggers (Model 861-1TP; Tru-Test, Auckland, New Zealand), each fitted with an external thermistor probe incased in a tapered Teflon sheath. The loggers were set to record temperatures between +40 and -20°C with an accuracy of ±0.25°C and resolution of 0.25°C at intervals of 15 minutes.

Surface temperatures were recorded from the persistently warmest point on carcass surfaces. That is, as medially and caudally as possible within the aitch bone pocket of sides or hind quarters (Gill *et al.*, 1991a). A disc of stainless steel (diameter 40mm) was held against a meat surface by means of a plastic staple passed through holes at opposite sides of the disc. The probe was then inserted into a cone-shaped slot running across the diameter of the disc that holds an inserted probe at the disc centre. After the placement of each probe, the data logger was attached to the carcass portion by means of a skewer passed through a slot in the casing.

Data loggers were similarly attached to the product for recording deep temperatures, after each probe had been inserted at the thickest point of the hind leg, until the tip lay at the centre of the tissue mass in that region.

Ten consignments from plant A and five consignments from each of plants B and C were monitored. Three product units were monitored in each consignment. Both surface and deep tissue temperature histories were obtained for each monitored unit. The monitored units in each consignment were located one at each end and one at the centre of each wagon or trailer.

Temperature history records were integrated with respect to a model describing the dependency on temperature of the growth rate of psychrotrophic pseudomonads (Gill and Jones, 1992a). The biphasic model has the form:

$y=(0.033x+0.27)^2$, when x is between -2 and 25;

y=1, when x is between 25 and 35;

y=0, when x is <-2 or >35;

where y is the growth rate expressed as generations h^{-1} and

x is the temperature in °C.

The model was applied in a program that interrogates a logger that has been associated with the program during logger set-up, request definition of the times that product temperature history recording began and ended, calculates the proliferation of pseudomonads during each record interval, and derives the total proliferation by summation of the incremental proliferations. The program subsequently calculates the time required for the calculated proliferation to be achieved at a temperature of -1 °C, and derives a storage efficiency factor from that calculated time and the duration of the temperature history. The storage efficiency factor is the percent ratio of the duration of the temperature history to the time calculated to be required for the calculated proliferation value to be attained at -1 °C (Gill and Jones, 1992b).

RESULTS AND DISCUSSION

At the times that beef sides and quarters were loaded to transport, their deep temperatures ranged from six to 18°C. The surface temperature of beef sides ranged from 0.5 to 5.5°C, while those of the beef quarters ranged from 3.5 to 6.5°C.

The refrigeration equipment on both wagons and trailers was set to deliver air of 0°C. The times that product was in transit by either rail or road were between about four and about seven days.

The surface temperatures of beef sides generally declined relatively rapidly to reach constant temperatures between +1 and -1°C within 24 hours. The surface temperatures of beef quarters declined only slowly and did not attain constant temperatures. When beef sides were unloaded, the surface and deep temperatures of most were between 0 and 1°C. When beef quarters were unloaded, the surface and deep temperatures were between 1 and 2.5°C.

The proliferations of pseudomonads calculated from the surface temperature histories ranged from 8.4 to 19.3 generations for the beef sides, and from 10.4 to 21.6 generations for the beef quarters (Figure 1). The three proliferation values from any rail consignment did not differ by more than one generation, whereas the values obtained from an individual consignment from either of the plants that shipped product by road could differ by more than three generations. However, there was no indication that the higher values within consignments were associated with a particular location (front, centre or rear) within the road trailers.

The storage efficiency factors that were calculated for the rail consignments ranged from 43 to 94%, with 77% in the range 44 to 70% (Figure 2). The three highest values were obtained for one consignment that was in transit for 6.9 days, and in which the product attained minimum surface temperatures that approached -1°C. The four values less than 55% were obtained from two consignments that experienced loss of temperature control, as evidenced in the one case by a large (5°C), prolonged (24 hours) upward excursion of temperature, and in the other by a relatively high (2.5°C), persistent minimum temperature.

The storage efficiency factors that were calculated for the road consignments ranged from 33 to 55%, with 83% in the range 40 to 55% (Figure 2). The five lowest storage efficiency values (<40%) were obtained from a quarter in each of five consignments.

On the day after slaughter, carcasses from a process that is well managed with respect to hygiene are likely to carry pseudomonads at numbers between 10 and 10^2/cm^2 (Grau, 1986). The analysis of the temperature histories obtained in this study indicates that the hanging beef arriving from the West in Eastern markets can generally be expected to carry spoilage flora at numbers between 10^4 and 10^7/cm^2, while on some fraction the flora will approach, or even exceed, the numbers that precipitate spoilage. That evaluation of the temperature history data agrees with the numbers of bacteria reportedly recovered from western hanging beef arriving in an eastern market (Simard *et al.*, 1984). Clearly, current transportation practices must result in some loss of the hanging beef distributed to eastern markets.

It appears that the chilled air in railway wagons is effectively distributed to all beef sides, and that the refrigeration equipment is capable of reducing the surface temperatures of warm product to the temperature of the air leaving the refrigeration coils within about 24 hours. With an off-coil air temperature of -1 °C, storage efficiencies in excess of 80% can thus be obtainable. However, it would appear that the off-coil air temperature is commonly set too high. If that matter were remedied, both beef packers and their customers could be sure that the storage life of hanging beef handled as at present would reduce at a near minimum rate during rail transport.

In contrast to the railway wagons, air movement through the stack in a road trailer is weak. Moreover, the refrigerative capacity of the trailer equipment is too small to rapidly reduce the temperature of warm product (Bogh-Sorensen and Olsson, 1990). Consequently, product temperature can be well controlled only when product is near the desired storage temperature when it is loaded to transport (Gill *et al.*, 1988). In those circumstances, the storage efficiencies obtained for warm-loaded product must be both relatively low and rather variable. Unless action can be taken to substantially reduce the temperature of product at load-out, then hanging beef must be assumed to store with only about 40% efficiency within road trailers and the storage life remaining may be too short for customers needs if the transportation time exceeds four days. Shippers of hanging beef should therefore avoid exceeding the very limited storage stability that the product will have when it is warm-loaded to, and carried in road trailers.

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