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Control of product temperatures during the storage and transport of bulk containers of manufacturing beef

C. O. Gill,[a]* J. C. McGinnis,[a] K. Rahn[b] & A. Houde[c]

[a]*Agriculture and Agri-Food Canada Research Centre, 6000 C&E Trail, Lacombe, Alba. Canada, T4L 1W1*
[b]*Agriculture and Agri-Food Canada Health of Animals Laboratory, 110 Stone Road West, Guelph, Ont. Canada, N1G 3E4,*
[c]*Agriculture and Agri-Food Canada Centre de Recherche, 3600 boul. Casavant ouest, St-Hyacinthe, Qué. Canada, J2S 8E3*

The temperatures of bulk containers of manufacturing beef dispatched from five packing plants to two processing plants were monitored. Central temperatures of containers selected at random were measured, immediately after containers were filled and on the arrival of containers at the processing plants. Temperature histories were recorded from the surfaces of meat masses in randomly selected containers, from the time that each container was filled to the time of its being emptied for processing of the meat. Each temperature history was integrated with respect to models describing the dependencies on temperature of the growths of *Escherichia coli* and leuconostocs. The addition of CO_2 snow to all containers being filled with meat reduced the temperatures of product from as high as 18°C to chiller temperatures. The average temperatures of the surfaces of meat masses, and their central temperatures on arrival at processing plants were <5°C. Consequently, most growth of *E. coli* was calculated to be insignificant, and none exceeded 1·2 generations. However, storage efficiency factors calculated from leuconostoc proliferations indicated that storage efficiencies were mostly <50%. Objective procedures for determining the amounts of CO_2 snow added to containers seem to be required to assure the attainment of low chiller temperatures and consequent good control of the proliferations of spoilage and cold tolerant, pathogenic bacteria © 1997 Published by Elsevier Science Ltd on behalf of the Canadian Institute of Food Science and Technology

Keywords: manufacturing beef, chilled meat, temperature control, storage, transport.

INTRODUCTION

Processors of manufacturing beef commonly obtain much of that meat as chilled, bulk-packed product. Processors who routinely monitor the microbiological condition of the product they receive perceive that numbers of *Escherichia coli* on manufacturing beef are higher during summer than during winter months (W. R. Usborne, Personal Communication). Although many processors now stipulate that the product temperature must not exceed 5°C at the time of delivery, and most product apparently meets that criterion, processors still consider that temperature abuse during storage and transport is the most likely explanation of the summertime increase in the numbers of *E. coli* on manufacturing beef. To determine if that could be so, processes for the storage and transport of manufacturing beef from five beef packing plants were examined.

*To whom correspondence should be addressed.

MATERIALS AND METHODS

Storage and transport processes

The storage and transport processes which were examined involved the delivery of manufacturing beef from five packing plants to two processing plants. At two of the packing plants (B and C), manufacturing beef is collected from the carcasses of animals slaughtered at each plant. At the other plants, carcasses are delivered for cutting from associated slaughtering plants.

The transport of product from four of the packing plants to one or the other processing plant involves journeys of less than one working day. However, the delivery of product from packing plant E involves a journey of 2 or 3 days.

At all the packing plants, manufacturing beef is collected into containers, each of which is lined with a plastic bag and holds approximately 450 kg (1000 lb) of meat. During the filling of a container, CO_2 snow is added to the meat as is considered appropriate by the person supervising the container-filling operation. Decisions on the addition of CO_2 snow may sometimes be guided by spot measurements of meat temperatures, but there is no accurate measurement of the quantities of CO_2 snow added to any container during filling. When filling of a container has been completed, the temperature at the approximate centre of the mass of meat is usually measured, and further CO_2 snow added if the temperature is considered too high. The mouth of the bag is then closed by clipping or taping, and the container is removed to a chilled storage area pending its loading to a refrigerated trailer.

Measurement of product temperatures

At each packing plant, on each of 5 days, temperatures were measured at three points close to the centre of the meat mass in each of ten containers immediately before the closure of each lining bag. The average of the three temperatures for each container was recorded. Temperatures were obtained, using thermistor thermometers, from containers selected at random from those filled during each day. Temperatures were similarly obtained from containers selected at random from those arriving at the processing plants from the specified packing plants.

On each of 5 days, at each packing plant, temperature data loggers (Tru-Test, Auckland, New Zealand) were placed on the top of the meat in each of five containers immediately before each liner was closed. The containers to be monitored were selected at random from those destined for delivery to either of the processing plants. The loggers were set to record temperatures at 15 min intervals, with an accuracy and resolution of $\pm 0{\cdot}25$°C. Each logger was retrieved when the container it was in was about to be emptied for processing of the product at a processing plant.

Temperature data were collected from each plant during a period of four late spring and summer months when daytime temperatures ranged from 10 to 30°C.

Analysis of temperature histories

Product temperature histories were integrated with respect to models describing the dependencies on temperature of the aerobic growth of *E. coli* and the growth of leuconostocs. The models used for those purposes have been previously reported (Gill *et al.*, 1991, 1995).

In addition, a storage efficiency factor was calculated for each temperature history from its duration and the calculated proliferation of leuconostocs. 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 for the spoilage bacteria obtained from the temperature history to be attained at a constant temperature of $-1{\cdot}5$°C (Gill & Phillips, 1993).

RESULTS

At the packing plants B, D and E, few of the temperatures measured at the centres of filled containers were above 5°C (Fig. 1). However, at plants A and C respectively, 30 and 46% of those temperatures were > 5°C.

The times between the packing and use of product ranged from about 20 h to about 120 h except for

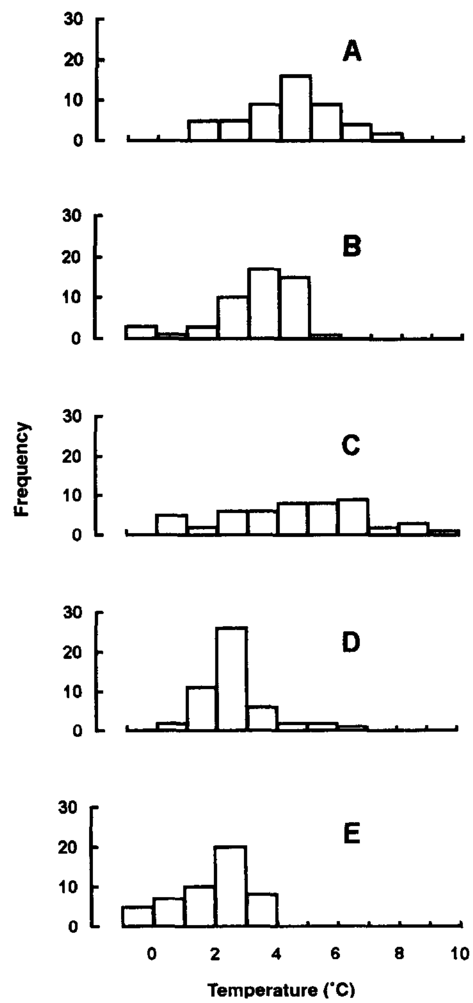

Fig. 1. The temperatures at the centres of 25 bulk containers of manufacturing beef at each of five beef packing plants.

product from plant E, little of which was used less than 80 h after packing, and some of which was not used until about 200 h after packing (Fig. 2).

The temperature histories generally showed initial rapid decreases in temperature, with subsequent slowly falling or steady temperatures. Some temperature histories showed an upward temperature excursion of 2 or 3°C for between 1 and 4 h, during periods of otherwise relatively constant temperatures. Consequently, the maximum temperatures in most histories occurred during the first few hours. Those maximum temperatures ranged up to about 18°C at plants A, B and C, but to only 11°C at plant E (Fig. 3). Despite the high initial temperatures, all the temperature histories gave average temperatures of < 5°C, while the average temperatures of product from plant E were < 1°C (Fig. 4).

The temperatures measured at the centres of containers arriving at the processing plants ranged from 4·7 to −1·1°C, and averaged 1·6°C. *E. coli* proliferations of < 0·2 generations were calculated for all histories for product from plants C and E, and for 22 and 21 of the temperature histories for product from plants B and D, respectively. The *E. coli* proliferations calculated from the remaining temperature histories from product from those latter plants were mostly < 0·4 generations. However, an *E. coli* proliferation value of about 1 generation was calculated for a temperature history for product from each of the plants B and D. Temperature histories for product from plant A yielded *E. coli* proliferation values that also ranged up to about 1 generation, with 12 values being < 0·4 generations and three values being 1 ± 0·2 generations.

Leuconostoc proliferations ranged up to about 3 generations for temperature histories for product from plants A, B and E, but to about 5 generations for temperature histories from product from plants C and D. The storage efficiencies calculated for product from plants A, B, C and D were mostly < 50%, but the storage efficiencies for product from plant E were mostly > 50% (Fig. 5).

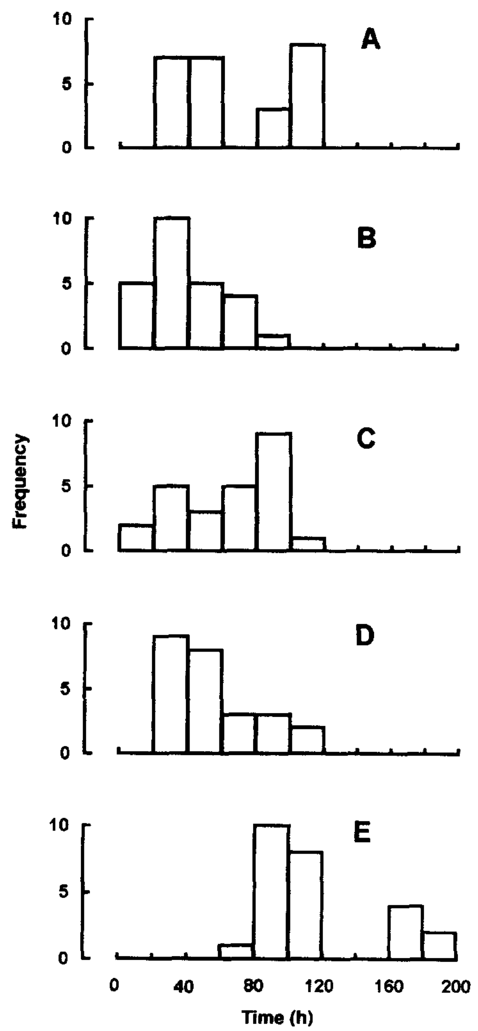

Fig. 2. The times between the packing of 25 bulk containers of manufacturing beef at each of five beef packing plants and emptying of the containers at one or other of two meat processing plants.

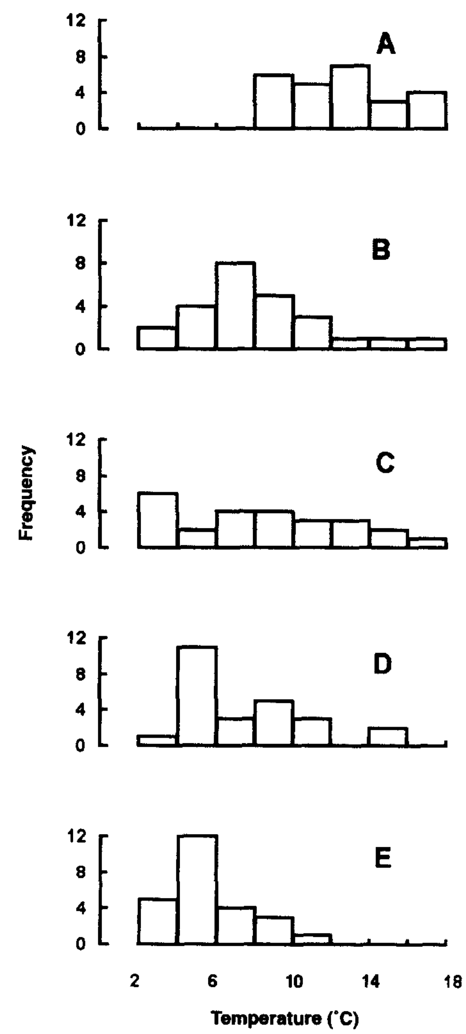

Fig. 3. The maximum temperatures recorded from the surfaces of the meat, in 25 bulk containers of manufacturing beef prepared at each of five beef packing plants, during the storage and transport of the product.

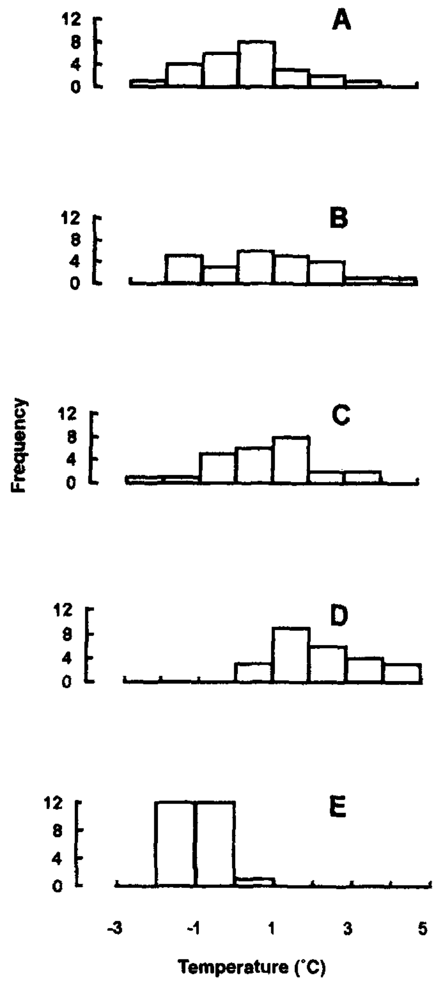

Fig. 4. The average temperatures of the surfaces of the meat, in 25 bulk containers of manufacturing beef prepared at each of five beef packing plants, during the storage and transport of the product.

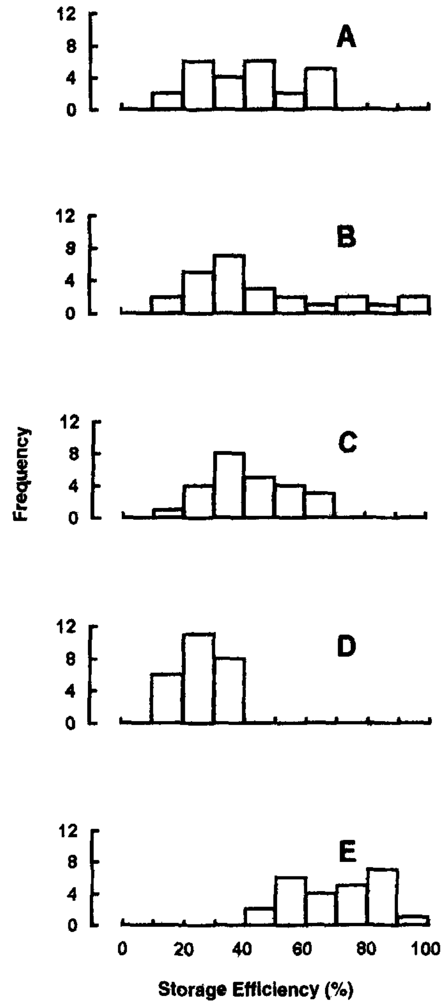

Fig. 5. The storage efficiencies calculated for the meat in 25 bulk containers of manufacturing beef from each of five beef packing plants, for the times of storage and transport of the product.

DISCUSSION

Commercial facilities for the storage and transport of meat are usually maintained at temperatures too low for the growth of *E. coli* and mesophilic pathogens. However, such facilities are generally not designed for the rapid cooling of product (Bogh-Sorensen & Olsson, 1990) and no chilling facility could rapidly cool large masses of meat. Consequently, if bulk meat is loaded to storage or transport with the product at temperatures > 7°C, growth of *E. coli* in the slowly cooling product would be expected (Reichel *et al.*, 1991).

When monitoring the temperatures of bulk containers of meat it would seem preferable to collect temperature histories from both the centres and surfaces of meat masses, as centres may remain warmer than surfaces close to high flows of cold air, while exposure of containers to higher air temperatures could warm product surfaces without obvious effect upon central temperatures. The collection of central temperature histories proved to be impracticable, because of difficulties with retrieving loggers when temperature probes were deep within meat masses. However, the comparability of average temperatures from temperature histories with the central temperatures of delivered product, and the observation of only small, upward fluctuations of surface temperatures indicate that, in practice, each surface temperature history reasonably represented the temperatures of the whole mass of meat in a bulk container.

The findings of this study therefore show that the current commercial practice of cooling manufacturing beef by the addition of CO_2 snow to bulk containers being filled with product, which may be cut from relatively warm carcasses in a relatively warm facility, is generally effective for containing the proliferation of *E. coli* during storage and transport. Consequently, the increased *E. coli* numbers on manufacturing beef perceived by processors during summer months is unlikely to arise from a widespread, gross loss of control over product temperatures during storage and transport when ambient temperatures are high.

However, the findings also indicate that current commercial practices may be inadequate in other respects. The relatively high initial temperatures recorded from some containers show that substantial quantities of the manufacturing beef were warm at the time that they were packed. If the microbiologically contaminated surfaces of the products experienced such temperatures for more than a short time before the meat was packed and cooled, substantial growth of potentially pathogenic and spoilage bacteria would be possible (Smith, 1985). Loss of control over product temperatures before rather than after packing might then account for a poorer hygienic condition of product during summer than in winter.

Moreover, the low storage efficiencies and relatively high average temperatures for product in some containers from most of the plants show that the temperatures achieved for some product are only marginally within the chill temperature range. The storage life, and perhaps the safety with respect to cold-tolerant pathogens in chilled, raw-meat items prepared from manufacturing beef would be compromised by storage and transport at the higher chiller temperatures (Palumbo, 1986; Gill, 1996). Unfortunately, variability in the temperature of manufacturing beef delivered to processors must be expected while the addition of CO_2 snow to affect cooling remains largely a matter of judgment by workers involved in the packing of bulk containers. Some practicable procedure for estimating, from meat and ambient temperatures, appropriate weights of CO_2 snow to add to containers would seem to be required if bulk manufacturing meat is to be stored and transported at consistently low chiller temperatures.

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