Contamination of Beef Chucks with *Escherichia coli* during Carcass Breaking†

C. O. GILL,* J. C. McGINNIS, AND J. BRYANT

Agriculture and Agri-Food Canada, Lacombe Research Centre, 6000 C&E Trail, Lacombe, Alberta, Canada T4L 1W1

ABSTRACT

Samples were obtained by swabbing the whole of the chuck portion on each of the first 500 sides that entered a beef carcass breaking process and the whole of the outer surface of each of the chuck primal cuts that were prepared from those portions. Swabs obtained from groups of 10 sides or cuts that entered or emerged from the process consecutively were combined, and the coliforms and *Escherichia coli* recovered from each group were enumerated. Coliforms and *E. coli* were recovered only sporadically from groups of sides at log total numbers of 4.0 and 3.5 log CFU/500 sides, respectively. Coliforms were recovered from three and *E. coli* from none of the first six groups of cuts. Coliforms and *E. coli* were recovered from all subsequent groups of cuts, initially at log numbers mostly <3 log CFU/10 cuts, but ultimately at log numbers mostly >3 log CFU/10 cuts. The log total numbers of coliforms and *E. coli* recovered from cuts were >6.0 and 5.5 log CFU/500 cuts, respectively. After the breaking of about 600 sides, samples were obtained by swabbing a table onto which the part of the side that included the chuck portion was deposited after it was cut from the hanging side, and the belt that was used for conveying chucks. The numbers of coliforms and *E. coli* recovered from the table and conveyor belt were comparable with the numbers recovered from sides and cuts, respectively. Those findings show that most of the coliforms and *E. coli* recovered from the cuts were not present on carcass sides but that they originated largely from the cut conveying equipment.

It is generally assumed that the *Escherichia coli* found on beef is deposited on the product during carcass dressing processes and that few or no further numbers of *E. coli* are added to the product during carcass breaking, provided that the equipment and facilities used for carcass breaking are routinely cleaned to the satisfaction of meat inspecting authorities (10). However, in recent studies, the numbers of *E. coli* recovered from cuts or manufacturing beef at the ends of carcass breaking processes were far larger than the numbers recovered from carcasses entering those processes (3, 8). Such findings indicate that at some, possibly most, beef plants, the majority of the *E. coli* found on the final products originates from persisting sources in inadequately cleaned carcass breaking equipment. That interpretation is supported by the finding of detritus contaminated with *E. coli* in parts of carcass breaking equipment that do not contact meat, after routine cleaning of the equipment, and regulatory inspection and approval of its condition (8).

Despite that, the possibility of some substantial fraction of the *E. coli* found on the final products having been present on carcasses entering the processes could not be entirely discounted (8), because only a small fraction of the total area of carcasses entering a process at any time was sampled. In such circumstances, sporadic, localized contamination of carcasses with large numbers of *E. coli* would not necessarily be detected. During carcass breaking, any such localized contamination would be redistributed over the meat and equipment. Then, sampling of the final product would recover more *E. coli* than was recovered from carcasses, although the numbers on the meat as a whole remained much the same. Confusion of redistribution and the addition of contaminants during carcass breaking might well occur when the routine sampling of carcasses required by regulatory authorities yields few *E. coli*, because such sampling is restricted to only three sites on a small minority of carcasses (2). Consequently, even moderate, sporadic contamination at other than the designated sites could result in more *E. coli* being recovered from cuts than from carcasses when no *E. coli* was added to the meat during carcass breaking.

It therefore seemed desirable to better define the extent to which redistribution of bacteria might account for increased recovery of *E. coli* from cuts, by examination of the total loads of *E. coli* on cuts and the portions of carcasses from which they were prepared during the normal operation of a carcass breaking process.

MATERIALS AND METHODS

Carcass breaking operations. The microbiological conditions of the chuck portions of carcasses and of chuck primal cuts were examined at a plant that breaks about 200 beef carcasses per hour. Hanging carcass sides enter the breaking facility from a grading floor. The hanging sides move continuously on a rail in the breaking facility, while parts are progressively removed to tables and conveyor belts for further fabrication. The forequarter...
which includes the chuck portion, is the first part to be removed from each side.

Several operations are performed on the forequarter part of each side before the forequarter is removed. First, the muscles between the fourth and fifth ribs are cut with a knife. Then, nitrogen is injected between the shoulder muscles to facilitate their being freed from the scapula. A hand-held circular saw is used to cut through the back bone in line with the cut between the ribs and to cut through the anterior ribs near to their attachment to the sternum. Fat is then trimmed from the breast and front leg before the front leg is secured by a clamp, which is attached to a chain from a trolley on the forequarter rail. The forequarter is raised by means of the chain, and the tissues between the forequarter and the sternum are cut to free the forequarter from the rest of the carcass.

The inner side of the separated forequarter is trimmed, and the scapula is freed from the muscles that are attached to it. The suspended forequarter is moved on the rail and is dropped to a table to lie with the outer surface down. The front leg is unclamped, and the forequarter is pushed to a fixed, vertical circular saw, which is used to cut the brisket and front leg portion from the chuck portion. The brisket portion is passed to a second table, while the chuck portion is passed to a conveyor belt, where the back bone is cut from the portion by automatically operating circular saws. Chuck portions are freed of ribs, then trimmed and fabricated to various cuts as they pass along the conveyor. During the period of sampling for this study, each chuck was fabricated as a single primal cut.

**Sampling of carcass sides and cuts.** At the start of processing on day 1, the surface of the chuck portion on each of the first 500 sides that entered the carcass breaking facility and the chuck primal cut obtained from each side were sampled. Sides were sampled following the operation to cut between the fourth and fifth ribs. Cuts were sampled before they were packed, at the end of the conveyor used in the fabrication process.

Samples were obtained by swabbing the outer surface of each side, over and beyond the whole area of the chuck portion, and swabbing all of the corresponding surface on each primal cut. Surfaces were swabbed with sterile, 3- by 4-cm cellulose acetate sponges (speci sponge, VWR Canlab, Mississauga, Ontario, Canada) that had each been moistened with 5 ml of 0.1% wt/vol peptone water. A single sponge was used to sample five carcasses or five cuts, which arrived consecutively at the respective points in the process where samples were obtained. Pairs of sponges used on consecutive groups of five carcasses or cuts were collected into stomacher bags and were stored in ice until they were processed within 4 h of being collected.

**Sampling of equipment.** On day 2, during the morning break from work in the carcass breaking facility, samples were obtained from the meat contacting surface of the table, to which forequarters are dropped for sawing into brisket and chuck portions, and the conveyor belt, for chuck portions. Samples were obtained by swabbing the surfaces with sponges moistened as for the sampling of meat.

The whole of the table surface was sampled by swabbing six areas, each approximately 1,000 cm². About 30% of the belt surface was sampled by swabbing 10 areas, each approximately 10,000 cm². Each sponge was collected into a separate stomacher bag and was stored on ice until it was processed within 4 h of being collected.

**Enumeration of bacteria.** Each pair of sponges used on meat or each sponge used on equipment was stomached for 2 min with an additional 10 ml of 0.1% wt/vol peptone water. The sponges within the bag were squeezed to expel much of the stomacher fluid. A 1-ml portion of the fluid was used to prepare serial, 10-fold dilutions, to obtain 10 ml of a 100-fold dilution of the fluid. The whole volume of that diluted fluid and 10 ml of undiluted fluid was each mixed with 1 ml of a papain solution (EZ-Enzyme; QA Life Sciences, San Diego, Calif.). The fluids were then incubated at 25°C for 20 min before each was filtered through a separate hydrophobic grid membrane filter (QA Life Sciences).

Each filter was placed on a plate of lactose monensin gluconate agar (QA Life Sciences), which was incubated at 35°C for 24 h. Squares containing blue colonies were counted, and a most probable number value for coliforms on each filter was obtained by application of the following formula: MPN = N × log \(_{\frac{N-1}{N}} - X\), where \(X\) is the total number of squares on a filter and \(N\) is the number of squares containing blue colonies.

Each filter was then transferred to a plate of buffered 4-methylumbelliferyl-\(\beta\)-D-glucuronide agar (QA Life Sciences), which was incubated at 35°C for 3 h. After incubation, the filter was illuminated with long-wavelength UV light, and squares containing blue-white fluorescent colonies were counted. A most probable number value for \(E. coli\) was obtained from that count by the same calculation as was used for the coliform counts.

**RESULTS**

The study yielded 50 counts each of coliforms and \(E. coli\) from each of the chuck portions on carcass sides and chuck primal cuts. Each count was the number recovered from 10 sides or cuts, with bacteria being recovered at the level of 2 CFU/10 sides or cuts. The areas sampled were about 1,500 cm² on each carcass and about 1,000 cm² on each cut. Thus, each count represented the number recovered from about 1.5 or 1.0 m² of meat surface.

Both coliforms and \(E. coli\) were recovered only sporadically from groups of sides, with coliforms and \(E. coli\) not being recovered from 22 and 30 groups of sides, respectively (Fig. 1). Most groups of sides from which bacteria were recovered yielded coliforms and \(E. coli\) at log numbers \(\leq 1\) log CFU/10 sides. Coliforms and \(E. coli\) at log numbers \(\geq 2\) log CFU/10 sides were recovered from only four and three groups of sides, respectively.

Coliforms were recovered from only three and \(E. coli\) was recovered from none of the first six groups of cuts (Fig. 1). Coliforms were recovered at log numbers \(< 3\) log CFU/10 cuts from all but one of the groups of cuts 7 to 18, inclusive, but were recovered at log numbers \(\geq 3\) log CFU/10 cuts from all but two of the subsequent groups of cuts. \(E. coli\) was recovered at log numbers \(< 3\) log CFU/10 cuts from all but two of the groups of cuts 7 to 31, inclusive, but was recovered at log numbers \(\geq 3\) log CFU/10 cuts from all but two of the subsequent groups of cuts.

For 5 groups of sides but for 41 groups of cuts, the log numbers of coliforms and \(E. coli\) recovered from a group differed by \(\geq 0.5\) log units. The log total numbers of coliforms recovered from sides and cuts were 4.0 and \(\geq 6.0\) log CFU/500 sides or cuts, respectively, and the log total numbers of \(E. coli\) recovered from sides and cuts were 3.5 and \(\geq 5.5\) log CFU/500 sides or cuts, respectively.

Most coliforms and \(E. coli\) recovered from the table were obtained from the same single swab. The log total...
FIGURE 1. Log numbers of (A) coliforms and (B) Escherichia coli recovered from the chuck regions of consecutive groups of 10 beef carcass sides (●) or from groups of 10 chuck primal cuts prepared from those sides (□), with hatching indicating the recovery of the same numbers from corresponding groups of sides and cuts, and “nd” indicating none detected, when samples were collected from all sides passing through a carcass breaking process from the time of the process commencing on day 1.

numbers recovered were 2.34 and 2.13 log CFU/0.6 m², and the log mean numbers were 1.56 and 1.35 log CFU/1,000 cm², respectively, for coliforms and E. coli recovered from the table. Coliforms and E. coli were recovered from all samples from the belt, with similar numbers being recovered from all samples. The log total numbers recovered were 5.83 and 5.62 log CFU/35 m², and the log mean numbers were 3.26 and 3.08 log CFU/1,000 cm², respectively, for coliforms and E. coli recovered from the belt.

DISCUSSION

At the plant involved in the study, carcass sides are subjected to a pasteurizing treatment before they are cooled under conditions that reduce the numbers of coliforms and E. coli on the surfaces of sides (5). Consequently, coliforms and E. coli have been recovered only sporadically and in small numbers from any site on the surfaces of cooled sides (6, 7). In those circumstances, sampling of all the sides entering the breaking process appeared to be necessary to ascertain the numbers of sporadic contaminants that might be redistributed over the product during the carcass breaking process.

As most of the groups of sides yielded few or no coliforms or E. coli, it is likely that the chuck portions of most of the sides in any group similarly bore few coliforms or E. coli. The relatively high numbers of 10³ coliforms and E. coli recovered from two groups of sides therefore indicate contamination at that level of only 2 of the 500 sides that were sampled during the study. Although it proved impractical to sample all the brisket portion as well as all the chuck portion of each carcass forequarter, sampling of the chuck portion included much of the foreleg and the part of the brisket above the leg. Moreover, a previous study had given no indication of sites on the briskets of the cooled sides being more heavily contaminated than sites in other areas, while redistribution of bacteria or additional contamination of the product during operations on hanging carcasses is apparently trivial (7). It was therefore very likely that when forequarters were dropped to the table for sawing into chuck and brisket portions, they carried coliforms and E. coli in numbers little more than those recovered by the swabbing of sides.

The numbers of coliforms and E. coli recovered from cuts were two orders of magnitude more than the numbers recovered from sides, with the additional organisms evidently being deposited on the meat during the operations for fabricating the cuts. The additional organisms are unlikely to have originated from the powered saws used at the start of the fabrication process, because the speeds of saw blades and drives would ensure that contaminated material in a saw would be carried to the product soon, if not immediately, after the start of processing, whereas the first 60 portions were processed with only sporadic contamination of cuts with coliforms and no contamination of cuts with E. coli. The limited contamination of cuts at the start of processing also suggests that personal equipment was not the major source of the additional contaminants, as contamination from personal equipment would likely be apparent and heaviest on the first cuts emerging from the process (4). The data from the sampling of carcass sides and cuts therefore indicate the conveying equipment for chuck portions as the source of the additional contaminants found on the final product.

During the use of equipment, the surfaces that contact meat and the product will carry similar numbers of bacteria. If equipment were contaminated by sporadic, heavy contamination of forequarters, then after the processing of several hundred sides, similar, relatively large numbers of coliforms and E. coli would be recovered from both the table that receives forequarters and the chuck conveyor belt. However, when the equipment had been in use for about 2 h, the numbers recovered from the conveyor belt were similar to the numbers previously recovered from cuts, but the numbers recovered from the table were few and similar to the numbers previously recovered from sides. Those findings therefore confirm that the coliforms and E. coli found on cuts originated mainly from the cut conveying equipment and not from rare and highly localized, heavy contamination on carcass forequarters.

Although only one item of equipment appears to be involved in the contamination of chucks, the contaminants may originate from more than one source within the equipment. Multiple sources of the contaminants are suggested by the relatively abrupt changes in the numbers and types
of contaminants on cuts. Those changes were first from sporadic contamination with coliforms and no *E. coli*, to moderate, consistent contamination with both, and then to higher, consistent contamination, with the final increase in coliform numbers preceding the increase in numbers of *E. coli*.

The numbers of coliforms and *E. coli* on the product increased greatly during the carcass breaking process, but the mean numbers on the cuts at the end of the sampling period were only about 3 and about 1 CFU/cm² for coliforms and *E. coli*, respectively. Such numbers of *E. coli* on carcasses are considered acceptable by regulatory authorities (10). However, the immediate origins of most of the contaminants from detritus persisting in conveying equipment raise the possibility of the product being routinely contaminated with enteric pathogens associated with the indicator organisms, rather than the product being sporadically contaminated with pathogens from individual animals, as is often assumed (1). Certainly, routine contamination of pork with *Salmonella* that persist in packing plants has been reported (9). The derivation from packing plant equipment of 99% of the *E. coli* found on at least some beef points to the distinct possibility of beef at some plants also being routinely contaminated with persisting *Salmonella* or pathogenic strains of *E. coli*. The matter would seem to merit further investigation, as current actions aimed at ensuring the microbiological safety of beef may well be ineffective for controlling such contamination.

**ACKNOWLEDGMENTS**

We thank the staff of the plant involved in the study for facilitating and assisting with the collection of samples. Funding for the study was provided by the Alberta Agricultural Research Institute.

**REFERENCES**