Microbial Contamination Occurring on Lamb Carcasses Processed in the United States


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ABSTRACT

Lamb carcasses (n = 5,042) were sampled from six major lamb packing facilities in the United States over 3 days during each of two visits (fall or winter, October through February; spring, March through June) in order to develop a microbiological baseline for the incidence (presence or absence) of Salmonella spp. and for populations of Escherichia coli after 24 h of chilling following slaughter. Samples also were analyzed for aerobic plate counts (APC) and total coliform counts (TCC). Additionally, incidence (presence or absence) of Campylobacter jejuni/coli on lamb carcasses (n = 2,226) was determined during the slaughtering process and in the cooler. All samples were obtained by sponge-sampling the muscle-adipose tissue surface of the flank, breast, and leg of lamb carcasses (100 cm² per site; 300 cm² total). Incidence of Salmonella spp. in samples collected from chilled carcasses was 1.5% for both seasons combined, with 1.9% and 1.2% of fall or winter and spring samples being positive, respectively. Mean (log CFU/ cm²) APC, TCC, and E. coli counts (ECC) on chilled lamb carcasses across both seasons were 4.42, 1.18, and 0.70, respectively. APC were lower (P < 0.05) in samples collected in the spring versus fall or winter, while TCC were higher in samples collected in the spring. There was no difference (P > 0.05) between ECC from samples collected in the spring versus winter. Only 7 out of 2,226 total samples (0.3%) tested positive for C. jejuni/coli, across all sampling sites. These results should be useful to the lamb industry and regulatory authorities as new regulatory requirements for meat inspection become effective.

With increased focus on food safety and the implementation of hazard analysis critical control point (HACCP) plans, lamb slaughter plant practices are continually being improved to reduce the visible and bacterial contamination on lamb carcasses. In the United States, the Pathogen Reduction and HACCP Final Rule of 1996 required slaughter and processing plants (including lamb plants) to control physical, chemical, and biological contaminants on meat (12). As lamb packing and processing plants develop and improve their HACCP plans to adhere to new regulations regarding microbiological performance criteria for Escherichia coli and standards for Salmonella spp., there will be increased attention on efforts to minimize slaughter-lamb contamination. As of 25 January 2000, the U.S. Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) is now requiring establishments that slaughter sheep, as an extension to the 25 July 1996 final rule, to sample and test carcasses for E. coli to verify the adequacy of their process controls for contamination with feces, ingesta, and/or other animal-derived contaminants (13).

National baseline carcass contamination studies have already been completed by FSIS for steers and heifers, cows and bulls, and hogs (9–11). The objective of this study was to develop a microbiological baseline for the incidence (presence or absence) of Salmonella spp. and for populations of E. coli (E. coli counts [ECC]) on chilled lamb carcasses (in the cooler following 24 h of chilling) processed in six packing facilities in the United States in 1998 and 1999. These data will now allow the microbiological status of lamb carcasses in the United States to be evaluated as has already been done for the other major red meat species. There have been at least two outbreaks of salmonellosis associated with the consumption of lamb, which suggests that lamb is potential source of foodborne infection (8, 27). In addition to Salmonella spp. and E. coli, analyses also included aerobic plate counts (APC) and total coliform counts (TCC) to gain more information regarding the general level of microbiological contamination of chilled lamb carcasses. Additional samples were collected from chilled lamb carcasses and also from hot carcasses at two other in-plant processing locations (previsceration and postvisceration) and were analyzed for the incidence (presence or absence) of Campylobacter jejuni/coli, an emerging foodborne pathogen. C. jejuni/coli, often responsible for causing Campylobacter enteritis (campylobacteriosis) in humans, is the most common bacterial form of acute infective diarrhea, is the most commonly reported bacterial cause of foodborne infections in the United States (2, 24). In the United States, an estimated 2.1 to 2.4 million cases of human campylobacteriosis occur each year (28).

MATERIALS AND METHODS

Study design. The study was conducted in six geographically dispersed (Texas, California, Iowa, Michigan, and Colorado)
TABLE 1. **General characteristics of the six lamb slaughtering plants (as of June 1999)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shifts per day</td>
<td>1</td>
</tr>
<tr>
<td>Carcass steam vacuuming (yes/no)</td>
<td>6/0</td>
</tr>
<tr>
<td>Final carcass-rinsing chemical (AA/LA/none)</td>
<td>1/2/3</td>
</tr>
<tr>
<td>Automatic pelt removal (yes/no)</td>
<td>5/1</td>
</tr>
<tr>
<td>Inverted chain (yes/no)</td>
<td>2/4</td>
</tr>
</tbody>
</table>

\* AA, acetic acid; LA, lactic acid.

U.S. lamb packing plants. Processing characteristics of the plants in which samples were collected are shown in Table 1. Each plant was visited twice for sample collection; one visit occurred during the fall or winter season (October through February 1998), and one visit occurred during the spring season (March through June 1999). During each plant visit, samples were collected over a 3-day period to obtain a sample population comprised of lambs from several different lots (lams originating from a variety of production sources).

Samples tested for the incidence (presence or absence) of *Salmonella* spp. and for APC, TCC, and ECC were collected from chilled carcasses in the cooler (post-24 h carcass chilling). Samples tested for the incidence of *C. jejuni/coli* were collected in three locations including at a prepeeviscerated site, at a postpevisceration site (but before any final washing), and at a post-24 h carcass chilling site.

**Carcass sampling.** Lamb carcasses were sampled using the same procedures that are used for beef and pork carcass sampling and as are described in the new Meat and Poultry Inspection Regulations (12). All samples were collected using aseptic techniques. Sterile sponges in sterile sample bags (Biopro Enviro-sponge Bags; International Bioproducts, Inc., Redmond, Wash.) were used, and before obtaining each sample, latex gloves and plastic 100-cm² templates (Biopro; International Bioproducts) used for sampling were presanitized by immersion in 82.2°C water for a minimum of 10 s.

To follow the USDA approved three-site sampling protocol as specified for beef and pork carcass sampling, lamb carcasses were sponged at the flank, leg, and breast. A sterile plastic 100-cm² (10 by 10 cm) template was first placed directly on the flank area of the carcass, and the surface within the template (adipose-muscle tissue surface) was sampled by swabbing with the sponge 10 times in a vertical direction and 10 times in a horizontal direction according to USDA recommended procedures (12). The same template was then placed on the breast and the same side of the sponge was to be used to swab this region (10 vertical and 10 horizontal passes of the sponge). After completing the sponging of the flank and breast, the same template was placed on the leg region, and the reverse side of the sponge was used to sponge the surface using the same protocol. A total of 300 cm² of surface area was sponged on each sampled carcass and each sample was collected from a separate carcass.

**Sample preparation, transportation, and analysis.** Before sampling, sterile sponges (in sterile bags) were hydrated with 10 ml of 0.1% sterile, buffered peptone water (International Bioproducts). After sample collection, sponges to be evaluated for APC, ECC, TCC, or the incidence of *Salmonella* spp. were placed aseptically into sterile sample bags and were hydrated with an additional 15 ml of buffered peptone water. If the samples were to be evaluated for the incidence of *C. jejuni/coli*, an additional 15 ml of Hunt’s enrichment broth was added following sponging (21). After being hydrated with an additional 15 ml of the appropriate buffer, the samples were placed in prechilled coolers containing a temperature-recording device and commercial ice substitutes and were shipped via overnight delivery to the microbiology laboratory (Center for Red Meat Safety, Colorado State University, Fort Collins, Colo.).

Samples analyzed for *Salmonella* spp. and *C. jejuni/coli* followed enrichment, isolation, and identification procedures recommended by USDA-FSIS (21, 22). TCC and ECC were determined by plating appropriate dilutions onto Petrifilm ECC plates (3M Microbiology Products, St. Paul, Minn.). Following incubation for 48 h at 35°C, both non-*E. coli* and *E. coli* colonies (red and blue colonies associated with a gas bubble) growing on the plates were counted manually to determine TCC, while only dark blue colonies associated with a gas bubble were counted to determine ECC. APC were determined on trypticase soy agar (Difco Laboratories, Detroit, Mich.) using the spiral plating method (Spiral Plater model D; Spiral Biotech, Bethesda, Md.). Plates were incubated at 35°C for 48 h, and colonies were counted using a laser bacteria colony counter (model 500A; Spiral Biotech, Inc.) and a computer-assisted spiral bioassay data processor (CASBA model 800; Spiral Biotech, Inc.).

**Statistical analysis.** *Salmonella* spp. and *C. jejuni/coli* data are reported as a percentage of samples that tested positive for each pathogen. Comparisons of the incidence of *Salmonella* spp. by season were completed using the chi-square option of the frequency procedure of SAS (23). Bacteria populations (APC, TCC, and ECC) were converted from CFU/ml to log_{10} CFU/cm² of carcass surface area sampled. Minimum detection limits for APC, TCC, and ECC were 0.23, −1.08, and −1.08 log CFU/cm², respectively, based on the maximum sensitivity of the tests. Values for APC, TCC, and ECC that were below the minimum detection limit were entered into the data as 0.23, −1.08, and −1.08 log CFU/cm², respectively.

In order to evaluate the influence of the main fixed effects (i.e., plant and season) and their interactions on the microbiological contamination of lamb carcasses, APC, TCC, and ECC were analyzed using the general linear model procedures of SAS (23). Least squares means were separated using a protected pairwise test of SAS. All differences were reported at a significance level of α = 0.05.

**RESULTS AND DISCUSSION**

**Pathogen incidence.** *Salmonella* spp. was present in 1.5% of samples collected from carcasses in the cooler (following 24 h of chilling). It must be noted that only 300 cm² of surface area was sampled on each carcass, and therefore, the actual prevalence of *Salmonella* spp. on lamb carcasses is likely to be higher than 1.5%. Typical holding times at the plants were generally 1 day or less, which could also account for the low prevalence of *Salmonella* spp. on lamb carcasses. Grau and Smith (14) found that *Salmonella* spp. were first shed in the feces after 2 to 3 days of holding. In another study completed in Australia, the incidence of *Salmonella* spp. on chilled lamb carcasses, using a tissue excision technique, was determined to be 5.7% (29). Numerous studies have reported a higher recovery of bacteria when using a tissue excision sampling method versus a sponge or swabbing sampling method (3, 7, 31). There was a numerical, but not a statistical, difference (P ≥ 0.05) in the incidence of *Salmonella* spp. on samples collected from...
TABLE 2. Incidence of Salmonella spp. on lamb carcasses, in the cooler, following 24 h of chilling (across six plants)

<table>
<thead>
<tr>
<th>Item</th>
<th>Sampling period</th>
<th>n</th>
<th>No.</th>
<th>Incidence, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. plants positive</td>
<td>Fall or winter</td>
<td>6</td>
<td>4</td>
<td>66.7 A&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>6</td>
<td>2</td>
<td>33.3 A&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>No. samples positive</td>
<td>Fall or winter</td>
<td>1,262</td>
<td>24</td>
<td>1.9 A&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>1,260</td>
<td>15</td>
<td>1.2 A&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2,522</td>
<td>39</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<sup>a</sup> Fall or winter sampling period (October through February); spring sampling period (March through June).

<sup>b</sup> Number of plants with at least one sample positive for Salmonella spp. or number of samples positive for Salmonella spp.

<sup>c</sup> Percentages within an item bearing a common letter are not different (P > 0.05).

TABLE 3. Mean (log CFU/cm<sup>2</sup>) APC, TCC, and ECC on lamb carcasses in the cooler after 24 h of chilling, for all six plants by season

<table>
<thead>
<tr>
<th>Plant</th>
<th>APC</th>
<th>TCC</th>
<th>ECC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall or winter</td>
<td>Spring</td>
<td>Fall or winter</td>
</tr>
<tr>
<td>A&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>5.2 FY&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.5 Hz&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.0 FY&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>B&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.1 FY&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5.2 FY&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.8 FY&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>C&lt;sup&gt;c,c&lt;/sup&gt;</td>
<td>4.1 GY&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.4 HZ&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.0 FY&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>D&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.4 EY&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5.6 EY&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.1 EY&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>E&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.0 FY&lt;sup&gt;e&lt;/sup&gt;</td>
<td>4.6 GZ&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.8 GY&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>F&lt;sup&gt;c,c&lt;/sup&gt;</td>
<td>2.9 HY&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.3 IZ&lt;sup&gt;e&lt;/sup&gt;</td>
<td>-0.2 HY&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Plants applied an organic acid rinse (acetic or lactic) prior to chilling.

<sup>b</sup> Plants used a previsceral wash (ambient temperature water wash).

<sup>c</sup> Plants used an inverted pelt-removal system. Plant C used a conventional pelt-removal system during winter sampling and an inverted system during the spring sampling.

<sup>d</sup> Plants removed pelt manually. Plant D used an automatic pelt-removal system during spring sampling.

<sup>e</sup> Means in a column bearing a common letter (e through i) are not different (P > 0.05). Means in a row within a type of microbiological plate count and bearing a common letter (y, z) are not different (P > 0.05).
TABLE 4. Mean (log CFU/cm²) APC, TCC, and ECC on lamb carcasses in the cooler after 24 h of chilling, across six plants during both seasons

<table>
<thead>
<tr>
<th>Sampling location</th>
<th>n</th>
<th>Sampling period</th>
<th>APC</th>
<th>TCC</th>
<th>ECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooler (after 24 h chill)</td>
<td>1,259</td>
<td>Spring</td>
<td>4.23 A</td>
<td>1.29 b</td>
<td>0.63 b</td>
</tr>
<tr>
<td></td>
<td>1,261</td>
<td>Fall or winter</td>
<td>4.61 b</td>
<td>1.08 A</td>
<td>0.76 b</td>
</tr>
<tr>
<td></td>
<td>2,520</td>
<td>Both periods</td>
<td>4.42</td>
<td>1.18</td>
<td>0.70</td>
</tr>
</tbody>
</table>

a Fall or winter sampling period (October through February); spring sampling period (March through June).
b Means in a column, bearing a common letter, are not different (P > 0.05).

Duffey et al. (17) found that, overall, acetic acid and water temperature were the most important factors in reducing APC and fecal contamination on lamb adipose tissue. For both sampling times, mean TCCs were lower (P < 0.05) in plants using an organic acid (plants A, C, F) compared to plants using only water (at an ambient temperature) to wash carcasses or plants that relied on trimming alone (plants B, D, E). Similar to these results, Hardin et al. (15) reported that application of an organic acid rinsing treatment following washing of beef carcasses was more effective than washing only or trimming to reduce microbiological contamination. During the spring sampling period, mean APC were lower (P < 0.05) in plants applying an organic acid rinse to carcasses before chilling.

Some large differences in bacterial counts were observed between seasonal sampling periods in plant C. Admittedly, the difference in plate counts may not have been entirely due to seasonal effects. Between the two sampling times, this particular plant (plant C) converted its conventional dressing system (lamb hangs by the hind legs during pelt removal) to an inverted chain system (lamb hangs by front legs during pelt removal) that may have contributed to the decreased bacterial counts on carcass surfaces. Inverted lamb-harvesting systems have been shown to produce carcasses with lower visible and bacterial contamination levels when compared to conventional systems (4, 29). With the inverted dressing system, the pelt-opening cuts are made in the forequarter region of the carcass rather than in the hindquarter region, which is an area associated with high contamination. The pelt is pulled from the fore-quarter down, keeping the contamination around the leg and anus from being spread across the carcass. Mean APC, TCC, and ECC (Table 3) all were lower (P < 0.05) for samples collected from carcasses processed in plant C during the spring sampling period compared to samples collected during the fall or winter sampling period.

Overall mean APC, TCC, and ECC (log CFU/cm²), across all six plants and for both seasons are presented in Table 4. APC were lower (P < 0.05) in samples collected in the spring versus fall or winter sampling periods, while TCC were higher in samples collected in the spring sampling period. There was no difference (P > 0.05) between ECC from samples collected in the spring versus the fall or winter season.

Frequency distributions for APC, TCC, and ECC on lamb carcasses in the cooler following 24 h of chilling are presented in Figures 1, 2, and 3, respectively. As illustrated in Figure 1, 34.6% of the APC were greater than 5 log CFU/cm². These APC were high and could probably be lowered by utilizing microbiological intervention strategies not already in place and by paying closer attention to sanitation practices, handling procedures, and overall plant sanitation. For TCC (Fig. 2), 47.2% of values were less than 1 log CFU/cm² and 62.1% of values for ECC (Fig. 3) were less than 1 log CFU/cm² of carcass surface sampled.

CONCLUSIONS

This study presented a general overview of the level of microbiological contamination occurring on chilled lamb carcasses processed in the United States at the period of

FIGURE 1. APC distribution on lamb carcasses in the cooler following 24 h of chilling.

FIGURE 2. TCC distribution on lamb carcasses in the cooler following 24 h of chilling.
time that these samples were collected. Results of this study suggested that the use of in-plant processing technologies and the utilization of in-plant decontamination interventions assist in the reduction of microbiological contamination on lamb carcasses. Some lamb packing facilities included in this study need to improve their slaughter and dressing procedures and/or facilities in order to lower the microbiological contamination levels. These results should be useful to the lamb industry and regulatory authorities as a means to identify improvements in the microbiological status of lamb after the implementation of new regulations and/or the installation of new lamb carcass decontamination technologies.

REFERENCES


