Microbiology of Pork Carcasses from Pigs with Differing Origins and Feed Withdrawal Times†

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ABSTRACT

The effects of buying source (terminal market, buying station, outdoor farm, and indoor farm), feed withdrawal before slaughter (0, 2, 4, and 6 h), and the incidence of punctured gastrointestinal (GI) tracts during evisceration on the numbers of pathogenic and spoilage bacteria on pork carcasses were determined. Of the 932 samples tested, a 0% incidence of the pathogens Salmonella spp., Listeria monocytogenes, Campylobacter spp., Clostridium perfringens, and Yersinia enterocolitica was found. A significant (P < 0.05) location effect was found, with the belly-sternum region having higher total plate counts than the head, pelvic cavity, and diaphragm regions of the carcass. A significant (P < 0.05) buying-source effect indicated that pigs from buying stations had higher lactic acid bacteria counts than pigs from outdoor and indoor farms. A buying source by fasting time interaction (P < 0.05) was noted for GI tract weights, with the indoor farm pigs having the highest incidence of ruptured GI tracts. The removal of feed prior to slaughter resulted in lighter GI tract weights and a lowered incidence of visceral rupture resulting in a lowered risk of pathogen contamination of carcasses. The extent of punctured GI tracts during evisceration was influenced by fasting time and buying source and may be useful in a HACCP system for the pork-processing industry.

Key words: Microorganisms, feed withdrawal, pork carcasses

When developing an effective hazard analysis critical control point (HACCP) system to reduce possible pathogenic bacteria from pork carcasses, it is essential to begin with preharvest (on-farm) issues. Many on-farm factors can contribute to the extent of bacterial contamination of pork carcasses. One of these factors is feed withdrawal before slaughter.

Most animals that have feed withdrawn before slaughter are easier to eviscerate and have more thorough bleeding. If the intestines are distended with feed when pigs are exposed to the stress and excitement of handling and transportation, the mucosa may be put under greater pressure and may be subject to small ruptures. Also, when the intestinal tract contains a large amount of ingesta, it is more difficult to handle during evisceration and is more likely to break or be accidentally cut, causing carcass contamination and economic loss to the packer.

Another on-farm factor that can contribute to the extent of bacterial contamination of pork carcasses is pig handling before and during transportation. Swine production facilities, both indoor and outdoor, can affect the extent of bacterial contamination. Outdoor production facilities will most likely result in an animal contaminated with soil and from the surrounding environment before transportation. Additionally, the source of pigs (terminal markets, buying stations, indoor farms, or outdoor production farms) could have a profound influence on gut fill and the extent of fasting or feed removal the animal is subjected to before slaughter. The immediate objective of this study was to determine the effect of different sources and feed withdrawal times before slaughter on the incidence of pathogenic as well as aerobic bacteria and lactic acid bacteria on pork carcasses. The percentage of broken viscera was correlated with the fasting time and buying source of the pigs. This research was designed to show whether buying source and feed withdrawal time can be used as critical control points in a HACCP system to lower the numbers of pathogens to which pork carcasses are exposed and to show the economic value or costs to the pork industry.

MATERIALS AND METHODS

Sample selection

Four hundred slaughter pigs from each of four single buying sources (terminal market, buying station, outdoor farm, and indoor farm) were selected at a commercial pork packing plant (see Table 1). All pigs were transported in double-decked 18-wheeler trucks from the buying source to the packing plant. As pigs were received at the packing plant, they were allotted to four feed withdrawal and resting time groups (0, 2, 4, and 6 h), and all were allowed free access to water.

Slaughter

Pigs were slaughtered following normal industry slaughter practices at the Monfort pork processing facility in Marshalltown,
IA. Thirty GI tracts from pigs in each feed withdrawal time and
buying source were collected and weighed. Ten carcasses from pigs
with punctured viscera as well as ten pigs without punctured
viscera were marked for sample collection. Because viscera were
not intentionally punctured, some treatments did not have 10
carcasses from pigs with punctured viscera. Carcasses were chilled
at 0°C for 24 h.

Sample collection
Carcasses were placed on a separate rail in the chill cooler.
Surface samples of approximately 454 g were aseptically collected
from the head, diaphragm muscle, belly-sternum, and pelvic cavity
regions. Samples were cut from these four regions to represent
areas of possible heavy contamination; the cutting knife was
sterilized with 95% ethyl alcohol and allowed to dry between each
sample. Samples were placed in Whirl-Pac® bags (Cole-Parmer,
Niles, IL) and packed in dry ice. Samples were shipped overnight
to the Warren G. Monfort Analytical Laboratory in Greeley,
Colorado for microbiological analyses.

Microbiological analyses
For aerobic plate count (APC) and lactic acid bacteria (LAB)
enumeration, 25-g meat samples were macerated in a Stomacher
400 lab blender for 1 min in a sterile bag containing 250 ml of
Butterfield's phosphate buffer. Serial dilutions in sterile Butter-
field's phosphate buffer were prepared from the macerate (6). The
APC bacteria were enumerated using standard methods agar
(BioPro, Redmond, WA) incubated at 35°C for 48 h ± 2 h and LAB
were enumerated using MRS Broth with .015% granulated agar
(BioPro) incubated at 25°C for 48 h ± 2 h.

For Salmonella spp., 25-g samples were enriched in 250 ml of
sterile 0.1% peptone water at 35°C for 24 h ± 3 h. For selective
enrichment, 1 ml of buffered peptone water was transferred to 9 ml
each of tetrathionate (BBL Microbiology Systems, Cockeysville,
MD) and selenite cystine broth (Difco Laboratories, Detroit, MI)
and incubated in a water bath at 42°C for 16 to 20 h. For
nonselective enrichment, 0.5 ml from each selective enrichment
was transferred into a single 9-ml tube of sterile M broth (Difco)
and incubated in a water bath at 42°C for 6 h. Samples then were
analyzed for the presence or absence of Salmonella spp. using a
TECRA Salmonella Visual Immunoassay (TECRA Diagnostics,
Roseville, Australia).

For Listeria monocytogenes, 25-g samples were enriched in
250 ml of UVM modified listeria broth (BioPro) at 25°C for 24 h ±
3 h. One milliliter of this enrichment was inoculated into 9 ml of
Fraser broth (Difco) and incubated at 35°C for 24 h ± 3 h. After
incubation, samples were streaked on Oxford medium base (Difco)
and incubated at 35°C for 24 h ± 3 h. Tiny black colonies were
considered typical Listeria colonies. Typical colonies were streaked
for isolation on Columbia blood agar base (Difco) and incubated at
35°C for 24 h ± 3 h. Small translucent colonies were stabbed into
motility medium (Difco) and incubated at room temperature for
7 days. Samples positive for motility were considered positive for
Listeria spp. Samples that demonstrated hemolysis on Columbia
blood agar were subjected to a CAMP test using Trypticase soy
agar (BioPro, Redmond, WA) incubated at 25°C for 24 ± 3 h. For
nonselective enrichment, 0.5 ml from each selective enrichment
was transferred into a single 9-ml tube of sterile M broth (Difco)
and incubated in a water bath at 42°C for 6 h. Samples then were
analyzed for the presence or absence of Salmonella spp. using a
TECRA Salmonella Visual Immunoassay (TECRA Diagnostics,
Roseville, Australia).

For Campylobacter spp., 25-g samples were enriched under
microaerophilic conditions in 250 ml of brucella broth (BBL) at
44°C for 18 h. A microaerophilic atmosphere was attained by using
Campy Paks (BBL) that generated a 5% O2, 10% CO2, and 85% N2
atmosphere. After enrichment, samples were analyzed using a
Gene-Trak® Campylobacter Assay (Gene-Trak Systems, Framing-
ham, MA).

For Yersinia enterocolitica, 25-g samples were enriched in
peptone sorbitol bile broth (Difco) at 10°C for 10 days. After the
10-day enrichment, 1 ml of the sample was placed in 9 ml of 0.5%
KOH in 0.5% saline, and 0.1 ml of the resulting solution was spiral
plated on MacConkey agar (Difco) and incubated at 20.4°C for
48 h ± 2 h. Suspicious colonies appearing colorless or pale pink
and 1 to 2 mm in diameter were streaked onto a lysine arginine
iron agar slant (Difco) and incubated at 25°C for 48 h ± 2 h. Positive
tubes contained an alkaline slant and acid butt.

Data analysis
Data were analyzed using the general linear models procedure
(4). The independent variables of buying source, fasting time, and
location were analyzed using a completely randomized block
design with a 4 (buying source) by 4 (fasting time) by 4 (carcass
location) factorial arrangement. When a main effect showed a
significant F value, mean separation was accomplished through a
comparison of least squares means using orthogonal polynomials
(5). The predetermined level of probability was $P < 0.05$.

RESULTS

Even though Salmonella and Listeria species are not
very competitive (3), a 0% incidence of the assay pathogens
was found from the 932 samples tested. No differences in
APC were found due to buying sources, fasting times, or the
incidence of punctured GI tracts. A carcass-location effect

### TABLE 1. Main effects of carcass sample location and buying
source on aerobic plate counts and numbers of lactic acid
bacteria

<table>
<thead>
<tr>
<th>Sample location</th>
<th>Microorganism (mean log CFU/g of tissue; $n = \bullet$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Aerobic plate count</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>5.32a</td>
</tr>
<tr>
<td>Belly-sternum</td>
<td>4.63A</td>
</tr>
<tr>
<td>Pelvic cavity</td>
<td>5.65b</td>
</tr>
<tr>
<td></td>
<td>5.28A</td>
</tr>
<tr>
<td></td>
<td>5.26x</td>
</tr>
<tr>
<td></td>
<td>5.34x</td>
</tr>
<tr>
<td></td>
<td>5.44x</td>
</tr>
<tr>
<td></td>
<td>5.31x</td>
</tr>
</tbody>
</table>

*Values in the same column for either sample location or buying
source followed by different letters are significantly different
($P < 0.05$).
The effect of the buying source and fasting time on the weight of the gastrointestinal tract of slaughtered pigs

<table>
<thead>
<tr>
<th>Buying source</th>
<th>Fasting time (h)</th>
<th>Mean gastrointestinal tract weight (kg); n = 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal market</td>
<td>0</td>
<td>8.1BCDE</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8.2BCDE</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>7.8ABCD</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>7.4A</td>
</tr>
<tr>
<td>Buying station</td>
<td>0</td>
<td>8.4CDE</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8.9EF</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>9.8F</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>8.9E</td>
</tr>
<tr>
<td>Outdoor farm</td>
<td>0</td>
<td>8.5DE</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8.1BCDE</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>8.6E</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>7.7ABC</td>
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<tr>
<td>Indoor farm</td>
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<td></td>
<td>2</td>
<td>8.3CDE</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>7.5AB</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>8.7E</td>
</tr>
</tbody>
</table>

*Values followed by different letters are significantly different (P < 0.05).*

(P < 0.05) was noted with higher APC from the belly-sternum region than from the head, pelvic cavity, and diaphragm regions (Table 1). No significant differences of LAB counts between the different fasting times, locations, or the incidence of a punctured GI tract were noted. A significant (P < 0.05) buying-source effect was noted, with pork from pigs acquired at buying stations having higher LAB compared with that from outside farms and indoor farms (Table 1). Pork samples from pigs from buying stations and terminal markets were not different in LAB counts.

A significant (P < 0.05) buying-source by feed-removal time interaction for GI tract weights was found (Table 2). The pigs obtained from the four sources did not differ in mean GI tract weight at the 0-h fasting time. All of these pigs had access to water when they arrived at the slaughter plant. Approximately 1 h elapsed between arrival at the plant and slaughter of this 0-h group. After 2 h of feed removal, GI tract weights also were not significantly affected (P > 0.05) by the source of the pigs. However, after 4 h, pigs from the buying station had the heaviest (P < 0.05) GI tracts and those from the outdoor facility had heavier (P < 0.05) GI tract weights than those from the terminal market and indoor farm. After 6 h of fasting, pigs from the buying station and indoor farm had heavier (P < 0.05) GI tracts than those from the terminal markets and outdoor farm. These results support the belief that the amount of fill in the GI tracts varies across buying source and feed withdrawal time and should have an impact on the percentage of broken viscera. Of the 1,600 carcasses, 4.5% had viscera punctured during evisceration: 1.6% after a 0-h feed withdrawal, 1.5% after a 2-h withdrawal, 0.5% after a 4-h withdrawal, and 0.7% after a 6-h withdrawal (Figure 1). Feed withdrawal for more than 2 h before slaughter reduced broken viscera by at least 50%. The distribution of the percentage of broken viscera from the different buying sources was also determined: 0.6% were from terminal-market hogs, 0.6% from buying-station hogs, 1.1% from outdoor-farm hogs, and 2.0% from indoor-farm hogs (Figure 2). These data support the assumption that a greater number of carcasses with broken viscera will come from hogs with the shortest feed withdrawal time (Figure 1). These data also support the assumption that carcasses of hogs that come from an outdoor farm or indoor farm will likely have a higher percentage of punctured viscera (Figure 2), since there is a shorter withdrawal time from feed than for those hogs that come from terminal markets or buying stations.

**DISCUSSION**

The incidence of pathogens such as *Salmonella* spp., *Campylobacter* spp., and *Yersinia enterocolitica* in slaughter pigs and swine carcasses has been well documented. Mafu et al. (3) evaluated the degree of contamination of cooler-ready hog carcasses. Of the muscle samples assayed (448), 1.5% yielded *Salmonella* spp. and approximately 20% yielded *Campylobacter coli*. Both Mafu et al. (3) and Kotula et al. (2) recovered *Y. enterocolitica* isolates from cecal contents. Pork carcasses contain relatively low numbers of bacteria after scalding because of the high scalding temperatures and the alkalinity of the water (1). The zero incidence of pathogens observed in this study, even on carcasses with punctured viscera, indicates that buying source and fasting time will not play a role in the incidence of pathogens on pork carcasses. These results also show that the slaughter plant from which these samples were obtained must be meeting strict sanitation guidelines after scalding necessary to keep contamination levels low.

The GI tract weights were affected by a feed-withdrawal time by buying-source interaction. The pigs from the terminal market had been trucked the longest time. Apparently, during the time of approximately 1 h from arrival at the slaughter plant and slaughter, the pigs from the

![FIGURE 1. Percentage of broken viscera in carcasses from hogs with different rest times.](http://meridian.allenpress.com/jfp/article-pdf/60/3/242/2322044/0362-028x-60_3_242.pdf)
terminal market drank water after having had none during transport. They actually had slightly higher GI tract weights after 2 h of feed withdrawal, but a decline in GI tract weight began after that time.

The pigs from the outdoor farm facility were trucked the second greatest distance. They too apparently drank water after arriving at the slaughter plant and did not lose GI tract weight until 6 h of fasting. Pigs from the buying station had access to water but apparently drank more water after arriving at the slaughter plant. Their GI tracts weighed more after 4 h of fasting than after 0 or 6 h. Pigs from the indoor farm facility were taken off feed and trucked directly to the slaughter plant. They had the lowest GI tract weights after 4 h of feed removal and apparently drank water after that time.

The difference in percentage of punctured viscera between carcasses of hogs with different feed withdrawal times and buying sources is a very important finding of this study. The incidence of punctured viscera (4.5%) in carcasses from the hogs in this study was relatively low. The greatest number of punctures occurred in carcasses from pigs that had the shortest feed withdrawal time and from pigs that came from an indoor swine farm. Hogs that come from outdoor or indoor farms are likely to have the least amount of feed withdrawal time as compared to terminal-market or buying-station hogs. Although these data do not show an increased risk of bacterial contamination from carcasses that have punctured viscera, the hazard is always present. The conclusions concerning the percentage of broken viscera from different fasting times and buying sources can be used as two preslaughter critical control points for inclusion into implementation of a HACCP system for controlling bacterial contamination of pork carcasses.

The economic impact of utilizing feed withdrawal for hogs prior to slaughter is of significant importance. The cost benefit to the packer would be approximately $.30 per pig as a result of reduced solids and waste removal. The exception would be if an increase in pen space is needed to accommodate a greater number of hogs on the plant grounds before slaughter. The economic impact on the hog producer would depend on whether the hogs were purchased on a live or a hot-carcass weight basis, since pigs withdrawn from feed 24 h prior to shipment would have lower live weights. Feed savings for the producer would result in a $0.50 per head savings. Therefore, the removal of feed from pigs prior to slaughter would reduce the contamination of pork carcasses and should be added to any HACCP system utilized by pork slaughter facilities.

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REFERENCES