Salmonella Enteritidis in Broiler Chickens, United States, 2000–2005
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US Department of Agriculture Food Safety and Inspection Service (FSIS) data on Salmonella enterica serotype Enteritidis in broiler chicken carcass rinses collected from 2000 through 2005 showed the annual number of isolates increased >4-fold and the proportion of establishments with Salmonella Enteritidis–positive rinses increased nearly 3-fold (test for trend, p<0.0001). The number of states with Salmonella Enteritidis in broiler rinses increased from 14 to 24. The predominant phage types (PT) were PT 13 and PT 8, 2 strains that a recent Foodborne Diseases Active Surveillance Network (FoodNet) case-control study associated with eating chicken. FSIS is directing more sampling resources toward plants with marginal Salmonella control to reduce prevalence in products including broilers. The policy targets establishments with common Salmonella serotypes of human illness, including Salmonella Enteritidis. Voluntary interventions should be implemented by industry.

During the 1990s, Salmonella enterica serotype Enteritidis briefly surpassed S. Typhimurium as the predominant Salmonella serotype isolated from humans in the United States (1). Eggs were frequently implicated as the cause of outbreaks of human infection (2,3), and the outbreak strain was often detected in the implicated egg production flock (4). After egg producers implemented quality assurance programs in the late 1990s, human Salmonella Enteritidis infection rates decreased by ≈50% (1).

Recently, 2 US case-control studies in Foodborne Diseases Active Surveillance Network (FoodNet) sites identified eating chicken as a risk factor for sporadic human Salmonella Enteritidis infection (5,6), replicating findings of a case-control study performed in England in the late 1980s (7). While the overall incidence of human salmonellosis in FoodNet sites was lower in 2005 than in the mid-1990s, the incidence of Salmonella Enteritidis infections was ≈25% higher (8). We present US Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) Salmonella testing program data collected from 2000 to 2005 that suggest a need for interventions to prevent the emergence of this Salmonella serotype in broiler chickens in the United States.

Methods
FSIS Salmonella Testing Program
As of January 2000, an FSIS performance standard for Salmonella was set for all establishments that slaughter US broiler chickens (9). Establishments that slaughtered >20,000 chickens per year were eligible for FSIS regulatory Salmonella testing. These establishments accounted for >95% of raw poultry marketed in the United States.

The sampling frame for the present study included all eligible FSIS-inspected establishments. Each month, eligible facilities were randomly selected for Salmonella testing to begin in the following month. In each broiler slaughter setting that was tested, 1 broiler chicken carcass rinse (hereafter referred to as broiler rinse) was collected per day for 51 days of operation. The 51 broiler rinses constitute a “Salmonella set.” Sets were scheduled approximately once a year. When a plant did not meet the Salmonella performance standard, a follow-up set was scheduled. To limit bias, this report does not include data from follow-up sets.

Carcasses were collected after they exited the chiller, downstream from the slaughter line. The chiller is designed to bring carcass temperatures down to the refrigeration range. The postchill collection site was selected as
the sampling site because interventions for pathogen reduction are generally located before this point.

Broiler Rinse Collection
Carcasses were collected after they exited the chiller and aseptically placed in a sterile bag. A 400-mL volume of buffered peptone water was added to the carcass in the bag. Half the volume was poured into the interior cavity and the other half over the skin. The carcass was rinsed with a rocking motion for 1 minute at a rate of \(\approx 35\) cycles per minute. After the carcass was removed from the bag, the rinse was poured into a sterile container and shipped on a freezer pack by overnight mail to 1 of 3 FSIS laboratories (Athens, GA; Alameda, CA; St. Louis, MO, USA) for analysis (10).

Microbiologic Testing
Testing of broiler rinses for Salmonella was performed by using standard FSIS isolation methods (11). Before October 2003, an immunoassay system (Assurance polyclonal enzyme immunoassay, BioControl Systems, Inc., Bellevue, WA, USA) was used to screen enrichment broths for Salmonella. Beginning in October 2003, Salmonella gene amplification (BAX System PCR Assay, DuPont Qualicon, Wilmington, DE, USA) was performed on lysed cells after overnight incubation in buffered peptone broth (35°C). Broiler rinses that tested positive on the screening test were cultured for Salmonella with standard methods (i.e., selective enrichment, plating, serologic and biochemical confirmation). Three presumptive Salmonella colonies with the predominant colony form were selected from each plate for biochemical and serologic confirmation. One confirmed Salmonella isolate was sent to the National Veterinary Services Laboratories (NVSL, USDA-APHIS-VS, Ames, IA, USA) for Salmonella serotyping (12).

Beginning in 2001, isolates of Salmonella Enteritidis were phage typed at NVSL (13). Because the predominant Salmonella Enteritidis phage types were clonal (6,14) and pulsed-field gel electrophoresis and antimicrobial susceptibility patterns were not available on all isolates during the study period, no further characterization of the isolates was performed for this report.

Analysis
Analysis was restricted to Salmonella sets performed in calendar years 2000–2005. A \(\chi^2\) test (2-sided) was used to test trends for annual percent of Salmonella Enteritidis isolates among Salmonella-positive broiler rinses and all analyzed broiler rinses, respectively. A \(\chi^2\) test for trend was also performed to assess the percent of establishments tested annually with Salmonella Enteritidis–positive broiler rinses, with subanalyses by establishment size. Approximately two thirds of establishments were large (\(>500\) employees), one fourth were small (\(<500\) but \(\geq 10\) employees), and \(5\%\) were very small (\(<10\) employees). In addition, a \(\chi^2\) test for trend was performed on the number of isolates per Salmonella Enteritidis–positive establishment, by year (SAS version 9.1, SAS Institute, Inc., Cary, NC, USA).

The number of positive broiler rinses per state was plotted on a US map that showed the geographic density of broiler chicken production by county for the year 2002 (15). Results were plotted for 2 periods: calendar years 2000–2002 and 2003–2005. Phage types of isolates were tabulated by year.

The present study preceded a new FSIS policy to control Salmonella. The new policy emphasizes improvement in Salmonella control in product classes that have not reduced Salmonella prevalence in the past decade, such as broilers, and focuses on plants that test positive for common serotypes of human illness, such as Salmonella Enteriditis (16).

Results
During the 6-year study period, 280 (0.5%) Salmonella Enteritidis isolates were recovered from 51,327 broiler rinses (Table 1). From 2000 to 2005, the proportion of Salmonella isolates that were Salmonella Enteritidis increased (test for trend, \(p<0.0001\)). The percentage of all broiler rinses that tested positive also increased (test for trend, \(p<0.0001\)).

Overall, 90 establishments tested positive from 2000 through 2005. The number of establishments testing positive increased from 17 (9%) of 197 in 2000 to 47 (25%) of 187 in 2005 (test for trend, \(p<0.0001\), Table 2).

Table 1. Salmonella Enteritidis (SE) isolates per year as a proportion of Salmonella-positive broiler rinses and total broiler rinses, 2000–2005

<table>
<thead>
<tr>
<th>Year</th>
<th>No. SE isolates</th>
<th>Salmonella-positive rinses</th>
<th>SE as a proportion of all salmonellae (%)</th>
<th>No. rinses tested</th>
<th>SE-positive rinse as a proportion of all rinses</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>23</td>
<td>914</td>
<td>2.5</td>
<td>10,057</td>
<td>0.2</td>
</tr>
<tr>
<td>2001</td>
<td>17</td>
<td>1,065</td>
<td>1.6</td>
<td>8,955</td>
<td>0.2</td>
</tr>
<tr>
<td>2002</td>
<td>33</td>
<td>1,059</td>
<td>3.1</td>
<td>9,183</td>
<td>0.4</td>
</tr>
<tr>
<td>2003</td>
<td>29</td>
<td>828</td>
<td>3.5</td>
<td>6,468</td>
<td>0.5</td>
</tr>
<tr>
<td>2004</td>
<td>58</td>
<td>957</td>
<td>6.1</td>
<td>7,072</td>
<td>0.8</td>
</tr>
<tr>
<td>2005</td>
<td>120</td>
<td>1,559</td>
<td>7.7</td>
<td>9,592</td>
<td>1.3</td>
</tr>
<tr>
<td>Total</td>
<td>280</td>
<td>6,382</td>
<td>4.4</td>
<td>51,327</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Test for trend, \(p=0.0001\); SE isolates as a proportion of Salmonella isolates and all broiler rinses by year.
increase in the number of positive establishments per year remained significant after stratification by large versus small establishment size. While most establishments with Salmonella Enteritidis–positive broiler rinses were large, in most years, a higher proportion of the small establishments that were tested had positive rinses.

During the 6-year study period, the proportion of Salmonella Enteritidis–positive establishments with multiple positive broiler rinses per year also increased significantly (p<0.01, test for trend, Figure 1). In addition, the proportion of establishments with ≥4 positive broiler rinses per year (of 51 broiler rinse tests per set) increased, beginning in 2002.

From 2000 to 2002, Salmonella Enteritidis was isolated from broiler rinses in 14 states, compared with 24 states from 2003 to 2005 (Figure 2). Phage type (PT) 13 was predominant, accounting for half of all isolates, followed by Salmonella Enteritidis PT 8, which accounted for more than one third of isolates (Table 3). In 2005, the number of isolates that were PT 8 increased >3-fold compared with 2004.

Discussion

The principal finding of this study was a significant increase in the number of broiler chicken slaughter establishments with Salmonella Enteritidis–positive broiler rinses in the years from 2000 through 2005. The 90 slaughter establishments with positive rinses were dispersed across 24 states, reflecting the geographic distribution of the US broiler industry. During the study period, increases were seen in the proportion of both large and small establishments that had such positive broiler rinses.

Some caution is warranted when interpreting our findings. The purpose of the FSIS Salmonella program is to assess performance of individual establishments. The program is not designed to estimate national prevalence of poultry contamination because it does not fully account for production volume or regional or seasonal effects. Furthermore, samples are collected after slaughter processes that are intended to reduce carcass contamination. Nonetheless, the apparent emergence of Salmonella Enteritidis in broilers is noteworthy given the increase in human Salmonella Enteritidis infection rates in the United States (8) and recent findings that eating chicken is a new and important risk factor for sporadic infection (5,6). Additional epidemiologic studies are recommended to further elucidate the role of contaminated chicken in human Salmonella Enteritidis infections and estimate the extent of illness attributable to chicken. Retail food surveillance and laboratory subtyping studies (6) may also be valuable because they enable comparisons of human and poultry strains.

In this report, 2 Salmonella Enteritidis phage types, PT 8 and PT 13, accounted for most isolates from broiler rinses. In a recent FoodNet study, the association between Salmonella Enteritidis infection and eating chicken strengthened in analyses restricted to patients infected with these 2 phage types (6). The possible emergence of these phage types in broiler chickens suggests that industry should implement appropriate Salmonella Enteritidis controls for broiler chickens (17,18).

The present study preceded a new FSIS policy to control Salmonella in broilers that emphasizes common serotypes of human illness (16). As part of this effort, FSIS

![Figure 1](https://example.com/figure1.png)
held 2 public meetings on Salmonella in broilers: 1 in Athens, Georgia, in August 2005 on controls before slaughter (preharvest), and another in Atlanta, Georgia, in February 2006 on controls in the slaughter plant (postharvest). Information from these meeting was used to prepare guidelines to help broiler plants control salmonellae. The agency is also monitoring progress of meat and poultry plants in controlling this organism. If, in July 2007, most plants (e.g., 90%) that manufacture a specific product (e.g., broiler carcasses) have not reduced the percentage of Salmonella tests that are positive to at least half the FSIS performance standard, the agency will consider actions to improve control of salmonellae. One option that FSIS is considering is to post Salmonella results on the web for product classes that have not made sufficient progress, listing data by plant name.

In the 1990s, successful voluntary quality assurance programs to control Salmonella Enteritidis were developed by the egg industry and state poultry health officials. Many of the interventions are adaptable to the control of this organism in broilers. For example, control points for the organism in broilers are likely to include monitoring and sanitation of breeding flocks, hatcheries, broiler flocks, and slaughter establishments. Serotype data that FSIS provides to plants on each isolate as part of its new Salmonella policy may also assist plant officials to make informed SE risk management decisions.

Acknowledgments

We thank the FSIS headquarters, inspection, and laboratory personnel and APHIS laboratory personnel who made the report possible.

Dr Altekruse is a veterinary epidemiologist in the Public Health Service assigned to the USDA Food Safety and Inspection Service. His research interests include characterization of Salmonella isolates from meat and poultry and reductions in indicator and pathogen counts during slaughter.

References


Table 3. Salmonella Enteritidis (SE) phage types from broiler rinses, 2001–2005*

<table>
<thead>
<tr>
<th>Year</th>
<th>SE isolates no.</th>
<th>PT 13 no. (%)</th>
<th>PT 8 no. (%)</th>
<th>Other† no. (%)</th>
<th>No data‡ no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>17</td>
<td>11 (65)</td>
<td>4 (24)</td>
<td>1 (6)</td>
<td>1 (6)</td>
</tr>
<tr>
<td>2002</td>
<td>33</td>
<td>12 (36)</td>
<td>8 (24)</td>
<td>5 (15)</td>
<td>6 (24)</td>
</tr>
<tr>
<td>2003</td>
<td>29</td>
<td>13 (45)</td>
<td>14 (48)</td>
<td>1 (3)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>2004</td>
<td>58</td>
<td>37 (64)</td>
<td>15 (26)</td>
<td>4 (7)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>2005</td>
<td>120</td>
<td>56 (47)</td>
<td>50 (42)</td>
<td>9 (8)</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Total</td>
<td>257</td>
<td>129 (50)</td>
<td>91 (35)</td>
<td>20 (8)</td>
<td>17 (7)</td>
</tr>
</tbody>
</table>

*Phage type (PT) data were not available for 2000. Row percents do not sum to 100 because of rounding.
†Other phage types: 13a (7); PT 23 (7); PT 28 (3); PT 2 (2); PT 14B (1).
‡No phage type data were available for 17 isolates.


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