



Salmonella and Campylobacter on U.S. Dairy Operations, 1996–2007

Salmonella and *Campylobacter* organisms are recognized as the two most common bacterial causes of foodborne illness in humans in the United States. Each year in the United States, *Salmonella* spp. are estimated to cause 1.4 million cases of disease with 500 deaths and *Campylobacter* spp. are estimated to cause 2.5 million cases of disease with 100 deaths.¹ Both of these pathogens can cause fever, abdominal cramping, and diarrhea in humans. Severe cases can result in systemic infections and death.

Salmonella spp. also can cause disease, occasionally leading to death, in cattle. Clinical signs of salmonellosis in cattle include fever, diarrhea, anorexia, abortion, and decreased milk production.² Cattle can shed *Salmonella* in their feces during and after episodes of clinical disease or without showing any clinical signs.

Campylobacter data presented in this report are for *C. jejuni* and *C. coli*, which are most commonly associated with human disease. These *Campylobacter* species are not important as disease-causing organisms in cattle. In the past, foodborne transmission of *Campylobacter* to humans was attributed primarily to handling and consumption of contaminated poultry meat.³ Molecular subtyping suggests, however, the role of nonpoultry sources of human infection is underestimated.⁴

NAHMS Dairy 2007 study

The National Animal Health Monitoring System (NAHMS) studied *Salmonella* and *Campylobacter* as part of the Dairy 2007 study. Goals of the Dairy 2007 study relating to *Salmonella* and *Campylobacter* were to

- Describe occurrence of *Salmonella* and *Campylobacter* and associated antimicrobial resistance on dairy operations in the United States, and
- Evaluate strategies for detection of *Salmonella* by comparing pooled and environmental samples with samples from individual cattle.

The Dairy 2007 study represented 79.5 percent of U.S. dairy operations and 82.5 percent of U.S. dairy

cows and was conducted in 17 of the Nation’s major dairy States.*

Salmonella prevalence and antimicrobial susceptibility

Prior to the Dairy 2007 study, NAHMS examined *Salmonella* occurrence in cows on dairy operations in two studies: Dairy 1996 and Dairy 2002. Table 1 presents results from these three NAHMS studies. In each study, fecal samples were collected from cows that were healthy, sick, or soon-to-be-culled at the time of sampling. The results in table 1 are limited to healthy cows because these populations were comparable across the three studies. In Dairy 1996, about 40 healthy cows were sampled on each of 90 operations (from 19 States), and in Dairy 2002, about 40 healthy cows were sampled on each of 97 operations (from 21 States). In Dairy 2007, approximately 30 healthy cows were sampled on each of 121 dairy operations (from 17 States). Samples were collected from the end of February through July for Dairy 1996, from the end of March through September for Dairy 2002, and from the end of February through August for Dairy 2007.

Table 1. Comparison of Salmonella Fecal-culture Results from Three NAHMS Dairy Studies¹

Study	Positive for <i>Salmonella</i> / Total Sampled	
	Operations ²	Cows
Dairy 1996	19/90 (21.1 percent)	198/3,640 (5.4 percent)
Dairy 2002	30/97 (30.9 percent)	259/3,645 (7.1 percent)
Dairy 2007	48/121 (39.7 percent)	523/3,804 (13.7 percent)

¹Only cows healthy at the time of collection are included.

²Operations with at least one positive cow were considered positive.

For Dairy 2007, the percentage of positive operations was almost double that of Dairy 1996, and the percentage of positive cows more than doubled over the same time period. Slight differences in sampling methodology, such as the number of operations sampled, might account for some of the differences among the three studies. *Salmonella* might be becoming more common on U.S. dairies, however.

*** States/Regions**

- **West:** California, Idaho, New Mexico, Texas, and Washington
- **East:** Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Vermont, Virginia, and Wisconsin

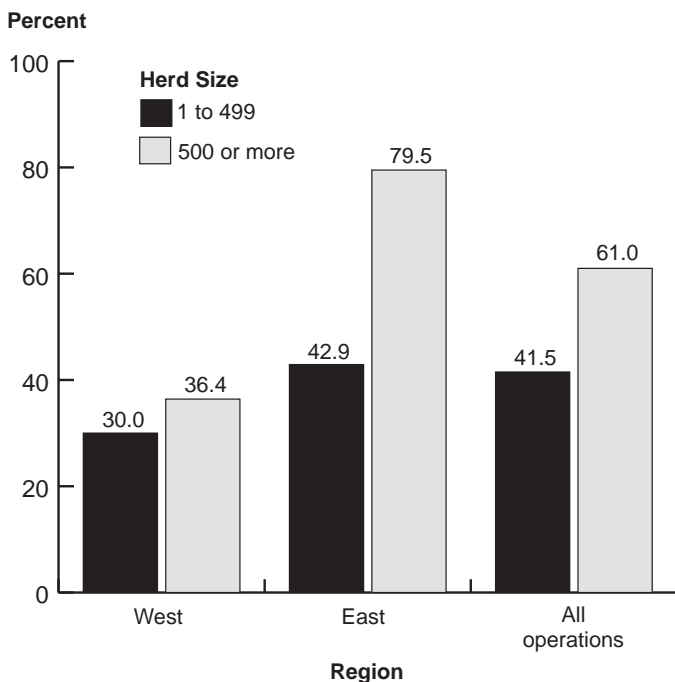
To evaluate strategies for detection of *Salmonella* in Dairy 2007, field personnel collected individual fecal samples from up to 35 cows (with up to 10 samples from sick and to-be-culled cows) and 6 samples from the dairy environment (environmental samples) on 116 operations. Samples from individual cows were also pooled at the laboratory, with each pool representing up to five cows. On an additional set of operations, only environmental samples were collected. Of the 265 operations with any of these types of samples taken for *Salmonella* testing, 47.2 percent were positive.

In 2007, the three sample types performed similarly in identifying operations with *Salmonella*, but environmental sampling identified a slightly higher percentage of positive operations. Among the 116 operations with all 3 sample types, the percentage of positive operations by testing method was as follows.

- Pooled: 39.7 percent
- Individual: 41.4 percent
- Environmental: 49.1 percent.

The percentage of operations on which *Salmonella* shedding was detected differed by herd size (see figure). Herd-size differences were more pronounced in the East region than in the West region. In the East region, almost 80 percent of operations with 500 or more cows had a least 1 *Salmonella*-positive sample, compared with only 42.9 percent of operations with fewer than 500 cows. In the West region, operations with fewer than 500 cows were just as likely to be *Salmonella*-positive as large operations. Overall, large operations were more likely to be *Salmonella*-positive, with 61.0 percent of

For Dairy 2007, Percentage of Operations with any *Salmonella*-positive Samples (n=265) by Herd Size*, and by Region



*Number of milk cows present on January 1, 2007.

operations with 500 or more cows being *Salmonella*-positive compared with 41.5 percent of operations with fewer than 500 cows.

The six most common serotypes identified from at least one sample from participating operations for each of the three NAHMS dairy studies are listed in table 2. Three serotypes—Meleagridis, Montevideo, and Mbandaka—ranked in the top six for each of the three NAHMS dairy studies. Of these three serotypes, *S. Montevideo* has been among the top 10 serotypes identified from humans in every year from 1996 through 2006, the last year for which results are available.⁵ *S. Meleagridis* and *S. Mbandaka* were not among the top 10 serotypes in humans for any year from 1996 through 2006.

Table 2. Most Common *Salmonella* Serotypes Identified from at Least One Sample from Participating Operations from Three NAHMS Dairy Studies

Rank	Dairy 1996	Dairy 2002	Dairy 2007
1	Montevideo	Kentucky/ Montevideo	Cerro/ Kentucky
2	Meleagridis		
3	Cerro/ Mbandaka/ Typhimurium	Mbandaka/ Meleagridis/ Newport	Montevideo/ Muenster
4			Meleagridis
5			
6	Anatum	Senftenberg	
7	Give/Kentucky/ Muenchen/ Senftenberg	Agona/Anatum/ Muenster/ Typhimurium	Mbandaka/ Newport

Salmonella isolates from the three NAHMS Dairy studies have shown relatively little resistance to antimicrobial agents. Of all *Salmonella* isolates tested for antimicrobial susceptibility, 88.9, 83.0, and 92.8 percent of isolates were susceptible to all antimicrobials tested in Dairy 1996, Dairy 2002, and Dairy 2007, respectively (table 3). In each study, about 5 percent of *Salmonella* isolates were resistant to two or more antimicrobials.

Table 3. Percent of *Salmonella* Isolates by Number of Antimicrobials to Which Resistance* was Observed, by NAHMS Study (n=number of isolates)

Susceptibility	Dairy 1996 (n=758)	Dairy 2002 (n=294)	Dairy 2007 (n=1,282)
Susceptible to all antimicrobials	88.9	83.0	92.8
Resistant to a single antimicrobial	6.6	12.2	1.7
Resistant to two or more antimicrobials	4.5	4.8	5.5
Total	100.0	100.0	100.0

*Intermediate isolates were classified as susceptible.

Resistance to tetracycline was most commonly observed in each of the three NAHMS Dairy studies (table 4). Resistance to amikacin, ciprofloxacin, and nalidixic acid was not observed in any of the studies. Dairy 2007 was the first study in which resistance to ceftriaxone was observed, but it was observed in only a single isolate. Resistance to ceftriaxone in cattle is of interest because it is commonly used to treat severe *Salmonella* infections in children.⁶

Table 4. Percent of Resistant* Isolates from all *Salmonella* Isolates Tested for Antimicrobial Susceptibility, by NAHMS Study and Antimicrobial (n=number of isolates)

Antimicrobial (Abbreviation)	Dairy 1996 (n=758)	Dairy 2002 (n=294)	Dairy 2007 (n=1,282)
Amikacin (AMI)	0.0	0.0	0.0
Amoxicillin-Clavulanic acid (AMO)	1.1	4.8	4.5
Ampicillin (AMP)	4.1	4.4	5.5
Apramycin (APR)	0.0	N/A	N/A
Cefoxitin (FOX)	N/A	3.7	4.2
Ceftiofur (TIO)	0.0	4.4	4.7
Ceftriaxone (AXO)	0.0	0.0	0.1
Cephalothin (CEP)	1.7	4.8	N/A
Chloramphenicol (CHL)	1.6	4.4	5.0
Ciprofloxacin (CIP)	0.0	0.0	0.0
Gentamicin (GEN)	0.1	0.7	0.1
Kanamycin (KAN)	1.7	0.7	0.7
Nalidixic Acid (NAL)	0.0	0.0	0.0
Streptomycin (STR)	4.1	9.5	5.4
Sulfamethoxazole** (SUL)	2.9	3.7	5.3
Tetracycline (TET)	8.0	11.9	6.6
Ticarcillin (TIC)	3.6	N/A	N/A
Trimethoprim-Sulfamethoxazole (TRI)	0.1	0.0	0.6

*Intermediate isolates were classified as susceptible.

**Sulfisoxazole replaced Sulfamethoxazole in 2007.

Of the 1,282 isolates tested in 2007, 65 isolates were resistant to multiple drugs. One resistance pattern (AMO, AMP, FOX, TIO, CHL, STR, SUL, TET) was found in *Salmonella* Newport isolates from three different operations. For one of these operations, this resistance pattern was also found in *S. Reading* and *S. Montevideo* isolates from the operation. In Dairy 1996 and Dairy 2002, more *S. Typhimurium* isolates were resistant to multiple drugs than other serotypes. In Dairy 2007, however, only one multidrug-resistant *S. Typhimurium*

was observed. Dairy 2007 is the first NAHMS Dairy study in which multidrug resistance has been observed in *S. Montevideo*, which has been one of the top three serotypes identified in each of the previous NAHMS studies (table 2).

***Campylobacter* prevalence and antimicrobial susceptibility**

Previous NAHMS studies have found *Campylobacter* to be present on most U.S. dairy operations. In Dairy 1996, *Campylobacter* was detected in at least one healthy cow on all sampled operations, based on detection by a multiplex polymerase chain reaction (PCR) assay (table 5). In Dairy 2002, culture methods found that 97.9 percent of operations sampled had at least one healthy cow shedding *Campylobacter* in its feces. In Dairy 2007, culture methods found that 92.6 percent of 121 operations had at least 1 healthy cow shedding *Campylobacter* in its feces, and all positive operations had at least 1 healthy cow shedding *C. jejuni*. Of the 1,885 healthy cows tested in Dairy 2007, 635 (33.7 percent) were positive for *Campylobacter*.

Table 5. Comparison of *Campylobacter* Fecal-culture Results from Three NAHMS Dairy Studies¹

Study	Positive for <i>Campylobacter</i> / Total Sampled	
	Operations ²	Cows
Dairy 1996	31/31 (100.0 percent)	Not available
Dairy 2002	95/97 (97.9 percent)	730/1,424 (51.3 percent)
Dairy 2007	112/121 (92.6 percent)	635/1,885 (33.7 percent)

¹Only cows healthy at the time of collection are included.

²Operations with at least one positive cow were considered positive.

Antimicrobial-resistance testing was conducted on *Campylobacter* isolates from Dairy 2002 and Dairy 2007; because of the small number of *C. coli* isolates, results are presented only for *C. jejuni*. In Dairy 2002, one-half of the *C. jejuni* isolates were susceptible to all antimicrobials against which they were tested, while in Dairy 2007, 36.6 percent of the *C. jejuni* isolates were susceptible to all antimicrobials (table 6).

Table 6. Percent of *C. jejuni* Isolates by Number of Antimicrobials to Which Resistance* was Observed, by NAHMS Study (n=number of isolates)

Susceptibility	Dairy 2002 (n=473)	Dairy 2007 (n=623)
Susceptible to all antimicrobials tested	49.5	36.6
Resistant to a single antimicrobial	46.9	61.2
Resistant to two or more antimicrobials	3.6	2.2
Total	100.0	100.0

*Intermediate isolates were classified as susceptible.

Of the antimicrobials in table 7, ciprofloxacin and erythromycin are especially important because they are often used to treat humans infected with *Campylobacter*.⁷ Very few of the *C. jejuni* isolates were resistant to ciprofloxacin or erythromycin in the Dairy 2002 and Dairy 2007 studies. Tetracycline had the highest percentages of resistant isolates, with 47.4 percent and 62.9 percent of the *C. jejuni* isolates from Dairy 2002 and Dairy 2007, respectively, showing resistance.

Table 7. Percent of Resistant* Isolates from all *C. jejuni* Isolates Tested for Antimicrobial Susceptibility, by NAHMS Study and Antimicrobial (n=number of isolates)

Antimicrobial	Dairy 2002 (n=473)	Dairy 2007 (n=623)
Azithromycin	1.1	0.3
Ciprofloxacin	0.0	1.6
Chloramphenicol	2.5	N/A
Clindamycin	0.8	0.2
Erythromycin	0.4	0.3
Florfenicol	N/A	0.0
Gentamicin	0.2	0.0
Nalidixic Acid	4.0	1.9
Telithromycin	N/A	0.0
Tetracycline	47.4	62.9

*Intermediate isolates were classified as susceptible.

Conclusions

The percentage of *Salmonella*-positive dairy operations, based on individual culture of feces from healthy cows, has increased with each NAHMS Dairy study, from 21.1 percent in 1996 to 39.7 percent in 2007. The percentage of *Salmonella*-positive cows also has increased, from 5.4 percent in 1996 to 13.7 percent in 2007. Each NAHMS dairy study has had different objectives with regard to *Salmonella*, and sampling and culture techniques have differed slightly among studies. Results suggest, however, that *Salmonella* occurrence is increasing.

Salmonella isolates have shown relatively little resistance to antimicrobial agents in the three NAHMS Dairy studies. Most U.S. dairy operations were observed to have *Campylobacter*-positive cows in each of the three NAHMS Dairy studies. *C. jejuni* isolates collected during NAHMS studies have shown little resistance to antimicrobials, with the exception of tetracycline.

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