

# Diversity of *Salmonella* serovars in feedyard and nonfeedyard playas of the Southern High Plains in the summer and winter

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**Objective**—To compare *Salmonella* isolates cultured from feedyard and nonfeedyard (control) playas (ie, temporary shallow lakes) of the Southern High Plains.

**Sample Population**—Water and muck (sediment) samples were obtained from 7 feedyard playas and 3 nonfeedyard playas in the winter and summer.

**Procedure**—Each water and muck sample was enriched with sulfur-brilliant-green broth and incubated in a shaker at 37°C for 24 hours. A sample (100 mL) of the incubated bacterial-enriched broth was then mixed with 100 mL of fresh sulfur-brilliant-green enrichment broth and incubated in a shaker at 37°C for 24 hours. After the second incubation, a swab sample was streaked on differential media. Suspect *Salmonella* isolates were further identified by use of biochemical tests, and *Salmonella* isolates were confirmed and serovar determinations made.

**Results**—*Salmonella* isolates were not recovered from the 3 control playas. Seven *Salmonella enterica* serovars were isolated from 5 of 7 feedyard playas in the summer, and 13 *S enterica* serovars were isolated from 7 of 7 feedyard playas in the winter. In the summer, 296 isolates were cultured, and 47 were *Salmonella* organisms. In the winter, 288 isolates were cultured, and 171 were *Salmonella* organisms.

**Conclusions and Clinical Relevance**—Results indicated that feedyard playas are frequently contaminated with many *Salmonella* serovars. These pathogens should be considered whenever feedyard managers contemplate the use of water from these playas. Water from feedyard playas should not be used to cool cattle in the summer or for dust abatement. (*Am J Vet Res* 2004;65:40–44)

Playas (ie, temporary shallow lakes) are the main structures that contain surface water in much of the Southern High Plains, a semiarid region encompassing northwestern Texas and land in adjoining states.<sup>1</sup> Most feedyards in this area have a playa in which there is natural drainage from the feedyard to the playa; thus, many playas serve as retention ponds.

Nonfeedyard playas are numerous, and they may appear as large lakes at certain times of the year. It has been estimated that there are as many as 20,000<sup>2</sup> to 24,600<sup>3</sup> nonfeedyard playas in the Southern High

Plains. Nonfeedyard playas provide a ready source of water for cattle and wildlife, including migratory waterfowl.

Nonfeedyard playas have been the topic of more than 140 publications<sup>3</sup> during the past 40 years. These publications have reviewed many aspects of playas, such as problems with mosquitos, which are the vectors of viral encephalitis in western Texas<sup>4</sup>; plankton production<sup>4</sup>; water quality as assessed by anions and cations; amount of carbon dioxide dissolved in the water; and pollution from storm runoff.<sup>5</sup> Microbial studies of these playas have not been a priority.

The water from all playas normally evaporates. However, feedyard playas usually have some water in them provided by a continuous flow of waters from the feedyard. Playas are important to the environment and the ecosystems because they often provide the only surface water available. For this reason, they are referred to as the jewels of the plains.<sup>6</sup>

The Spanish conquistadors were the first to write about the playas of the Southwestern High Plains; however, Paleo-Indians of the area (including Clovis, Folsom, Plainview, and Firstview cultures) used the playas beginning approximately 11,000 years ago, long before the Spanish arrived.<sup>6</sup> In the early ranching days, it was said that bankers assessed rainfall by gauging water levels of local playas and adjusted their loans to farmers accordingly.<sup>7</sup> Playa water became less important after the Texas Land and Development Company drilled the first well and installed a windmill. Water from this well flooded a playa near the Plainview train station in 1913.<sup>8</sup> However, with the current depletion in the water level of the Ogallala aquifer,<sup>9,10</sup> playas are once again becoming important. There is economic pressure to use playa water when it is available. However, the movement of a larger number of feedyards from the Midwest to the Southern High Plains during the 1970s has increased the risk of introducing harmful microbes and parasites in playas adjoining feedyards.<sup>11</sup> This risk of pathogens draining into playas has only recently been addressed.<sup>1,12</sup> The objectives of the study reported here were to determine whether *Salmonella* pathogens could be isolated in the feedyard or nonfeedyard playas and the serovars of any salmonellae recovered.

## Materials and Methods

**Sample population**—Ten playas were used in the study. Three nonfeedyard (control) playas (CP 1, 9, and 10) and 7 feedyard playas (FY 1, 2, 3, 5, 7, 8, and 11) were identified for use in this study. Samples were obtained from all playas in the winter and summer, except for 2 control playas that were dry at the time of the winter sample collection.

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Collection of samples—A sample (2 L) of surface water was collected just below the surface of a playa into a sterile labeled plastic bottle. A second 2-L water sample was collected at the same depth but 3 m distant from the first sample. Each duplicate set of samples was collected once in the winter and once in the summer. A round-nosed shovel was used to collect muck (ie, sediment) from the bottom of the playa at the same sites from which the water samples were collected. Each muck sample (approx 1,000 g) was placed in a labeled screw-top plastic jar. Samples were collected from the north, south, east, and west part of each of the 10 playas. Samples were placed on ice and transported immediately to the microbiology laboratory for analysis.

*Salmonella* culture procedure—The duplicate samples of playa water were pooled, and an aliquot (100 mL) of the water was mixed with 100 mL of freshly prepared, double-strength, sulfur-brilliant-green enrichment broth<sup>1</sup> plus novobiocin<sup>b</sup> (25 µg/mL). This sample was incubated in a shaker incubator<sup>c</sup> at 37°C for 24 hours. Then, 100 mL of the bacterial broth was mixed with 100 mL of freshly prepared, sulfur-brilliant-green enrichment broth plus novobiocin, and this sample was similarly incubated in a shaker incubator at 37°C for 24 hours. Ten grams of the muck sample was mixed with 90 mL of freshly prepared, single-strength, sulfur-brilliant-green enrichment broth plus novobiocin (25 µg/mL) and then incubated in a shaker incubator at 37°C for 24 hours. Then, 100 mL of that incubated broth was mixed with 100 mL of freshly prepared, double-strength, sulfur-brilliant-green enrichment broth plus novobiocin and was similarly incubated in a shaker incubator at 37°C for 24 hours.

After the second incubation, samples were cultured for *Salmonella* spp on 3 types of differential media (MacConkey agar,<sup>d</sup> brilliant green agar,<sup>e</sup> and xylose-lysine-desoxycholate agar<sup>f</sup>). Each medium was prepared in separate petri plates<sup>g</sup> for isolation of the bacteria. A cotton-tipped swab<sup>h</sup> was dipped into the second of the incubated broths, and the specimen was applied to an area on one-fourth of the outer circumference of each plate. A platinum loop was used to make 2 sets of dilution streaks extending from the swab streak. Culture plates were incubated at 37°C for 24 hours and then examined to detect any colonies suspected of being *Salmonella* spp.<sup>13,14</sup> When no suspicious colonies were seen, the plates were incubated for an additional 24 hours and then reexamined. Any suspect *Salmonella* spp colonies were then cultured in a set of differential media tubes<sup>i</sup> that contained triple-sugar-iron agar,<sup>1</sup> lysine-iron agar,<sup>k</sup> motility indole ornithine,<sup>1</sup> and urease.<sup>m</sup> These tubes were incubated at 37°C for 18 hours. When the suspected culture qualified as a *Salmonella* isolate on the basis of results for the differential test, it was then placed on nutrient agar<sup>n</sup> supplemented with 5% bovine blood and incubated at 37°C for 24 hours. When a culture remained nonhemolytic, it was considered a *Salmonella* suspect. A duplicate of each culture was stored at -85°C. The *Salmonella* cultures were shipped to the National Veterinary Services Laboratory in Ames, Iowa, for verification as *Salmonella enterica* and serotyping.

Statistical analysis—Bacterial species were compared between winter and summer and between muck and water samples by use of a generalized linear model procedure, with the assumption that the data had a Poisson distribution.<sup>15</sup> The same procedure was used to make comparisons among playas; however, the high frequency of zero values resulted in the procedure not being able to fit the model. Significance was determined at values of  $P < 0.05$ .

## Results

Culture of samples collected during the summer yielded 296 isolates, of which 148 were suspected

*Salmonella* isolates. Thirty were verified as *S enterica* isolates, and we identified 7 serovars. These came from samples collected from the 7 feedyard playas (Table 1). Of the 7 serovars, 1 was isolated only from muck samples, 3 were isolated only from water samples, and 3 were isolated from both types of samples. The most numerous *S enterica* serovars isolated from muck samples were *Salmonella* ser Infantis (n = 5) and *Salmonella* ser Kentucky (8). The most numerous serovars isolated from water samples were *Salmonella* ser Cerro (14) and *Salmonella* Kentucky (10).

Culture of samples collected during the winter yielded 288 isolates, of which 192 were suspected *Salmonella* isolates. One hundred nineteen were verified as *S enterica* isolates, and we identified 13 serovars. These came from samples collected from the 7 feedyard playas (Table 2). Of the 13 serovars, 5 were isolated only from muck samples, 4 were isolated only from water samples, and 4 were isolated from both types of samples. The most numerous serovars cultured from water samples were *Salmonella* ser Mbandaka (n = 31), *Salmonella* ser Typhimurium (24), *Salmonella* Kentucky (19), *Salmonella* ser Montevideo (17), *Salmonella* ser Reading (12), and *Salmonella* ser Kiambu (10). The most numerous serovars cultured from muck samples were *Salmonella* Mbandaka (n=18), *Salmonella* Montevideo (8), *Salmonella* Cerro (6), and *Salmonella* Typhimurium (6).

Table 1—*Salmonella* serovars identified in cultures of samples collected during the summer from feedyard (FY) and nonfeedyard playas

Isolate	No. of isolations			Distribution
	Water	Muck	Total	
<i>Salmonella enterica</i>				
ser Agona	0	1	1	FY 1
ser Anatum	1	3	4	FY 2, 3, and 11
ser Cerro	14	0	14	FY 11
ser Infantis	2	5	7	FY 1
ser Kentucky	10	8	18	FY 1 and 3
ser Mbandaka	2	0	2	FY 3
ser Montevideo	1	0	1	FY 7
Subtotal <i>Salmonella</i> spp	30	17	47	
Not <i>Salmonella</i> spp	118	131	249	
<b>Total</b>	<b>148</b>	<b>148</b>	<b>296</b>	

Table 2—*Salmonella* serovars identified in cultures of samples collected during the winter from FY and nonfeedyard playas

Serovar	No. of isolations			Distribution
	Water	Muck	Total	
<i>Salmonella enterica</i>				
ser Agona	3	0	3	FY 5
ser Anatum	0	4	4	FY 1
ser Cerro	0	6	6	FY 3 and 5
ser Give	0	3	3	FY 11
ser Kentucky	19	2	21	FY 3
ser Kiambu	10	0	10	FY 1
ser Mbandaka	31	18	49	FY 2, 3, 7, and 11
ser Meleagridis	0	2	2	FY 7
ser Montevideo	17	8	25	FY 1, 7, and 8
ser Oranienburg	3	0	3	FY 2
ser Reading	12	0	12	FY 5, 7, 8, and 11
ser Thomsville	0	3	3	FY 5
ser Typhimurium	24	6	30	FY 8 and 11
Subtotal <i>Salmonella</i> spp	119	52	171	
Not <i>Salmonella</i> spp	73	44	117	
<b>Total</b>	<b>192</b>	<b>96</b>	<b>288</b>	

*Salmonella* isolates were not recovered from 3 control nonfeedyard playas during the summer. Samples could not be collected from 2 of the control playas during the winter, because they had no water in them.

The *S enterica* serovars isolated from water and muck samples collected during the summer that had the widest distribution among feedyards were *Salmonella* ser Anatum (3 feedyards) and *Salmonella* Kentucky (2 feedyards). In the winter, the most widely distributed serovars were *Salmonella* Mbandaka (4 feedyards), *Salmonella* Reading (4 feedyards), *Salmonella* Montevideo (3 feedyards), *Salmonella* Cerro (2 feedyards), and *Salmonella* Typhimurium (2 feedyards). The most numerous and widely distributed *S enterica* serovar among all feedyard playas throughout the year was *Salmonella* Mbandaka.

In the summer, there were significantly more non-*Salmonella* suspects as well as *Salmonella* Cerro, *Salmonella* Infantisis, and *Salmonella* Kentucky; however, in the winter, there were significantly more *Salmonella* ser Give and *Salmonella* Kiambu. There were significantly more *Salmonella* Anatum and *Salmonella* Give in muck samples, whereas there were significantly more *Salmonella* Cerro, *Salmonella* Kentucky, and *Salmonella* Kiambu in water samples.

## Discussion

Identification of *Salmonella* reservoirs is critical to the understanding of its dissemination in the environment. Managing multiple-host reservoirs is important in disease control.<sup>16</sup> Many emerging diseases of humans, livestock, and wildlife populations are assumed to be maintained in a reservoir host.<sup>17</sup> However, these reservoirs may include more than the assumed host or multiple-host reservoirs.<sup>18</sup> *Salmonella* organisms are found in feed mills and especially in the cooling systems used to prevent overheating of pelleted or mash feeds.<sup>19</sup> Nonmammalian hosts such as wild birds (passerines) can be a reservoir of *Salmonella* Typhimurium infections.<sup>20-22</sup> However, wild birds were not considered to be an important reservoir of *Salmonella* organisms on California dairies because of the low incidence of the pathogen and dissimilar serotypes in the dairies.<sup>23</sup>

*Salmonella* spp are widely disseminated in environments disrupted by human activities, and water plays an important role in the spread of these pathogens. The control of salmonellae must start by decreasing the flow of *Salmonella* spp into the environment<sup>24</sup> where they can remain viable for as long as 18 months.<sup>25</sup> For example, in 1 report,<sup>12</sup> *Salmonella* ser Dublin survived outside of the bovine host-reservoir for > 390 days in a feedyard playa. During that 390-day period, the *Salmonella* titer decreased from  $10 \times 10^{10}$  to  $1.44 \times 10^6$ . It is probable that during such a prolonged period, the genetic information (eg, antimicrobial resistance) is exchanged between members of the same bacterial species as well as among several species of bacteria.<sup>26</sup> Ecologic characteristics of antibiotic-resistant bacteria in animals and the manner in which these bacteria affect their environment is not well understood. It has been documented<sup>27</sup> that there is transfer of R-plasmid information between *Salmonella* Typhimurium and *Escherichia coli* isolated from calves.

The prevalence of *Salmonella* spp in the feces of feedyard cattle was 38% (38/100) of feedyards and 5.5% (273/4,977) of all samples in 1 study.<sup>28</sup> A higher percentage (7.4%) of *Salmonella* spp were isolated from the feces of cattle that had been fed the longest, compared to those fed the shortest period (3.5%).<sup>28</sup> The most common serovars recovered were *Salmonella* Anatum (27.9%), *Salmonella* Montevideo (12.9%), *Salmonella* ser Muenster (11.8%), *Salmonella* Kentucky (8.2%), and *Salmonella* ser Newington (4.3%).<sup>28</sup> Fecal samples collected from 187 production facilities in 22 states were analyzed for *Salmonella* spp, and *Salmonella* organisms were isolated from 21 (11.2%) of the facilities. There were 22 *Salmonella* serovars identified from beef cows. The 5 most common *Salmonella* serovars isolated were *Salmonella* ser Oranienburg (21.8%), *Salmonella* Cerro (21.8%), *Salmonella* Anatum (10.3%), *Salmonella* ser Bredeney (9.0%), and *Salmonella* Mbandaka (5.1%). Three of the most common *Salmonella* serovars (ie, Mbandaka, Cerro, and Anatum) isolated from the feedyard playas in the study reported here are the same as those isolated from dairy cows in another study.<sup>29</sup>

Other hosts inhabiting the playas were migratory waterfowl, many species of birds, wild mammals, reptiles, and amphibians. These hosts can also potentially contribute *Salmonella* organisms to the feedyard playas; however, *Salmonella* spp were not found in the nonfeedyard playas, despite the fact the same wildlife also inhabited those playas. A word of caution must be mentioned regarding nonfeedyard playas. Because 2 of them were dry in the winter, we were unable to obtain samples to test them. Thus, the number of tested nonfeedyard playas was lower than we would have liked.

In the study reported here, water and muck from feedyard playas contained many *Salmonella* serovars. There were significant differences in the isolation of some *Salmonella* serovars between summer and winter and between muck and water. Another report<sup>1</sup> on water quality of samples collected from the same feedyard playas found only 1 of 7 feedyard playas contaminated with *Salmonella* Typhimurium in isolation attempts on 72 samples. The reason for the difference was probably attributable to the culturing technique and type of enrichment process used. In that other study, peptone enrichment was followed by incubation in tetrathionate broth with 2% iodine. This was used to select *Salmonella* spp and inhibit contaminating microbes from the playa water samples. This appears to be an acceptable technique for the isolation of *Salmonella* organisms from clinical specimens. However, environmental samples probably have lower numbers of *Salmonella* spp per quantity of sample; thus, enhanced enrichment procedures are required.

We documented in the study reported here that there are many *Salmonella* serovars in water of feedyard playas. These *Salmonella* spp are prominent zoonotic disease agents capable of infecting nearly all animals, including humans. However, this playa water is a valuable resource in a semiarid region with limited amounts of available water. The use of playa water containing such pathogens should be carefully examined before pathogens are disseminated to a wider environmental area.

To prevent exposure and potential infections, domestic livestock and humans should not have access to feedyard playas that contain potentially pathogenic *Salmonella* organisms. Wildlife, birds, and migratory waterfowl have access to these bodies of water, and because of the size and number of these playas, there appears to be little that can be done to prevent those animals from inhabiting playas. Fortunately, the structure of playas appears to pose no risk of contaminating groundwater or an aquifer with bacterial pathogens.<sup>1,30</sup>

Armed with the knowledge that playa water contains many pathogens, feedyard owners and managers need to prevent further spread of these pathogens to the environment. For example, playa water should not be sprayed on feeder calves to keep them cool in the summer, because the hair of the calves would become contaminated<sup>31</sup> and the calves would ingest the pathogens during grooming activities. Contamination of hair is even more critical when cattle are transported to packing plants.<sup>32</sup> Providing adequate shaded areas would be a preferable practice, although shades are hard to maintain because of severe winds in this region.

Additionally, pathogen-contaminated playa water should not be used to abate feedyard dust in pens in which cattle, horses, and humans would be exposed. Furthermore, feedyard playa water should not be used to abate dust in feedyard roads and alleyways. Vehicle tires can potentially pick up the *Salmonella* organisms and disseminate them throughout the feedyard. Horses and humans can potentially pick up the pathogens on the soles of their hooves and shoes, respectively.

Playa water should not be used to irrigate root crops, vegetables, or fruits<sup>33-35</sup> because this could potentially lead to human ingestion of the pathogens. It is not known how long these pathogens survive on plants or produce. The answer is complicated because of environmental conditions (humidity, amount of ultraviolet light, soil or air moisture, type of soil, and microbial diversity of the soil) and the amount of pathogens on the foodstuff. For example, *Salmonella* spp can survive on tomatoes from the time of inoculation of the tomato flower until the fruit is ripe.<sup>34</sup>

To safely use feedyard playa water, it should be treated to kill all pathogens. It appears that a good solution for the contamination problem of feedyard playa water is to remove biosolids, pump the water to a holding tank, and treat the water with a chlorine product to kill pathogens. This would allow the water to be used without the risk of exposing animals or contaminating the environment.

<sup>a</sup>Sulfur-brilliant-green enrichment broth, Difco, Detroit, Mich.

<sup>b</sup>Novobiocin, Sigma Chemical Co, St Louis, Mo.

<sup>c</sup>Shaker incubator C25, New Brunswick Scientific Co Inc, Edison, NJ.

<sup>d</sup>MacConkey agar, Difco, Detroit, Mich.

<sup>e</sup>Brilliant-green agar, Difco, Detroit, Mich.

<sup>f</sup>Xylose-lysine-deoxycholate agar, Difco, Detroit, Mich.

<sup>g</sup>Sterile plastic petri plates (100 X 15 mm), Becton Dickinson & Co, Franklin Lakes, NJ.

<sup>h</sup>Sterile cotton-tipped applicators, Puritan Hardwood Products Co, Guilford, Me.

<sup>i</sup>Sterile plastic tubes (9.5 X 1.5 cm), Becton Dickinson & Co, Franklin Lakes, NJ.

<sup>j</sup>Triple-sugar-iron agar, Difco, Detroit, Mich.

<sup>k</sup>Lysine-iron agar, Difco, Detroit, Mich.

<sup>l</sup>Motility-indol-ornithine semisolid media, Difco, Detroit, Mich.

<sup>m</sup>Urease agar, Difco, Detroit, Mich.

<sup>n</sup>Blood agar base, Difco, Detroit, Mich.

## References

1. Purdy CW, Straus DC, Parker DB, et al. Water quality in cattle feedyard playas in winter and summer. *Am J Vet Res* 2001;62:1402-1407.
2. Gustavson TC, Holliday NT, Hovorka SD. Development of playa basins, Southern High Plains, Texas and New Mexico, in *Proceedings. Playa Basin Symp* 1994;5-14.
3. Mollhagen TR, Fish EB. Playa basin classification using geographical information systems, in *Proceedings. Playa Basin Symp* 1994;137-152.
4. Reddell DL. Multipurpose modification of playas—studies from the 1960's, in *Proceedings. Playa Basin Symp* 1994;37-52.
5. Ramsey RH III, Zartman RE, Buck LS, et al. Water quality studies in selected playas in the Southern High Plains, in *Proceedings. Playa Basin Symp* 1994;127-135.
6. Steiert J. A History of the playas. In: Steiert J, ed. *Playas of the plains*. Lubbock, Tex: Texas Tech University Press, 1995;5-19.
7. Johnson V. Land Boom. In: Johnson V, ed. *Heaven's tableland: the dust bowl story*. New York: Farrar, Straus, and Co, 1947;71-86.
8. Brunson BR. *The Texas Land and Development Company: a panhandle promotion, 1912-1956*. Austin, Tex: University of Texas Press, 1970.
9. The Texas Water Development Board. Groundwater supplies, section 5.3.1.3. Doc No. GP-7-1. In: *Water for Texas—2002*. Vol I to III. Texas Water Development Board, Austin, Tex, 2002;45-47.
10. The Texas Water Development Board. Regional summaries, section 11.0. Doc No. GP-7-1. In: *Water for Texas—2002*. Vol I to III. Texas Water Development Board, Austin, Tex, 2002;86-121.
11. Uvacek E Jr. The economics of the cattle industry. In: Loan RW, ed. *Bovine respiratory disease: a symposium*. College Station, Tex: Texas A&M University Press, 1984;7-15.
12. Purdy CW, Straus DC, Harp JA, et al. Microbial pathogen survival study in a High Plains feedyard playa. *Tex J Sci* 2001;53:247-266.
13. Martin WJ, Washington JA II. Enterobacteriaceae. In: Lennette EH, ed. *Manual of clinical microbiology*. 3rd ed. Washington, DC: American Society for Microbiology, 1980:195-219.
14. *Dehydrated culture media and reagents for microbiology*. 10th ed. Detroit: Difco Laboratories, 1984.
15. *SAS user's guide: statistics, version 8*. Cary, NC: SAS Institute Inc, 1999.
16. Haydon DT, Cleaveland S, Taylor LH, et al. Identifying reservoirs of infection: a conceptual and practical challenge. *Emerg Infect Dis* 2002;8:1468-1473.
17. Daszak P, Cunningham AA, Hyatt AD. Wildlife ecology emerging infectious diseases of wildlife: threats to biodiversity and human health. *Science* 2000;287:443-449.
18. Warnick LD, Crofton LM, Pelzer KD, et al. Risk factors for clinical salmonellosis in Virginia, USA cattle herds. *Prev Vet Med* 2001;49:259-275.
19. Davies RH, Wray C. Mice as carriers of *Salmonella enteritidis* on persistently infected poultry units. *Vet Rec* 1995;137:337-341.
20. Kapperud G, Stenwig H, Lassen J. Epidemiology of *Salmonella typhimurium* O:4-12, infection in Norway: evidence of transmission from an avian wildlife reservoir. *Am J Epidemiol* 1998;147:774-782.
21. Morishita TY, Aye PP, Ley EC, et al. Survey of pathogens and blood parasites in free-living passerines. *Avian Dis* 1999;43:549-552.
22. Tauni MA, Osterlund A. Outbreak of *Salmonella typhimurium* in cats and humans associated with infection in wild birds. *J Small Anim Pract* 2000;41:339-341.
23. Kirk JH, Holmberg CA, Jeffrey JS. Prevalence of *Salmonella* spp in selected birds captured on California dairies. *J Am Vet Med Assoc* 2002;220:359-362.
24. Murray CJ. Salmonellae in the environment. *Rev Sci Tech* 1991;10:765-785.
25. Kohler B. Example of the concentration of salmonellae in the environment. *Dtsch Tierarztl Wochenschr* 1993;100:264-274.
26. Guardabassi L, Dalsgaard A, Olsen JE. Phenotypic characterization and antibiotic resistance of *Acinetobacter* spp isolated from aquatic sources. *J Appl Microbiol* 1999;87:659-667.
27. Linton AH, Hinton MH. The ecology of antibiotic-resistant

bacteria in animals and their environment, in *Proceedings. 4th Int Symp Antibiot Agric: Benefits Malefits* 1983;533-549.

28. Cray-Fedorka PJ, Dargatz DA, Thomas LA, et al. Survey of *Salmonella* serotypes in feedlot cattle. *J Food Prot* 1998;61:525-530.

29. Dargatz DA, Cray-Fedorka PJ, Ladely SR, et al. Survey of *Salmonella* serotypes shed in feces of beef cows and their antimicrobial susceptibility patterns. *J Food Prot* 2000;63:1648-1653.

30. Lehman OR. Playa water quality for groundwater recharge and use of playas for impoundment of feedyard runoff, in *Proceedings. Playa Lake Symp* 1972;25-30.

31. Ransom JR, Belk KE, Bacon RT, et al. Comparison of sampling methods for microbiological testing of beef animal rectal/colonal feces, hides, and carcasses. *J Food Prot* 2002;65:621-626.

32. Barham AR, Barham BL, Johnson AK, et al. Effects of the

transportation of beef cattle from the feedyard to the packing plant on prevalence levels of *Escherichia coli* O157:H7 and *Salmonella* spp. *J Food Prot* 2002;65:280-283.

33. Natvig EE, Ingham SC, Ingham BH, et al. *Salmonella enterica* serovar typhimurium and *Escherichia coli* contamination of root and leaf vegetables grown in soils with incorporated bovine manure. *Appl Environ Microbiol* 2002;68:2737-2744.

34. Guo X, Chen J, Brackett RE, et al. Survival of salmonellae on and in tomato plants from the time of inoculation at flowering and early stages of fruit development through fruit ripening. *Appl Environ Microbiol* 2001;67:4760-4764.

35. Ercolani GL. Differential survival of *Salmonella typhi*, *Escherichia coli*, and *Enterobacter aerogenes* on lettuce in the field. *Zentralbl Bakteriol [Orig A]* 1979;134:402-411.