

## Frequency and Antimicrobial Resistance of *Salmonella* Serotypes on Beef Carcasses at Small Abattoirs in Jalisco State, Mexico

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### ABSTRACT

The prevalence and antimicrobial resistance of *Salmonella* serotypes on beef carcasses from four small abattoirs in Jalisco State, Mexico, were investigated during a 10-month period. Following U.S. Department of Agriculture Food Safety and Inspection Service protocols, *Salmonella* was isolated from 78 (15.4%) beef carcasses ( $n = 505$ ) after the final carcass water wash. Isolation frequency differed by establishment ( $P < 0.05$ ) and was higher ( $P < 0.05$ ) during the wet season (May through September) for all establishments. Thirteen *Salmonella* serotypes and four serogroups (partially serotyped isolates) were identified. The most prevalent were *Salmonella enterica* Give (24.4%), *Salmonella Typhimurium* (17.9%), and *Salmonella* Group B (14.1%). Antimicrobial susceptibility was tested against 11 drugs, and results indicated that 46.2% of the isolates were resistant to tetracycline, 42.3% were resistant to streptomycin, 23.1% were resistant to chloramphenicol, 21.8% were resistant to trimethoprim-sulfamethoxazole, and 19.2% were resistant to gentamicin. No resistance to ceftriaxone or ciprofloxacin was observed, and 33% of the isolates were resistant to three or more antimicrobials. Although *Salmonella* Give was the most prevalent serotype, 95% of the isolates of this serotype were susceptible to all antimicrobials tested. Antimicrobial resistance was more common in *Salmonella Typhimurium*, and 93% (13 of 14) of the isolates of this serotype were resistant to at least five antimicrobials. The frequency of multidrug-resistant *Salmonella* isolates differed among establishments ( $P < 0.05$ ) and may be related to the origin of the cattle presented for harvesting. These findings highlight the need for control measures to reduce *Salmonella* prevalence on beef carcasses in small abattoirs in Mexico and for strategies to ensure the cautious use of antimicrobials in animal production to prevent and control the spread of antimicrobial-resistant foodborne pathogens.

*Salmonella* is one of the most important foodborne pathogenic bacteria worldwide. In the United States, the Centers for Disease Control and Prevention recently estimated that nontyphoidal *Salmonella* isolates are responsible for one million foodborne illnesses (11% of total reported) each year and are the leading cause of hospitalizations (35% of total) and deaths (28% of total) (21). In Mexico, *Salmonella* is the bacterial pathogen most commonly reported as the cause of gastrointestinal infections, and a total of 120,414 cases of salmonellosis were reported in 2010 to the National Center for Epidemiological Surveillance and Control of Diseases (22).

Food producing animals are the principal reservoir of nontyphoidal *Salmonella* (6), and the pathogen can be transferred from the intestinal contents and hides of cattle to carcasses during the harvesting and dressing process (2). *Salmonella* prevalence on beef carcasses has been reported as 1.4 to 58.0% at the preevisceration stage and before application of antimicrobial interventions (3, 4, 25). For beef carcasses that received antimicrobial treatments pre- or

postevisceration, *Salmonella* prevalence was estimated as 0.0 to 3.0% (1, 20, 26). In a previous study conducted in a small, non-federally inspected abattoir in Mexico, *Salmonella* was found on 14% of beef carcasses that had no antimicrobial treatment (15). This establishment failed to comply with good manufacturing practices, and the microbial counts on beef carcasses and environmental samples indicated poor hygienic conditions throughout the slaughter and dressing process. However, not enough information is available to estimate *Salmonella* prevalence on beef carcasses in Mexico.

Serotyping provides an opportunity to examine the association of *Salmonella* isolates from foods of animal origin and from human cases of salmonellosis (32, 33). In the United States, the *Salmonella* serotypes most commonly isolated from bovine carcasses in 2009 were *Salmonella* Montevideo, *Salmonella* Give, and *Salmonella* Newport (32). In contrast, *Salmonella* Enteritidis, *Salmonella* Typhimurium, and *Salmonella* Newport were most frequently isolated from human infections during the same year (7). In Mexico, *Salmonella* Anatum, *Salmonella* Meleagridis, *Salmonella* Agona, and *Salmonella* Typhimurium were the serotypes most commonly found in cattle and retail beef

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from 2000 to 2005 (36, 37), and *Salmonella* Typhimurium, *Salmonella* Enteritidis, *Salmonella* Typhi, and *Salmonella* Agona were the serotypes most commonly isolated from human infections from 1972 to 1999 (14).

The emergence of multidrug-resistant (MDR) *Salmonella* isolates among animals and humans has been documented and represents a public health concern. Some reports have indicated that the use of antimicrobials in animal production for disease therapy, prophylaxis, and growth enhancement promotes the selection of resistant bacteria, although the impact of these uses on human health is not clearly understood (18, 35). Resistance of pathogenic bacteria to antimicrobials used in human therapy may result in lower efficacy of these drugs against infections and may subsequently threaten public health. Foodborne outbreaks caused by MDR *Salmonella* Typhimurium have been reported in Europe and the United States, and in some cases no effective antibiotic therapy was available for patients (11). According to the World Health Organization (35), surveillance programs are needed to monitor the prevalence and antimicrobial resistance of *Salmonella* isolates from animals, humans, and foods. These programs can be useful to develop public health policies for the regulation of drugs used in food producing animals and to design control measures to prevent the spread of MDR bacteria (34, 35). The purpose of this study was to determine the frequency, serotype diversity, and antimicrobial resistance of *Salmonella* on beef carcasses at small abattoirs in Jalisco State, Mexico.

## MATERIALS AND METHODS

**Sample collection.** A total of 505 sponge samples were collected from beef carcass sides at four small abattoirs located in different geographical regions of Jalisco State, Mexico, during a 10-month period from December 2008 to September 2009. The abattoirs included in this study (A, B, C, and D) had harvesting capacities of 1,065, 158, 138, and 106 head of cattle per week, kill floor areas of 1,500, 1,200, 1,200, and 450 m<sup>2</sup>, and a total number of employees for the slaughter and dressing process of 45, 18, 15, and 29, respectively. The establishments are located in central (abattoir A), southern (abattoir B), northern (abattoir C), and western (abattoir D) Jalisco, within approximately 65 to 195 km of each other. All the establishments followed similar slaughter and dressing procedures. None of the establishments were federally inspected, and hazard analysis and critical control point systems had not been implemented in any of them. Each abattoir was visited six times, and during each visit approximately 21 beef carcass sponge samples were collected. Beef carcass sides were randomly selected for sampling after the water wash and before chilling. At each establishment, the carcass water wash consisted of spraying tap water at room temperature; no antimicrobial interventions were applied. Beef carcass surface samples were collected from three sites (brisket, flank, and rump), for a total area of 300 cm<sup>2</sup>. Sterile sponges (Speci-Sponge, Nasco Whirl-Pak, Modesto, CA) moistened with 20 ml of buffered peptone water (BD, Franklin Lakes, NJ) were used to collect the samples according to the procedure described by the U.S. Department of Agriculture (USDA) Food Safety and Inspection Service (29). Each sampling sponge was returned to its sterile bag, and all samples were placed in insulated containers with refrigerants, transported to the Laboratory of Food Safety (University of

Guadalajara, Guadalajara, Mexico), and analyzed within 24 h of collection.

**Salmonella isolation.** Each beef carcass sponge sample was added to 40 ml of buffered peptone water for a total volume of 60 ml, homogenized for 2 min with a BagMixer (Interscience, Mourjou, France), and incubated at 35°C for 18 to 22 h. After incubation, aliquots of 1.0 and 0.1 ml were inoculated into 9 and 9.9 ml of tetrathionate broth (BD) and Rapaport-Vassiliadis-10 broth (BD), respectively. Both selective enrichment broths were incubated at 42°C for 16 to 20 h. After incubation, 1.0-ml aliquots of each enrichment broth were individually transferred to tubes containing 10 ml of M broth (BD) and incubated at 35°C for 6 to 8 h. After incubation, 0.5-ml aliquots of M broth culture from each tube were combined for an enzyme-linked immunosorbent assay (*Salmonella* VIA, TECRA International Pty. Ltd., Bringelly New South Wales, Australia) (16) according to the instructions described by the manufacturer. Aliquots of tetrathionate and Rapaport-Vassiliadis-10 broths from samples that were positive for *Salmonella* with the enzyme-linked immunosorbent assay were individually streaked onto brilliant green sulfa agar (BD), bismuth sulfite agar (Bioxon, Mexico City, Mexico), and xylose lysine Tergitol 4 agar (BD). All plates were incubated at 35°C for 24 to 48 h. From each selective agar type, at least three colonies with characteristics typical for *Salmonella* were selected and streaked onto triple sugar iron agar (BD) and lysine iron agar (BD) and incubated at 35°C for 24 h. Isolates with typical biochemical reactions were then streaked onto tryptic soy agar (TSA; BD), incubated at 35°C for 24 h, and tested for slide agglutination using polyvalent serum A-Vi (BD).

Isolates that produced nontypical triple sugar iron agar and lysine iron agar reactions and/or negative serological reactions were tested for additional biochemical reactions in methyl red-Voges Proskauer medium, Simmons citrate agar, urease Rustigian and Stuart broth, motility medium, and phenol red salicin and dulcitol fermentation broths (Bioxon) (31). Those isolates with nontypical biochemical and/or serological reactions were confirmed as *Salmonella* with a multiplex PCR assay for detecting the presence of the *invA* (544 bp) and *fimA* (686 bp) genes. DNA was obtained by cell lysis at 90°C for 5 min. The multiplex PCR was performed using the not previously reported primers *invA*-F (5'-CGT TGA CCA CCA TAT CAA CAT AGA-3') plus *invA*-R (5'-CAA AGA GCT GAT AGG CGT TT-3') and *fimA*-F (5'-CCT CGC TGT CAG TTA ACG-3') plus *fimA*-R (5'-CGT AAA GCC GGC GGT AC-3'). Oligonucleotides (0.5 μM) and *Taq* polymerase (0.6 U) were used in PCRs carried out under the following conditions standardized for this assay: one cycle of 95°C for 10 min, 30 cycles of 95°C for 1 min, 56°C for 50 s, and 72°C for 1 min, and one cycle of 72°C for 10 min (Thermocycler ESCO Swift MiniPro, Hatboro, PA). PCR products were electrophoresed in 1% agarose (Promega, Madison, WI) gels, stained with ethidium bromide (7 μg/ml; AMRESCO Inc., Solon, OH), and visualized under UV transillumination (Gel Logic 100 Imaging System, Eastman Kodak Co., Rochester, NY). A 2-log DNA ladder marker (New England Biolabs, Ipswich, MA) was used to confirm the size of the amplified products. *Salmonella* Montevideo was used as a positive control. *Salmonella* isolates were stored in 15% glycerol plus tryptic soy broth (TSB; BD) at -20°C, and working cultures were maintained on TSA slants at 4°C. One isolate from each positive sample was randomly chosen for serotyping and antimicrobial susceptibility testing.

**Serotyping.** *Salmonella* cultures were reactivated in TSB at 35°C for 24 h and then individually streaked on brilliant green

sulfa agar plates. From each culture, one colony with characteristics typical for *Salmonella* was individually inoculated on TSA slants, incubated at 35°C for 24 h, reconfirmed by biochemical and serological testing as previously described, and then shipped to the National Laboratory for Diagnosis and Epidemiological Reference (Mexico City, Mexico) for serotype identification according to the Kauffmann-White scheme.

**Antimicrobial susceptibility testing.** Antimicrobial susceptibility was determined according to the disk diffusion method on Mueller-Hinton agar as described by the Clinical and Laboratory Standards Institute (8). Antimicrobial susceptibility test discs (BBL, BD, Sparks, MD) were used for the following antimicrobials of veterinary and human health importance: ampicillin (AMP, 10 µg), gentamicin (GEN, 10 µg), tetracycline (TET, 30 µg), trimethoprim-sulfamethoxazole (SXT, 1.25 and 23.75 µg), chloramphenicol (CHL, 30 µg), ceftriaxone (CRO, 30 µg), ciprofloxacin (CIP, 30 µg), kanamycin (KAN, 30 µg), nalidixic acid (NAL, 30 µg), streptomycin (STR, 10 µg), and cephalothin (CEP, 30 µg). *Escherichia coli* ATCC 25922 was used as a quality control. Inhibition zones were measured as MIC breakpoints according to the Clinical and Laboratory Standards Institute supplement (9). Multidrug resistance was reported when resistance to three or more antimicrobials was observed for a single *Salmonella* isolate (19).

**Data analysis.** The significance of differences ( $P < 0.05$ ) in *Salmonella* isolation frequency by abattoir and season and in the frequency of antimicrobial-resistant *Salmonella* strains by abattoir were assessed with the chi-square test in the Statistical Package for Social Science, version 11.5 for Windows (SPSS, Chicago, IL).

## RESULTS AND DISCUSSION

*Salmonella* was isolated from 78 (15.5%) of 505 beef carcass sponge samples collected at four small abattoirs in Jalisco State, Mexico. The isolation frequency of *Salmonella* was 28.6, 13.5, 13.3, and 6.4% for abattoirs C, D, A, and B, respectively (Table 1) and was significantly higher ( $P < 0.05$ ) for abattoir C. These findings are similar to those previously reported for beef carcasses that had not been treated with antimicrobial agents in Mexico and other countries. In the United States, *Salmonella* prevalence on beef carcasses at the preevisceration stage has been reported as 1.4 to 57.8% (2, 4, 25). In the United Kingdom, *Salmonella* was isolated from 0 to 20% of beef carcasses sampled before water washing and chilling (24). In Senegal, 42.8% of beef carcasses sampled before chilling were positive for *Salmonella* in an abattoir where good hygiene practices were not followed (27). In Mexico, information related to the presence of *Salmonella* on beef carcasses is scarce, and one report indicated that this pathogen was present in 14.0% (5 of 36) of beef carcasses sampled at a small abattoir (15).

All abattoirs included in the present study had failed to comply with good manufacturing practices and sanitation standard operating procedures, and none had implemented a food safety system. Fecal contamination on beef carcasses was visible and cross-contamination was common during operations at all abattoirs. *E. coli* was detected in 96% of beef carcass sponge samples at  $-1.5$  to  $4.0 \log \text{CFU/cm}^2$  (data not shown). The population of this microorganism is commonly used as an indicator of fecal contamination on

TABLE 1. Frequency of *Salmonella* on beef carcasses at four small abattoirs in Jalisco, Mexico

Abattoir	n <sup>a</sup>	Dry season						Wet season						Total no. positive	Total % positive <sup>b</sup>
		Dec	Jan	Feb	Mar	Apr	% positive	May	Jun	Jul	Aug	Sep	% positive		
A	128	0/21	0/0	1/21	0/21	0/0	1.6	3/21	0/0	4/23	0/0	9/21	24.6	17/128	13.3
B	125	0/0	0/21	1/22	0/0	0/21	1.6	0/0	1/18	2/22	0/0	4/21	11.5	8/125	6.4
C	126	0/0	0/20	1/21	0/0	0/0	2.4	3/21	8/21	0/0	11/25	13/18	41.2	36/126	28.6
D	126	0/0	6/11	0/0	2/21	0/0	25.0	1/21	2/22	0/0	3/20	3/31	9.6	17/126	13.5
Total no.	505	0/21	6/52	3/64	2/42	0/21	5.5	7/63	11/61	6/45	14/45	29/91	22.0	78/505	15.5
Total % positive	0.0	11.5	4.7	4.8	0.0	11.1	13.3	18.0	11.1	31.1	31.9				

<sup>a</sup> Number of beef carcass sponge samples analyzed.

<sup>b</sup> Within this column, values with different letters are significantly different ( $P < 0.05$ ).

carcasses (29). The presence of *E. coli* on 96% of the beef carcasses sampled clearly indicated that the abattoirs included in the present study did not control fecal contamination.

*Salmonella* isolation frequency was significantly higher ( $P < 0.05$ ) from May to September (22.0%; Table 1), which corresponds to the wet season in this region, compared with December to April (5.5%; the dry season), and the pathogen was more frequently isolated in September (31.9%). These findings are in agreement with those of previous studies, indicating that *Salmonella* contamination on beef carcasses is affected by the season. Sofos et al. (25) found *Salmonella* isolation frequencies of 5.2 and 8.5% on preeviscerated beef carcasses during the dry and wet seasons, respectively. After final carcass washing, *Salmonella* frequencies were 1.8 and 3.0% during the dry and wet seasons, respectively. Barkocy-Gallagher et al. (2) reported that *Salmonella* prevalence on preeviscerated beef carcasses was higher during the summer and fall (19.7 to 24.9%) than in winter and spring (3.0 to 4.1%). During the wet season, cattle hides are more likely to be soiled with mud and feces, increasing the possibility of carcass contamination during hide removal and evisceration (20).

A total of 78 *Salmonella* isolates recovered from beef carcass sponge samples were serotyped (one isolate per positive sample). Thirteen serotypes and four serogroups (partially serotyped isolates) were identified (Table 2). *Salmonella* Give was the predominant serotype and was recovered from 24.4% of the samples, followed by *Salmonella* Typhimurium (17.9%), *Salmonella* Group B (14.1%), *Salmonella* Infantis (10.3%), and *Salmonella* Anatum (5.1%). Differences in the isolation frequency of these serotypes during the period of time studied were observed ( $P < 0.05$ ). *Salmonella* Give predominated in August (10 of 14 isolates recovered that month), *Salmonella* Group B predominated in June (7 of 11 isolates), and *Salmonella* Typhimurium (11 of 29 isolates) and *Salmonella* Infantis (8 of 29 isolates) were most frequently isolated in September. Serotype distribution differed among establishments (Tables 2 and 3). At abattoir A, six serotypes and two serogroups were identified, and *Salmonella* Infantis (35.3%) was the most common type isolated. At abattoir B, two serotypes and two serogroups were found, and *Salmonella* Group B (37.5%) was the most common type. *Salmonella* Give predominated in abattoirs C and D, where eight and seven different serotypes were identified, respectively. In general, *Salmonella* Give, *Salmonella* Group B, and *Salmonella* Infantis were the most widely distributed types and were found in beef carcass samples from three different abattoirs; *Salmonella* Havana, *Salmonella* Muenster, and *Salmonella* Livingstone were found exclusively on samples from abattoir A. *Salmonella* Enteritidis, *Salmonella* Panama, and *Salmonella* Sinstorf were exclusively isolated on samples from abattoir D. The cattle at each abattoir came from different feedlots, which may explain the diversity of *Salmonella* serotypes identified. *Salmonella* Group B may be prevalent on cattle across the state because it was recovered from beef carcass samples collected at three different establishments.

TABLE 2. *Salmonella* serotypes isolated from beef carcasses at four small abattoirs in Jalisco, Mexico

<i>Salmonella</i> serotype	No. (%) of isolates	Abattoir(s)
Give	19 (24.4)	A, C, D
Typhimurium	14 (17.9)	C, D
Infantis	8 (10.3)	A, C, D
Anatum	4 (5.1)	A, C
Bovismorbificans	3 (3.8)	B, C
Montevideo	3 (3.8)	C, D
Havana	2 (2.6)	A
Muenster	2 (2.6)	A
Enteritidis	1 (1.3)	D
Livingstone	1 (1.3)	A
Oranienburg	1 (1.3)	B
Panama	1 (1.3)	D
Sinstorf	1 (1.3)	D
Partially serotyped		
Group B	11 (14.1)	A, B, C
Group E1	3 (3.8)	A
Group B monophasic	1 (1.3)	C
Group E1 monophasic	1 (1.3)	B
Untypeable	2 (2.6)	B, D
Total	78 (100)	

To the best of our knowledge, this is the first report of *Salmonella* serotypes isolated from beef carcasses in Mexico. *Salmonella* Anatum, *Salmonella* Montevideo, *Salmonella* Muenster, *Salmonella* Give, *Salmonella* Infantis, *Salmonella* Typhimurium, *Salmonella* Enteritidis, and *Salmonella* Oranienburg found in this study have been isolated from beef carcasses in other countries, including the United States (32), Australia (10), Belgium (12), Senegal (27), and the United Kingdom (24). Serotype prevalence on beef carcasses changes over time (6, 32) and might be related to the predominant serotypes present in cattle from a particular geographical region or influenced by serotypes established in the abattoir environment (24). Some of the serotypes identified in the present study have been associated with human cases of salmonellosis. *Salmonella* Enteritidis has been the most frequent serotype related to human infections in the United States since 2007, followed by *Salmonella* Typhimurium, *Salmonella* Newport, *Salmonella* Javiana, *Salmonella* Heidelberg, and *Salmonella* Montevideo (7). In The Netherlands, *Salmonella* Typhimurium and *Salmonella* Enteritidis have been the most prevalent serotypes in humans with clinical infections (33). In Mexico, the top five serotypes related to human infections from 1972 to 1999 were *Salmonella* Typhimurium, *Salmonella* Enteritidis, *Salmonella* Typhi, *Salmonella* Agona, and *Salmonella* Newport (14). Seven serotypes (39%) isolated from beef carcasses during the present investigation were among the 20 most common serotypes associated with human infections in Mexico. However, more prevalence studies are needed, and additional supporting epidemiological evidence of association will be required to establish a relationship between beef *Salmonella* isolates and human cases of salmonellosis in Mexico (5).

TABLE 3. Diversity of *Salmonella* serotypes isolated from beef carcasses by abattoir

Abattoir	Total no. of isolates	<i>Salmonella</i> serotype	No. (%) of isolates
A	17	Infantis	6 (35.3)
		Group E1 <sup>a</sup>	3 (17.6)
		Havana	2 (11.8)
		Muenster	2 (11.8)
		Anatum	1 (5.9)
		Give	1 (5.9)
		Group B <sup>a</sup>	1 (5.9)
		Livingstone	1 (5.9)
		Group B <sup>a</sup>	3 (37.5)
		Bovismorbificans	2 (25.0)
B	8	Group E1 monophasic <sup>a</sup>	1 (12.5)
		Oranienburg	1 (12.5)
		Untypeable	1 (12.5)
		Give	11 (30.6)
		Typhimurium	10 (27.8)
C	36	Group B <sup>a</sup>	7 (19.4)
		Anatum	3 (8.3)
		Montevideo	2 (2.6)
		Group B monophasic <sup>a</sup>	1 (2.8)
		Bovismorbificans	1 (2.8)
		Infantis	1 (2.8)
		Give	7 (41.2)
		Typhimurium	4 (23.5)
		Enteritidis	1 (5.9)
		Infantis	1 (5.9)
D	17	Montevideo	1 (5.9)
		Panama	1 (5.9)
		Sinstrof	1 (5.9)
		Untypeable	1 (5.9)

<sup>a</sup> Partially serotyped isolates.

The susceptibility of 78 *Salmonella* isolates was tested against 11 antimicrobial drugs: penicillins, cephems, aminoglycosides, tetracyclines, fluoroquinolones, quinolones, folate pathway inhibitors, and phenicols. Testing revealed that 48.7% of isolates (38 isolates) were resistant to at least one antimicrobial and 16.7% (13 isolates) had intermediate resistance to at least one antimicrobial. Resistance to TET was the most common profile and it was exhibited by 46.2% of the isolates (36 isolates), followed by resistance to STR in 42.3% (33 isolates), to CHL in 23.1% (18 isolates), to SXT in 21.8% (17 isolates), to GEN in 19.2% (15 isolates), to NAL in 17.9% (14 isolates), to AMP in 9% (7 isolates), to CEP in 3.8% (3 isolates), and to KAN in 1.3% (1 isolates). No isolates were resistant to CRO or CIP.

No previous reports on antimicrobial resistance of *Salmonella* isolates recovered from beef carcasses in Mexico were found for comparison purposes. However, our findings are similar to those of previous studies from other countries. In the United States and Canada, resistance to TET and/or STR was the most common profile observed among *Salmonella* isolates recovered from beef carcasses; 5.8 to 36.8% of isolates were resistant to TET and 29.2% were resistant to STR (3, 17). Previous studies conducted in Mexico on beef products in retail establishments revealed that

TABLE 4. Multidrug resistance phenotypes of *Salmonella* isolates recovered from beef carcasses

<i>Salmonella</i> serotype	Multidrug resistance profile <sup>a</sup>	No. of isolates (n = 26)	
Typhimurium	GEN-TET-SXT-CHL-STR <sup>b</sup>	7	
	GEN-TET-SXT-CHL-NAL-STR <sup>c</sup>	5	
	GEN-TET-SXT-CHL-KAN-STR	1	
	TET-NAL-STR	5	
Group B	AMP-CHL-STR-SXT-TET-NAL-CEP	1	
	TET-CHL-NAL-STR	1	
	AMP-TET-STR-CHL <sup>d</sup>	1	
	GEN-TET-SXT-CHL-STR <sup>b</sup>	1	
Group B monophasic			
	Infantis	GEN-TET-SXT-CHL-STR <sup>b</sup>	1
	Havana	AMP-TET-SXT-STR <sup>e</sup>	1
	Untypeable	AMP-TET-NAL-CEP	1
	AMP-NAL-CEP <sup>f</sup>	1	

<sup>a</sup> GEN, gentamicin; TET, tetracycline; SXT, trimethoprim-sulfamethoxazole; CHL, chloramphenicol; STR, streptomycin; NAL nalidixic acid; KAN, kanamycin; AMP, ampicillin; CEP, cephalothin.

<sup>b</sup> Intermediate susceptibility to KAN.

<sup>c</sup> Intermediate susceptibility to CIP.

<sup>d</sup> Intermediate susceptibility to SXT, CEP, and NAL.

<sup>e</sup> Intermediate susceptibility to NAL.

<sup>f</sup> Intermediate susceptibility to CHL.

28.6 to 92.5% of the recovered *Salmonella* isolates were resistant to TET and 63.3 to 87.8% were resistant to STR (19, 36, 37). Our findings and those of previous researchers suggest that resistance to antimicrobials that have been used over long periods in animal production, such as TET, STR, SXT, and CHL, is common among *Salmonella* isolates recovered from raw beef in Mexico (19).

In the present study, 33.3% (26 of 78) of *Salmonella* isolates were resistant to three or more antimicrobials and thus considered MDR isolates: 13 *Salmonella* Typhimurium isolates, 8 *Salmonella* Group B isolates, 1 *Salmonella* Group B monophasic isolate, 1 *Salmonella* Havana isolate, 1 *Salmonella* Infantis isolate, and 2 untypeable isolates (Table 4). MDR *Salmonella* Typhimurium and *Salmonella* Group B made up 80% of all observed MDR *Salmonella* isolates. In general, the most common multiresistance phenotype was GEN-TET-SXT-CHL-STR, which was found for seven *Salmonella* Typhimurium isolates, one isolate of *Salmonella* Group B monophasic, and one isolate of *Salmonella* Infantis. MDR *Salmonella* Typhimurium isolates exhibited three multiresistance phenotypes, although none corresponded to the typical pentaresistance phenotype ACSSuT (ampicillin, chloramphenicol, streptomycin, sulfonamides, and tetracycline) usually found in *Salmonella* Typhimurium DT104. However, one *Salmonella* Group B isolate that was resistant to seven different antimicrobials had the phenotype AMP-CHL-STR-SXT-TET-NAL-CEP and may represent an important public health threat. The resistance to NAL observed in this isolate may be an additional concern because this type of resistance has been related to decreased susceptibility to CIP (28), which is the preferred treatment for nontyphoidal salmonellosis in adults (13). Decreased susceptibility to several

antimicrobials was observed among MDR isolates (Table 4), and one *Salmonella* Typhimurium isolate that was resistant to NAL also had decreased susceptibility to CIP, which is associated with a greater risk of treatment failure.

The frequency of MDR *Salmonella* isolates differed ( $P < 0.05$ ) among establishments, and abattoir C had the highest proportion of MDR isolates (44.7%), followed by abattoirs D (13.2%), B (7.9%), and A (2.6%). Abattoir C is located in one of the most important livestock production areas of Mexico and has the larger cattle inventory in Jalisco State, and intensive production systems are more common in the area where this abattoir is located compared with other areas included in this investigation, where extensive farming methods predominate (23). Antimicrobial use is more commonly used in intensive farming systems to prevent and limit disease. According to the USDA, approximately 25% of small cattle feedlot operations and 70% of large feedlot operations used antimicrobials, and the cattle in the large operations were almost twice as likely to receive antibiotics in their feed and water than were cattle in the small operations (30). Antimicrobials may have been used more extensively on the large cattle feedlots that supplied animals for abattoir C, which may be related to the high frequency of MDR *Salmonella* isolates found on beef carcasses from this abattoir. However, more studies are required to confirm these results because of lack of information on antimicrobial use in food animals in Mexico.

The results of the present investigation revealed that implementation of good manufacturing practices and pathogen control measures in non-federally inspected abattoirs in Mexico is needed to reduce *Salmonella* prevalence on beef carcasses. This investigation highlights the importance of conducting subsequent studies to monitor the antimicrobial resistance of foodborne pathogens. This information is needed for the establishment of science-based strategies to prevent the emergence and spread of antimicrobial resistance among foodborne pathogens in animals used for food production.

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