Salmonella on Raw Poultry in Retail Markets in Guatemala: Levels, Antibiotic Susceptibility, and Serovar Distribution

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ABSTRACT

The objective of this study was to determine Salmonella numbers on retail raw chicken carcasses in Guatemala and to phenotypically characterize the isolates (serotyping and antibiotic susceptibility). In total, 300 chicken carcasses were collected from seven departments in Guatemala. Salmonella numbers were determined using the most-probable-number method following the U.S. Department of Agriculture’s Food Safety and Inspection Service protocol. In total, 103 isolates were obtained, all of which were tested for antibiotic susceptibility, whereas 46 isolates were serotyped. Overall, Salmonella prevalence and mean number (mean log most probable number per carcass) was 34.3% and 2.3 (95% confidence interval: 2.0 to 2.5), respectively. Significant differences (P < 0.05) in Salmonella prevalence were found by storage condition (refrigerated or ambient temperature), market type (wet markets, supermarkets, and independent poultry stores), chicken production system (integrated or nonintegrated production company), and chicken skin color (white or yellow). Chickens produced by integrated companies had lower Salmonella numbers (P < 0.05) than nonintegrated companies, and white-skin carcasses had lower numbers (P < 0.05) than yellow-skin carcasses. Among 13 different Salmonella serovars identified, Paratyphi B (34.8%) was most prevalent, followed by Heidelberg (16.3%) and Derby (11.6%). Of all the Salmonella isolates, 59.2% were resistant to one to three antibiotics and 13.6% to four or more antibiotics. Among all the serovars obtained, Salmonella Paratyphi B and Heidelberg were the most resistant to the antibiotics tested. Salmonella levels and antibiotic resistant profiles among isolates from raw poultry at the retail market level were high relative to other reports from North and South America. These data can be used by Guatemalan stakeholders to develop risk assessment models and support further research opportunities to control transmission of Salmonella spp. and antibiotic-resistant isolates from chicken meat to humans.

Salmonella species are gram-negative bacilli bacteria capable of causing diarrheal illness in humans and are one of the most commonly reported causes of foodborne illnesses. More than 2,500 known serotypes of Salmonella have been identified. Salmonella infections account for an estimated 80.3 million cases globally each year, posing a large public health and economic burden due to associated medical costs, loss of sales, recalls, and labor losses (17, 23, 38). Salmonellae live in the intestinal tract of humans and animals, including poultry. Salmonella pathogens are usually transmitted to humans by eating foods contaminated with animal feces. Many foods may be contaminated with Salmonella, including fruits and vegetables, but those foods most often contaminated and associated with outbreaks are of animal origin, such as milk, eggs, beef, and poultry (14, 23, 28, 38).

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Guatemala is the most populous country in Central America, with an estimated population of 14.5 million in 2011 (19). Poultry, especially chicken, is the most widely consumed meat among the Guatemalan population (33.5 lb [ca. 15.2 kg] per capita annually (18)). Most poultry locally consumed is produced in Guatemala, and the majority of local consumers prefer whole fresh or refrigerated meat. Although a surveillance system for Salmonella spp. in chicken carcasses in slaughter houses has been established (12), there are no published studies that report the levels of Salmonella spp. in whole chicken meat at retail stores in the country.

In Guatemala, the National Epidemiology Center reports for 2014 revealed an incidence of 2,834 diarrheal episodes per 100,000 inhabitants (6); however, it is not known exactly how many of these episodes could be attributed to Salmonella. Reports from the Guatemalan National Health Laboratory indicate that from 2001 to 2010, 344 Salmonella isolates were received for serotyping, among which predominant serovars were Salmonella Enter-
itidis, *Salmonella* Typhimurium, and *Salmonella* Typhi (32). Interestingly, typhoid fever outbreaks in the United States have been linked with food products imported from Guatemala (20, 22).

To date, there are no published data available on the levels of *Salmonella*, distribution of *Salmonella* serotypes, and their antibiotic susceptibility profiles on raw poultry in Guatemala. Data regarding the amount of *Salmonella* customers are potentially exposed to from retail chicken meat, as well as the circulating serovars and antibiotic susceptibility profiles, can provide a baseline for comparison to design interventions to reduce the risk of exposure and salmonellosis in humans. Furthermore, this information can aid in establishing a precedent for a periodic surveillance system that can help strengthen the capacity to detect *Salmonella*. The main objective of this study was to determine the *Salmonella* numbers, serotypes, and antibiotic resistance patterns on raw chicken meat in retail markets in seven departments in Guatemala.

**MATERIALS AND METHODS**

Study design and sampling procedure for quantitative *Salmonella* analysis. A cross-sectional study was carried out in which a convenience sample of 300 whole chicken carcasses (locally produced, not imported) was collected between July 2012 and March 2013 from seven departments in Guatemala: Guatemala, Alta Verapaz, Chimaltenango, Jutiapa, Escuintla, Huehuetenango, and Quetzaltenango (Fig. 1). Departments were chosen to obtain a sample from different regions of the country, based on their documented human population (19). In each department, one to three municipalities (equivalent to U.S. counties) that accounted for 10% or more of the departmental population were selected to include in the sampling scheme. The sample number distribution was calculated based on the relative population size of each municipality within the department and was divided equally among the three types of sampling markets for each municipality. Markets were not sampled on repeated occasions.

Whole chicken carcass samples were collected from three different types of markets in the capital cities in each of the selected municipalities: supermarkets (chain stores offering a variety of food and household items, $n = 80$), wet (municipal) markets ($n = 125$), and independent poultry shops ($n = 95$). In those cases where there were no supermarkets in the selected municipalities, the total number of samples for that municipality was divided equally among wet markets and independent poultry shops.

Supermarkets (27 establishments) were markets where meat was sold in refrigerated or frozen condition, mostly individually packaged. Wet (municipal) markets (28 establishments) were open food markets and included butcher shops that handled meat and poultry products and had other stands for fruits and vegetables. Refrigeration of raw chickens in this setting was limited, although...
Salmonella for storage condition (frozen, ambient temperature, or chilled), included information on collection site, market type, market individual butcher shops that handled meat and poultry products be sold fresh. Independent poultry shops (37 establishments) were chicken products are stored for short periods as they are intended to 1644 JARQUIN ET AL. J. Food Prot., Vol. 78, No. 9

Salmonella the bag. The carcass was then rinsed with a rocking motion for 1

BD, Sparks, MD) was poured into the cavity of the carcass inside

a plastic bag to which 400 ml of buffered peptone water (Difco,

MPN) procedure

poultry, and egg products by using the most-probable-number

enumeration was conducted following the U.S. Department of

laboratory at the Universidad del Valle de Guatemala for

Salmonella analysis within 24 h.

Whole chicken carcass rinse. Upon arrival, chickens were

placed in refrigerators to maintain a cold chain. Analytical testing for Salmonella was carried out in the Food and Water Analysis Laboratory at Universidad del Valle de Guatemala. Salmonella enumeration was conducted following the U.S. Department of Agriculture’s Food Safety and Inspection Service (USDA-FSIS) protocol for isolation and identification of Salmonella for meat, poultry, and egg products by using the most-probable-number (MPN) procedure (33).

Each chicken sample (whole carcass) was placed aseptically in a plastic bag to which 400 ml of buffered peptone water (Difco, BD, Sparks, MD) was poured into the cavity of the carcass inside the bag. The carcass was then rinsed with a rocking motion for 1 min.

Isolation and identification of Salmonella. For the three-tube MPN method, 10-ml portions of the chicken carcass rinse were added to three empty tubes, and subsequently 1.0-ml portions were serially diluted twice (10-fold) in 9-ml buffered peptone water tubes. All nine tubes were incubated at 37°C for 24 h. After incubation, 0.5 ml of the preenrichment culture was transferred into 10 ml of tetrathionate broth (Oxoid Ltd., Basingstoke, UK), and 0.1 ml of the preenrichment culture was transferred to 10 ml of modified Rappaport-Vassiliadis (Oxoid Ltd.) broth, agitated for 30 s at 1,500 rpm by vortex (VWR Vortex Mixers, VWR International, Radnor, PA), and incubated at 42°C for 20 to 24 h. After incubation, a loopful of each Rappaport-Vassiliadis and tetrathionate broth culture tubes was streaked onto one brilliant yellowing of the chicken skin is achieved via the diet with

carcasses are available in retail locations. On some chicken farms, this yellowing of the chicken skin is achieved via the diet with which chickens are fed. On other farms, the yellow color may be achieved by dyeing the chicken carcass after slaughtering. Specific information on the possible sources of chicken (i.e., specific company names) and methods of yellowing was not collected.

Whole chicken carcass samples weighed between 0.75 and 1.5 kg. Samples were placed in identified sterile sample bags and stored in an insulated cooler at 2 to 8°C for transport back to the laboratory at the Universidad del Valle de Guatemala for Salmonella analysis within 24 h.

Salmonella antisera (Salmonella O antisera poly A-I and Vi, Difco, BD) for agglutination reaction.

Quantitative Salmonella analysis. The MPN calculations per milliliter were performed according to the USDA-FSIS protocol (33) and then multiplied by the dilution factor of 400 (i.e., 400 ml of buffered peptone water rinse) to obtain MPN per carcass.

Antibiotic susceptibility testing of Salmonella isolates. Upon completion of Salmonella identification in all 300 samples, all 103 archived pure Salmonella cultures were isolated in brain heart infusion agar (Oxoid Ltd.) and incubated at 37°C for 24 h. The Kirby-Bauer disk diffusion method was used to determine the antibiotic resistance profile of Salmonella spp. by using 0.5 McFarland standard and Mueller-Hinton agar (Oxoid Ltd.). Results were interpreted based on criteria of the Clinical and Laboratory Standards Institute guidelines for human medicine as resistant, intermediate, or susceptible (8). Disk diffusion results for enrofloxacin and ceftiofur, which are only used in animals, were interpreted according to the Clinical and Laboratory Standards Institute animal health criteria (7). Intermediate results were reclassified as susceptible.

Antibiotic disks (Oxoid Ltd.) representative of the following antibiotic classes were evaluated: aminoglycosides (gentamicin, streptomycin), β-lactamase combination (amoxicillin–clavulanic acid), cephalosporins (ceftiofur, ceftixime), penicillins (ampicillin), penicillins (chloramphenicol), fluoroquinolones (enrofloxacin), tetracyclines (tetracycline), and folate pathway inhibitors (trimethoprim-sulfamethoxazole). The selection criteria included elective antibiotics for control and therapy of bacterial enteric infections, for animal growth purposes, and those used in surveillance of antibiotic resistance according to the National Antibiotic Resistance Surveillance System for Enteric Bacteria (25).

Salmonella serovar identification. Due to economic constraints, a subset of 46 Salmonella isolates (44.7%, n = 103) was selected to represent the positive samples distribution by the study variables (indicated in “Statistical analysis”). Isolates were serotyped through the identification of surface antigens with somatic antisera, and flagella antisera with flagellar antisera following the Kauffman-White scheme (15) by using commercial reagents according to manufacturer’s instructions (Difco, BD). Antigenic characterization was tested by the slide agglutination technique with poly- and monovalent antisera, somatic and flagellar. Serotyping was carried out by team members from the Colombian Integrated Program for Antibiotic Resistance Surveillance at the Colombian Corporation of Agricultural Research’s Center for Biotechnology and Bioindustry (Bogotá, Colombia).

Statistical analysis. MPN data per ml were adjusted to the original rinse volume (400 ml) and then log transformed to approximate normality. The relationship between the log MPN per carcass and the study variables market storage condition (ambient temperature, refrigerated or chilled), market type (independent, wet market, and supermarket), chicken production system (integrated and nonintegrated), chicken skin color (yellow and white), and department was assessed using a generalized linear model, with identity link function and adjustment for dependency within city by using generalized estimated equations in STATA 10.1 software (Stata Corp., College Station, TX). A difference was considered statistically significant if P < 0.05. The Salmonella prevalence (i.e., Salmonella detection via MPN method per total number of samples tested) data were cross-tabulated with each of the study
variables by using a Fisher’s exact test or 2-by-n likelihood ratio chi-square test, as appropriate, in STATA. Salmonella serotypes were cross-tabulated by the study variables. Furthermore, the proportion of isolates resistant to each antibiotic was compared by market type, market storage condition, chicken production system, and serovar by using either Fisher’s exact test or 2-by-n likelihood ratio chi-square test, as appropriate, in STATA. Multidrug resistance (of 10 antibiotics) was compared by market type, storage condition, production system, and serovar by using m×n likelihood ratio chi-square test. For the purpose of data analysis, serovars that did not fall in the top five most frequent serotypes were collapsed into one category (i.e., other serotypes).

RESULTS

Salmonella prevalence and numbers. From the 300 total chicken samples collected, 103 (34.3%) were positive for Salmonella. Salmonella prevalence ranged from 0 to 56.5% among the departments sampled (Table 1). The department with the highest prevalence (56.5%) and highest Salmonella numbers (3.2 log MPN per carcass; 95% confidence interval [CI]: 2.7 to 3.8) was Chimaltenango. Jutiapa had the lowest Salmonella prevalence, with no Salmonella-positive samples identified.

There were significant differences (P < 0.05) in Salmonella prevalence by storage condition, market type, chicken production system, and chicken skin color (Table 1). Salmonella prevalence was highest among samples that were stored at room or ambient temperature, collected from municipal markets, and samples from nonintegrated production systems. Salmonella prevalence was twice as high in yellow-colored chicken samples compared with white-colored chicken samples.

The overall mean count (log MPN per carcass) was 2.3 (95% CI: 2.1 to 2.5) and ranged from 2.1 (95% CI: 1.8 to 2.3) in Guatemala to 3.2 (95% CI: 2.7 to 3.8) in Chimaltenango (Table 1), not including the department of Jutiapa. Figure 2 shows the overall distribution of the log MPN counts of Salmonella in carcass rinses. For chicken carcasses on which Salmonella was identified, 47.6% had numbers between 1.0 and 2.0 log MPN per carcass, but most carcasses had numbers greater than 2.0 log MPN per carcass. Significant differences in mean Salmonella numbers were observed by chicken production system and skin color.

<table>
<thead>
<tr>
<th>Variable (no. of samples)</th>
<th>No. (%) of Salmonella-positive samples</th>
<th>Mean log MPN/carcass (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refrigerated or chilled (n = 124)</td>
<td>21 (16.9) A</td>
<td>2.1 (1.7–2.5) A</td>
</tr>
<tr>
<td>Room or ambient (n = 176)</td>
<td>82 (47.2) B</td>
<td>2.4 (2.2–2.6) A</td>
</tr>
<tr>
<td>Market type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supermarket (n = 80)</td>
<td>11 (13.8) A</td>
<td>1.9 (1.3–2.5) A</td>
</tr>
<tr>
<td>Municipal market (n = 125)</td>
<td>64 (51.2) B</td>
<td>2.4 (2.2–2.7) A</td>
</tr>
<tr>
<td>Independent poultry shop (n = 95)</td>
<td>28 (29.5) C</td>
<td>2.3 (1.9–2.7) A</td>
</tr>
<tr>
<td>Chicken production system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated (n = 124)</td>
<td>27 (21.8) A</td>
<td>1.8 (1.5–2.2) A</td>
</tr>
<tr>
<td>Nonintegrated (n = 176)</td>
<td>77 (43.8) B</td>
<td>2.5 (2.3–2.7) B</td>
</tr>
<tr>
<td>Chicken skin color</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (n = 110)</td>
<td>23 (20.9) A</td>
<td>1.6 (1.3–1.9) A</td>
</tr>
<tr>
<td>Yellow (n = 190)</td>
<td>81 (42.6) B</td>
<td>2.5 (2.3–2.8) B</td>
</tr>
<tr>
<td>Department</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guatemala (n = 168)</td>
<td>51 (30.4) A</td>
<td>2.1 (1.8–2.3) A</td>
</tr>
<tr>
<td>Alta Verapaz (n = 38)</td>
<td>13 (34.2) A</td>
<td>2.2 (1.7–2.7) A</td>
</tr>
<tr>
<td>Escuintla (n = 24)</td>
<td>11 (45.8) A</td>
<td>2.6 (2.0–3.2) A</td>
</tr>
<tr>
<td>Quetzaltenango (n = 24)</td>
<td>10 (41.7) A</td>
<td>2.3 (1.7–3.0) A</td>
</tr>
<tr>
<td>Chimaltenango (n = 23)</td>
<td>13 (56.5) A</td>
<td>3.2 (2.7–3.8) A</td>
</tr>
<tr>
<td>Huehuetenango (n = 11)</td>
<td>5 (45.5) A</td>
<td>2.6 (1.7–3.5) A</td>
</tr>
<tr>
<td>Jutiapa (n = 12)</td>
<td>0</td>
<td>NA b</td>
</tr>
</tbody>
</table>

a Mean log MPN of Salmonella per carcass and 95% CI. Log MPN within each variable followed by a different letter are significantly different (P < 0.05).

b NA, not applicable.

FIGURE 2. Bar chart of the distribution of the percentage of log most probable number (MPN) of Salmonella numbers on broiler chicken carcasses at retail stores in Guatemala (n = 103).
with yellow chickens and those coming from nonintegrated production systems having higher mean *Salmonella* counts ($P < 0.05$). Yellow chickens had higher *Salmonella* numbers than white chickens; log MPN per carcass was 2.5 (95% CI: 2.3 to 2.8). No differences in mean *Salmonella* numbers were observed by department, market type, or storage condition.

**Salmonella serotypes.** Of the 103 positive *Salmonella* isolates identified, 46 were serotyped. However, results were obtained for only 43 isolates (41.7% of *Salmonella* isolates), as the serotype of three isolates was not identified. Among the 43 isolates, 13 different *Salmonella* serovars were identified: Albert, Budapest, Derby, Dublin, Enteritidis, Essen, Haifa, Heidelberg, Israel, Paratyphi B, Saintpaul, Stanley, and Typhimurium. *Salmonella* Paratyphi B was the most prevalent serovar (34.8%), followed by Heidelberg (16.3%) and Derby (11.6%). The remaining 37.3% of the isolates corresponded to the different serovars named above.

Table 2 presents the serovar distributions by market storage condition, market type, and chicken skin color. Differences in serovar distributions by market type and storage condition were not statistically significant ($P > 0.05$) and could be a result from selection bias (as the majority of samples collected were from municipal markets and found at room or ambient temperatures).

**Antibiotic resistance patterns.** All 103 positive *Salmonella* isolates were tested for antibiotic susceptibility to 10 antibiotics of veterinary and human health importance (Table 1). Antibiotics to which resistance was most commonly found were enrofloxacin (52.4% of isolates), tetracycline (40.7%), trimethoprim-sulfamethoxazole (37.9%), and streptomycin (35.9%). Results of susceptibility of isolates to these antibiotics by market type, market storage condition, and chicken production system are presented in Table 3. Significant differences were seen among resistance to enrofloxacin and trimethoprim-sulfamethoxazole by market type, with chicken purchased from supermarkets having the highest resistance proportions (81.8%) to each of the aforementioned antibiotics. Significant differences were also seen among resistance to trimethoprim-sulfamethoxazole by market storage condition: refrigerated chickens had a greater proportion of resistant isolates (66.7 versus 30.5%) compared with those stored at ambient temperature. Samples produced by integrated poultry companies had a higher proportion of isolates resistant to trimethoprim-sulfamethoxazole (63.0 versus 28.9%).

The number of antibiotics to which isolates were resistant is shown in Figure 3. Thirty-one percent of the *Salmonella* isolates identified were multidrug resistant (i.e., to at least three antibiotics). Seventy-three percent (75 of 103) of the isolates were resistant to at least 1 antibiotic, and the number of antibiotics to which isolates were resistant ranged from 0 to 7 of the 10 antibiotics tested. Among the *Salmonella* isolates, 59.2% ($n = 61$) were resistant to one to three antibiotics, 11.7% ($n = 12$) to four to six antibiotics, and 1.9% ($n = 2$) to seven antibiotics.

Antibiotic susceptibility results for the most commonly identified *Salmonella* serovars in the study are presented in Table 4. Antibiotics to which *Salmonella* isolates were most commonly resistant were enrofloxacin and trimethoprim-sulfamethoxazole. Significant differences in the proportion of resistant isolates were observed only for trimethoprim-sulfamethoxazole, for which *Salmonella* Paratyphi B and Heidelberg had greater proportions of resistant isolates.

**DISCUSSION**

In Guatemala, there is a large information gap related to public health and the microbiological safety of chicken meat. This source of animal protein is an important staple in the diet of Guatemalans, and thus one of the principal reasons why ensuring its safety is important. Most of the chicken is produced in-country to be consumed locally. According to the National Association of Poultry Farmers,
90% of local consumers prefer fresh or chilled chicken meat (versus frozen). *Salmonella* is one of the most common causes of foodborne illnesses in humans and has been associated with contaminated poultry and poultry products (14, 28, 36). Our study determined the numbers, serovar distributions, and antibiotic resistance patterns of *Salmonella* isolates obtained from raw chicken meat at the retail level in seven Guatemalan departments.

The overall prevalence of *Salmonella* (34.3%, n = 300) found on raw chicken carcasses in Guatemala was similar to that of other reports from retail chicken meat (1, 2, 9, 10, 16, 41), but was higher than the prevalence reported by a study conducted in two poultry processing plants in Guatemala, which was 9.2% (12). The difference in *Salmonella* prevalence between these two studies could be due to the number of sampling sites included in each study: Estrada et al. (12) surveyed only three processing plants (two of which are found in two of the departments that were included as part of this study), whereas the current study surveyed 92 retail locations. The prevalence in each of the departments included in this study was higher than what Estrada and colleagues report as their overall prevalence. In addition, although there is no published study that evaluated the microbial quality of chicken meat during transportation and distribution from processing plants to retail or that examined handling practices at retail locations, the possibility exists for breaches to occur in safe food handling practices and temperature abuse. Such breaches could likely increase *Salmonella* prevalence in chicken meat sold in the different markets sampled. For example, temperature abuse could occur due to market storage condition (27), as 97% of chicken carcasses collected from municipal markets were stored at ambient temperatures (average yearly temperatures for the departments sampled ranging from 8 to 10°C in Huehuetenango and Quetzaltenango and from 25.5 to 28°C in Escuintla and Jutiapa), which may promote the growth of potentially harmful organisms such as *Salmonella*. Furthermore, in several of these municipal markets, chicken carcasses were displayed next to other meat products, which could potentially allow for cross-contamination.

This study revealed significant differences in *Salmonella* prevalence by market storage condition, market type, chicken production system, and chicken skin color. Storage condition, chicken production system, and market type were also significant risk factors for differences in *Salmonella* prevalence in the studies conducted in Colombia by Donado-Godoy et al. (9, 10). Based on our findings, *Salmonella* prevalence was higher in chicken carcasses stored at ambient temperatures than among those that are refrigerated or chilled, re-emphasizing the fact that storage temperature is an important risk factor for pathogen proliferation (14, 27). *Salmonella* prevalence was also lower in chicken carcasses purchased at supermarkets, perhaps due

![Frequency bar chart illustrating the distribution of phenotypic antibiotic resistance to up to seven antibiotics among *Salmonella* isolates (n = 103) from retail chicken meat samples in Guatemala.](http://example.com/frequency_bar_chart.png)
to the samples being stored refrigerated and coming from integrated production systems (as our study revealed, 100% of chicken samples collected in supermarkets were refrigerated versus 3% of samples from municipal markets and 29% of samples from independent poultry stores). Finally, both Salmonella prevalence and numbers were significantly lower in chicken meat produced through integrated poultry systems, and in white chicken carcasses (versus yellow chicken carcasses). In our study, 85% of white chicken carcasses were produced through integrated production systems that are likely to adhere to safe processing and handling practices more commonly than nonintegrated production systems; this could account for the lower Salmonella numbers and prevalence in this group. Yellow chickens are commonly produced through nonintegrated systems and dyed after slaughter (13), which may increase the likelihood of contamination during improper handling.

The overall mean Salmonella number in chicken meat in Guatemala was 2.3 log MPN per carcass, a value that is slightly greater than counts found in other developing countries, such as Colombia (2.1 log MPN per carcass (9)) and Vietnam (2.0 log MPN per carcass (31)). The mean Salmonella count we found is higher than what has been determined in poultry from developed countries, such as the United States (1.75 log MPN per carcass (34)), New Zealand (<1 log MPN/g (37)), China (1.7 log MPN per carcass (39, 40)), and Australia (1.42 to 1.6 log MPN/cm² (29)). Salmonella numbers are important, as low pathogen loads may not pose a risk even though the prevalence is high. The log MPN distribution (Fig. 2) reveals that 45% of the samples in this study were contaminated with Salmonella numbers ranging from 1.0 to 2.0 log MPN per carcass versus 14% in Colombian samples and 3.7% of U.S. samples in that interval; 25% of our samples had Salmonella numbers between 2.1 and 3.0 log MPN per carcass versus 17% in Colombian samples and 1.2% in U.S. samples; and 24% of our samples were in the 3.1- to 4.0-log MPN per carcass range versus 4.7% in the Colombian samples and 0.27% in U.S. samples (9, 34). Therefore, the presence of high Salmonella numbers on Guatemalan chicken meat, especially in the 3- to 4-log MPN per carcass range, indicates that human risk of exposure to Salmonella from chicken meat can be high. It is important to note, though, that comparisons with other countries may be biased as both Salmonella prevalence and levels vary over the years.

Salmonella Paratyphi B was the most commonly identified serovar (34.8%), followed by Heidelberg (16.3%) and Derby (11.6%). Salmonella Paratyphi B and Heidelberg were also the two most commonly identified serovars in the studies conducted at farms and in retail meat in Colombia (9–11) and in slaughterhouses in Venezuela (4). None of these serovars were identified on retail meat in a study conducted by Zaidi et al. (41) in Mexico. It is interesting to note that Salmonella Paratyphi B is not a common serovar identified on chicken meat worldwide (21, 26, 31, 39, 42), but has been identified as a predominant serovar in Latin America. Reports from the pulsed field gel electrophoresis subtyping surveillance carried out by the National Health Laboratory in Guatemala also revealed that Salmonella Paratyphi B is not a commonly identified serovar in human cases; Salmonella Enteritidis and Typhimurium are two of the main serovars commonly associated with human diarrheal cases in Guatemala (3, 24). In this study, Salmonella Enteritidis and Typhimurium were the fourth and fifth most common serovars, suggesting that chicken meat could be a potential source of these serovars, but not necessarily the only source responsible for human salmonellosis in Guatemala.

There was a high percentage of resistance to several antibiotics among the Salmonella isolates identified through this study. Among all the isolates, 59.2% were resistant to one to three antibiotics, 11.7% (n = 12) to four to six antibiotics, and 1.9% (n = 2) to seven antibiotics. Multidrug resistance seen among isolates in this study can pose an important public health risk, not only through chicken meat consumption but also if these isolates are present in other food production systems (e.g., using poultry litter as fertilizer for vegetable crops). Resistance to several antibiotics was lower for isolates in this study than in Colombia: enrofloxacin (53 versus 66.2%), tetracycline

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>Paratyphi B (n = 15)</th>
<th>Heidelberg (n = 7)</th>
<th>Derby (n = 5)</th>
<th>Other serovars (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amoxicillin–clavulanic acid</td>
<td>0</td>
<td>2 (28.6)</td>
<td>0</td>
<td>1 (6.3)</td>
</tr>
<tr>
<td>Ampicillin</td>
<td>1 (6.7)</td>
<td>2 (28.6)</td>
<td>0</td>
<td>2 (12.5)</td>
</tr>
<tr>
<td>Cefitofur</td>
<td>4 (26.7)</td>
<td>4 (57.1)</td>
<td>1 (20.0)</td>
<td>2 (12.5)</td>
</tr>
<tr>
<td>Ceftriaxone</td>
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<td>1 (14.3)</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Chloramphenicol</td>
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<td>0</td>
<td>0</td>
<td>1 (6.3)</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>12 (80.0)</td>
<td>3 (42.9)</td>
<td>3 (60.0)</td>
<td>7 (43.8)</td>
</tr>
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<td>Gentamicin</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Streptomycin</td>
<td>5 (33.3)</td>
<td>3 (42.9)</td>
<td>1 (20.0)</td>
<td>6 (37.5)</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>4 (26.7)</td>
<td>1 (14.3)</td>
<td>3 (60.0)</td>
<td>8 (50.0)</td>
</tr>
<tr>
<td>Trimethoprim-sulfamethoxazole</td>
<td>12 (80.0)</td>
<td>3 (42.9)</td>
<td>1 (20.0)</td>
<td>2 (12.5)</td>
</tr>
</tbody>
</table>

a Percentages of individual antibiotic-resistant Salmonella isolates are presented and contrasted by serovars.

b The other serovars category represents 37.2% of the total isolates (n = 43).

c Antibiotic-resistant Salmonella isolates to trimethoprim-sulfamethoxazole differed significantly (P < 0.05) by serovars by using the likelihood ratio chi-square test.
Sulfamethoxazole are first-line antibiotics recommended for generation cephalosporins, ampicillin, and trimethoprim-distributions, and antibiotic resistance profiles of outbreak control and prevention.

Sulfamethoxazole and to enrofloxacin (part of the fluoro-

Salmonella seven departments in Guatemala. The study revealed that the on raw chicken meat sampled at different retail markets in Colombia. Seventy-three percent of the isolates identified in this study were resistant to at least one antibiotic, a percentage that is higher than that of isolates from retail chicken meat from the United States (64%) and Canada (19%) (30, 35). Among the isolates obtained in this study, Salmonella Paratyphi B had the greatest level of resistance, which was also observed in Colombia (9, 11).

Among the antibiotics tested, fluoroquinolones, third-generation cephalosporins, ampicillin, and trimethoprim-sulfamethoxazole are first-line antibiotics recommended for treating salmonellosis (5, 35). In this study, the three main serovars identified (Salmonella Paratyphi B, Heidelberg, and Derby) all presented a high resistance to trimethoprim-sulfamethoxazole and to enrofloxacin (part of the fluoroquinolones). Salmonella resistance to these antibiotics poses a significant public health threat, particularly in terms of outbreak control and prevention.

This study presents findings on numbers, serovar distributions, and antibiotic resistance profiles of Salmonella on raw chicken meat sampled at different retail markets in seven departments in Guatemala. The study revealed that the overall Salmonella prevalence was high (34.3%), and 52% of the samples had numbers between 2.0 to 4.0 log MPN per carcase. Salmonella Paratyphi B and Heidelberg were the most commonly identified serovars, and they had the highest percentages of multidrug resistance. Data are lacking on attribution of poultry meat consumption to outbreaks or cases of human salmonellosis in Guatemala. Further studies to evaluate handling practices during transport and at the retail level would be useful to help identify critical points to target for reducing the poultry meat contamination levels and therefore the risk of illness in humans. Furthermore, proper food handling practices should continue to be promoted at all levels to reduce the prevalence and numbers of Salmonella on chicken carcasses. Results on antibiotic-resistant Salmonella from several countries have created awareness about the hazard of resistant bacteria and their potential for spread. It is important to continue monitoring antibiotic-resistant bacteria, especially in developing countries where inadequate health care systems and antibiotic misuse are common. This study has provided data on Salmonella in retail chicken meat in Guatemala that can be used as a baseline from which an integrated surveillance system can be established in collaboration with agricultural and health authorities, to identify and assess risk, and to establish control practices to reduce the burden of salmonellosis.

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REFERENCES