Prevalence and quantification of *Salmonella* contamination in raw chicken carcasses at the retail in China

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**Abstract**

The quantitative contamination load of *Salmonella* in raw chicken carcasses at the retail level in six provinces and cities of China was determined within 1595 carcasses over 12 consecutive months. The overall *Salmonella* contamination rate was 41.6% and the median load of those contaminated was 4.6 MPN/100 g with 1.8 MPN/100 g as the 25th percentile and 18.0 MPN/100 g as the 75th percentile. There were significant variations in prevalence among carcasses sampled either in different provinces or sampling months. Carcasses collected in August had not only the highest prevalence of contamination (55.8%), but also the highest median (14.0 MPN/100 g) and 75th percentile load (120.0 MPN/100 g) values compared to January with lowest prevalence (26.5%), median (1.5 MPN/100 g) and 75th percentile load (7.6 MPN/100 g). The chilled (55.1%) stored carcasses was significantly higher in prevalence than those frozen (33.5%) and those freshly slaughtered (28.3%), those unpackaged (45.1%) was more likely to be contaminated with *Salmonella* than those packaged (37.4%). The present study revealed the widely prevalent *Salmonella* contamination among retail carcasses, indicating a strong potential of the cross-contamination occurred before and/or at the retail level. The study also provided quantitative data for a risk assessment evaluating potential intervention methods to reduce the risk of salmonellosis by consuming chicken meat of Chinese origin.

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1. Introduction

Salmonellosis is one of the major foodborne diseases in the world and it is estimated that 93.8 million cases of gastroenteritis due to *Salmonella* species occur globally each year, with 155,000 deaths (Majowicz et al., 2010). There is a wide range of foods implicated in foodborne illness attributable to *Salmonella*. Foods of animal origin, especially poultry and poultry products, are often involved in sporadic cases and outbreaks of human salmonellosis (Sánchez-Vargas, Abu-El-Haija, & Gómez-Duarte, 2011).

In last decades, there had been several quantitative microbiological risk assessments (QMRA) studies for *Salmonella*-chicken meat combinations including the whole or part of the poultry food chain performed in the world, which showed the strong linkages between the prevalence and density of *Salmonella* infection in chicken meat and human cases of salmonellosis (Guo et al., 2011; Oscar, 2004; Straver et al., 2007; World Health Organization and Food and Agriculture Organization of the United Nations, 2002). Control of *Salmonella* in food animals had been successful in the United States (M’ikanatha et al., 2010), Sweden and Denmark (Wegener et al., 2003) and had led to low levels of salmonellosis in these countries.

China has a high case rate of salmonellosis. It was found that non-typhoid *Salmonella* annually caused 9.874 million gastroenteritis cases in China and 91.5% of them were caused by food...
transmission (Mao, Hu, & Liu, 2011). It had been found that more than half of the retail chicken carcasses in China were contaminated with *Salmonella* (Yang et al., 2011), however, the quantitative load among those contaminated chicken meat was still unknown which made both scientists and government unable to evaluate the risk of salmonellosis among Chinese populations and explore the potential interventions under Chinese dietary habits.

The aim of the study was to determine the prevalence and loads of *Salmonella* on retail raw chicken carcasses in parts of China and to provide the data for quantitative risk assessments of *Salmonella*.

2. Materials and methods

2.1. Sample collection and preparation

From April 2011 to March 2012, 1595 samples including freshly slaughtered, chilled and frozen chicken carcasses were collected from supermarkets and farmer's markets in Beijing, Changchun of Jilin province, Huhehaote of Inner Mongolia Autonomous, Yanglin of Shanxi province, Yangzhou of Jiangsu province and Guangzhou of Guangdong province, respectively. Each sample was weighed, marked, placed in a 3500 mL stomach (Seward, UK) plastic bag and was transported to local laboratories immediately in an ice box. 500 mL of buffered peptone water (BPW; BD, Beijing, China) per kilogram of chicken sample was added and the carcass was thoroughly manually massaged for 3–5 min to ensure the surface, internal and external of the chicken carcass fully contact with the rinse. The rinse was used for *Salmonella* MPN analysis. The whole analysis process should be finished in no more than 2 h after sampling in order to avoid the potential growth of *Salmonella* during sample storage and transportation.

2.2. Salmonella MPN

The analytical procedure for *Salmonella* mainly followed the Food Safety and Inspection Service (FSIS) of United States Department of Agriculture (USDA/FSIS, 2008, 2010) with a bit modification. Briefly, a triplicate-10 mL of the chicken rinse was taken directly from the stomach bags and placed into three empty sterile tubes, transferring triplicate-1 mL of the rinse to three tubes containing 9 mL of BPW followed by making 10-fold dilution, respectively. All tubes were pre-enriched in a shaking incubator at 100 rpm/min for 20–24 h at 37 °C. A portion (0.5 ± 0.05 mL) or 0.1 ± 0.02 mL of the pre-enrichment culture was transferred into 10 mL tetraionate broth (TT; BD) or Rappaport Vassiliadis broth (RV; BD) and incubated at 42 ± 0.5 °C in a shaking incubator at 100 rpm for 22–24 h for selective enrichment. After incubation, a loopful of TT and RV broth culture was streaked onto xylose lysine deoxycholate (XLD) and Bertani agar and confirmed by API 20E test kit (bioMérieux, Beijing, China). The MPN of each sample would be acquired by searching the table of MPN index and 95% confidence limits for various combinations of positive tubes in a three dilution series using inoculums quantities of 10 mL, 1 mL and 0.1 mL recommended by the FSIS of United States Department of Agriculture.

Since each kilogram of chicken sample was rinsed in 500 mL BPW, MPN/100 g of chicken carcass was equal to the MPN of 50-mL chicken rinses (Wang, Yu, & Liu, 2005).

2.3. Statistical analysis

The Pearson Chi-Square test and the nonparametric test (Mann–Whitney Test for two independent samples and Kruskal–Wallis Test for several independent samples) were used to determine the significant difference of prevalence and median loads of *Salmonella* in chicken carcasses sampled in different provinces, months, storage conditions, packaged conditions, and market types. Statistical software SPSS for Windows (version 11.5, SPSS, Inc., Chicago, IL) was used for descriptive analysis. The results were considered significant at the 5% (with α = 0.05) level to evaluate whether there is any association between the prevalence and quantifications of *Salmonella* contamination and their characteristics at the retail.

3. Results

3.1. Overall Salmonella prevalence and MPN determination

There were totally 1595 chicken carcasses and 41.6% of them found to be positive of *Salmonella* contamination. The quantitative microbiological method adopted in the present study used most probable number (MPN) as the unit to quantify load values of the contaminated chicken carcasses and the range was from 1.5 MPN/100 g to 550 MPN/100 g. The median value of *Salmonella* loads among those positive samples was 4.6 MPN/100 g. The 25th percentile (Q1) and the 75th percentile (Q3) of the contamination were 1.8 MPN/100 g and 18.0 MPN/100 g, respectively.

3.2. Varied prevalence and quantification of Salmonella contamination among chicken carcasses from different provinces and months

The prevalence of *Salmonella* among chicken carcasses sampled from different provinces varied significantly (Table 1) with the highest contamination rate from Jilin province (65.0%) and the lowest from Inner Mongolia Autonomous (15%). However, the quantification of *Salmonella* in terms of median MPN values among those positive carcasses was found highest from Guangdong provinces, 7.5 MPN/100 g (1.8 MPN/100 g for Q1 and 21.5 MPN/100 g for Q3), which was more than 4 times higher than lowest median values found in carcasses from Inner Mongolia 1.8 MPN/100 g (1.8 MPN/100 g for Q1 and 4.6 MPN/100 g for Q3). The Kruskal Wallis Test observed significant difference in quantifications of *Salmonella* contaminations among those positive carcasses collected from different provinces (*P* < 0.001).

The present study also observed significant differences both in prevalence and quantification among those carcasses collected in different seasons (*P* < 0.001) in Table 2. The prevalence among those carcasses collected in summer, including those in June, July and August, was significantly higher than those collected in autumn (including September, October and November, *P* < 0.001) and those collected in winter (including December, January and February, *P* < 0.001), but not significantly different from those collected in spring (including March, April and May, *P* = 0.177). Using Mann–Whitney Test, the median load value (MPN/100 g) of carcasses collected in summer, 8.0 MPN/100 g, was all significantly higher than those collected in spring (4.6 MPN/100 g, *P* < 0.001), autumn (4.6 MPN/100 g, *P* = 0.005) and winter (3.6 MPN/100 g, *P* < 0.001), respectively.

Fig. 1 showed varied prevalence of *Salmonella* contamination among carcasses collected in different months with significant difference (*P* < 0.001) using the Pearson Chi-Square Test. The prevalence increased from January to August and decreased from then to December and those collected in August had higher
prevalence (55.8%) than those collected in January (26.5%, \( P < 0.001 \)), February (31.9%, \( P < 0.001 \)), April (39.1%, \( P = 0.009 \)), September (36.3%, \( P = 0.001 \)), October (43.5%, \( P = 0.044 \)), November (38.5%, \( P = 0.005 \)), and December (31.7%, \( P < 0.001 \)), but was no significant difference found compared to those in March (46.2%, \( P = 0.107 \)), May (51.4%, \( P = 0.465 \)), June (50.0%, \( P = 0.352 \)) and July (46.2%, \( P = 0.114 \)).

Fig. 2 showed median load values and 25th and 75th percentiles among those contaminated carcasses collected from different months. The Kruskal Wallis Test observed the median values, the numeric values showed in the figure, were significantly varied among contaminated carcasses collected in different months (\( P < 0.001 \)). Using Mann–Whitney Test, the median load value in August (14.0 MPN/100 g) was significantly higher than those in January (1.5 MPN/100 g, \( P < 0.001 \)), February (4.2 MPN/100 g, \( P = 0.002 \)), March (4.6 MPN/100 g, \( P < 0.001 \)), April (4.6 MPN/100 g, \( P = 0.001 \)), May (4.6 MPN/100 g, \( P < 0.001 \)), June (4.6 MPN/100 g, \( P = 0.001 \)), September (4.6 MPN/100 g, \( P = 0.012 \)), October (5.5 MPN/100 g, \( P = 0.011 \)), November (4.6 MPN/100 g, \( P < 0.001 \)) and December (4.6 MPN/100 g, \( P = 0.003 \)), respectively, but not significantly different with that in July (11.5 MPN/100 g, \( P = 0.675 \)).

Moreover, the present study observed extremely higher load values at 75th percentiles both in July and August (120 MPN/100 g) which was about 10 times higher than those found in the rest of months (7.6–18.8 MPN/100 g). The results indicated that people purchasing chicken carcasses in July and August would not only have higher probability of consuming meat with Salmonella contamination, but also exposure doses would be higher than the remainder of the year.

### 3.3. Comparison of Salmonella contamination in samples from different location, storage and packaging conditions

The present study collected 715 chilled carcasses, 400 frozen carcasses and 480 freshly slaughtered carcasses and their prevalence were 55.1%, 33.5% and 28.3%. The Pearson Chi-Square test showed the prevalence of chilled carcasses was significantly higher than those of frozen carcasses (\( P < 0.001 \)) and those of freshly slaughtered (\( P < 0.001 \)). However, the nonparametric test did not reject the null hypothesis that the median load of contaminated chilled carcasses (4.7 MPN/100 g) was not significantly higher than the median load of contaminated frozen carcasses (4.6 MPN/100, \( P = 0.056 \)) and those of contaminated freshly slaughtered one (4.6 MPN/100, \( P = 0.498 \)), even if 75th percentile of loads of those contaminated chilled one (21.5 MPN/100 g) was about twice of those of contaminated frozen carcasses (11.5 MPN/100 g) (Table 3).

There were 398 out of 883 unpackaged and 266 out of 712 packaged chicken carcasses found to be positive for Salmonella contamination (\( P < 0.001 \)). The median (Q1–Q3) values of those contaminated unpackaged and packaged chicken carcasses were 5.5 (1.8–21.5) and 4.6 (1.8–11.5), respectively with significant difference (\( P = 0.001 \), Mann–Whitney Test). The present study found 42.6% carcasses from farmer’s markets and 40.6% from supermarkets contaminated with no significant difference using Pearson Chi-Square test (\( P = 0.428 \)). However, the median loads of contaminated carcasses from farmer’s markets, 5.5 (1.8–21.5) was significantly higher than those from supermarkets, 4.6 (1.8–11.5).

### 4. Discussion

The Salmonella contamination in chicken and chicken products had been widely investigated in many countries of the world but the prevalence varied (FSIS, 2009; M’ikanatha et al., 2010; Soomro et al., 2010; Tibaijuka, Molla, Hildebrandt, & Kleer, 2003). The inconsistency of prevalence from different countries might be biased because of different stages where they sampled, varied compositions of sample types and detection methods. Using the prevalence of Salmonella contamination in chicken carcasses as the worst case for all chicken and their products at the retail level, the present study showed 41.6% of chicken carcasses were contaminated with Salmonella at the retail level which was lower than what Yang had observed (52.2%, \( N = 1152 \)) using chicken carcasses as well (Yang et al., 2011). The variation in Salmonella prevalence might be attributed to the difference in sampling months and provinces. In Yang’s study, chicken carcasses from Beijing were collected in May and June, while carcasses from Guangdong were collected in November and December. Moreover, the sampling method could be a very important factor to cause the difference between Yang’s study and the present study. In Yang’s study, after chicken carcasses were collected in provinces or cities outside Shaxi province, samples or rinse solutions were shipped to the laboratory at Northwest A&F University. Although it was shipped on ice and less than 14 h, it was likely to multiply during the transportation. Therefore, the prevalence of chicken carcasses collected from Beijing city in May and June was 41.7% (25/60) in the present study which was lower than what Yang had found 63.9% using the same sampling months and provinces, so as the prevalence in samples collected from Guangdong province in November and December, 32.5% (13/20) in the present study and 64.6% in Yang’s study. Nevertheless, two studies showed closer prevalence of Salmonella contamination among carcasses collected inside Shaxi province during same sampling month (March, April, November and December), 43.8% (35/80) in the present study and 50% in Yang’s study. Therefore, the present study was representative of the Salmonella contamination in chicken carcasses at retail in part of China because of eliminating probability of Salmonella multiplying during carcasses transportation that might happen in previous study in China.

### Table 1

The overall and provincial prevalence and loads distributions of Salmonella contamination in the chicken carcasses at the retail in China.

<table>
<thead>
<tr>
<th>Province</th>
<th>No. of samples detected</th>
<th>No. (%) of positive samples</th>
<th>Load values (MPN/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Median</td>
</tr>
<tr>
<td>Overall</td>
<td>1595</td>
<td>664/41.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Beijing</td>
<td>395</td>
<td>197/40.9</td>
<td>7.0</td>
</tr>
<tr>
<td>Guangdong</td>
<td>240</td>
<td>92/38.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Jilin</td>
<td>240</td>
<td>156/65.0</td>
<td>5.1</td>
</tr>
<tr>
<td>Inner Mongolia Autonomous</td>
<td>240</td>
<td>36/15.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>240</td>
<td>104/43.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Shaxi</td>
<td>240</td>
<td>79/32.9</td>
<td>4.6</td>
</tr>
</tbody>
</table>

* Significant difference in prevalence of Salmonella contamination among carcasses collected in different provinces (\( df = 5, P < 0.001 \)).

* Significant difference in loads of Salmonella contamination among carcasses collected in different provinces using Kruskal Wallis Test (\( df = 5, P < 0.001 \)).
Consistent with what had been found in Yang’s study, the present study showed significant variation in prevalence of Salmonella contamination among carcasses sampled from different provinces. It might be the very different temperatures in different provinces. There were four provinces in the present study collected freshly slaughtered chicken carcasses and from north to south, they were Inner Mongolia Autonomous, Shanxi, Jiangsu and Guangdong. Theoretically, northern provinces should have the lower average temperatures than southern provinces. This phenomena was observed with prevalence rates of freshly slaughtered carcasses from Inner Mongolia Autonomous (3/120) being significantly lower than those from Shanxi (36/120, \( P < 0.001 \)), Jiangsu (45/120, \( P < 0.001 \)), and those from Guangdong (52/120, \( P < 0.001 \)).

The present study found the seasonal and monthly variations in prevalence of Salmonella contamination in chicken carcasses with highest in summer, especially those in August which was in accordance with previous investigations showing a higher probability of chicken becoming infected during the summer (Zdрагas et al., 2012). Moreover, not only the median, but also the high persistence. The present study found the seasonal and monthly variations in prevalence of Salmonella contamination in chicken carcasses with highest in summer, especially those in August which was in accordance with previous investigations showing a higher probability of chicken becoming infected during the summer (Zdрагas et al., 2012). Moreover, not only the median, but also the high percentiles of loads for those contaminated carcasses sampled in August and July were substantially higher than the other months. This might occur because the wet and hot season enhanced the survival of Salmonella as it would provide favorable growth conditions for Salmonella, and consequently increased their persistence.

The present study indicated the prevalence of Salmonella contamination among unpackaged carcasses (45.1%) was significantly higher than those packaged (37.4%). This result was in agreement with what Bucher et al. concluded in a systematic review-meta-analysis (Bucher, Farrar, et al., 2012; Bucher, Fazil, et al., 2012) that the package was effective in achieving relative reductions (compared to baseline with no interventions) in the load and prevalence of Salmonella which might be attributed to a reduction in the cross-contamination during transportation, delivery and retail. However, the present study observed 20.6% reduction in prevalence of Salmonella from those unpackaged carcasses (45.1%) to those packaged (37.4%), which was much smaller than what Bucher et al. (Bucher, Farrar, et al., 2012; Bucher, Fazil, et al., 2012) had estimated by packaging carcasses from on-farm and processing, 43.88%–87.78%. It indicated the packaging process might occur much more behind the stage of on-farm and processing in China and there would be a strong potential of cross-contamination occurred before and/or at the retail level for at least.

Another factor indicating cross-contamination at the retail level in China was storage conditions of chicken carcasses. This study found those chilled carcasses would be more likely to have Salmonella contamination than those freshly slaughtered one. Although Bucher et al. found that chilling was effective at reducing Salmonella load and prevalence in chicken (Bucher, Farrar, et al., 2012; Bucher, Fazil, et al., 2012), chilled carcasses sold at retail might experience cross-contamination during transportation and storage. In contrast, fresh carcasses purchased in a market are slaughtered, defeathered and eviscerated within 20 min (Capita, Alvarez-Astorga, Alonso-Calleja, Moreno, & del Camino Garcia-Fernandez, 2003) of purchase and may be less likely to experience cross-contamination.

Although the present study did not observe a significant difference in prevalence of Salmonella contamination among chicken carcasses from a farmer’s market and a supermarket, the median load among contaminated carcasses from a farmer’s market was

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**Table 2**
The prevalence and loads distributions of Salmonella contamination among carcasses sampling in different seasons.

<table>
<thead>
<tr>
<th>Season</th>
<th>Month</th>
<th>No. of samples detected</th>
<th>No. (%) of positive samples</th>
<th>Load values (MPN/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Median</td>
</tr>
<tr>
<td>Spring</td>
<td>3–5</td>
<td>413</td>
<td>190 (46.0)*</td>
<td>4.6</td>
</tr>
<tr>
<td>Summer</td>
<td>6–8</td>
<td>388</td>
<td>197 (50.8)</td>
<td>8.0</td>
</tr>
<tr>
<td>Autumn</td>
<td>9–11</td>
<td>407</td>
<td>160 (39.3)</td>
<td>4.6</td>
</tr>
<tr>
<td>Winter</td>
<td>1,12</td>
<td>387</td>
<td>117 (30.2)</td>
<td>3.6</td>
</tr>
</tbody>
</table>

* Significant difference in prevalence of Salmonella contamination among carcasses collected in different seasons (df = 3, \( P < 0.001 \)).

**Fig. 1.** Varied prevalence and confidence intervals of Salmonella contamination among carcasses collected in different months. *the prevalence of Salmonella contamination in months other than August was compared to that in August using Chi-square test, \( P < 0.05 \), \( P < 0.01 \), \( *** P < 0.001 \).

**Fig. 2.** Median loads and its upper and lower quartiles among contaminated carcasses collected in different months. The digit number above the bar donated the median values of contamination loads among those contaminated in different month, the lower bound of the interval denoted the 25th percentiles of loads and the upper bound denoted the 75th percentiles.
significantly higher than those from a supermarket. It might be because the farmer’s market had limited supply of potable water available when the carcass was rinsed and the water was frequently recycled use, less packaged carcasses sold in farmer’s market than in supermarket and poorer hygiene management and operation in farmer’s market which lead to higher chance of cross-contamination.

The present study indicated that more than 40% of raw chicken carcasses at the retail level had been contaminated with Salmonella in China. Those unpackaged or chilled carcasses were in high risky which indicated a strong potential of the cross-contamination occurred at and/or before the retail level. The extreme high probabilities and loads of contamination among carcassesretailed in July and August should be fully concerned in food safety education champions and risk communications. Using the quantitative data, the QMRA study would be launched to investigate the potential pathway the Salmonella would be introduced and multiplied in the chain from farm to table and evaluate potential intervention methods to reduce the risk of salmonellosis by consuming chicken meats among Chinese populations.

### References


