Foodborne Disease Caused by Salmonella

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Foodborne disease caused by *Salmonella* is an important public health concern worldwide. Animal-based food, especially poultry meat, is the main source of human salmonellosis.

Keywords: foodborne pathogen ; salmonellosis ; chicken ; antibiotic resistance ; microbial contamination ; food safety

1. Introduction

Salmonella, one of the most important foodborne pathogens in the world, is frequently implicated in foodborne disease outbreaks. It is estimated that *Salmonella* is responsible for approximately 1.3 billion cases of salmonellosis worldwide each year[1]. China has a high incidence of salmonellosis[2]. It was found that approximately 70% to 80% of foodborne diseases are caused by *Salmonella* in China[3]. Epidemiological studies have suggested that foods of animal origin, especially poultry and poultry products, are common vehicles of *Salmonella* transmission to human beings[4][5][6].

The monitoring and tracking of *Salmonella* in poultry meat and the establishment of efficient surveillance systems are the basis for effective public health protection and food safety management. In Europe, a baseline survey was conducted to estimate the prevalence of *Salmonella* and *Campylobacter* on broiler carcasses in 2008[7]. In the USA, the United States Department of Agriculture Food Safety Inspection Service (USDA/FSIS) has established a verification program to inspect raw poultry products for the presence of *Salmonella* and *Campylobacter*[8]. In China, numerous studies investigated retail chicken meat for *Salmonella* contamination, which showed that up to 50% of retail chicken samples were contaminated with *Salmonella*[9][10]. However, limited information is available concerning *Salmonella* contamination of other poultry meats, such as duck, goose, and pigeon. Furthermore, these previous studies only included samples from one or a few regions from the whole territory of China. Given the variations in data availability and quality observed in the European Union[11], it is expected that the prevalence and contamination level will be different among the various regions of China. As such, there is a lack of comprehensive data on *Salmonella* contamination in poultry meat at the retail level in the whole region of China.

According to the Food and Agriculture Organization (FAO)[12], China's poultry production is second only to the USA, and its consumption is increasing steadily. Therefore, it ie necessary to quantify *Salmonella* prevalence in Chinese retail poultry meat, to analyze the differences in *Salmonella* prevalence among sub-categories, and to evaluate the levels of the heterogeneity of the published prevalence data.

2. The Prevalence and Epidemiology of *Salmonella* in Retail Raw Poultry Meat in China

Microbiological foodborne hazards have attracted the attention of the food safety management system in China[13]. The Chinese Food Safety Law implemented in 2019 has legally clarified the roles and duties of the national food safety surveillance system for foodborne pathogens in foods[14]. In 2010, this national food safety surveillance system covered all 31 provinces, major municipalities, and autonomous regions in China, to support early detection, diagnosis, and management of foodborne pathogens[15]. Since then, a downward trend is apparent from the publicly available reports on the incidence of foodborne pathogens in foods[16]. However, reducing the incidence of foodborne diseases is a constant topic of concern for the Chinese government as well as the public.

Herein demonstrated the widespread prevalence of *Salmonella* in retail poultry meat in China. The contaminated retail poultry may become an issue of concern because the products can be in direct contact and be used by consumers. Although raw meat generally receives a certain lethal treatment (e.g., conventional cooking, microwaving, etc.) before consumption, cross-contamination incidents and undercooking are still the greatest risks in consumers' kitchens[17][18]. In the present study, the pooled prevalence of *Salmonella* in raw poultry meat in China was 23.0%, which is significantly higher than that reported in retail poultry from the European Union (7.1%)[5] and Africa (13.9%)[19]. Thus, raw poultry meat in retail may be an important source of human salmonellosis in China.

According to the prediction by the Organization for Economic Co-operation Development and the Food and Agricultural Organization (OECD-FAO)[20], poultry meat will continue to be the primary driver of meat production growth over the next ten years. Low production costs, a short production cycle, high feed conversion ratios, and low product prices have contributed to making poultry the meat of choice for both producers and consumers. Regarding the different poultry meat categories, chicken is the greatest concern as it bears the highest pooled prevalence of *Salmonella*. The high prevalence of *Salmonella* in raw chicken samples in our study suggests that chicken may be the main vehicle of transmission for *Salmonella* in China. In China's meat consumption structure, chicken takes the largest proportion in poultry meat consumption and is on the rise, becoming the second-largest meat product after pork[21]. Similarly, in Chinese poultry farming operations, densities are generally higher for chickens, while they are considerably lower for ducks and geese (111.2, 27.4, and 6.7 thousand per km^2 maximum, respectively)[22]. Thus, in response to potential public health pressures, more effective intervention strategies during processing should be implemented to control the quality and safety of chicken products.

In terms of geographical distribution, the occurrence of *Salmonella* in retail raw poultry meat is common in China. The pooled prevalence of *Salmonella* in poultry meat samples is the highest in Shaanxi, followed by Henan, Sichuan, and Beijing. There is no known scientific rationale for the observed geographical differences in the prevalence levels of *Salmonella*. From the spatial distribution of poultry animals in China, chickens are most ubiquitous, with high densities across much of eastern China, particularly the Yellow River Basin. Duck densities are highest in southeastern China and the Sichuan Basin[22]. Notably, farm practices can affect the prevalence of *Salmonella* in the final product[23]. Moreover, because the cold chain coverage of agricultural products in China is still much lower (20.0%) than that in developed countries (90.0%)[24], the supply of poultry meat in China's market mainly depends on the centralized distribution of producing regions. This may be the main reason for the high prevalence levels of *Salmonella* in retail poultry meat across several regions of China. In addition, some potential reasons may be related to the differences in the retail environments[25], economic conditions[26], and market supervision[27] between these regions.

Herein*,* *Salmonella*prevalence on chilled poultry meat was significantly higher than that on the poultry meat held at both ambient and frozen temperatures. The results showed that preservation methods of poultry meat may be a potential factor indicating cross-contamination at the retail level in China. Chilling is the most commonly utilized processing intervention to control *Salmonella* growth in the poultry meat production chain. Chilled poultry meat is usually kept at a low temperature by maintaining a monitored chill chain through portioning, packaging, transport, and retail storage[28][29]. In China, immersion chilling is employed more frequently. However, once a sample is contaminated with *Salmonella* during the immersion process, the contamination may spread among the whole batch of carcasses, leading to an increase in the prevalence of pathogens on finished products[30]. Consumers generally believe that freshly slaughtered meat has the advantages of higher nutritional value and superior taste[31]. Therefore, Chinese consumers have a preference for ambient meat (60% market share) over chilled meat (25% market share) or frozen meat (15% market share)[31]. Compared with the chilled poultry meat, fresh poultry meat purchased on the market can often be slaughtered, stripped, and eviscerated within 20 min[32] and may be less likely to experience cross-contamination. However, prevalence estimates are not sufficient to assess the probability and severity of illness to which people may be exposed. In a QMRA, implementation of quantitative exposure assessment depends on the concentration data of pathogens in food samples[33][34]. There is a general lack of quantitative data pertaining to *Salmonella* loads in food because most surveillance studies focus on the detection on a presence/absence basis. Therefore, viable cell numbers are often not known because most culture-based standard methods involve enrichment, while molecular methods (aside from RT-qPCR) do not assess viability. According to a few quantitative data on *Salmonella* in poultry meat, the average concentrations of *Salmonella* in the ambient stored samples are higher than that in the chilled samples[35][36]. Therefore, we speculate that although the pooled prevalence of *Salmonella* in freshly slaughtered poultry meat is low, its concentration levels are high, which may pose a greater risk to consumers.

The serotyping results of *Salmonella* isolates obtained from poultry meat in the current study revealed that *S*. Enteritidis, *S*. Indiana, and *S*. Typhimurium were the predominant serovars in poultry meat. The results of previous studies focusing on only one or several cities are consistent with the current nationwide data, indicating that *S*. Enteritidis, *S*. Indiana, and *S*. Typhimurium may be the main serotypes in poultry meat throughout China[37]. A global epidemiological meta-analysis of *Salmonella* serovars in animal-based foods indicated that *S*. Enteritidis was the most prevalent in Asia, Latin America, Europe, and Africa, while *S*. Typhimurium presented a global distribution[38]. There have been reports of *S*. Indiana in retail raw poultry meat in China since 2009, and this serotype appeared relatively late[39]. In particular, *S*. Enteritidis is most commonly associated with chickens and eggs and has a much smaller relationship with other food animal species[40]. What is more, *Salmonella* serovars Enteritidis, Typhimurium, and Indiana are also reported as the most common serotypes associated with human infections and outbreaks[41][42]. Thus, the high prevalence of these *Salmonella* serotypes in poultry meat indicates a significant risk to consumers. The dominant serotypes of *Salmonella* in food will change over time[43], which reminds us that the monitoring of the emergence and prevalence of different serotypes of *Salmonella* is essential for the better control of salmonellosis.

Nowadays, antimicrobial resistance is becoming an urgent threat and challenge to humans and the public. Herein, more than half of *Salmonella* isolates were antimicrobial resistant. *Salmonella* isolates recovered from retail poultry meat showed a high frequency of resistance to nalidixic acid, tetracycline, ampicillin, chloramphenicol, trimethoprim/sulfamethoxazole, gentamicin, streptomycin, ciprofloxacin, sulfisoxazole, and ampicillin/sulbactam. Among them, whether in poultry meat or chicken, the highest rates of antimicrobial resistance were observed for nalidixic acid. Nalidixic acid is one of the most widely used antibacterial agents in feed additives and veterinary drugs worldwide. The uncontrolled use of quinolone in China will cause the emergence and increasing prevalence of antimicrobial-resistant *Salmonella*, complicating the treatment of *Salmonella* infections in humans and animals[44]. Resistance to tetracycline was the second most frequently observed, with tetracycline and ciprofloxacin also being front-line antibiotics for the treatment of salmonellosis. However, *Salmonella* isolates in the current study were relatively susceptible to ciprofloxacin, a finding that is similar to a previous study in Iran[45]. Unfortunately, in several studies, *Salmonella* strains isolated from food, animals, and humans have been found to show multidrug-resistant (MDR) properties[46][47]. Furthermore, *S*. Indiana isolates with a high detection rate had been found to have high MDR levels. The existence of MDR *Salmonella* isolates poses a major risk to public health, and food safety risk managers should continue to monitor their significant increase in resistance and implement further legislation on the prudent use of antimicrobials.

3. Conclusions

Herein presented the prevalence and epidemiology of *Salmonella* in retail raw poultry meat in China before 2020. *Salmonella* was more prevalent among chicken samples, especially chilled ones. Among the Chinese provincial regions, Shaanxi, Henan, Sichuan, and Beijing were high-risk areas for *Salmonella* contamination in poultry meat. The recovered Salmonella isolates belonged to multiple serovars. S . Enteritidis was the most commonly identified serovar in retail raw poultry meat in China. Meanwhile, poultry-derived *Salmonella* isolates showed a high prevalence of antimicrobial resistance, which represents a threat to human health. However, the qualitative sampling data of *Salmonella* accounts for the majority in the published reports on retail raw poultry meat across China. The scarcity of quantitative data on the contamination levels of *Salmonella* on poultry meat indicated the importance of future studies focusing on this topic and making possible quantitative microbial risk assessment studies.

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