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A risk assessment of salmonellosis linked to chicken meals prepared in households of China

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ABSTRACT

A quantitative microbiological risk assessment model was used to quantify the risk of salmonellosis caused by bacterial growth and cross-contamination of chicken meals prepared in households of China. Chinese data on initial loads of *Salmonella* in chicken carcasses sold at retail, storage time and handling of raw chicken meat in household kitchens and confirmatory transfer rates of *Salmonella* among different kitchen objects were collected. Only one third of Chinese families in our sample separated the cutting board between raw and ready-to-eat foods. The cross-contamination of ready-to-eat foods from chicken meals via the cutting board, the knife and cooks' hands increased the frequency of pathogen ingestion and the risk of salmonellosis. A significant decrease in the risk of salmonellosis could be achieved by reducing the cross-contamination when handling raw chicken meat and ready-to-eat foods. Decreasing the prevalence of *Salmonella* contamination to 8.8% or removing chicken carcasses with contamination densities higher than 100 MPN/100 g at retail was less effective. Using transfer rates of *Salmonella* from raw chicken meat to the wooden cutting board instead of that from references, a statistically higher risk of salmonellosis per serve due to the cross-contamination in households was observed. The present study validated values of hygiene practices in China to reduce the risk of salmonellosis from contaminated raw chicken meat at retail. Deliberate surveys for cooking behaviors and transfer rates of *Salmonella* from and to different objects including wooden cutting boards were needed.

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 causing 155,000 deaths (Majowicz et al., 2010). A wide range of foods had been implicated in the foodborne illness attributable to *Samonella*. 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, quantitative microbiological risk assessment (QMRA) had been widely adopted to evaluate the public health effect of intervention measures for the reduction of foodborne disease burdens. These risk assessments were based on the propagation of a pathogen from the farm via slaughter and retail to the consumer's home. There had been several QMRA studies performed for the *Salmonella*-chicken meat combination covering the whole or part of the poultry food chain in the world, which showed the linkages between the prevalence and density of *Salmonella* contamination in chicken meat and human cases of salmonellosis (Guo et al., 2011; Oscar, 2004; Pouillot et al., 2012; Straver et al., 2007; World Health Organization and Food and Agriculture Organization of the United Nations, 2002). Controls of *Salmonella* in food animals had been adopted along the food chain in the United States (M'ikanatha et al., 2010), Sweden and Denmark (Wegener et al., 2003) and led to low levels of salmonellosis in these countries (World Health Organization, 2007, pp. 1–4).

Additionally these studies indicated that "cross-contamination events such as use of the same cutting board or spreading of pathogens via the kitchen environment, were of greater

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importance than the risk associated with undercooking of poultry meat" (Luber, 2005). A QMRA study conducted in Dakar, Senegal by Pouillot et al., indicated a higher risk of salmonellosis attributed to raw chicken sources and poor hygiene habits in households played important roles (Pouillot et al., 2012).

China is one of the countries in the world with the high burden of salmonellosis. It is estimated that non-typhoid *Salmonella* caused 9.874 million gastroenteritis cases in China annually and 91.5% of these cases were caused by food transmission (Mao, Hu, & Liu, 2011). Poultry is one of the most common animal foods in China and was found that 52.2% of retail chicken carcasses were contaminated with *Salmonella* (Yang et al., 2011). However, the link between *Salmonella* contamination in raw chicken meat sold at retail to salmonellosis due to Chinese household hygiene habits during preparation of chicken meat had not been assessed. The present study aimed to quantify the cross-contamination of *Salmonella* from raw chicken meat in Chinese households and to evaluate the risk of salmonellosis from this exposure route.

2. Materials and methods

2.1. Data collection

The initial level of *Salmonella* contamination in raw chicken meat at retail was based on a surveillance program from 6 provincial markets in China from April 2011 to March 2012 (Zhu et al., 2014). It was estimated that 41.8% (664/1587) of retail chicken carcasses were contaminated by *Salmonella* in China. The *Salmonella* bacterial load in chicken carcasses which were stored (chilled, frozen and freshly slaughtered) and packed (packaged and unpackaged) at retail, as well as types of markets (supermarket and farmers' market) sold was quantified.

To evaluate the potential of *Salmonella* growth in chicken meat from the time of purchase to consumption and the likelihood of cross-contamination occurred during preparation, more than 300 university students were invited to interview their family members for handling practices during chicken meals preparation. 251 questionnaires from families in 22 provinces of China were collected. The interview included questions on time interval from markets to meal preparations, probability of storage at room temperatures (21–25 °C), probability of separating the cutting board and the knife between preparing ready-to-eat foods (RTE foods) and raw chicken meat, as well as preferences of washing cutting boards, cutting knifes and hands (Table 1). **No consent was required in the survey because data were analyzed anonymously and personal identifications (like names and identity) were not noted down.** The RTE foods defined in the present study included traditional RTE foods consumed in households of China, like sausage and raw edible vegetables. Vegetables, like tomato and cucumber which are frequently eaten raw in households of China would be considered as RTE foods if these items were served with chicken meals on the same date. The consumption data of chicken meat and RTE foods at the individual household size were derived from the Chinese Nutrition and Health Survey of 2002.

Table 1
Results of the questionnaire on chicken meats preparation completed by 251 families, China.

Questions to investigate potential bacterial growth		
Did you store chicken meat at room temperature in more than 0.5 h from market to meat preparations	Yes	113
	No	118
If store at room temperature, how long at the average	Min(hour)	0.5
	Most likely(hour)	2.0
	Max(hour)	24.0
Questions on cross-contamination in the kitchen		
Is uncooked or RTE food placed on the same cutting board (or knife) with raw chicken meats	Yes	202[a]
	No	78
If using same board, how is the cutting board (or knife) washed.	Not wash	2
	cold water only	83
	cold water and soap	87
How are the hands washed after cutting raw chicken	Not wash	1[b]
	cold water only	40
	cold water and soap	206

[a] 1 interviewee did not respond to this question.
[b] 5 interviewees did not respond to this question.

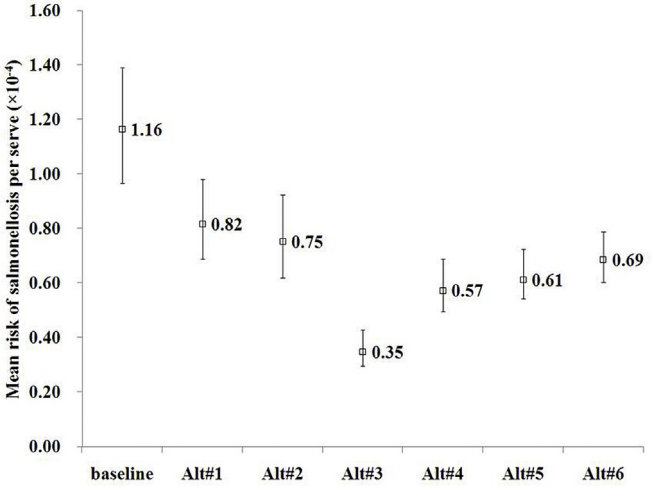

Fig. 1. Model diagram of the quantitative exposure assessment for *Salmonella*-chicken meat combination in China. t_{CH}, transfer rate for *Salmonella* cells from raw chicken meat to hands during the cross-contamination; t_{CB}, raw chicken meat to the board; t_{CK}, raw chicken meat to the knife; t_{HT}, from hands to the faucet; t_{TH}, from the faucet to hands; t_{HS}, from hands to RTE foods es and ready-to-eat foods; t_{BS}, from the board to RTE foods; t_{KS}, from the knife to RTE foods; RTE, ready-to-eat foods.

2.2. Exposure assessment model description

The exposure model quantified the change in the number of *Salmonella* per serving portion from the **initial contamination** in raw chicken meat at retail to right through to consumption. These changes were caused by **bacterial growth** during transportation, home storage, and preparation (Fig. 1). We presumed that sole route of human exposure to *Salmonella* for the Chinese population was via the cross-contamination from raw chicken meat to RTE foods which occurred through the kitchenware (the board and the knife) and cook's hands.

2.2.1. Initial contamination

Using the number of positive samples and total samples from the surveillance program, a discrete empirical distribution was used to describe the variability of *Salmonella* contamination in each purchased chicken carcass. The output of the distribution (0 or 1) would determine whether the contamination was from positive samples or negative samples. Since the *Salmonella* concentrations were right censored (>550 MPN/100 g) in positive samples (Zhu et al., 2014), the present study fitted these concentrations using a lognormal distribution and calculated the mean and the standard deviation (*SD*) using the "fitdistrplus" package in R software (Pouillot & Delignette-Muller, 2010). A uniform distribution from 0 to 1.5 MPN/100 g with the $\log_{10}$ transformation represented ignorance among negative samples (Table 2).

2.2.2. Bacterial growth

The growth of *Salmonella* in chicken meat was quantified from