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Public Health Risk of *Salmonella spp.* in Ready-to-Eat Grilled Chicken from Street Vendors in Khartoum, Sudan: A Quantitative Risk Assessment

D. Iskander[1,2], Adil M. A. Salman[2] and M. I. M. Fangama[1*]

[1]*Food Safety Department, Ministry of Public Health, Doha, Qatar*
[2]*College of Veterinary Medicine, University of Bahri, Khartoum, Sudan*

**Corresponding author*

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A B S T R A C T

Quantitative microbial risk assessment (QMRA) remains underutilized in food safety systems across sub-Saharan Africa. This study aimed to estimate the public health risk associated with *Salmonella spp.* in ready-to-eat grilled chicken sold by vendors in Khartoum State, Sudan. A secondary QMRA model was developed using previously published contamination data. Dose–response modeling was conducted using the exponential model with an infectivity parameter (r = 0.00752). A serving size of 220 g was applied. Monte Carlo simulation (10, 000 iterations) analysis was performed to evaluate uncertainty and key risk drivers. At a contamination level of 1 log10 CFU/g, the estimated illness probability per contaminated serving approached unity. With a contamination prevalence of 16%, the conditional probability of illness was estimated at 0.16. Monte Carlo simulation yielded a median probability of 0.158 (95% uncertainty interval: 0.12–0.21). Ready-to-eat grilled chicken sold by vendors represents a significant and preventable public health risk. Risk reduction strategies should prioritize contamination control and hygiene interventions at vendor level.

Introduction

Foodborne diseases remain a major global public health concern, with an estimated 600 million cases and 420, 000 deaths annually worldwide (1). Non-typhoidal *Salmonella* is among the leading causes of bacterial gastroenteritis globally (2), and poultry products are an important transmission pathway (3, 4, 5). Recent international reports continue to emphasize the importance of integrated surveillance, source attribution, and risk-based control measures for *Salmonella* along the food chain (3, 6, 7, 8).

In high-income settings, integrated control measures such as vaccination, HACCP systems, and cold-chain management have reduced contamination and disease burden (3, 4). In contrast, low- and middle-income countries (LMICs) continue to experience higher contamination levels, particularly in informal retail and street food sectors (9, 10). Structural factors including

poor hygiene, inadequate temperature control, unstable electricity supply, and weak regulatory oversight contribute to increased microbial risk (9, 11, 12). In Sudan, unsafe food handling practices related to poultry consumption have also been documented at household level, further supporting the need for stronger food safety interventions (13).

In Sudan, recent studies have reported *Salmonella spp.* contamination in ready-to-eat grilled chicken sold in urban markets, with levels ranging from 2 to 3.4 log10 CFU/g (14). These findings exceed Codex-aligned microbiological expectations for ready-to-eat foods (14, 15). However, contamination prevalence alone does not quantify public health impact.

QMRA provides a structured framework to translate contamination data into probability of illness and population-level risk (16, 17, 18).

Therefore, the aim of this study was to apply a quantitative microbial risk assessment framework to estimate the probability of illness associated with consumption of ready-to-eat grilled chicken sold by vendors in Khartoum State and to identify the key determinants of risk under local conditions.

Materials and Methods

Materials Studied and Study Area This study used previously published microbiological data on *Salmonella spp.* contamination in ready-to-eat grilled chicken obtained from urban Khartoum State, Sudan (14). No new sampling or laboratory analysis was conducted.

Study Design A secondary QMRA approach was applied to translate contamination data into probability of illness and public health risk.

Hazard Identification The hazard of interest was non-typhoidal *Salmonella spp.* detected in ready-to-eat grilled chicken. The presence of *Salmonella* in ready-to-eat food is considered unacceptable according to established microbiological food safety principles (14, 15).

Exposure Assessment Exposure was estimated using three components: probability of consumption, probability of contamination, and dose per serving. Serving size was fixed at 220 g based on local consumption data (13). Dose was calculated as follows:

Dose (CFU/serving) = Concentration (CFU/g) × Serving size (g)

A contamination level of 1 log10 CFU/g was used, resulting in an estimated ingested dose of 2200 CFU per serving.

Dose–Response Model The exponential dose–response model was applied:

$P = 1 - \exp(-r \times dose)$

Where P is the probability of illness and r = 0.00752 (17).

Risk Characterization Conditional risk and population-level risk were estimated using contamination prevalence and consumption data derived from the source dataset (14, 13). The probability of illness following consumption of a contaminated serving was approximately 1 under the assumed contamination level and model parameters. Considering a contamination prevalence of 16%, the estimated probability of illness per randomly selected serving was approximately 0.16 (16%). The simulation incorporated uncertainty in contamination prevalence and consumption probability. The resulting distribution was summarized using the median and 95% uncertainty interval.

Results and Discussion

Risk Estimates As illustrated in Figure 1, The estimated probability of illness per randomly selected serving was approximately 0.16 (16%), based on the assumed contamination prevalence and dose–response model. Monte Carlo simulation produced a median probability of 0.158 (15.8%), with a 95% uncertainty interval of 0.12–0.21 (12–21%). These estimates reflect uncertainty in the modeled risk under the specified assumptions.

At the population level, incorporation of consumption probability (P(G)) resulted in a median population probability of approximately 7.9×10^{-3}. The Monte Carlo distribution for population-level probability, shown in Figure 1, exhibits greater dispersion relative to conditional probability due to compounding uncertainty in both exposure frequency and contamination prevalence. Nevertheless, the 95% uncertainty interval (approximately 0.0048–0.0116) confirms that projected population burden remains non-negligible even under conservative assumptions.

Figure.1 Monte Carlo distribution (n = 10, 000) of conditional illness probability associated with consumption of ready-to-eat grilled chicken contaminated with *Salmonella spp.*

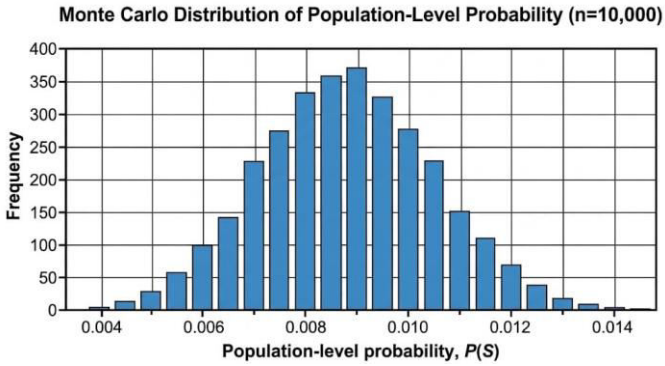
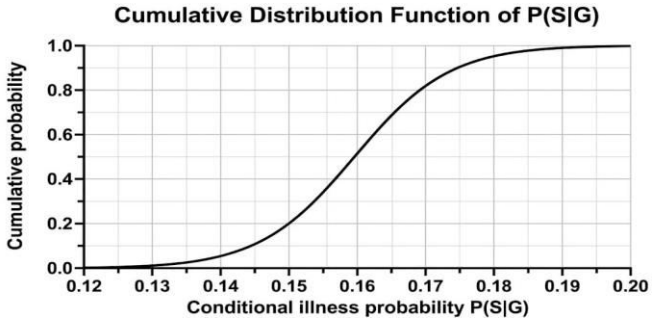


Figure.2 Cumulative distribution function (CDF) of P(S|G), showing the 2.5th–97.5th percentile uncertainty interval.



Cumulative distribution function (CDF) shown in Figure 2 further illustrates the stability of the estimate. The CDF demonstrates that more than 95% of simulated iterations produce conditional illness probabilities exceedingly approximately 0.13, reinforcing the conclusion that risk remains elevated across uncertainty bounds.

This study demonstrates that contamination prevalence is the dominant driver of public health risk in ready-to-eat poultry products. Once exposure exceeds infectious dose thresholds, dose–response variability has limited additional influence. This finding is consistent with established QMRA frameworks and poultry risk models (16, 17, 18, 19).

The results are also supported by recent international evidence emphasizing the importance of integrated surveillance, source attribution, and preventive food safety systems for controlling *Salmonella* (3, 6, 7, 20, 8, 21). In LMIC settings, structural factors such as poor hygiene, cross-contamination, temperature abuse, and infrastructure limitations remain important contributors to foodborne risk (9, 11, 12, 5, 22, 23).

The present study adds quantitative interpretation to microbiological findings from Sudan and addresses an important gap in African food safety research, where many investigations remain limited to prevalence reporting without formal risk estimation. These results support the use of risk-based inspection, vendor hygiene improvement, and One Health-oriented food safety planning.

In conclusion, Ready-to-eat grilled chicken sold by vendors in Khartoum represents a measurable public health risk due to *Salmonella spp.* contamination. Risk reduction should focus on contamination prevention, vendor hygiene, and risk-based inspection. Integration of QMRA into food safety systems is recommended to support evidence-based decision-making.

Author Contributions

D. Iskander: Investigation, formal analysis, writing—original draft. Adil M. A. Salman: Validation, methodology, writing—reviewing. M. I. M. Fangama:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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