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Salmonella sp. Contamination in Broiler Chicken Meat at Gorontalo Central Market: A Quantitative Microbial Risk Assessment Approach

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ABSTRACT

Gorontalo Central Market is the largest marketplace for broiler chicken meat sales in Gorontalo. Contamination of broiler chicken meat may occur during storage or at the point of sale (market) and can proliferate if the cooking process is inadequate. Laboratory test results revealed the presence of Salmonella sp. in broiler chicken meat at levels exceeding the maximum permissible limits for microbial contamination in food. This study aimed to assess the quantitative health risk posed by Salmonella sp. contamination in broiler chicken meat sold at Gorontalo Central Market. This was a descriptive observational study employing a Quantitative Microbial Risk Assessment (QMRA) approach. The study samples consisted of seven broiler chicken meat samples collected from seven meat stalls at Gorontalo Central Market and 85 consumers who purchased and consumed broiler chicken meat sold at the market. Respondents were selected using an accidental sampling technique. The results showed that broiler chicken meat sold at Gorontalo Central Market contained Salmonella sp. ranging from 1.4e3 to 3.0e5 CFU/g. Health risk assessment indicated that, among the seven meat stalls evaluated, five were classified as high-risk (Pinf/day/meal = 3.83–4.85), while two stalls were classified as no risk (Pinf/day/meal = 0). It is recommended that vendors improve sanitation practices at their selling locations and maintain proper personal hygiene to reduce the potential for pathogenic microbial contamination.

INTRODUCTION

Salmonella sp. bacteria were first discovered by Theobald Smith, an American microbiologist, in 1885 in pigs (1). These bacteria are characterized as straight rod-shaped, motile, Gram-negative, and facultative anaerobic microorganisms. They commonly inhabit the digestive systems of almost all homoeothermic (warm-blooded) and poikilothermic (cold-blooded) vertebrates and invertebrates. Salmonella sp. is also a major cause of food poisoning and foodborne diseases (2). Foodborne diseases are currently among the leading causes of mortality in both developed and developing countries. According to the World Health Organization (3), approximately 600 million people worldwide (nearly 1 in 10 individuals) become ill each year after consuming food contaminated with pathogenic bacteria, and about 420,000 people die annually as a result. One of the most common foodborne diseases is salmonellosis.

Salmonellosis is the second most frequently reported gastrointestinal infection in the EU/EEA and is a significant cause of foodborne outbreaks. In 2021, a total of 60,494 laboratory-confirmed cases of salmonellosis were reported, of which 73 were fatal. The notification rate of salmonellosis was 16.6 cases per 100,000 population (4). In Indonesia, the incidence of salmonellosis caused by Salmonella sp. reaches 33.1 cases per 1,000 population, occurring across all age groups and in nearly all major cities. Broiler chicken meat is one of the food products most susceptible to contamination by Salmonella sp., primarily due to its high moisture, fat, and protein content, which provide favorable conditions for bacterial growth (5).

Broiler chicken meat is one of the livestock products with high economic and nutritional value. Broiler chickens are a breed specifically raised for meat production. Broiler chicken meat contains protein and other essential nutrients, including fats, carbohydrates, vitamins, minerals, and water, all of which are beneficial to human health (6). Therefore, broiler chicken meat is one of the most popular sources of animal protein among the Indonesian population. According to data from Statistics Indonesia (7), broiler chicken meat production in Indonesia reached 3.2 million tons in 2021 and increased to 3.8 million tons in 2022, representing a growth of 18.75% from 2021 to 2022. Similarly, broiler chicken meat production in Gorontalo Province showed a continuous increase from 2020 to 2022. In 2020, production was approximately 4,550 tons, rising to 6,134 tons in 2021, and further increasing to 6,200 tons in 2022. The increasing production of broiler chicken meat may lead to accumulation during storage and distribution, thereby increasing the risk of bacterial contamination.

Contamination of broiler chicken meat can occur during storage or at points of sale, such as traditional markets, and bacterial growth may increase if the meat is inadequately cooked. Meat provides an ideal medium for microbial growth due to its high moisture, fat, and protein content, making it highly susceptible to spoilage caused by bacterial contamination (8). The Gorontalo Central Market is the largest broiler chicken meat trading center in Gorontalo City. However, traditional markets are often associated with poor sanitation and unpleasant odors resulting from scattered waste and inadequate waste management practices (9).

Based on preliminary observations, the sanitation conditions at Gorontalo Central Market were categorized as inadequate. Waste was observed scattered along market aisles and accumulated beside waste disposal bins, making the market appear dirty and producing unpleasant odors. In terms of personal hygiene, broiler chicken meat vendors were found not to use gloves, aprons, head coverings, or masks, and they washed their hands without using soap. Preliminary laboratory testing of two broiler chicken meat samples collected from Gorontalo Central Market revealed that both samples were positive for Salmonella sp. contamination, with colony counts of 9.2×10^2 CFU/g and 1.0×10^2 CFU/g, respectively. These results indicate that the contamination levels exceeded the maximum permissible limit for Salmonella sp. in food established by the National Standardization Agency of Indonesia (SNI 7388:2009) (10), which requires Salmonella to be absent in 25 g of food sample (negative/25 g). These preliminary laboratory findings highlight the importance of conducting a quantitative microbial risk assessment, particularly to estimate the magnitude of potential health risks associated with the consumption of broiler chicken meat sold at Gorontalo Central Market.

Quantitative Microbial Risk Assessment (QMRA) is a structured process used to identify and characterize risks associated with biological hazards in food. QMRA is widely applied in food safety risk assessment because it provides a logical and systematic approach for evaluating the risks arising from the consumption of specific hazards present in food products. This approach has evolved into a rapidly developing method that systematically integrates available information on exposure and dose–response relationships to estimate the burden of disease resulting from exposure to pathogenic microorganisms (11). Based on the issues described above, further research is needed to conduct a Quantitative Microbial Risk Assessment (QMRA) of Salmonella sp. contamination in broiler chicken meat sold at Gorontalo Central Market. This assessment is expected to provide scientific evidence regarding the potential health risks associated with the consumption of contaminated broiler chicken meat and to support the development of appropriate food safety interventions.

RESEARCH METHODS

The study was conducted at the meat section of Gorontalo Central Market, and sample analyses were carried out at the Public Health Laboratory of Universitas Negeri Gorontalo. The research was conducted from January to February 2025. This study employed a descriptive observational design using the Microbial Risk Assessment (MRA) approach to estimate the health risks associated with exposure to Salmonella sp. through the consumption of broiler chicken meat. The study population consisted of all broiler chicken meat sold in the meat section of Gorontalo Central Market and all consumers who consumed broiler chicken meat at least once per month. The object samples consisted of seven broiler chicken meat samples collected from vendors at Gorontalo Central Market, representing each row of the meat section. The subject samples were consumers selected using an accidental sampling technique. The sample size for an unknown population was determined using the Cochran formula (12). Based on a salmonellosis prevalence rate of 5.82%, a total of 85 respondents were included in the study. Data collection involved the detection and enumeration of Salmonella sp. on Salmonella Shigella Agar (SSA) using the pour plate method, as well as the administration of a structured questionnaire to obtain information on exposure characteristics among consumers.

The data were analyzed using the Quantitative Microbial Risk Assessment (QMRA) approach (13). The analytical procedure consisted of the following steps.

a) Hazard Identification: The initial stage of environmental health risk analysis aimed at identifying potential hazards and collecting information on the disease history of consumers who consume broiler chicken meat sold at Gorontalo Central Market.
b) Dose–Response Assessment: The process of estimating the daily probability of infection ($P_{inf/day}$) caused by Salmonella sp. present in broiler chicken meat that is ingested by consumers.

$$P_{inf/day} = 1 - (1 - \frac{d}{\beta})^{-\alpha} \text{..... (Formula 1)}$$

Where,

$P_{inf/day}$ = daily probability of infection
d = dose (CFU)
α = infectivity model parameter for Salmonella sp. (0,23)
β = infectivity model parameter for Salmonella sp. (0.910)

c) Exposure Assessment: The process of estimating the annual probability of infection ($P_{inf,annual}$) and the annual probability of illness (P_{ill}) resulting from exposure to Salmonella sp. through the consumption of broiler chicken meat.

$$P_{inf.annual} = 1 - \left(1 - P_{inf/day}\right)^{n} \text{..... (Formula 2)}$$

Where,

$P_{inf.annual}$ = annual probability of infection, ranging from 0 to 1, where 0 indicates no risk of infection and 1 indicates certainty of infection.
n = number of exposure events per year.

$$P_{ill} = P_{inf/.annual}\ x\ P_{ill/inf} \text{..... (Formula 3)}$$

Where,

P_{ill} = annual probability of illness resulting from infection.
$P_{ill/inf}$ (Salmonella) = 0,19 (14)

d) Risk Characterization: The process of categorizing the annual probability of illness (P_{ill}) according to the magnitude of risk.

1) Low risk : $\frac{P_{inf/day}}{P_{ill}} < 10^{-6}$
2) Moderate risk : $\frac{P_{inf/day}}{P_{ill}} = 10^{-6}$
3) High risk : $\frac{P_{inf/day}}{P_{ill}} > 10^{-6}$

RESULTS

This study was conducted at Gorontalo Central Market, and sample analyses were carried out at the Public Health Laboratory of Universitas Negeri Gorontalo, from January to February 2025. Each sample represented a different meat stall section. The results of Salmonella sp. testing in broiler chicken meat sold at Gorontalo Central Market are presented in Table 1.

Table 1. Salmonella sp. Contamination in Broiler Chicken Meat Sold at Gorontalo Central Market

Sampling Location	Salmonella sp. Count (CFU/g)
Stall 1	1.4e3
Stall 2	6.5e3
Stall 3	0
Stall 4	0
Stall 5	1.7e4
Stall 6	5.0e4
Stall 7	3.0e5

Data Source: Laboratory analysis results, 2025

Table 1 shows that five samples tested positive for Salmonella sp., while the remaining two samples were negative. According to the Indonesian National Standard (SNI) 7388:2009 concerning the maximum limits of microbial contamination in food, fresh chicken meat must be free from Salmonella sp., meaning that the bacterium should not be detected in a 25-g sample (negative/25 g). Therefore, the positive samples exceeded the microbiological safety standard for fresh poultry meat.

Next, the steps involved in the Quantitative Microbial Risk Assessment (QMRA) were carried out. The assessment consisted of four stages: hazard identification, dose–response assessment, exposure assessment, and risk characterization.

Hazard identification

Hazard identification is the first step in QMRA and is used to identify specific risk agents that have the potential to cause adverse health effects when individuals are exposed.

Table 2. Hazard identification

Identification	Description
Specific risk agent	Salmonella sp.
Potential environmental medium	Broiler chicken meat
Risk concentration	1.4e3 to 3.0e5 CFU/g
Potential health hazards	Based on field observations, the sanitation conditions of the meat section at Gorontalo Central Market were categorized as inadequate, as indicated by scattered waste, open and overflowing garbage bins, and poor water sanitation, resulting in wastewater from chicken slaughtering coming into contact with meat products being sold. In addition, the personal hygiene practices of meat vendors were found to be insufficient, as most vendors did not use gloves, aprons, head coverings, or masks and washed their hands without soap. Poor sanitation and hygiene conditions can increase the risk of microbiological contamination of meat, including contamination by Salmonella sp. Consumption of food contaminated with this bacterium may cause gastrointestinal disorders such as diarrhea, nausea, vomiting, abdominal pain, fever, and headaches due to the bacterium's ability to invade intestinal epithelial cells.

Data Source: Authors' calculations, 2025

Dose–response assessment, exposure assessment, and risk characterization

Dose–response assessment describes the relationship between the pathogen dose and the exposed individual, which may result in the occurrence of daily infection. Exposure assessment is used to estimate the annual probability of infection in a population and individuals following exposure to a pathogen. Exposure estimates range from 0 to 1, where 0 indicates safety (no risk of infection) and 1 indicates certainty of infection (unsafe). Risk characterization is performed to characterize the risk of infection associated with the consumption of broiler chicken meat contaminated with Salmonella sp.

Table 3. Dose–response assessment

Sampling Location	d (CFU/g)	$P_{inf/day}$	$P_{inf.annual}$	P_{ill}	$\frac{P_{inf/day}}{P_{ill}}$	Risk Characterization
Stall 1	1.4e3	0,72	1	0,19	3,83	High risk
Stall 2	6.5e3	0,80	1	0,19	4,26	High risk
Stall 3	0	0	0	0	0	No risk
Stall 4	0	0	0	0	0	No risk
Stall 5	1.7e4	0,84	1	0,19	4,46	High risk
Stall 6	5.0e4	0,88	1	0,19	4,63	High risk
Stall 7	3.0e5	0,92	1	0,19	4,85	High risk

Data Source: Authors' calculations, 2025

Table 3 shows that the probability of daily infection resulting from exposure to Salmonella sp. ranged from 0.72 to 0.92. The annual probability of infection among consumers was predominantly classified as being at risk of infection. The annual probability of illness resulting from infection among broiler chicken meat consumers was estimated at 19%. Furthermore, risk characterization indicated that most sampling locations fell within the high-risk category for adverse health outcomes associated with Salmonella sp. infection.

DISCUSSION

In general, this study was conducted to determine the quantitative risk posed by Salmonella sp. contamination in broiler chicken meat sold at Gorontalo Central Market and its potential impact on public health. Based on field observations, the water used by vendors to moisten chicken meat during the selling process appeared to be mixed with fluids from other chicken meat products. This condition may increase the risk of cross-contamination among the products being sold. Water sanitation and equipment sanitation are closely associated with bacterial contamination, including the availability of clean water for all activities, regular replacement of contaminated rinse water, and the provision of adequate equipment. From the personal hygiene perspective, most vendors were observed not wearing gloves, aprons, head coverings, or masks, and they washed their hands without using soap while handling meat. Vendor hygiene practices play an important role in determining the quality and safety of food products. Poor hygiene practices can lead to microbiological contamination of food because food handlers are a primary and potential source of food contamination and the transmission of microorganisms (15).

Salmonella sp. is a gram-negative bacterium that can cause various diseases in humans and animals. It is rod-shaped, Gram-negative, facultatively anaerobic, non-spore-forming, motile, and measures approximately 1–3.5 μm × 0.5–0.8 μm (16). This bacterium is part of the normal flora of the body, particularly in the digestive tract; however, it can become pathogenic when present in excessive numbers (17). One of the major health impacts associated with Salmonella sp. is foodborne disease, commonly manifested as diarrhea, abdominal pain, vomiting, and fever, a condition known as salmonellosis (18). Two major disease syndromes caused by Salmonella sp. are salmonellosis and enteric fever. Salmonellosis is primarily caused by Salmonella choleraesuis and Salmonella enteritidis, whereas enteric fever (typhoid fever) is caused by Salmonella typhi and Salmonella paratyphi. The incubation period of salmonellosis ranges from 5 to 72 hours, most commonly 12–48 hours, and is characterized by symptoms such as abdominal pain, diarrhea, fever, vomiting, dehydration, headache, and weakness (19).

Consumption of broiler chicken meat contaminated with pathogenic microorganisms may lead to adverse health effects. The clinical manifestations depend on the source of infection, with diarrhea being the most commonly reported symptom (20), followed by vomiting, nausea, abdominal pain, fever, and headache. Acute diarrhea is often associated with a single source of contamination, such as bacterial infection (21). Salmonella sp. present in contaminated food and beverages can enter the intestinal tract and invade intestinal epithelial cells, leading to infection and gastrointestinal illness (22).

The presence of bacteria in food products is influenced not only by poor sanitation conditions but also by the use of certain preservatives. One substance that is frequently misused as a food preservative is borax, due to its ability to inhibit the growth of fungi and bacteria. Borax is a chemical compound that was originally widely used in non-food industries. However, with the expansion of the food industry, borax has often been improperly used as a preservative in perishable food products (23). The addition of borax to food can improve texture, increase elasticity, extend shelf life, and inhibit the growth of fungi and bacteria (24). Therefore, the use of borax may influence the presence and growth of bacteria in food products, even though its use in food is prohibited because of its potential adverse effects on human health.

The most important variable influencing the level of health infection risk is the microbial dose consumed by an individual. The greater the number of microorganisms entering the body, the higher the probability of developing an infection. When Salmonella typhi infects humans in large numbers and the intestinal mucosal IgA humoral immune response is inadequate, the bacteria can reach the small intestine. They initially invade epithelial cells, particularly M cells, and subsequently penetrate the lamina propria. Within the lamina propria, the bacteria multiply and are phagocytosed by scavenger cells, primarily macrophages. Salmonella typhi can survive and proliferate within macrophages and are subsequently transported to the distal intestine, reaching the Peyer's patches and mesenteric lymph nodes. Through the thoracic duct, the bacteria enter the bloodstream, resulting in bacteremia (often asymptomatic) and potentially leading to typhoid fever (25). Consumption of food contaminated with Salmonella sp. may cause typhoid fever when the bacteria are present in sufficient quantities and exceed safe limits. In addition, Salmonella sp. contamination can also lead to food poisoning due to the toxins produced by the bacteria (22).

Previous research demonstrated that all 11 wells tested in the laboratory were classified as having a high risk of causing diarrhea among consumers, as indicated by Pinf/day or Pill values greater than 10^{-6}. Furthermore, a strong association was found between groundwater quality and the risk level of diarrheal disease at the study site, indicating that poorer groundwater quality was associated with a higher risk of adverse health outcomes in the community (26). Another study reported that Salmonella sp. primarily affects the digestive system. Contamination of food products by this bacterium can lead to various illnesses, including typhoid fever, which is characterized by symptoms such as high fever, constipation, abdominal pain, dizziness, skin irritation, the appearance of reddish skin spots, and, in severe cases, decreased consciousness. Infections caused by Salmonella sp. are collectively known as salmonellosis and are classified as zoonotic diseases that can be transmitted from animals to humans through the consumption of contaminated food products (1).

CONCLUSION

This study concluded that Salmonella sp. contamination was detected in five of the seven broiler chicken meat stalls at Gorontalo Central Market, with bacterial concentrations ranging from 1.4e3 to 3.0e5 CFU/g, while no contamination was detected in Stalls 3 and 4. Quantitative Microbial Risk Assessment (QMRA) indicated that the probability of daily infection ($P_{inf/day}$) among consumers ranged from 0.72 to 0.92 in contaminated stalls, demonstrating a substantial risk of infection following consumption. The annual probability of infection ($P_{inf.annual}$) and the annual probability of illness (P_{ill}) further confirmed the potential public health risk, with contaminated stalls showing a 19% probability of illness per year. Risk characterization classified Stalls 1, 2, 5, 6, and 7 as high-risk locations for Salmonella sp. infection, whereas Stalls 3 and 4 were categorized as having no risk. These findings indicate that broiler chicken meat sold in several stalls at Gorontalo Central Market poses a significant microbiological health risk to consumers.

SUGGESTION

For broiler chicken meat vendors, it is recommended that they maintain proper sanitation and hygiene practices in their selling areas, as well as good personal hygiene, to prevent contamination of the meat with harmful microorganisms before it is sold. For future researchers who intend to conduct a Quantitative Microbial Risk Assessment (QMRA) in the meat stalls of Gorontalo Central Market, it is recommended to identify specific microbial species and examine other types of meat products in order to expand the available references regarding potential hazards that may be present in food products. For market management, it is recommended to conduct routine monitoring of sanitation conditions in stalls and facilities selling various food products within Gorontalo Central Market to ensure food safety and reduce the risk of microbial contamination.

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