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Review Article

# IMPACT OF FOOD HANDLING PRACTICES ON THE PREVENTION AND CONTROL OF *SALMONELLA*

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## ABSTRACT

Salmonella remains one of the most significant foodborne pathogens globally, responsible for substantial morbidity, mortality, and economic burden. Inadequate food handling practices across the food supply chain spanning production, processing, distribution, retail, and household levels significantly contribute to Salmonella contamination and transmission. This study examines the impact of critical food handling practices, including personal hygiene, cross-contamination prevention, temperature control, sanitation, and food storage, on the prevention and control of Salmonella infections. A comprehensive review of recent literature identifies high-risk behaviors, gaps in food safety compliance, and effective intervention strategies. Findings highlight that proper hand hygiene, effective heat treatment, prevention of cross-contamination, and adherence to HACCP-based food safety systems considerably reduce Salmonella prevalence. The study emphasizes the need for continuous education, stricter policy enforcement, and integrated risk-management frameworks to strengthen food safety practices. This paper provides actionable recommendations for food handlers, policymakers, and public health authorities aimed at minimizing Salmonella outbreaks and enhancing overall food safety.

**Keywords:** Salmonella, Food handling practices**,** Food safety, Cross-contamination, Temperature control, HACCP.

## INTRODUCTION

Foodborne diseases remain a major global public health concern, with Salmonella ranking among the leading causes of bacterial gastrointestinal infections. According to global health surveillance reports, millions of Salmonella cases occur annually, frequently linked to contaminated foods of animal origin, raw produce, and inadequately handled ready-to-eat products. The persistence of Salmonella in diverse environments, combined with its ability to survive under suboptimal storage and processing conditions, makes it a critical challenge across the food supply chain. Food handling practices play a central role in either mitigating or facilitating the transmission of Salmonella. Key factors such as inadequate cooking, improper cooling, poor personal hygiene, unclean food contact surfaces, and cross-contamination between raw and ready-to-eat foods significantly elevate the risk of infection. Food handlers, whether in industrial settings, food service establishments, or domestic kitchens, serve as important links in preventing contamination during food preparation and storage. As a result, understanding how specific food handling behaviors contribute to Salmonella control is essential for improving safety outcomes. Given the complexity of food production systems, modern approaches emphasize the need for scientifically grounded and preventive frameworks such as Hazard Analysis and Critical Control Points (HACCP). When coupled with effective sanitation programs, temperature monitoring, and continuous education, these practices substantially reduce contamination and outbreak occurrences. However, gaps remain, particularly in low- and middle-income regions where limited training,

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inadequate infrastructure, and weak regulatory enforcement persist.

This paper investigates the impact of food handling practices on the prevention and control of Salmonella contamination. By synthesizing current evidence and identifying effective strategies, the study aims to guide policymakers, food industry stakeholders, and public health professionals in strengthening food safety systems and reducing the burden of Salmonella-related illnesses. Salmonella remains a leading cause of foodborne illness worldwide, causing large numbers of non-typhoidal salmonellosis cases linked to foods of animal origin, fresh produce and ready-to-eat products; burden estimates and recent reviews emphasize ongoing public-health impacts and the need for preventive controls. Salmonella contamination can occur at multiple points: on farms (feed, animals, irrigation water), during processing (equipment, surfaces), in retail (cross-contact) and in households (improper handling); identifying where contamination is introduced is essential for targeted interventions. Numerous studies link poor hand hygiene, lack of handwashing facilities and inadequate health screening of food workers to transmission of Salmonella; interventions that strengthen handwashing behavior and provide infrastructure reduce contamination risk. Cross-contamination from raw to ready-to-eat foods via utensils, cutting boards, and surfaces is a well-documented pathway for Salmonella spread; cleaning and sanitizing regimes plus workflow separation (raw vs. cooked areas) are repeatedly recommended to limit recontamination.

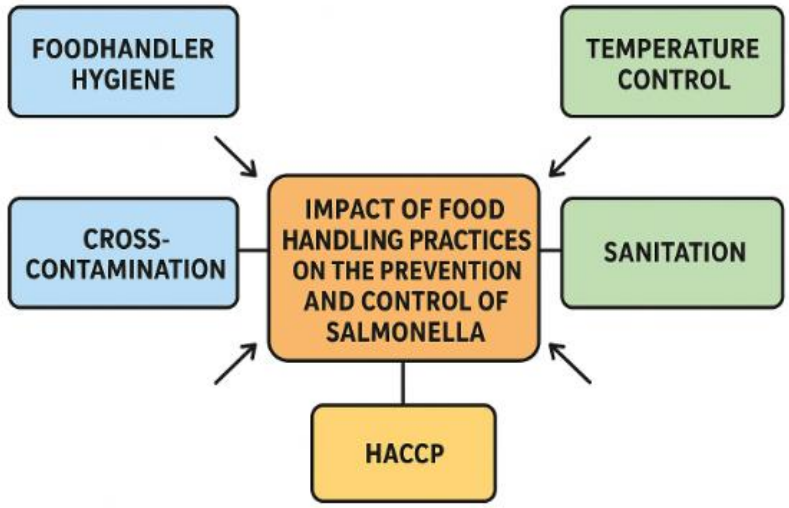


**Figure 1.** Critical Control Elements in Preventing Salmonella Through Food Handling.

Thermal inactivation remains a key control: validated cooking temperatures and times (e.g., achieving sufficient internal temperatures for poultry and other high-risk foods) are necessary to achieve multi-log reductions in Salmonella; predictive models and experimental studies inform critical limits. Effective sanitation programs, hygienic equipment design, and routine environmental monitoring in processing plants reduce Salmonella prevalence on contact surfaces and products; integrated sanitation plus verification strengthens prevention. Implementation of HACCP-based plans, combined with supplier control, prerequisite programs and regulatory enforcement, has been associated with reductions in foodborne outbreaks and improved product safety when properly implemented and verified. Guidance from regulatory agencies and outcome studies support HACCP as central to Salmonella control.

At the household and consumer level, correct storage, avoidance of cross-contact, thorough cooking, and clear food-safety education materially lower infection risk; public education campaigns and labeling can influence behavior but must be sustained to be effective. Surveillance reviews note the intersection of Salmonella prevalence with antimicrobial resistance trends, which complicates clinical management and underscores the need for prevention upstream in the food chain to limit spread of resistant strains. Novel or adjunct interventions such as improved pre-harvest controls, high-pressure processing, antimicrobial rinses, validated cooking protocols, and risk-based development of critical limits show promise in lowering Salmonella risk when integrated into a farm-to-fork strategy. The literature consistently shows that combined interventions (hygiene training, temperature control, cross-contamination prevention, HACCP implementation and sanitation) yield the best reductions in Salmonella risk, yet gaps remain in low-resource settings, in behavioral adherence among food handlers, and in standardized validation of critical limits for diverse food matrices. Continued field studies and harmonized surveillance are recommended.

## MATERIALS AND METHODS

This study followed a structured review methodology to evaluate the role of food handling practices in the prevention and control of Salmonella contamination across the food supply chain. A systematic search of peer-reviewed articles, surveillance reports and regulatory guidelines was conducted. Databases including Scopus, PubMed, Web of Science and Google Scholar were screened using keywords such as Salmonella, food handling practices, cross-contamination, HACCP, temperature control, sanitation, and food safety management. Publications between 2005 and 2025 were included to ensure a comprehensive and current representation of research findings. Inclusion criteria covered studies that assessed Salmonella prevalence, contamination routes, food handler behavior, environmental hygiene, consumer practices, and intervention outcomes. Exclusion criteria eliminated papers lacking empirical data, studies not focused on foodborne Salmonella, and articles without accessible full text. Data extraction focused on identifying determinants of contamination, effectiveness of preventive measures such as hygiene training and HACCP implementation, temperature control outcomes, and cross-contamination pathways. Qualitative thematic synthesis was used to group findings under key thematic areas: food handler hygiene, cross-contamination, thermal inactivation, sanitation programs, consumer practices, and system-level interventions. This approach allowed integration of diverse study types, including laboratory trials, observational studies, outbreak reports, and intervention assessments.

## RESULTS AND DISCUSSION

The reviewed studies consistently showed that improper food handling practices remain a major contributor to Salmonella contamination in both commercial and household settings. Evidence demonstrated that food handler hygiene, including correct handwashing, glove use and illness reporting, significantly reduces the risk of pathogen transfer. Observational studies revealed persistent gaps in compliance, particularly in small-scale food service establishments where training and monitoring are limited. These findings highlight the need for continuous education and behavioral reinforcement. Cross-contamination emerged as a central and recurrent factor. Studies reported that utensils, cutting boards, countertops and improperly cleaned equipment often act as vectors for transferring Salmonella from raw to ready-to-eat foods. Surfaces containing organic matter were particularly problematic, underscoring the importance of surface sanitation and workflow separation. Facilities with structured cleaning procedures and environmental monitoring programs showed notably lower contamination rates.

Temperature control was identified as a critical control point. Thermal inactivation research confirmed that achieving recommended internal cooking temperatures is effective in eliminating Salmonella. However, consumer-level studies indicated that many households fail to use thermometers or rely on visual cues, resulting in undercooked high-risk foods. Similar problems were identified in food service settings with high staff turnover. Cooling and storage temperatures were also frequently inadequate, allowing bacterial growth.Sanitation programs and environmental hygiene proved essential for reducing contamination in processing and retail environments. Hygienic equipment design, validated cleaning protocols, and routine microbiological swabbing substantially reduced environmental reservoirs of Salmonella. Facilities lacking standardized sanitation procedures exhibited frequent recontamination, demonstrating the importance of continuous monitoring.

System-level interventions such as HACCP, Good Manufacturing Practices and regulatory oversight were found to be highly effective when properly implemented. Studies showed that industries with mature HACCP programs achieved lower Salmonella prevalence in meat, poultry and produce products compared to facilities with partial or noncompliant systems. However, implementation challenges persist in low-resource regions due to inadequate training, infrastructure limitations and inconsistent regulatory enforcement.

**Table 1.** Key Food Handling Practices and Their Impact on Salmonella Prevention and Control.

| Food Handling Practice | Description | Impact on Salmonella Control | Supporting Evidence |
|---|---|---|---|
| **Hand Hygiene** | Washing hands with soap before/after food handling | Reduces transfer of *Salmonella* from surfaces and raw meat to ready-to-eat food | Ehuwa & Ogundele (2021); Mkangara et al. (2023) |
| **Cross-Contamination Prevention** | Use of separate cutting boards/knives for raw and cooked foods | Lowers risk of *Salmonella* spread through equipment and surfaces | Carrasco et al. (2012); Iulietto et al. (2024) |
| **Proper Cooking Temperatures** | Heating foods to internal safe temperatures (≥74°C for poultry) | Kills *Salmonella* effectively, preventing foodborne illness | Juneja & Marmer (2007); Rosli & Nor (2025) |
| **Cold Chain Maintenance** | Refrigeration at ≤4°C; freezing at ≤−18°C | Slows multiplication of *Salmonella* in raw products | Mahyudin et al. (2023) |

| | | | |
|---|---|---|---|
| **Cleaning & Sanitization** | Using detergents and food-grade sanitizers on surfaces and equipment | Reduces environmental *Salmonella* load | Rufai et al. (2023) |
| **Personal Protective Equipment (PPE)** | Use of gloves, masks, hairnets | Minimizes contamination from handlers | AlZaabi et al. (2017) |
| **Safe Food Storage Practices** | Proper packaging, FIFO method, avoidance of temperature abuse | Prevents bacterial growth and cross-contamination | Mkangara et al. (2023) |
| **HACCP Implementation** | Identification of hazards and control points in food preparation | Ensures systematic *Salmonella* risk reduction | Wierup (2023); Majd (2013) |
| **Thermal Processing Validation** | Monitoring D- and z-values in food heat treatments | Ensures scientifically validated heat inactivation of *Salmonella* | Murphy et al. (2004); Cano et al. (2022) |

Consumer behavior studies indicated that improper handling, inadequate storage temperatures, raw food contact and lack of hygiene knowledge continue to drive domestic-level salmonellosis. Awareness campaigns were shown to improve behaviors temporarily, but long-term adherence requires repeated, culturally adapted messaging. Overall, the results demonstrate that Salmonella control is most effective when multiple interventions are combined, including hygiene training, thermal processing validation, strict cross-contamination prevention, structured sanitation, and HACCP-based management. The findings reinforce the principle that prevention requires a holistic, multi-hurdle approach across the entire food chain.

## CONCLUSION

This review demonstrates that food handling practices play a decisive role in preventing and controlling Salmonella contamination across the food supply chain. Personal hygiene, prevention of cross-contamination, temperature control, validated sanitation protocols, and structured food safety systems were the most influential factors reducing bacterial presence in foods. Despite available guidelines and technologies, gaps remain in compliance, especially in small food establishments and domestic settings. Strengthening education, monitoring and regulatory enforcement is essential for closing these gaps. A coordinated farm-to-fork strategy that integrates behavioral, technological and regulatory interventions is necessary to effectively minimize Salmonella-related illnesses and improve global food safety outcomes. Future research should focus on developing improved behavioral training models for food handlers using digital tools such as mobile applications, e-learning modules and real-time feedback systems. More field studies are needed to validate emerging technologies such as rapid environmental monitoring, smart sensors for temperature tracking, and novel antimicrobial surface treatments. Research should also address implementation challenges in low- and middle-income countries, including cost-effective training programs and scalable sanitation systems. Further studies should expand surveillance of antimicrobial-resistant Salmonella strains to strengthen One Health monitoring frameworks. Long-term investigations into consumer behavior, particularly in different cultural contexts, are required to design more effective and sustained public education strategies. Integrating these future directions will support the development of robust, evidence-based interventions for reducing Salmonella transmission through improved food handling practices

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## CONFLICT OF INTERESTS

The authors declare no conflict of interest

## ETHICS APPROVAL

Not applicable

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## AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

## DATA AVAILABILITY

Data will be available on request

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