Preharvest and Postharvest Food Safety

Contemporary Issues and Future Directions
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Preharvest and Postharvest Food Safety

Contemporary Issues and Future Directions

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Foreword by the Honorable Elsa A. Murano
Afterword by Neville P. Clarke
The concept for this book originated in a meeting of the Center for Food Safety, Institute of Food Science and Engineering (IFSE), Texas A&M University, College Station, Texas. We began this book by looking at many of the U.S. government’s high priorities in food safety and matching these priorities to Center for Food Safety scientists engaged in those areas of research. Later, other government and academic scientists were added to broaden the scope of the book. This book is the result of collaboration of researchers engaged in the area of food safety and sponsored by IFSE.

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Contents

Contributors xi
Foreword xix
The Honorable Elsa A. Murano xxiii
Preface xxiii

Part I: Pathogen/Host Interactions 1

1 Foodborne Salmonella Infections 3
Andreas J. Bäumler

2 Pathogenic Escherichia coli 13
Suryakant D. Waghela

3 Foodborne Enterohemorrhagic Escherichia coli Infections 27
Vernon L. Tesh

4 Bacterial Hazards in Fresh and Fresh-Cut Produce: Sources and Control 43
Alejandro Castillo and M. Ofelia Rodríguez-García

5 Campylobacter Species and Fresh Produce: Outbreaks, Incidence, and Biology 59
Robert E. Mandrell and Maria T. Brandl

6 Campylobacter and Campylobacteriosis: What We Wish We Knew 73
Richard L. Ziprin

7 Global Analysis of the Mycobacterium avium subsp. paratuberculosis Genome and Model Systems Exploring Host–Agent Interactions 87
Thomas A. Ficht, L. Garry Adams, Sangeeta Khare, Brian O’Shea, and Allison C. Rice-Ficht

8 Viruses in Food 101
Sagar M. Goyal

Part II: Ecology, Distribution, and Spread of Foodborne Hazards 119

9 Microbial Ecology: Poultry Foodborne Pathogen Distribution 121
J. Allen Byrd II
10 Microbial Ecological Principles Underlying Preharvest Intervention Strategies
Todd R. Callaway, Robin C. Anderson, Thomas S. Edrington, Kenneth M. Bischoff, Kenneth J. Genovese, Toni L. Poole, and David J. Nisbet

11 Limiting Avian Gastrointestinal Tract Salmonella Colonization by Cecal Anaerobic Bacteria, and a Potential Role for Methanogens
Steven C. Ricke, Casendra L. Woodward, Young Min Kwon, Leon F. Kubena, and David J. Nisbet

12 Distribution and Spread of Enteric Pathogens in Swine: Outlook for the Future
Roger B. Harvey and H. Morgan Scott

13 Environmental Reservoirs and Transmission of Foodborne Pathogens
Scot E. Dowd, Jeanette A. Thurston-Enriquez, and Mindy Brashears

14 Do Animal Transmissible Spongiform Encephalopathies Pose a Risk for Human Health?
Mary Jo Schmerr

Part III: Antimicrobial Resistance

15 Antimicrobial Susceptibility Testing
Patrick F. McDermott, David G. White, Shaohua Zhao, Shabbir Simjee, and Robert D. Walker

16 Antimicrobial Resistance in Food Animals
Kenneth M. Bischoff, Toni L. Poole, and Ross C. Beier

17 Antimicrobial Resistance and the Microflora of the Gastrointestinal Tract
Toni L. Poole, Kenneth J. Genovese, Ross C. Beier, Todd R. Callaway, and Kenneth M. Bischoff

18 Disinfectants (Biocides) Used in Animal Production: Antimicrobial Resistance Considerations
Ross C. Beier, Kenneth M. Bischoff, and Toni L. Poole

19 Prevalence of Antimicrobial-Resistant Bacteria in Retail Foods
David G. White, Shaohua Zhao, Shabbir Simjee, Jianghong Meng, Robert D. Walker, and Patrick F. McDermott

Part IV: Verification Tests

20 The Hazard Analysis and Critical Control Point System and Importance of Verification Procedures
Jimmy T. Keeton and Kerri B. Harris
21 Are They Vibrios? How Do You Know?  
Sam W. Joseph  

22 Molecular Methods for Microbial Detection  
Suresh D. Pillai  

23 Methods for Differentiation among Bacterial Foodborne Pathogens  
Steven L. Foley and Robert D. Walker  

Part V: Decontamination and Prevention Strategies  

24 Chemical Methods for Decontamination of Meat and Poultry  
Jimmy T. Keeton and Sarah M. Eddy  

25 Decontamination Systems  
M. Elena Castell-Perez and Rosana G. Moreira  

26 Control of Listeria monocytogenes in Ready-to-Eat Foods  
Douglas L. Marshall  

27 Bacteriophage: Potential Role in Food Safety  
William E. Huff, Gerry R. Huff, Narayan C. Rath, Janice M. Balog, and Annie M. Donoghue  

28 Food Irradiation  
Suresh D. Pillai  

29 Clay-Based Interventions for the Control of Chemical and Microbial Hazards in Food and Water  
Henry J. Huebner, Paul Herrera, and Timothy D. Phillips  

Part VI: Risk Analysis  

30 Food Safety Risk Communication and Consumer Food-Handling Behavior  
Wm. Alex McIntosh  

31 Addressing Microbial Food Safety Issues Quantitatively: A Risk Assessment Approach  
Kristina D. Mena, Joan B. Rose, and Charles P. Gerba  

32 How to Manage Risk—The Way Forward  
Ewen C. D. Todd  

Afterword  
Agricultural Biosecurity: An Important Component of Homeland Security  
Neville P. Clarke  

Index
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Foreword

The Honorable Elsa A. Murano

Over the last decade, food safety has emerged as a tremendously significant issue, not only for consumers, regulatory agencies, and industry, but also for the research community. It is the latter on which the others depend to identify and understand foodborne hazards and to develop strategies to mitigate the risks associated with them. As such, there are many questions that have already been answered through the efforts of leading researchers in food safety. For one, the last decade has seen great progress made in determining the prevalence of certain microbial pathogens on foods. These data have been used by regulatory agencies such as the Food Safety and Inspection Service to establish criteria to determine whether food safety programs used in meat and poultry processing plants are sound and effective. Second, the world of diagnostic microbiology has also benefited from the focus paid to research in this area over the last few years. This is evident in the fact that health agencies such as the Centers for Disease Control and Prevention have completely moved toward the use of advanced methods such as pulsed field gel electrophoresis in identifying and typing isolates during epidemiological investigations. Finally, we have seen an explosion in the variety and sophistication of decontamination methods used by the food industry to reduce, and even eliminate pathogenic bacteria. From organic acid rinses on beef carcasses, to vacuum-steam-vacuum application on ready-to-eat deli products, to ionizing radiation, significant effort and resources have been invested in research on intervention strategies to improve the safety of our food supply.

In spite of these accomplishments, a simple perusal through the scientific literature suggests that there are many questions yet to be answered. For example, although knowing the prevalence of hazards in food is important, we have come to realize that elucidating how various hazards interact with their environment, and with each other, can provide us with even more essential information on how these factors can be manipulated to minimize food contamination. Similarly, we know that even the sophisticated diagnostic methods of today have limitations, lacking the ability to provide real-time results. In addition, the lack of non-destructive sampling protocols, requiring that sample collection be based on statistical probability of finding contaminants, limits its usefulness for ensuring the safety of individual production lots. Last, there remains a need for better intervention strategies capable of achieving a greater degree of hazard reduction without adversely affecting product quality. Such strategies are available to some extent at present, but they certainly are not applicable to all products, nor are they available to be used at all stages of the farm-to-table continuum.

The authors of this book, all experts in their respective fields, have attempted to provide a thoughtful treatise on the specific research questions that remain to be answered in food safety. They have indeed succeeded in their task, having resisted the temptation to list all possible areas of study, focusing instead on those key questions that are fundamental to
advancing our knowledge and, therefore, that are the most important to answer. Chapters dealing with specific pathogens are very useful, providing sound reviews of the state of the knowledge regarding their prevalence and survival in the environment. Research needs related to virulence of *Escherichia coli* O157:H7, for example, are discussed in various chapters, including the need to characterize colonization and adherence factors using protein profiling and other molecular dissection methods. The need to determine the nature and origin of antimicrobial resistance is also included, with suggestions for examining the factors that inhibit dissemination of plasmids, and that bring about point mutations that confer resistance. In addition, the topic of resistance to biocides by pathogens, and how this may engender cross-resistance to antibiotics, is also presented as a fundamental question in need of further exploration.

The book is indeed thorough, also covering questions on topics that are of practical importance, and through which great immediate benefits could be derived. For example, there is a need to further study the effect of diet on carriage rate of human pathogens by food animals. Similarly, examining how rearing practices, feed withdrawal, and transport stress can be successfully manipulated by producers to effect a reduction in the presence of salmonellae and other pathogens at the farm and feedlot, is presented as a topic deserving of significant research focus. Development of better detection and identification methods for pathogens such as *Campylobacter* is also identified as a topic worthy of attention, one that can undoubtedly improve our knowledge of the distribution of this and other pathogens in the environment, in foods, and in clinical samples. Excellent discussions on novel decontamination systems are also included, with the development and standardization of processing parameters with respect to the kinetics of microbial inactivation of various pathogens and in various food matrices being identified as necessary for progress to continue in this area.

There are also chapters that tackle the all-important topics of risk management and risk communication. Food safety objectives and acceptable level of protection are discussed, offering suggestions on how these can be used by regulatory agencies as public health tools. However, the authors point out that before these can be applied, research is needed to determine the maximum correlation of microbial hazards that could be considered as acceptable in achieving consumer protection. A presentation of the Health Belief Model is also included, with suggestions on how research that provides information on the susceptibility, severity, and cost versus benefit of behavioral changes could help predict how consumers may respond to food safety messages.

The authors of the book make the point that these, and many other important questions, need to be addressed if we are to protect the public from foodborne hazards. Obviously, this is no easy task. It will require our keenest scientific minds and most dedicated efforts. As British essayist Samuel Johnson once said, “To expect that the intricacies of science will be pierced by a careless glance, or the eminences of fame ascended without labor, is to expect a peculiar privilege, a power denied to the rest of mankind; but to suppose that the maze is inscrutable to diligence, or the heights inaccessible to perseverance, is to submit tamely to the tyranny of fancy, and enchain the mind in voluntary shackles.”

This book is indeed a call to arms for the researcher in the field of food safety. It provides a type of roadmap that can help us engage in the most rewarding work one could endeavor, that of advancing knowledge that will ultimately enhance the health of our citizenry. As a scientist, I can attest to the fact that a more rewarding challenge would be difficult to find. I commend each and every author for their labor in compiling the necessary information in
reviews of their individual topics and for the many hours of critical thinking that undoubtedly went into their excellent analysis of research questions yet to be answered. We all look forward to the great scientific work that will emerge in the future as a result of their efforts.

Notes

1Dr. Elsa A. Murano currently serves as Undersecretary for Food Safety at the United States Department of Agriculture, Washington, D.C.
Preface

The purpose of this book is to present material on preharvest and postharvest food safety issues, and it covers a wide range of food safety–related research. Food safety is so vast a subject area that one certainly could compile an entire library on this subject alone. The uniqueness of this book stems from an effort made by each author to not only review their area of research but also to provide insights into important unanswered questions, newly advanced theories, and future directions in their area of research.

The concept of the book originated from a brainstorming session that was chaired by Dr. Elsa Murano when she was Director of the Center for Food Safety, a unit of the Institute for Food Science and Engineering, at Texas A&M University. We were searching for ways to bring together Texas A&M University faculty members and Agricultural Research Service/U.S. Department of Agriculture research scientists located in College Station, Texas, who were members of the Institute for Food Science and Engineering. An idea was put forth that one way to catalyze interactions might be by writing short chapters that could later be expanded into a marketable book. Each participant was asked not only to indicate the nature of their personal research but to be creative and forward looking and to attempt to discuss the future research needs and directions in each of their areas.

At the outset, we felt that this exercise would bring some cohesion and unity to the wide array of scientists in College Station and also result in a book with some unique features. Most food safety books are written as textbooks or subject matter reviews. We aimed for something different, a book that points to the future; one that not only reviews the known but that examines the unknown in each of the areas of research.

The six sections in this book were selected on the basis of research priorities identified by an American Academy of Microbiology report (Doores 1999), and the specific areas are the following: (1) Pathogen/Host Interactions; (2) Ecology, Distribution, and Spread of Foodborne Hazards; (3) Antimicrobial Resistance; (4) Verification Tests; (5) Decontamination and Prevention Strategies; and (6) Risk Analysis.

We are positive that you will find that each of the chapters is well conceived and directly relates to the scope of the book. We would also like to point out that some chapters are very innovative for a book of this type. For instance, Chapter 7 discusses the potential for the organism that may be responsible for chronic inflammatory bowel disease of ruminants (Johne’s) to be transferred through the food supply to humans, potentially causing inflammatory bowel disease in humans (i.e., Crohn’s disease). We felt that though this is a highly controversial issue, it is a contemporary one that was worthy of inclusion. Chapter 14 is also quite contemporary, for it discusses transmissible spongiform encephalopathies, or prion diseases, including BSE, and the risks to animal and human health from them. Chapter 20 nicely spans the breadth of the whole book with a superb discussion of “The Hazard Analysis and Critical Control Point System and Importance of Verification Procedures.” This chapter presents the nuts and bolts of hazard analysis and critical control point systems and
would be useful to anyone involved in hazard analysis and critical control point systems, from the technician to the quality control supervisor, or even perhaps the plant manager. Chapter 29 is interesting because it discusses a new approach to controlling chemical and microbial hazards in food by sorption of these contaminants on clays. Another example of the uniqueness of this book is found in Chapter 30, which discusses both risk communication and consumer food-handling behavior. The author suggests that high schools may be an important place for instructing young people about proper food-handling procedures and food safety philosophies.

Though we could continue mentioning brief anecdotes about the other chapters, we will leave further discoveries of the important concepts presented by each author to the reader. We are confident that the broad range of material covered in this book, and the quality of the material presented, will appeal to the reader.

As we began the task of finding authors for chapters, we realized that this book could not be limited to only the Institute of Food Science and Engineering faculty. We reached out to additional Agricultural Research Service scientists, to other government scientists, and to faculty at other universities to bring quality, balance, and the broadest scope possible to this book.

When we approached various prospective publishers, some felt that a contemporary food safety book should contain a considerable amount of material on the subjects of food biosecurity and bioterrorism. The editors discussed whether or not to include such material and decided against including a section on food biosecurity or bioterrorism. Although we were well aware of the topical nature and market enhancing value of such chapters, we feared that publishing such material might somehow serve as a roadmap, guideline, or manual for those who would misuse the information to harm us.

However, Neville Clarke, DVM, Ph.D., former Dean of the Texas Agriculture Experiment Station, presently serving as the Director of the Texas A&M University Institute for Counter Measures Against Agricultural Bioterrorism, who also serves in a key role in Homeland Security for the state of Texas, has written some brief comments on the issues of agricultural biosecurity and bioterrorism and these comments are found in the Afterword.

References


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Part I

Pathogen/Host Interactions
1 Foodborne *Salmonella* Infections

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Introduction

Nontyphoidal *Salmonella* serotypes continue to be among the most prominent food safety problems in the United States, as illustrated by the large annual numbers of human cases and outbreaks with which these pathogens are associated. Between 1993 and 1997, *Salmonella* serotypes were the leading cause of foodborne disease outbreaks in the United States, accounting for 41% of outbreaks with known etiology (Olsen et al. 2000). A recent estimate from the Centers of Disease Control and Prevention (CDC) suggests that *Salmonella* serotypes cause approximately 1.4 million illnesses annually. This makes salmonellosis the second most common cause of bacterial foodborne disease of known etiology in the United States (Mead et al. 1999). In addition, nontyphoidal *Salmonella* serotypes are the single most common cause of death from foodborne illness associated with viruses, parasites, or bacteria in the United States, causing an estimated 550 fatal cases each year (Mead et al. 1999). The high morbidity and mortality resulting from foodborne infections with *Salmonella* serotypes in the United States is associated with significant economic losses. The CDC’s Foodborne Diseases Active Surveillance Network (Food Net) estimates the annual cost of medical care and lost productivity caused by foodborne salmonellosis in the United States to range from $0.5 billion to $2.3 billion (Frenzen et al. 1999).

*Salmonella* serotypes implicated in foodborne infections are commonly associated with animal reservoirs, suggesting that infections in man result from animal-to-human transmission (St. Louis et al. 1988, Mishu et al. 1994). In outbreaks within the United States in which the sources were identified, the food vehicles most commonly implicated were chicken, beef, turkey, and eggs (Tauxe 1991, Olsen et al. 2000). Meat, meat products, eggs, or egg products may contain *Salmonella* serotypes either because animals are infected or because fecal contamination occurs during processing (Galbraith 1961). There are currently 2,449 known *Salmonella* serotypes (Brenner et al. 2000). Approximately 70% of the *Salmonella* serotypes have been isolated from human cases of disease (Kelterborn 1967), but only five *Salmonella* serotypes accounted for 61% of the human cases reported to the CDC between 1987 and 1997 (Olsen et al. 2000). These five serotypes include *S. enterica* serotype Typhimurium (23% of isolations between 1987 and 1997), *S. enterica* serotype Enteritidis (21%), *S. enterica* serotype Heidelberg (8%), *S. enterica* serotype Newport (5%), and *S. enterica* serotype Hadar (4%). Collectively, these surveillance data illustrate that the persistence of *Salmonella* serotypes in livestock and domestic fowl is directly responsible for their subsequent introduction into the derived food products and that some *Salmonella* serotypes are epidemiologically more successful than others. Both the preharvest occurrence of *Salmonella* in food animals and the epidemiological success of certain *Salmonella* serotypes are of importance for food safety. However, the molecular mechanisms responsible for these phenomena are poorly understood. For the rational design of innovative prevention strategies, research is needed on the basic mechanisms that enable certain *Salmonella* serotypes to persist successfully in food animal reservoirs.
Preharvest Occurrence of *Salmonella* Serotypes

*Salmonella* serotypes pose a threat to food safety in the United States by persisting in apparently healthy animals, thereby leading to introduction of these pathogens into animal-derived food products. Transmission between animals before harvest is therefore of prime importance for food safety.

Horizontal Transmission


Given the importance of fecal–oral transmission, it is not surprising that control measures aimed at reducing fecal contamination of the environment have been shown to be effective in lowering the preharvest occurrence of *Salmonella* serotypes (Dahl et al. 1997, Davies et al. 1997). However, proper sanitation may not suffice to reduce fecal contamination to a level that would eliminate *Salmonella* serotypes from livestock reservoirs (Twiddy et al. 1988).

Vertical Transmission

Vertical transmission (from an adult to its offspring) is important for the spread of *Salmonella* serotypes in two food animal reservoirs, namely, chickens and cattle. In cattle, *Salmonella* serotypes can persist in the udders of cows for up to 2.5 years, resulting in vertical transmission of the organism through milk (Giles et al. 1989), which may contribute to persistence of *Salmonella* serotypes in dairy herds (Richardson 1973, Giles et al. 1989). However, the widespread pasteurization of milk and dairy products has reduced the importance, for human health, of this mode of transmission in the United States (Tauxe 1991).