

SECOND EDITION

FOOD MICROBIOLOGY

An Introduction



THOMAS J. MONTVILLE
KARL R. MATTHEWS

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**FOOD
MICROBIOLOGY**
An Introduction

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SECOND EDITION

FOOD MICROBIOLOGY

An Introduction

*We dedicate this book to the thousands of scientists who
made the discoveries that are now presented as fact,
to all the scientists and regulators who use this knowledge
to ensure the safety of the food supply,
and to the advancement of food microbiology*

Preface

Food microbiology is an exciting field that reaches into every home and supports a multibillion-dollar food industry. This book provides a taste of its complexity and challenge. The safety of food requires more than memorization of microbiological minutiae. It calls for critical thinking, innovative approaches, and healthy skepticism. We have tried to foster these skills so that today's students will be able to solve tomorrow's problems.

We would have never attempted to write a textbook on such a wide and complex topic as food microbiology "from scratch." Fortunately, ASM Press had published an advanced text for researchers, graduate students, and professors who needed the most up-to-date and in-depth treatment of food microbiology. *Food Microbiology: Fundamentals and Frontiers* was written by an army of subject area experts who presumed that the reader had a working knowledge of microbiology, biochemistry, and genetics. The success of the first two editions of that book gave us the courage (and the resource) to write a food microbiology textbook for undergraduates. *Food Microbiology: an Introduction* is the child of the "big book." For the first edition of this book, we rewrote the experts' chapters to make them accessible to an undergraduate with a semester of microbiology and no biochemistry. Now we have rewritten them again in response to student input about the first edition. In some cases, this meant adding foundational material; in others, it entailed deleting details that only an expert needs to know. The chapters in this book are, therefore, quite different from those originally written for the "big book." In all cases, we have tried to write in a style, at a level, and in language appropriate for undergraduates. To enhance its utility as a textbook, we have added case studies, word puzzles, chapter summaries, questions for critical thinking, a glossary, and even a few cartoons.

The book is divided into five sections. Students should be aware that there is a substantial amount of material in the second edition that is not covered in the first edition. The first section covers the foundational material, describing how bacteria grow in food, how the food affects their growth, control of microbial growth, spores, detection, and microbiological criteria. Instructors may choose to use the other four sections in virtually any order. The gram-negative and gram-positive foodborne pathogens are covered in sections II and III, respectively. Section IV contains chapters on beneficial microbes and spoilage organisms. This edition has taken the single chapter on fermentations and split it into a chapter about lactic acid

bacteria and one about yeast fermentations. Molds are covered both as spoilage organisms and as potential toxin producers. Since viruses may cause more than half of all foodborne illnesses, treatment of viruses has been expanded to include explanations of lytic and temperate phages, the importance of bacteriophage infection prevention to the dairy industry, and the recent adoption of phages for pathogen control. Prions are not bacteria, molds, or viruses; in fact, they are not “microbes” at all. However, they are a major biological concern to the public and food safety experts. Section V covers the chemical, biological, and physical methods of controlling foodborne microbes and closes by examining industrial and regulatory strategies for ensuring food safety.

Although only our names appear on the cover of this book, many people have made important contributions to it. First and foremost, we acknowledge the subject experts whose chapters in *Food Microbiology: Fundamentals and Frontiers* were important sources of information for our writing. They are Gary R. Acuff, John W. Austin, J. Stan Bailey, Dane Bernard, Larry R. Beuchat, Gregory A. Bohach, Robert E. Brackett, Robert L. Buchanan, Herbert J. Buckenhüskes, Lloyd B. Bullerman, Iain Campbell, Michael L. Chikindas, Dean O. Cliver, Jean-Yves D’Aoust, P. Michael Davidson, James S. Dickson, Michael P. Doyle, Józef Farkas, Peter Feng, Graham H. Fleet, Joseph F. Frank, H. Ray Gamble, Per Einar Granum, Paul A. Hartman, Eugene G. Hayunga, Craig W. Hedberg, Ailsa D. Hocking, Lynn M. Jablonski, Timothy C. Jackson, Eric A. Johnson, Mark E. Johnson, James B. Kaper, Jimmy T. Keeton, Charles W. Kim, Sylvia M. Kirov, Todd R. Klaenhammer, Keith A. Lampel, Alex S. Lopez, Douglas L. Marshall, Anthony T. Maurelli, John Maurer, Bruce A. McClane, Jianghong Meng, Kenneth B. Miller, Irving Nachamkin, James D. Oliver, Ynes R. Ortega, Merle D. Pierson, John I. Pitt, Steven C. Ricke, Roy M. Robins-Browne, Peter Setlow, L. Michele Smoot, James L. Steele, Bala Swaminathan, Sterling S. Thompson, Richard C. Whiting, Karen Winkowski, Irene Zabala Díaz, Tong Zhao, and Shaohua Zhao.

The reader should thank the students who reviewed each chapter for level and depth of coverage, writing style, and “what an undergraduate could be expected to know,” in addition to grammar and usage. We thank Marcelo Bonnet, Jon Cruz, Rebecca Dengrove, Sylvia Dominguez, Siobain Duffy, Megha Gandhi, Callie Gunnet, Glynis Kolling, Wendy M. Iwanyshyn, Jennifer McEntire, Karla Mendoza, Rebecca I. Montville, Mohamed Badaoui Najjar, June Oshiro, Hoan-Jen Pang, Ethan Solomon, Sarah Smith-Simpson, and Ruth Wiranan for their reviews. Any errors, omissions, or oversimplifications fall on our shoulders.

All of these people, as well as Eleanor Riemer and Ken April (our editor and production editor, respectively, at ASM), helped make this text “student friendly.” We hope you find it so and encourage you to explore careers in food microbiology. Remember, there will always be people who have to eat and there will always be microbes. Food microbiologists have great long-term job security.

THOMAS J. MONTVILLE
KARL R. MATTHEWS

About the Authors



THOMAS J. MONTVILLE is Professor II (distinguished) of Food and Fermentation Microbiology at Rutgers University, where he received his B.S. in 1975. Dr. Montville received his Ph.D. from the Massachusetts Institute of Technology (MIT) and then worked at the U.S. Department of Agriculture (USDA) before returning to Rutgers. He has published over 100 research papers on *Clostridium botulinum*, *Listeria monocytogenes*, antimicrobial peptides, and, more recently, *Bacillus anthracis* spores. Dr. Montville was a member of the FDA's Food Advisory Committee, the Institute of Food Technologists' expert panel on antimicrobial resistance, and various grant review panels. Dr. Montville is a fellow of the American Academy of Microbiology and a fellow of the Institute of Food Technologists.

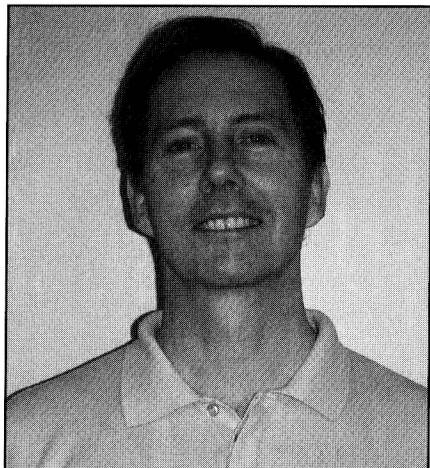
Author's Statement

My desire to see how things work drew me to science. When I was a kid, my aunts and uncles would save their broken appliances so that I could take them apart and see how they worked. My leanings toward science were finalized by microscopes; the ability to see bacteria sucked me into the field of microbiology. Rods, cocci, spores, motile, tumbling, germinating in front of my very eyes—how cool is that?

*Careers in science, or for that matter, any career, take strange turns. My undergraduate goal was to get a good job where I didn't have to work the night shift, but my professors badgered me to attend graduate school, and much to my surprise, I was admitted to MIT. My research there, on the dental bacterium *Streptococcus mutans*, had nothing to do with my subsequent career in food microbiology, but it did teach me about high-level science on a grand scale. The USDA was a great place to start a research career, but I soon realized that I didn't make a good civil servant. Never would I have predicted that I would return to Rutgers as a professor or that my station from Applied Microbiology would become part of my laboratory. Microbes have been good to me.*

It's possible, and even desirable, for scientists to have a life outside the lab. Indeed, my three children are more important to me than all the research papers in the

world. They've taught me about Boy Scouts, skiing, dance, theater, indie music, and the difference between an Xbox and a PlayStation. Now that they are grown up, I've become a serious distance bicyclist, having ridden the East Coast from Montreal to Charleston, SC (over a period of years), AIDS/LifeCycle 5 from San Francisco to Los Angeles, and a variety of other multiday rides in the mid-Atlantic region. At the end of a ride, it's always good to sit in front of a microscope.



KARL R. MATTHEWS is Associate Professor of Microbial Food Safety at Rutgers University. He received a Ph.D. from the University of Kentucky in 1988. Dr. Matthews has earned an international reputation for his work on the interaction of foodborne pathogens with fresh produce. This includes demonstrating the internal localization of bacteria during growth of leafy greens. He further demonstrated that the internalization process is a passive event by demonstrating the internalization of fluorescent polystyrene beads. Dr. Matthews has also been active in research on antimicrobial resistance of foodborne bacteria, specifically on intrinsic mechanisms of resistance and transfer of resistance genes among bacteria in food.

Author's Statement

My interest in microbiology was sparked one summer when I was working on a dairy farm. I regularly consumed the raw milk, but one time after doing so I became extremely ill (I won't go into the messy details). I became intrigued by microorganisms associated with milk and the disease bovine mastitis. These beginnings led me to an exciting career in food microbiology, where every day seems to bring a new problem to be addressed.

Contents

Preface xv

About the Authors xvii

SECTION I Basics of Food Microbiology 1

1

The Trajectory of Food Microbiology 3

Introduction 3

Who's on First? 3

Food Microbiology, Past and Present 4

To the Future and Beyond 8

Summary 10

Suggested reading 10

Questions for critical thought 10

2

Factors That Influence Microbes in Foods 11

Introduction 11

Food Ecosystems, Homeostasis, and Hurdle Technology 12

Foods as Ecosystems 12

Classical Microbiology and Its Limitations 13

Limitations of Detection and Enumeration Methods 13

Homeostasis and Hurdle Technology 27

Growth Kinetics 29

Microbial Physiology and Metabolism 32

Carbon Flow and Substrate Level Phosphorylation 34

The Tricarboxylic Acid Cycle Links Glycolysis to Aerobic Respiration 34

Conclusion 36

Summary 36

Suggested reading 36

Questions for critical thought 37

3

Spores and Their Significance 39

Introduction 39

Spores in the Food Industry 39

Low-Acid Canned Foods 40

Bacteriology of Sporeformers of Public Health Significance 42

Heat Resistance of *C. botulinum* Spores 44

Spoilage of Acid and Low-Acid Canned and Vacuum-Packaged Foods by Sporeformers 46

Spore Biology 47

Structure 47

Macromolecules 48

Small Molecules 48

Dormancy 48

Resistance 49

Freezing and Desiccation Resistance 49

Pressure Resistance 50

γ -Radiation Resistance 50

UV Radiation Resistance 50

Chemical Resistance 50

Spore Heat Resistance 50

The Cycle of Sporulation and Germination 52

Sporulation 52

Activation 53

Germination 53
 Outgrowth 54
Summary 54
Suggested reading 55
Questions for critical thought 55

4

Detection and Enumeration of Microbes in Food 57

Introduction 57
 Sample Collection and Processing 58
 Analysis 58
 Metabolism-Based Methods 61
 Surface Testing 62
Summary 63
Suggested reading 63
Questions for critical thought 63

5

Rapid and Automated Microbial Methods 65

Introduction 65
 Sample Processing 66
 Requirements and Validation of Rapid Methods 66
 Rapid Methods Based on Traditional Methods 66
 Immunologically Based Methods 69
 Molecular Methods 72

Potpourri of Rapid Methods 74
Summary 75
Suggested reading 75
Questions for critical thought 76

6

Indicator Microorganisms and Microbiological Criteria 77

Introduction 77
 The Purpose of Microbiological Criteria 77
 The Need To Establish Microbiological Criteria 77
 Definitions 78
 Who Establishes Microbiological Criteria? 79
 Sampling Plans 79
 Types of Sampling Plans 80
 Establishing Limits 81
 Indicators of Microbiological Quality 81
 Indicator Microorganisms 82
 Metabolic Products 83
 Indicators of Foodborne Pathogens and Toxins 84
 Indicator Organisms 86
 Fecal Coliforms and *E. coli* 88
 Metabolic Products 88
 Application and Specific Proposals for Microbiological Criteria for Food and Food Ingredients 89
 Current Status 90
Summary 93
Suggested reading 93
Questions for critical thought 93

SECTION II Gram-Negative Foodborne Pathogenic Bacteria 95

7

Salmonella Species 97

Outbreak 97
 Introduction 97
 Characteristics of the Organism 100
 Biochemical Identification 100
 Taxonomy and Nomenclature 101
 Serological Identification 101
 Physiology 102
 Reservoirs 105
 Characteristics of Disease 106

Symptoms and Treatment 106
 Preventative Measures 107
 Antibiotic Resistance 107
 Infectious Dose 108
 Pathogenicity and Virulence Factors 109
 Specific and Nonspecific Human Responses 109
 Attachment and Invasion 109
 Growth and Survival within Host Cells 110
 Virulence Plasmids 110
 Other Virulence Factors 110
Summary 111
Suggested reading 112
Questions for critical thought 112

8

Campylobacter jejuni* 113Outbreak* 113

Introduction 113

Characteristics of the Organism 114

Environmental Susceptibility 114

Reservoirs and Foodborne Outbreaks 114

Characteristics of Disease 117

C. jejuni and *C. coli* 117Other *Campylobacter* Species 117

Epidemiologic Subtyping Systems Useful for Investigating Foodborne Illnesses 117

Infective Dose and Susceptible Populations 118

Virulence Factors and Mechanisms of Pathogenicity 118

Cell Association and Invasion 119

Flagella and Motility 119

Toxins 120

Other Factors 120

Autoimmune Diseases 120

Immunity 120

Summary 120*Suggested reading* 121*Questions for critical thought* 121

9

Enterohemorrhagic *Escherichia coli* 123*Outbreak* 123

Introduction 124

Categories of *E. coli* 124Characteristics of *E. coli* O157:H7 and Non-O157:H7 EHEC 128

Acid Tolerance 128

Antibiotic Resistance 129

Inactivation by Heat and Irradiation 129

Reservoirs of *E. coli* O157:H7 130Detection of *E. coli* O157:H7 and EHEC on Farms 130Factors Associated with Bovine Carriage of *E. coli* O157:H7 130Cattle Model for Infection by *E. coli* O157:H7 130

Domestic Animals and Wildlife 130

Humans 131

Disease Outbreaks 131

Geographic Distribution 131

Seasonality of *E. coli* O157:H7 Infection 132

Age of Patients 132

Transmission of *E. coli* O157:H7 132

Examples of Foodborne and Waterborne Outbreaks 133

Characteristics of Disease 135

Infectious Dose 135

Mechanisms of Pathogenicity 135

Attaching and Effacing 136

The Locus of Enterocyte Effacement 137

The 60-MDa Plasmid (pO157) 137

Stxs 137

Conclusion 139

Summary 139*Suggested reading* 140*Questions for critical thought* 140

10

Yersinia enterocolitica* 141Outbreak* 141

Introduction 141

Characteristics of the Organism 141

Classification 142

Susceptibility and Tolerance 143

Characteristics of Infection 144

Reservoirs 145

Foodborne Outbreaks 146

Mechanisms of Pathogenicity 147

Pathological Changes 147

Virulence Determinants 147

Chromosomal Determinants of Virulence 147

Other Virulence Determinants 148

Pathogenesis of *Yersinia*-Induced Autoimmunity 148*Summary* 149*Suggested reading* 149*Questions for critical thought* 149

11

Shigella* Species 151Outbreak* 151

Introduction 151

Classification and Biochemical Characteristics 154

Shigella in Foods 154

Survival and Growth in Foods 155

Characteristics of Disease 155

Foodborne Outbreaks 156

Virulence Factors 157

Genetic Regulation 157

Conclusions 158
Summary 158
Suggested reading 158
Questions for critical thought 158

12

***Vibrio* Species 161**

Outbreak 161
 Introduction 161
 Characteristics of the Organism 162

Epidemiology 162
 Characteristics of Disease 163
 Susceptibility to Physical and Chemical Treatments 163
V. cholerae 163
V. mimicus 165
V. parahaemolyticus 166
V. vulnificus 167
V. fluvialis, *V. furnissii*, *V. hollisae*, and *V. alginolyticus* 168
Summary 169
Suggested reading 169
Questions for critical thought 170

SECTION III Gram-Positive Foodborne Pathogenic Bacteria 171

13

***Listeria monocytogenes* 173**

Outbreak 173
 Introduction 174
 Characteristics of the Organism 175
 Classification 175
 Susceptibility to Physical and Chemical Agents 176
 Listeriosis and Specific Foods 176
 Ready-to-Eat Foods 176
 Milk Products 177
 Cheeses 177
 Meat and Poultry Products 177
 Seafoods 178
 Other Methods of Food Preservation 178
 Sources of *L. monocytogenes* in the Environment 178
 Food-Processing Plants 179
 Prevalence and the Regulatory Status of *L. monocytogenes* 180
 Human Carriers 181
 Foodborne Outbreaks 182
 Characteristics of Disease 184
 Infectious Dose 184
 Virulence Factors and Mechanisms of Pathogenicity 185
 Pathogenicity of *L. monocytogenes* 185
 Specific Genes Mediate Pathogenicity 186
Summary 186
Suggested reading 187
Questions for critical thought 187
More questions than answers 187

14

***Staphylococcus aureus* 189**

Outbreak 189
 Characteristics of the Organism 190
 Historical Aspects and General Considerations 190
 Sources of Staphylococcal Food Contamination 190
 Resistance to Adverse Environmental Conditions 191
 Foodborne Outbreaks 192
 Incidence of Staphylococcal Food Poisoning 192
 A Typical Large Staphylococcal Food Poisoning Outbreak 193
 Characteristics of Disease 193
 Infective Dose and Susceptible Populations 194
 Numbers of Staphylococci Required 194
 Toxin Dose Required 194
 Microbiology, Toxins, and Pathogenicity 195
 Nomenclature, Characteristics, and Distribution of Staphylococcal Enterotoxin-Producing Staphylococci 195
 Introduction to, and Nomenclature of, the Staphylococcal Enterotoxins 195
 Staphylococcal Regulation of Staphylococcal Enterotoxin Expression 196
Summary 200
Suggested reading 200
Questions for critical thought 200

15

***Clostridium botulinum* 203**

Introduction 203
 Four Faces of Botulism 203
 Characteristics of the Disease 208

Toxic and Infectious Doses and Susceptible Populations 208

Characteristics of *C. botulinum* 209

Classification 209

Tolerance of Preservation Methods 211

Sources of *C. botulinum* 213

Occurrence of *C. botulinum* in the Environment 213

Occurrence of *C. botulinum* in Foods 213

Virulence Factors and Mechanisms of Pathogenicity 215

Structure of the Neurotoxins 215

Genetic Regulation of the Neurotoxins 216

Mode of Action of the Neurotoxins 217

Summary 218

Suggested reading 218

Questions for critical thought 218

16

***Clostridium perfringens* 221**

The Foodborne Illness 221

A Spore's-Eye View of *C. perfringens* Toxicoinfections 221

A Human View of *C. perfringens* Type A Foodborne Illness 221

Incidence 222

Food Vehicles for *C. perfringens* Foodborne Illness 222

Factors Contributing to *C. perfringens* Type A Foodborne Illness 222

Preventing *C. perfringens* Type A Foodborne Illness 223

Identification of *C. perfringens* Type A Foodborne Illness Outbreaks 223

Characteristics of *C. perfringens* Type A Foodborne Illness 224

Infectious Dose for *C. perfringens* Type A Foodborne

Illness 224

The Organism 224

Overview 224

Classification: Toxin Typing of *C. perfringens* 226

Susceptibility of *C. perfringens* to Preservation Methods 227

Reservoirs for *C. perfringens* Type A 227

Virulence Factors Contributing to *C. perfringens* Type A Foodborne Illness 228

Heat Resistance 228

C. perfringens Enterotoxin 228

Summary 230

Suggested reading 230

Questions for critical thought 231

17

***Bacillus cereus* 233**

Outbreak 233

Introduction 233

Characteristics of the Organism 234

Environmental Sources 234

Foodborne Outbreaks 235

Characteristics of Disease 236

Dose 236

Virulence Factors and Mechanisms of Pathogenicity 237

The Emetic Toxin 237

Enterotoxins 237

The Spore 238

Summary 238

Suggested reading 239

Questions for critical thought 239

SECTION IV Other Microbes Important in Food 241

18

Lactic Acid Bacteria and Food Fermentations 243

Introduction 243

The Biochemical Foundation of Food Fermentation 243

Catabolic Pathways 245

Dairy Fermentations 246

Starter Cultures 248

Production of Aroma Compounds 249

Genetics of Lactic Acid Bacteria 250

Fermented Vegetables 250

Ingredients and Additives Used during Fermentations 251

Sauerkraut Fermentation 251

Pickle Fermentation 252

Meat Fermentations 253

Summary 254

Suggested reading 254

Questions for critical thought 254

19

Yeast-Based and Other Fermentations 257

Introduction 257

Fermentations That Use Yeast 258

Bread 258

Beer 259

Wine 261

Vinegar Fermentation 263

Cocoa and Coffee Fermentations 264

Cocoa 264

Coffee 268

Fermented Foods of Non-Western Societies 268

Summary 269

Suggested reading 269

Questions for critical thought 269

20

Spoilage Organisms 271

Introduction 271

Meat, Poultry, and Seafood Products 272

Origin of Microflora in Meat 272

Origin of Microflora in Poultry 272

Origin of Microflora in Finfish 272

Origin of Microflora in Shellfish 273

Bacterial Attachment to Food Surfaces 273

Microbial Progression during Storage 273

Muscle Tissue as a Growth Medium 275

Factors Influencing Spoilage 276

Control of Spoilage of Muscle Foods 278

Milk and Dairy Products 281

Milk and Dairy Products as Growth Media 281

Psychrotrophic Spoilage 283

Spoilage by Fermentative Nonsporeformers 286

Spore-Forming Bacteria 287

Yeasts and Molds 288

Spoilage of Produce and Grains 289

Types of Spoilage 289

Mechanisms of Spoilage 291

Influence of Physiological State 291

Microbiological Spoilage of Vegetables 292

Microbiological Spoilage of Fruits 295

Microbiological Spoilage of Grains and Grain Products 296

Summary 298

Suggested reading 298

Questions for critical thought 298

21

Molds 301

Introduction 301

Isolation, Enumeration, and Identification 301

Aspergillus Species 304

A. flavus and *A. parasiticus* 308

Other Toxigenic *Aspergilli* 312

Penicillium Species 313

Significant *Penicillium* Mycotoxins 313

Fusaria and Toxigenic Molds Other than *Aspergilli* and *Penicillia* 316

Toxigenic *Fusarium* Species 316

Other Toxic Molds 319

Summary 319

Suggested reading 320

Questions for critical thought 320

22

Viruses and Prions 321

Introduction 321

Viruses 322

Elementary Virology 322

Viruses as Agents of Foodborne Illness 323

Bacteriophages in the Dairy Industry 327

Beneficial Uses of Viruses 328

Prions 329

A Short History of the Prion 330

Prion Biology 331

Summary 332

Suggested reading 332

Questions for critical thought 332

SECTION V Control of Microorganisms in Food 335

23

Antimicrobial Preservatives 337

Introduction 337

Factors That Affect Antimicrobial Activity 338

Organic Acids 339

Parabenzoic Acids 340

Nitrites 341

Phosphates 341

Sodium Chloride 341

Disinfectants 342

Sulfites 342

Chlorine 343

Quaternary Ammonium Compounds 343

Peroxides 344

Ozone 344

Naturally Occurring Antimicrobials 344

Lysozyme 344

Lactoferrin and Other Iron-Binding Proteins 345

Avidin 345

Spices and Their Essential Oils 346

Onions and Garlic 347

Isothiocyanates 347

Phenolic Compounds 347

Summary 348

Suggested reading 348

Questions for critical thought 348

24

Biologically Based Preservation and Probiotic Bacteria 351

Introduction 351

Biopreservation by Controlled Acidification 352

Bacteriocins 352

General Characteristics 352

Bacteriocin Applications in Foods 354

Probiotic Bacteria 357

The Human GI Tract Is a Microbial Ecosystem 358

Summary 360

Suggested reading 360

Questions for critical thought 360

25

Physical Methods of Food Preservation 363

Introduction 363

Physical Dehydration Processes 363

Drying 363

Freeze-Drying 364

Cool Storage 364

Controlled-Atmosphere Storage 365

Modified-Atmosphere Packaging 365

Freezing and Frozen Storage 366

Preservation by Heat Treatments 367

Technological Fundamentals 367

Thermobacteriology 369

Calculating Heat Processes for Foods 374

Microwave Heat Treatment 375

Preservation by Irradiation 375

UV Radiation 375

Ionizing Radiation 375

Microbiological Fundamentals 376

Technological Fundamentals 378

Consumer Acceptance of Food

Irradiation 379

Other Nonthermal Processes 381

Summary 383

Suggested reading 383

Questions for critical thought 383

26

Industrial Strategies for Ensuring Safe Food 387

Introduction 387

GMPs 387

General Provisions (Subpart A) 388

Buildings and Facilities (Subpart B) 388

Equipment (Subpart C) 389

Production and Process Controls
(Subpart E) 389

DALs (Subpart G) 390

Sanitation 390

SSOPs 393

HACCP 394

Conclusion 401

Summary 401

Suggested reading 401

Questions for critical thought 402

Glossary 403

Answers to Puzzles 409

Index 413