HANDBOOK OF FOOD BIOENGINEERING
VOLUME 15

FOODBORNE DISEASES

Edited by
Alina Maria Holban
Alexandru Mihai Grumezescu

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Foreword

In the last 50 years an increasing number of modified and alternative foods have been developed using various tools of science, engineering, and biotechnology. The result is that today most of the available commercial food is somehow modified and improved, and made to look better, taste different, and be commercially attractive. These food products have entered in the domestic first and then the international markets, currently representing a great industry in most countries. Sometimes these products are considered as life-supporting alternatives, neither good nor bad, and sometimes they are just seen as luxury foods. In the context of a permanently growing population, changing climate, and strong anthropological influence, food resources became limited in large parts of the Earth. Obtaining a better and more resistant crop quickly and with improved nutritional value would represent the Holy Grail for the food industry. However, such a crop could pose negative effects on the environment and consumer health, as most of the current approaches involve the use of powerful and broad-spectrum pesticides, genetic engineered plants and animals, or bioelements with unknown and difficult-to-predict effects. Numerous questions have emerged with the introduction of engineered foods, many of them pertaining to their safe use for human consumption and ecosystems, long-term expectations, benefits, challenges associated with their use, and most important, their economic impact.

The progress made in the food industry by the development of applicative engineering and biotechnologies is impressive and many of the advances are oriented to solve the world food crisis in a constantly increasing population: from genetic engineering to improved preservatives and advanced materials for innovative food quality control and packaging. In the present era, innovative technologies and state-of-the-art research progress has allowed the development of a new and rapidly changing food industry, able to bottom-up all known and accepted facts in the traditional food management. The huge amount of available information, many times is difficult to validate, and the variety of approaches, which could seem overwhelming and lead to misunderstandings, is yet a valuable resource of manipulation for the population as a whole.

The series entitled *Handbook of Food Bioengineering* brings together a comprehensive collection of volumes to reveal the most current progress and perspectives in the field of food engineering. The editors have selected the most interesting and intriguing topics, and have dissected them in 20 thematic volumes, allowing readers to find the description of

basic processes and also the up-to-date innovations in the field. Although the series is mainly dedicated to the engineering, research, and biotechnological sectors, a wide audience could benefit from this impressive and updated information on the food industry. This is because of the overall style of the book, outstanding authors of the chapters, numerous illustrations, images, and well-structured chapters, which are easy to understand. Nonetheless, the most novel approaches and technologies could be of a great relevance for researchers and engineers working in the field of bioengineering.

Current approaches, regulations, safety issues, and the perspective of innovative applications are highlighted and thoroughly dissected in this series. This work comes as a useful tool to understand where we are and where we are heading to in the food industry, while being amazed by the great variety of approaches and innovations, which constantly changes the idea of the "food of the future."

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Series Preface

The food sector represents one of the most important industries in terms of extent, investment, and diversity. In a permanently changing society, dietary needs and preferences are widely variable. Along with offering a great technological support for innovative and appreciated products, the current food industry should also cover the basic needs of an ever-increasing population. In this context, engineering, research, and technology have been combined to offer sustainable solutions in the food industry for a healthy and satisfied population.

Massive progress is constantly being made in this dynamic field, but most of the recent information remains poorly revealed to the large population. This series emerged out of our need, and that of many others, to bring together the most relevant and innovative available approaches in the intriguing field of food bioengineering. In this work we present relevant aspects in a pertinent and easy-to-understand sequence, beginning with the basic aspects of food production and concluding with the most novel technologies and approaches for processing, preservation, and packaging. Hot topics, such as genetically modified foods, food additives, and foodborne diseases, are thoroughly dissected in dedicated volumes, which reveal the newest trends, current products, and applicable regulations.

While health and well-being are key drivers of the food industry, market forces strive for innovation throughout the complete food chain, including raw material/ingredient sourcing, food processing, quality control of finished products, and packaging. Scientists and industry stakeholders have already identified potential uses of new and highly investigated concepts, such as nanotechnology, in virtually every segment of the food industry, from agriculture (i.e., pesticide production and processing, fertilizer or vaccine delivery, animal and plant pathogen detection, and targeted genetic engineering) to food production and processing (i.e., encapsulation of flavor or odor enhancers, food textural or quality improvement, and new gelation- or viscosity-enhancing agents), food packaging (i.e., pathogen, physicochemical, and mechanical agents sensors; anticounterfeiting devices; UV protection; and the design of stronger, more impermeable polymer films), and nutrient supplements (i.e., nutraceuticals, higher stability and bioavailability of food bioactives, etc.).

The series entitled *Handbook of Food Bioengineering* comprises 20 thematic volumes; each volume presenting focused information on a particular topic discussed in 15 chapters each. The volumes and approached topics of this multivolume series are:

Volume 1: Food Biosynthesis

Volume 2: Food Bioconversion

Volume 3: Soft Chemistry and Food Fermentation

Volume 4: Ingredients Extraction by Physicochemical Methods in Food

Volume 5: Microbial Production of Food Ingredients and Additives

Volume 6: Genetically Engineered Foods

Volume 7: Natural and Artificial Flavoring Agents and Food Dyes

Volume 8: Therapeutic Foods

Volume 9: Food Packaging and Preservation

Volume 10: Microbial Contamination and Food Degradation

Volume 11: Diet, Microbiome and Health

Volume 12: Impact of Nanoscience in the Food Industry

Volume 13: Food Quality: Balancing Health and Disease

Volume 14: Advances in Biotechnology for Food Industry

Volume 15: Foodborne Diseases

Volume 16: Food Control and Biosecurity

Volume 17: Alternative and Replacement Foods

Volume 18: Food Processing for Increased Quality and Consumption

Volume 19: Role of Materials Science in Food Bioengineering

Volume 20: Biopolymers for Food Design

The series begins with a volume on *Food Biosynthesis*, which reveals the concept of food production through biological processes and also the main bioelements that could be involved in food production and processing. The second volume, *Food Bioconversion*, highlights aspects related to food modification in a biological manner. A key aspect of this volume is represented by waste bioconversion as a supportive approach in the current waste crisis and massive pollution of the planet Earth. In the third volume, *Soft Chemistry and Food Fermentation*, we

aim to discuss several aspects regarding not only to the varieties and impacts of fermentative processes, but also the range of chemical processes that mimic some biological processes in the context of the current and future biofood industry. Volume 4, *Ingredients Extraction by Physicochemical Methods in Food*, brings the readers into the world of ingredients and the methods that can be applied for their extraction and purification. Both traditional and most of the modern techniques can be found in dedicated chapters of this volume. On the other hand, in volume 5, *Microbial Production of Food Ingredients and Additives*, biological methods of ingredient production, emphasizing microbial processes, are revealed and discussed. In volume 6, *Genetically Engineered Foods*, the delicate subject of genetically engineered plants and animals to develop modified foods is thoroughly dissected. Further, in volume 7, *Natural and Artificial Flavoring Agents and Food Dyes*, another hot topic in food industry—flavoring and dyes—is scientifically commented and valuable examples of natural and artificial compounds are generously offered. Volume 8, *Therapeutic Foods*, reveals the most utilized and investigated foods with therapeutic values. Moreover, basic and future approaches for traditional and alternative medicine, utilizing medicinal foods, are presented here. In volume 9, *Food Packaging and Preservation*, the most recent, innovative, and interesting technologies and advances in food packaging, novel preservatives, and preservation methods are presented. On the other hand, important aspects in the field of *Microbial Contamination and Food Degradation* are shown in volume 10. Highly debated topics in modern society: *Diet*, *Microbiome and Health* are significantly discussed in volume 11. Volume 12 highlights the *Impact of Nanoscience in the Food Industry*, presenting the most recent advances in the field of applicative nanotechnology with great impacts on the food industry. Additionally, volume 13 entitled *Food Quality*: *Balancing Health and Disease* reveals the current knowledge and concerns regarding the influence of food quality on the overall health of population and potential food-related diseases. In volume 14, *Advances in Biotechnology for Food Industry*, up-to-date information regarding the progress of biotechnology in the construction of the future food industry is revealed. Improved technologies, new concepts, and perspectives are highlighted in this work. The topic of *Foodborne Diseases* is also well documented within this series in volume 15. Moreover, *Food Control and Biosecurity* aspects, as well as current regulations and food safety concerns are discussed in the volume 16. In volume 17, *Alternative and Replacement Foods*, another broad-interest concept is reviewed. The use and research of traditional food alternatives currently gain increasing terrain and this quick emerging trend has a significant impact on the food industry. Another related hot topic, *Food Processing for Increased Quality and Consumption*, is considered in volume 18. The final two volumes rely on the massive progress made in material science and the great applicative impacts of this progress on the food industry. Volume 19, *Role of Materials Science in Food Bioengineering*, offers a perspective and a scientific introduction in the science of engineered materials, with important applications in food research and technology. Finally, in volume 20, *Biopolymers for Food Design*, we discuss the advantages and challenges related to the development of improved and smart biopolymers for the food industry.

All 20 volumes of this comprehensive collection were carefully composed not only to offer basic knowledge for facilitating understanding of nonspecialist readers, but also to offer valuable information regarding the newest trends and advances in food engineering, which is useful for researchers and specialized readers. Each volume could be treated individually as a useful source of knowledge for a particular topic in the extensive field of food engineering or as a dedicated and explicit part of the whole series.

This series is primarily dedicated to scientists, academicians, engineers, industrial representatives, innovative technology representatives, medical doctors, and also to any nonspecialist reader willing to learn about the recent innovations and future perspectives in the dynamic field of food bioengineering.

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Preface for Volume 15: Foodborne Diseases

The quality and amount of daily food intake represent one of the most important factors in balancing health and disease in humans. Along with the nutritional value of ingested food, other factors, such as contaminants, contribute to food quality and may determine foodborne diseases. These health-threatening conditions may occur as a result of various chemical and biological contaminants, which may also have a huge impact on the food quality. Biological contaminants include microorganisms, such as bacteria, microfungi, and protozoa; but also viruses and parasites and nonetheless their toxins. Infectious and parasitic foodborne diseases cause severe illness in consumers, and sometimes epidemiologic outbreaks. In this book, we aim to present and dissect basic and novel information on the types of food-associated risks, foodborne diseases, main contaminants, and their characteristics; but also current and future perspectives for the early detection and prevention of food contamination.

The volume contains 15 chapters prepared by outstanding authors from Turkey, Greece, Thailand, USA, Ukraine, Portugal, India, and Pakistan.

The selected manuscripts are clearly illustrated and contain accessible information for a wide audience, especially food scientists, microbiologists, medical doctors, engineers, biotechnologists, biochemists, industrial companies; and also for any reader interested in learning about the most interesting and recent advances in the field of foodborne diseases.

Chapter 1, entitled *Microbial Foodborne Diseases*, prepared by Ünüvar, introduces the readers in the field of foodborne diseases, focusing on the classification, causes, clinical features, and new approaches to reduce/prevent the risk of microbial related foodborne diseases.

Chapter 2, *Important Emerging and Reemerging Tropical Foodborne Diseases*, written by Wiwanitkit, reviews and discusses emerging and reemerging tropical foodborne diseases and ways to combat this public health problem.

Chapter 3, entitled *Foodborne Pathogens—Produced Toxins Acting on Signal Transduction*, was prepared by Ghosh. This manuscript discusses dominant pathogens that produce one or more toxins targeting signal transduction of the host, which finally leads to pathophysiological changes and subsequently to disease. Some inhibit protein synthesis; some are neurotoxic or some other target different cellular functions.

Chapter 4, *Toxoplasmosis*: *Prevalence and New Detection Methods*, written by Galat et al., describes toxoplasmosis, the causing parasite, as well as prevalence of this parasitic disease. It is currently believed that the use of advanced biosensors to detect contaminated products would decrease the rate of diseases and associated defects.

Chapter 5, entitled *Campylobacteriosis*: *An Emerging Infectious Foodborne Disease*, prepared by Hsieh and Sulaiman, offers an overview regarding *Campylobacter* infections, the wide spread of this disease and currently investigated methods to early detect and avoid the occurrence of massive infections. Recovery of these emerging infectious bacteria from food is still a difficult task. Molecular typing has been effective in characterizing *Campylobacter* isolated from food, outbreak, sporadic cases, surveillance, and environmental samples. Currently, multilocus sequence typing (MLST) and whole genome sequencing (WGS) is increasingly applied in epidemiologic investigations and transmission dynamics of bacteria causing foodborne diseases.

Chapter 6, Listeria monocytogenes: *A Foodborne Pathogen*, prepared by Thakur et al., describes the most frequent illness produced by this foodborne pathogen, such as invasive listeriosis, gastroenteritis, septicemia, endocarditis, meningitis, rhombencephalitis, perinatal infections, ophthalmitis, and abortion. Various aspects of *Listeria monocytogenes* pathogenesis involving mechanisms of virulence, survival under adverse conditions, incidence and growth in food, methods of detection, and control measures so as to facilitate the development of better ways of disease prevention are presented here.

Chapter 7, Bacillus *spp. as Pathogens in the Dairy Industry*, written by Grutsch et al., reveals the current status of knowledge with *Bacillus* spp. relevant to the dairy industry, virulence potential, and biofilm production from the perspective of food safety. This bacterial genus is capable of contaminating a wide range of food products, including rice, chicken, vegetables, spices, and dairy products, and causing many health-threatening conditions.

Chapter 8, Staphylococcus aureus, *a Food Pathogen*: *Virulence Factors and Antibiotic Resistance*, prepared by Castro et al., aims to show the main virulence determinants and issues related with *Staphylococcus aureus* food contamination, empathizing on the great risk of antibiotic resistance. Antibiotics were widely used not only in human but also in animal husbandry and other agricultural activities. The occurrence of multiresistant strains in food has been increasing; contaminated food is considered as an important vehicle for antimicrobial resistance. Methicillin-resistant *S. aureus* (MRSA) commonly carry enterotoxin genes and antibiotic resistance associated to enterotoxins genes made *S. aureus* an evolving threat.

In Chapter 9, *Food-Borne Mycotoxicoses*: *Pathologies and Public Health Impact*, Patial et al. present recent information regarding mycotoxins and the health-threatening conditions that they induce after the ingestion of contaminated food. This chapter discusses important food

mycotoxins and the main diseases they produce, such as: aflatoxin, a liver damaging toxin; ochratoxin A, associated with kidney damage; fumonisins, causing liver damage, cancer, and developmental defects; moniliformin, causing acute cardiac damage; deoxynivalenol and zearalenone, causing immunotoxicity and gastroenteritis.

Chapter 10, *Foodborne Botulism From a Systems Biology Perspective*, written by Lebeda et al., highlights the impact of a systems approach in helping scaling of the effectiveness of therapies and reduces the costs of hospitalizations in patients with botulism. Computational models describing *Clostridium botulinum* spore activation, bacterial growth, and neurotoxin production in food could be linked to risk assessments that help improve food safety procedures and public health policies. Combining experimental and clinical data is also critical in developing models designed to simulate illness onset times and durations.

Chapter 11, entitled *Pathogenic Biofilm Formation in the Food Industry and Alternative Control Strategies*, was prepared by Giaouris and Simões. The ability of foodborne bacterial pathogens, such as *Salmonella* spp., *Listeria monocytogenes*, *pathogenic Escherichia coli*, *Campylobacter* spp., *Bacillus cereus*, and *Staphylococcus aureus*, to attach to various surfaces and create biofilms on them is a worrying hygienic trouble for the food industry, as this may cause serious food contamination and diseases transmission. The purpose of this chapter is to review the current knowledge related to pathogenic biofilm formation in the main food industries (meat, dairy, fresh produce, and seafood) and also to provide up-to-date data on some potential alternative or supplementary antibiofilm strategies.

Chapter 12, *Biosensor-Based Methods for the Determination of Foodborne Pathogens*, written by Bozal-Palabiyik et al., gives an overview regarding the main progress made for the development of rapid methods for the detection of foodborne pathogens. Early screening of foodborne pathogens in foods plays an important role in preventing and controlling the outbreaks of foodborne diseases. Biosensors design is one of the important methods for foodborne pathogen detection, which present sensitive, rapid, and low-cost technologies. This study focused on the methods of immobilization of biological component to generate biosensors, applications of mostly used electrochemical and optical biosensors, and recent prospects for foodborne pathogen detection and determination.

Chapter 13, *Molecular Typing of Major Foodborne Pathogens*, prepared by Paramithiotis et al., presents accurate methods for the identification of the infection source and the transmission route for the effective implementation of preventive measures against microbial foodborne pathogens. Techniques, such as pulsed-field gel electrophoresis (PFGE), multilocus variable number of tandem repeats analysis (MLVA), and multilocus sequence typing (MLST) are dissected and examples on typing approaches in *Listeria monocytogenes*, *Salmonella* serovars, *Escherichia coli O157:H7*, and *Campylobacter* spp. are integrated and critically discussed.

In Chapter 14, *Environmental Pollution and the Burden of Food-Borne Diseases*, Deb reveals the connection linking environmental contamination to foodborne ailments. Various types of environmental pollutions lead to distress, as they are often indirect and reliant on numerous adaptive forces. Numerous menaces to ecosystem directing to foodborne ailments comprise change in climate, contaminated water, use of excess fertilizers-pesticides, poor sanitation, etc. Climate change lays stress on agricultural production causing mass malnutrition and vulnerability to diseases. Furthermore, the dissemination and activity of carriers of food-borne pathogens as insects and rodents alter with changes in weather conditions; producing diseases. Atmospheric contaminants often migrate in food in small amounts causing life-threats. Environmental pollution causing foodborne diseases being an area of serious concern at all echelons, the chapter discusses each of these issues in detail with special reference to the developing countries.

Chapter 15, *Foodborne Illness*: *Threats and Control*, prepared by Sharif et al., gives an overview of the current threats in foodborne diseases, types, pathology, symptoms, adverse effects, contributory factors, major foodborne pathogens, molecular detection methods, toxin synthesis, hazard and risk analysis, and control measures. Furthermore, current and future efforts to be made to comprehensively deliberate impact of food quality, storage, and preservation on human health, role of consumer toward ensuring food security will be also dissected.

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CHAPTER 1

Microbial Foodborne Diseases

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This chapter reviews microbial foodborne diseases caused by bacteria, parasites, and viruses and their significance as a health concern. Microbial foodborne illnesses constitute the majority of foodborne diseases (Fig. 1.1). Several pathogens cause serious microbial diseases in humans. Each year millions of people become sick or even die from food poisonings. Pathogen-induced foodborne diseases are a major health problem worldwide (Fig. 1.2).

1 Section 1. Bacterial Foodborne Diseases

This section focuses on the classification, causes, and clinical features of bacterial foodborne diseases and on risk reduction and prevention of these diseases (Table 1.1).

1.1 Aeromonas hydrophila–*Induced Gastroenteritis*

Aeromonas hydrophila is a Gram-negative, motile, nonspore-forming, facultatively anaerobic bacterium that causes *Aeromonas*-induced gastroenteritis. *Aeromonas* species can be found in various concentrations in drinking water, aquatic environments, sewage, and foods, including seafoods, raw milk, chicken, vegetables, and meats, such as lamb, veal, pork, and ground beef (Janda and Abbott, 2010; WHO, 2008a). The symptoms of infection include watery stools, abdominal cramps, mild fever, and vomiting. Bronchopneumonia and cholecystitis are observed in severe cases (Mossel et al., 1999). *Aeromonas* infections have been divided into four groups: (1) gastrointestinal tract syndromes, (2) wound infections and connective tissue infections, (3) bloodborne dyscrasias, and (4) a wide-ranging class that includes a myriad of less frequently encountered ailments and infectious processes (Janda and Abbott, 2010). Rehydration therapy and antimicrobial treatment are recommended in cases of chronic dysentery (Farrar et al., 2014). *A. hydrophila* strains are resistant to most of the β-lactams, including ceftazidime, cefepime, imipenem, and piperacillin-tazobactam (Janda and Abbott, 2010). Antimicrobials, such as fluoroquinolones may be effective (Farrar et al., 2014).

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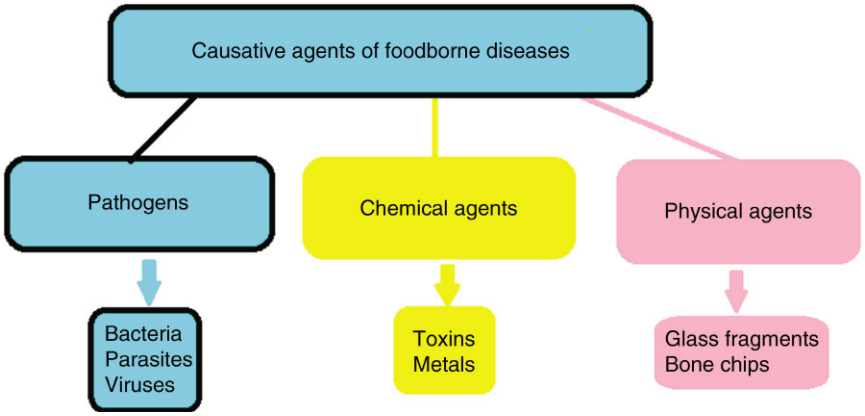

Figure 1.1: Classification of Foodborne Diseases.

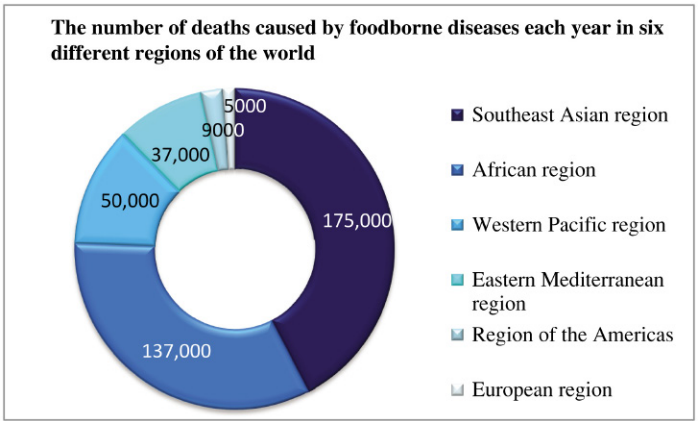

Figure 1.2: Global Burden of Foodborne Diseases—2015 (WHO, 2015).

1.2 Bacillus cereus–*Induced Gastroenteritis*

Bacillus cereus is a Gram-positive, facultatively anaerobic, generally mesophilic, heat-resistant, spore-forming rod widely distributed in the environment. The natural environmental reservoir for *B. cereus* consists of decaying organic matter, fresh and marine waters, foods, such as boiled or fried rice, spices, dried foods, milk, dairy products, vegetable dishes, sauces, fomites, and the intestinal tracts of invertebrates (Bottone, 2010; WHO, 2008a). The pathogenicity of *B. cereus* is associated with two toxins, namely diarrheal toxin and emetic toxin. Diarrheal toxin causes diarrheal syndrome characterized with acute diarrhea, nausea, and abdominal pain. Emetic toxin leads to emetic syndrome characterized with acute nausea, vomiting, abdominal pain, and rarely diarrhea (Ehling-Schulz et al., 2004). *B. cereus* strains have been generally resistant to penicillins, erythromycin, tetracycline, and carbapenem due to the consequence of β-lactamase production. Empiric antibiotic therapy is recommended

Table 1.1: Major bacterial foodborne diseases and clinical features (FDA, 2012; WHO, 2008a).

Organism	Illness	Incubation Period	Signs and Symptoms	Duration	Food Sources
Aeromonas hydrophila	*Aeromonas* enteritis	24–48 h	Dysentery-like symptoms, blood and mucus in the stool, abdominal cramps, mild fever, vomiting	Days to weeks	Seafood (fish, shrimp, oysters), snails, drinking water, meats (beef, pork, lamb, and poultry), certain vegetables, such as sprouts
Bacillus cereus	*B. cereus* gastroenteritis	10–16 h	Abdominal cramps, watery diarrhea, nausea, vomiting, and pain	24–48 h	Meats, stews, gravies, boiled or fried rice, spices, dried foods, milk, dairy products, vegetable dishes, fish and sauces, other starchy foods, potato, pasta, and cheese products; food mixtures; puddings, soups, casseroles, pastries, and salads
Brucella spp.	Brucellosis	3 weeks	Intermittent fever, lassitude, sweat, headache, chills, constipation, arthralgias, generalized aching, weight loss, anorexia, malaise, joint and muscle pain, arrhythmia, edema, or chest pain, meningoencephalitis, stiff neck, confusion or seizures, spondylitis, such as back pain	Weeks to months	Unpasteurized goat's or sheep's milk and products made from the milk of infected animals
Campylobacter jejuni	Campylobacteriosis	2–5 days	Bloody diarrhea, abdominal cramps, fever, vomiting, nausea, headache, and muscle pain	2–3 weeks	Raw and undercooked poultry, beef, pork, unpasteurized milk, contaminated drinking water, vegetables, and seafood
Clostridium botulinum	Botulism	12–36 h	Vomiting, abdominal pain, diarrhea, fatigue, blurred vision, double vision, muscle weakness, slurred speech, difficulty in swallowing, dry mouth, headache, dizziness, constipation	Weeks to months	Home-canned vegetables, fish and fish products, baked potatoes in aluminum foil, condiments (e.g., pepper), meat and meat products, green beans, soups, beets, asparagus, mushrooms, ripe olives, spinach, chicken and chicken livers, liver pâté
Clostridium perfringens	*Clostridium perfringens* enteritis	8–24 h	Abdominal cramps, watery diarrhea, rarely vomiting and fever	1–2 days	Meats, poultry, vegetables (spices and herbs), gravy, raw and processed foods, time- and/or temperature-abused foods

(*Continued*)

Table 1.1: Major bacterial foodborne diseases and clinical features (FDA, 2012; WHO, 2008a). (*cont.*)

Organism	Illness	Incubation Period	Signs and Symptoms	Duration	Food Sources
Coxiella burnetii	Q fever	2 weeks	Very high fever, severe headaches, muscle aches, chills, profuse sweating, nausea, vomiting, diarrhea, dry cough, abdominal cramps, chest pain	1–2 weeks	Contaminated unpasteurized milk or dairy products
E. coli	*E. coli* infection	1–6 days	Watery diarrhea, abdominal cramps, vomiting, high fever, nausea, malaise	Days to weeks	Water or food contaminated with human feces, raw or undercooked ground-meat products, raw milk from infected animals, vegetables
Enterobacter sakazakii	*Cronobacter* infection	Variable	Poor feeding response, irritability, jaundice, grunting respirations, instability of body temperature, seizures, brain abscess, hydrocephalus, developmental delay	2–8 weeks	Contaminated powdered infant formula, milk powders, cheese products, other dried foods
Francisella tularensis	Tularemia	3–6 days	Symptoms varying according to the type of tularemia from mild diarrhea to severe bowel damage, chills, fever, and headaches	Variable	Milk and undercooked meats from infected animals (particularly rabbits and hares)
Listeria monocytogenes	Listeriosis	Days to several weeks	Influenza-like symptoms, such as fever, headache and fever, muscle aches, stiff neck, confusion, loss of balance, convulsions, nausea, vomiting, diarrhea	Days to weeks	Unpasteurized and raw milk and products (soft cheeses), chocolate milk, ice cream, meat-based paste, hot dogs and deli meats, raw and smoked fish and other seafood, raw vegetables, coleslaw
Miscellaneous Enterobacteriaceae	Miscellaneous bacterial enteric	12–24 h	Acute gastroenteritis may include vomiting, nausea, fever, chills, abdominal pain, and watery diarrhea	Days to weeks	Dairy products, raw shellfish, raw vegetables
Mycobacterium bovis	Tuberculosis	Months to years	Fever, night sweats, fatigue, loss of appetite, weight loss, chronic cough, bloodstained sputum, chest pain, diarrhea, abdominal pain	Months to years	Raw and unpasteurized cow's milk and its products, raw or undercooked meats of infected animals
Plesiomonas shigelloides	*Plesiomonas shigelloides* enteric infection	20–50 h	Fever, chills, abdominal pain, nausea; watery, nonmucoid, nonbloody diarrhea; vomiting, dehydration	1–7 days	Contaminated water, raw shellfish, improperly cooked or raw foods, seafoods, such as crabs, fish, and oysters

Salmonella spp.	Salmonellosis	6–48 h	Diarrhea, fever, abdominal cramps, vomiting, nausea, headache	4–7 days	Raw eggs, poultry, meat, unpasteurized milk or juice, cheese, chocolate, contaminated raw fruits and vegetables, spices, salads
Salmonella typhi and *S. paratyphi*	Typhoid fever, paratyphoid fever	10–20 days	Nausea, high fever, abdominal pain, headache, rashes, loss of appetite	Several weeks to months	Prepared foods, dairy products, meat products, poultry, eggs, shellfish, shrimp; fruits and vegetables, such as tomatoes, peppers, and cantaloupes; chocolate, coconut, sauces
Shigella spp.	Shigellosis or bacillary dysentery	1–7 days	Abdominal cramps, fever, diarrhea, vomiting, pus or mucus in stools, tenesmus	5–7 days	Raw or uncooked foods, contaminated drinking water, mixed salads and vegetables, raw milk and dairy products
Staphylococcus aureus	*Staphylococcus aureus* intoxication	2–6 h	Severe nausea and vomiting, abdominal cramps, diarrhea and fever, prostration, dehydration, headache, muscle cramping, and transient changes in blood pressure and pulse rate	24–48 h	Unrefrigerated or improperly refrigerated meats and meat products, poultry and egg products; salads, such as egg, tuna, chicken, potato, and macaroni; milk and dairy products
Streptococcus spp.	*Streptococcus* spp. intoxication	1–3 days	Pain on swallowing, high fever, headache, nausea, vomiting, malaise, rhinorrhea	4 days	Milk (both pasteurized and unpasteurized), ice cream, cream, eggs, cooked seafood, salads, such as potato, egg, and shrimp; custard, rice pudding
Vibrio cholerae	Cholera	1–3 days	Profuse watery diarrhea, severe dehydration, abdominal pain and vomiting, with rice-water stools	Up to 7 days	Seafood, molluscan shellfish (oysters, mussels, and clams), crab, lobster, shrimp, squid, and finfish, vegetables
Vibrio parahaemolyticus	*Vibrio parahaemolyticus* gastroenteritis	4–90 h	Watery and/or bloody diarrhea, abdominal cramps, nausea, vomiting, fever	2–6 days	Undercooked or raw seafood, such as shellfish, raw or undercooked fish and fishery products, raw or improperly cooked oysters, other seafood products, including finfish, squid, octopus, lobster, shrimp, crab, and clams
Vibrio vulnificus	*Vibrio vulnificus* infection	12 h–21 days	Vomiting, diarrhea, abdominal pain, fever, bleeding within the skin, nausea, chills, pain in the extremities	Days to weeks	Undercooked or raw seafood, such as shellfish (especially raw oysters)
Yersinia enterocolitica	Yersiniosis	24–36 h	Abdominal pain, diarrhea, mild fever, sometimes vomiting	1–3 weeks	Raw milk and milk products, meats (pork, beef, lamb, etc.), oysters, fish, crabs

in suspected *B. cereus* infections while awaiting the antibiotic susceptibility testing profile. Vancomycin and broad-spectrum cephalosporins and ticarcillin-clavulanate should be choices for the empirical therapy of patients with suspected *B. cereus* infection (Bottone, 2010).

1.3 Botulism

Clostridium botulinum is a Gram-positive, spore-forming, anaerobic bacteria motile rod that produces potent neurotoxins. Seven types of toxins have been identified (A–G). F type has been associated with botulism. *C. botulinum* is responsible for four syndromes: foodborne botulism (due to ingestion of foods contaminated with toxin), infant botulism (intestinal infection, colonization, and toxin production), wound botulism (infection of a wound with *C. botulinum*), and adult intestinal toxemia botulism (intestinal colonization and toxin production in adults) (Sobel, 2005). Foodborne botulism is caused by ingestion of foods, such as vegetables, condiments, fish and fish products, and meat and meat products contaminated with *C. botulinum* toxin. Honey consumption is a common vehicle of transmission of infant botulism (Fratamico et al., 2005). Botulism occurs by accidental or intentional exposure to botulinum toxins. Vomiting, abdominal pain, fatigue, muscle weakness, headache, dizziness, visual disturbance, constipation, dry mouth, difficulty in swallowing and speaking, and ultimately paralysis and respiratory or heart failure occur in foodborne botulism. Toxins are potentially lethal in very small doses, binding to the neuromuscular junction, blocking acetylcholine transmission, and causing neuromuscular blockade and flaccid paralysis. Persons with clinically suspected botulism should be admitted to an intensive care setting, with frequent monitoring of vital capacity and institution of mechanical ventilation if required. Paralysis from botulism is protracted, lasting weeks to months, and meticulous intensive care is required during this period of debilitation. The administration of antitoxin is the only specific therapy available for botulism. Antitoxin can arrest the progression of paralysis and decrease the duration of paralysis and dependence on mechanical ventilation (Sobel, 2005).

1.4 Brucellosis

Brucellosis also known as undulant fever, Mediterranean fever, or Malta fever (Gul and Erdem, 2015). *Brucella abortus*, *B. melitensis*, and *B. suis* are the most common species that cause brucellosis in humans (Hossain et al., 2014). Characteristics of *Brucella* spp. are Gram-negative, aerobic, nonspore-forming, short, oval, nonmotile rods that grow optimally at 37°C and pH 6.6–7.4 and are heat-labile (Hui et al., 2001). Sources of *Brucella* spp. include common host species, especially cattle, sheep, goats, pigs, camels, yaks, buffaloes, and dogs, and consumption of raw or inadequately cooked milk or milk products, meat, and offal derived from these animals (WHO, 2006b). The clinical symptoms of brucellosis are nonspecific and include continuous, intermittent, or irregular fever, as well as lassitude, sweat, headache, chills, constipation, arthralgias, generalized aching, weight loss, and anorexia;

symptoms may persist for weeks or months. Osteoarticular problems are the most frequent complications of brucellosis, occurring in 20%–60% of cases; also, sacroiliitis, genitourinary complications (including orchitis, epididymitis, or sexual impotence), cardiovascular and neurological conditions, insomnia, and depression have been reported (Hui et al., 2001). Effective antibiotics can contribute to the treatment of human brucellosis. A variety of antimicrobial drugs have in vitro antimicrobial activity against *Brucella* spp.; however, the results of routine susceptibility tests do not always correlate with clinical efficacy. Tetracyclines (doxycycline), aminoglycosides (streptomycin, gentamicin), rifampicin, fluoroquinolones (nalidixic acid), trimethoprim-sulfamethoxazole, and cotrimoxazole have been used to treat brucellosis (WHO, 2006b).

1.5 Campylobacteriosis

Campylobacter jejuni and *C. coli* are the two predominant species that cause gastrointestinal infections in humans. *Campylobacter* is an enteric, Gram-negative, nonspore-forming bacterium often found in domestic and wild animals; livestock, such as pigs, cattle, sheep, and birds; and contaminated water. Human transmissions occur by the ingestion of contaminated meat and raw milk, and chickens and turkeys are also considered important vehicles for foodborne campylobacteriosis. Campylobacteriosis typically develops 2–5 days after exposure and is characterized by fever, severe abdominal pain, nausea, and watery and rarely bloody diarrhea. Campylobacteriosis is one of the most frequently reported foodborne diseases in industrialized countries, and is a cause of infant and traveler's diarrhea, hemolytic uremic syndrome, meningitis, pancreatitis, cholecystitis, colitis, endocarditis, erythema nodosum, and reactive arthritis occurring in approximately 2%–10% of cases. Infection is sometimes misdiagnosed as appendicitis. Campylobacteriosis is usually asymptomatic, and antibiotic treatment is often not required except for infants and children (Williams et al., 2015; WHO, 2008a).

1.6 Cholera

Vibrio cholerae is a Gram-negative aerobic organism. The bacterium can ferment sucrose and is often found in the environment. *V. cholerae* spp. are divided into four serogroups as O1, O139, non-O1, and non-O139 (Chowdhury et al., 2016). *V. cholerae* O1 and O139 can lead to severe dehydration as a consequence of profuse watery diarrhea. Salt and fluid replacement help prevent collapse and death. The other two serogroups, namely non-O1 and non-O139, are associated with cholera-like diarrhea. Cholera infections are generally observed due to ingestion of seafood, vegetables, cooked rice, and ice contaminated with *V. cholerae.* Person-to-person transmission through the fecal-oral route is also an important mode of transmission (Finkelstein, 1996). Antibiotics provide a beneficial complement to fluid replacement in cholera by substantially reducing the duration and volume of diarrhea and thereby lessening

fluid requirements and shortening the duration of hospitalization. Tetracycline and derivatives have been reported as effective agents in the treatment of cholera (Greenough et al., 1964). Erythromycin can use as an alternative antibiotic to tetracycline in young children and during pregnancy. Both single-dose azithromycin and ciprofloxacin have also been used for treating cholera in adults (Saha et al., 2006).

1.7 Clostridium perfringens–*Induced Necrotic Enteritis*

Clostridium perfringens is a Gram-positive, nonmotile, anaerobic, spore-forming bacterium (Wells and Wilkins, 1996). It can be found in many different environments but is most frequently found in the intestines of both sick and healthy animals (Lacey et al., 2016). The fecal-oral route of transmission is common, and other ways of transmission are contaminated feed, water, housing structures, and insects (Lee et al., 2011). *C. perfringens* causes several symptoms, including abdominal pain, diarrhea, rarely vomiting, fever, and a variety of diseases, such as gastrointestinal disorders, liver and kidney damage, dermatitis, and gas gangrene depending on the type of toxins produced by the microorganism (Lacey et al., 2016; WHO, 2008a). Morbidity is associated with these toxins. Food poisoning symptoms occur after ingestion of *C. perfringens*–contaminated foods (Omernik and Płusa, 2015). Subclinical necrotic enteritis infection is associated with decreased feed intake, which adversely affects growth rate, feed conversion, and flock uniformity; hepatitis; or cholangiohepatitis (Lee et al., 2011). In the absence of early radical surgery, antibiotic therapy, and (if available) hyperbaric treatment, the toxins can easily spread throughout the body, causing shock and coma and resulting in death. Epsilon-toxin produced by type B and D strains of *C. perfringens* is the third most potent clostridial toxin (Omernik and Płusa, 2015). Future studies that are focused on the immunobiology of host–pathogen interactions will contribute to novel control strategies against this disease, including second-generation recombinant vaccines, new delivery vectors, and novel adjuvants, as well as dietary immunomodulating agents, such as pre- or probiotics (Lee et al., 2011).

1.8 Enterobacter sakazakii *Infection*

Enterobacter sakazakii, recently reclassified as *Cronobacter*, is a Gram-negative, motile, rod-shaped, nonsporulating pathogenic bacterium that can cause foodborne illness, primarily among infants and immunocompromised adults. Newborn infants are at high risk due to *E. sakazakii* contamination of dried foods, such as powdered infant formula. Ingestion of contaminated food is the primary route of exposure. But *Cronobacter* does not survive in powdered milk that is pasteurized. *Cronobacter* has been detected in some foods, such as bread, cereal, rice, fruit, vegetables, legume products, herbs, spices, milk, cheese, sausage meat, teas, and fish (FDA, 2012; Hunter et al., 2008). Although the bacterium has also been found in a variety of other foods, only powdered infant formula has been linked to