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Omar A. Oyarzabal
Steffen Backert *Editors*

Microbial Food Safety

An Introduction

Springer

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ISSN 1572-0330
ISBN 978-1-4614-1176-5 e-ISBN 978-1-4614-1177-2
DOI 10.1007/978-1-4614-1177-2
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011941615

Preface

For many centuries humans have used empirical knowledge to cook and prepare foods, and although we have known for a long time about many different hazards inherent to food products, our understanding of infectious agents transmitted by foods did not materialize until the theory of germs was well established, approximately 150 years ago. Food hazards are classified as physical, chemical, and biological. By far, the biological hazards – primarily bacteria and viruses – pose the greatest risk in modern food safety. Like other infectious diseases, foodborne diseases repeat themselves, in part because we still do not fully understand their epidemiology to prevent their appearance, and in part because we do not always apply the acquired knowledge consistently. Therefore, there is always a need to revisit basic concepts to better understand food safety hazards. This book is intended to provide a review of the most prevalent biological hazards in the most common food categories.

In general, books related to food safety deal with a detailed description of known physical, chemical, and biological agents, emphasize the normative related to the presence of pathogens in foods, or review how these pathogens can be detected. More recently, some books have attempted to review our current knowledge of control strategies to reduce foodborne diseases. However, it appears that a general training tool for undergraduate and graduate students pursuing careers in food science, animal science, microbiology, and similar fields is still missing. Therefore, this book attempts to provide a study tool to advanced undergraduate and graduate students who need or wish to take a class on food safety. Nevertheless, any student with some basic knowledge in microbiology will find additional information related to different food safety topics in this book.

From the three major components that make up food safety – perception, regulations, and science – this book attempts to summarize the current scientific understanding of the most common biological hazards by food commodity. The book then provides an overview of the current regulations related to food safety in the United States. The first part includes a chapter that briefly describes our current understanding of the evolution of foodborne pathogens. The other chapters in this first part describe the basic microbiology concepts applied to food safety, the methodology used to identify microbial hazards transmitted by foods, the clinical presentations and pathogenicity of foodborne diseases, foodborne viruses, and the methodology used to type microbial pathogens for epidemiological studies. We have included a separate chapter for foodborne viruses because fewer scientists are working with viruses than are studying with bacterial agents. The methodologies that we have developed so far for viruses do not allow for an easy reproduction of viruses under laboratory conditions; thus, our studies of viruses depend heavily on molecular techniques. We have also added a chapter on molecular techniques for typing bacterial pathogens because these techniques provide unique tools to better understand the epidemiology of foodborne agents. We now know that strains from the same bacterial species have different pathogenicity potentials to humans. Therefore, as the methodologies for molecular studies become more simplified and available, we will be able to better understand the risk posed by certain bacterial strains in food commodities.

The second part of the book summarizes the major food commodities and the major biological hazards associated with these products. Several concepts may overlap in these chapters, such as the definition of certain bacterial pathogens. We believe that each of these chapters should be able to "stand alone"; if readers do skip some food commodity chapters, they will still get the basic concepts for the food commodities of interest.

The third part includes the chapters related to risk analysis, interventions, and regulations. Several books have already been written about interventions for those interested in this topic. Similarly, several books have recently emerged on the application of the risk analysis model to food safety. However, these two topics either are relatively new to food safety (risk assessment) or have undergone many different changes in the last few decades (interventions) to warrant some attention among food safety professionals. These areas of food safety are expanding rapidly, and as the world population will reach 10 billion in a few decades according to the United Nations's predictions, food safety and the control of food safety hazards will become increasingly important in the near future. The current regulations for food safety described in this area are all related to the United States and its federal agencies. Without food laws and guidelines addressing the presence of specific biological agents in food, little would be done to control these agents. As the international trade of food commodities becomes more complex, we will see more consolidation of food safety standards for an ever-expanding international market.

The last part of this book includes a list of other books and Internet resources related to food safety. Throughout the book, there is an assumption that the reader has a basic knowledge in microbiology, such as the way bacteria grow and multiply, the effect of temperature on the survival or destruction of bacteria, and the composition of viruses. For those interested in a more in-depth review of microbiology concepts, a list of microbiology books and Internet resources is also provided. It is important to highlight that many regulations and most of the documents generated by regulatory agencies in the United States are published mainly online. Therefore, the Internet can be a useful resource for food safety information. Throughout the book, there are italicized terms and words whose definitions are found in the Glossary.

We hope this book brings a new resource to undergraduate and graduate students, food professionals, biologists, and microbiologists interested in food safety. We also hope this book will expand the resources for those food safety professionals already working for the food industry, in academia, or in regulatory agencies. We welcome any feedback to improve future editions.

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Part I
Microorganisms and Food Contamination

Emerging and Reemerging Foodborne Pathogens

Omar A. Oyarzabal

1 Introduction

Emerging and "reemerging" pathogens are mainly zoonoses, and emerging foodborne diseases are not the exception. The interface between humans and food animals, the potential for new infectious diseases to emerge, and the adaptation of bacteria to infect humans by the species jump concept will be examined in this chapter. However, to understand how pathogens evolve and spread, it is important to remember that the microbiology events that happened in the last 200 years have consolidated our view of food as a source of microbial contamination and have helped us to recognize some of the events that result in the emergence of new pathogens, or the reemergence of known pathogens in food products. This chapter will focus mainly on bacterial foodborne pathogens and will review our current understanding of emerging foodborne pathogens.

2 Emerging and Reemerging Infectious Diseases

The term "emerging infectious diseases" is used to define those infections that newly appear in a population or have existed but are rapidly increasing in incidence or spreading in geographic range (Morse 1995). Emerging or reemerging *pathogens* appear because of a series of circumstances that favor their spread. In the case of foodborne pathogens, the factors that play an important role include those related to the pathogen itself, the environment, food production and distribution, and the consumers (Altekruse et al. 1997; Smith and Fratamico 2005). The World Health Organization (WHO) associates the appearance of foodborne diseases with factors that include changes in microorganisms, change in the human population and lifestyle, the globalization of the food supply, the inadvertent introduction of pathogens into new geographic areas, and exposure to unfamiliar foodborne hazards while abroad (Anonymous 2002).

There are approximately 1,415 species of microorganisms known to produce disease to humans. From this total, 60% of the species are *zoonotic* and the majority (72%) originates in wildlife. Approximately 175 pathogenic species are associated with diseases considered to be emerging, and approximately 54% of emerging infectious diseases are caused by bacteria or rickettsia (Tables 1 and 2).

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O.A. Oyarzabal and S. Backert (eds.), *Microbial Food Safety: An Introduction*, Food Science Text Series,
DOI 10.1007/978-1-4614-1177-2_1,

Table 1 Species of microorganisms known to be pathogenic to humans[a]

Category	Number of infectious organisms
Bacteria and rickettsia	538
Helminths	287
Viruses and prions	217
Protozoa	66
Fungi	30

[a]Adapted from Taylor et al. (2001)

Table 2 Examples of emerging infection diseases caused by bacteria and the probable factors explaining their appearance[a]

Infection or agent	Disease	Possible factors contributing to emergence
Haemophilus influenza (biotype aegyptius)	Brazilian purpuric fever	Probably new strain
Vibrio cholera	Cholera	Probably introduced from Asia to South America. Spread facilitated by reduced water chlorination
Helicobacter pylori	Gastric ulcers	Probably long widespread but just recently recognized
Escherichia coli O157:H7	Hemolytic-uremic syndrome	Mass food processing allowing point contamination of large amounts of meat
Legionella pneumophila	Legionnaires' disease	Cooling and plumbing systems
Borrelia burgdorferi	Lyme disease	Reforestation around homes and conditions favoring the expansion of deer (secondary reservoir host)
Streptococcus, group A	Necrotizing skin disease	Unclear

[a]Adapted from Morse (1995)

In general, zoonotic pathogens are more likely to be associated with emerging diseases than nonzoonotic pathogens, although there are variations among taxa, with protozoa and viruses more likely to emerge than helminthes. Presently, no association between the transmission route and the type of emerging infectious diseases has been found (Jones et al. 2008; Taylor et al. 2001). The U. S. National Institute of Allergies and Infectious Diseases has published a list of emerging and reemerging infectious agents; the different foodborne and waterborne pathogens are included in Category B. Within bacteria, this list includes *Escherichia coli* O157:H7, *Campylobacter jejuni*, *Listeria monocytogenes*, *Shigella* spp., *Salmonella* spp., and *Yersinia enterocolitica*. Several *protozoa* species (e.g., *Cryptosporidium parvum*, *Cyclospora cayatanensis*, *Giardia lamblia,* and *Entamoeba histolytica*) as well as viruses (Caliciviruses and Hepatitis A) also appear on the list. For instance, the *hemolytic-uremic syndrome* caused by certain strains of *E. coli* O157:H7 in the United States is an example of an emerging foodborne pathogen that was not reported prior to 1980. On the other hand, the increase in the number of human listeriosis cases in the 1980s was due to the concentration of food production that allowed for a known pathogen, *L. monocytogenes*, to disseminate in a novel way.

3 The Origin of Human Pathogens

It is important to remember that many species closely related to us, such as chimpanzees, have donated many zoonotic diseases. There are different reasons why an animal species that serves as host for a pathogen may become a source of contamination for humans. In the case of chimpanzees,

although they have few and infrequent encounters with humans, they may have donated several *zoonoses*. For example, molecular studies of hepatitis B viruses from chimpanzees and humans show that these viruses have a high phylogenetic relationship and therefore may have been donated from chimpanzees to humans. In addition, the emergence of agriculture and the domestication of livestock animals in the last 10,000 years have also favored the appearance of the major human infectious diseases (Wolfe et al. 2007). It has been theorized that in temperate regions of the world, these infectious diseases originated from animals and arrived at humans through what is defined as *species jumps*, which means that a pathogen that was originally confined to animal species evolved to infect humans. Figure 1 shows the proposed five stages in the evolutionary adaptation of a pathogen from being only an animal pathogen to becoming a pathogen that infects only humans (Wolfe et al. 2007). The second category depicted in this figure appears to be the right category in which most of the bacterial and viral foodborne pathogens would fall. Yet we have to recognize that our understanding of some of these diseases increases with time and that these disease agents and their host (humans) are evolving and, therefore, the degree of host–pathogen interaction is continuously in flux.

4 Modern Views of Disease Agents, Evolution, and Epidemiology

Until the 1670s, when Anton van Leeuwenhoek used high-quality lenses to observe living microorganisms (Black 1996), the prevalent theory was spontaneous generation, the idea that living organisms arise from nonliving molecules. The work of Ignaz Semmelweis, who demonstrated that the washing of hands could prevent the spread of childbirth fever; Louis Pasteur, who dismissed the theory of spontaneous generation and developed the *pasteurization* method to make milk safe, among other things; Joseph Lister, who combined the work by Semmelweis and Pasteur to develop and promote antiseptic surgery by the use of chemical compounds; and Robert Koch, who developed a series of postulates (*Koch's postulates*) to directly correlate a microorganism with a specific disease, consolidated the germ theory of disease (Rothman et al. 1995a, b, c).

These events happened in the last 150 years, and the germ theory of disease may be the most important contribution by the science of microbiology to medicine. This theory opened up the possibility for the treatment of diseases by antimicrobials. This theory is also the most important concept to explain biological hazards present in foods because the contamination of foods by pathogenic microorganisms is by far the most important hazard among the three hazard categories (physical, chemical, and biological).

At the same time, the theory of evolution by Charles Darwin provided the platform by which natural processes, including the reproduction, survival, and spread of bacteria, could be studied in an objective fashion. However, it has been within the last 50 years that our tools to study pathogenic microbes flourished to the point where we could interrogate different bacteria and the environment for clues on how these organisms spread and produce disease. Foodborne pathogens are not an exception when compared to other infectious disease agents. However, the systematic study of foodborne disease agents did not appear in a formalized curriculum until just 30–40 years ago.

Another important event that took place in England about 150 years ago allowed for scientists to think about disease agents as "transmissible" agents. When John Snow's request to close a water pump resulted in the control of a cholera outbreak in Soho, England, in 1854 (Porter 1997), the discipline that we now know as epidemiology started. This simple event appears almost an anecdote when compared to the complex epidemiological studies needed to understand modern foodborne outbreaks, in which just the simple association of a food product to a bacterial pathogen during an outbreak investigation becomes a real challenge. The variety of infectious agents