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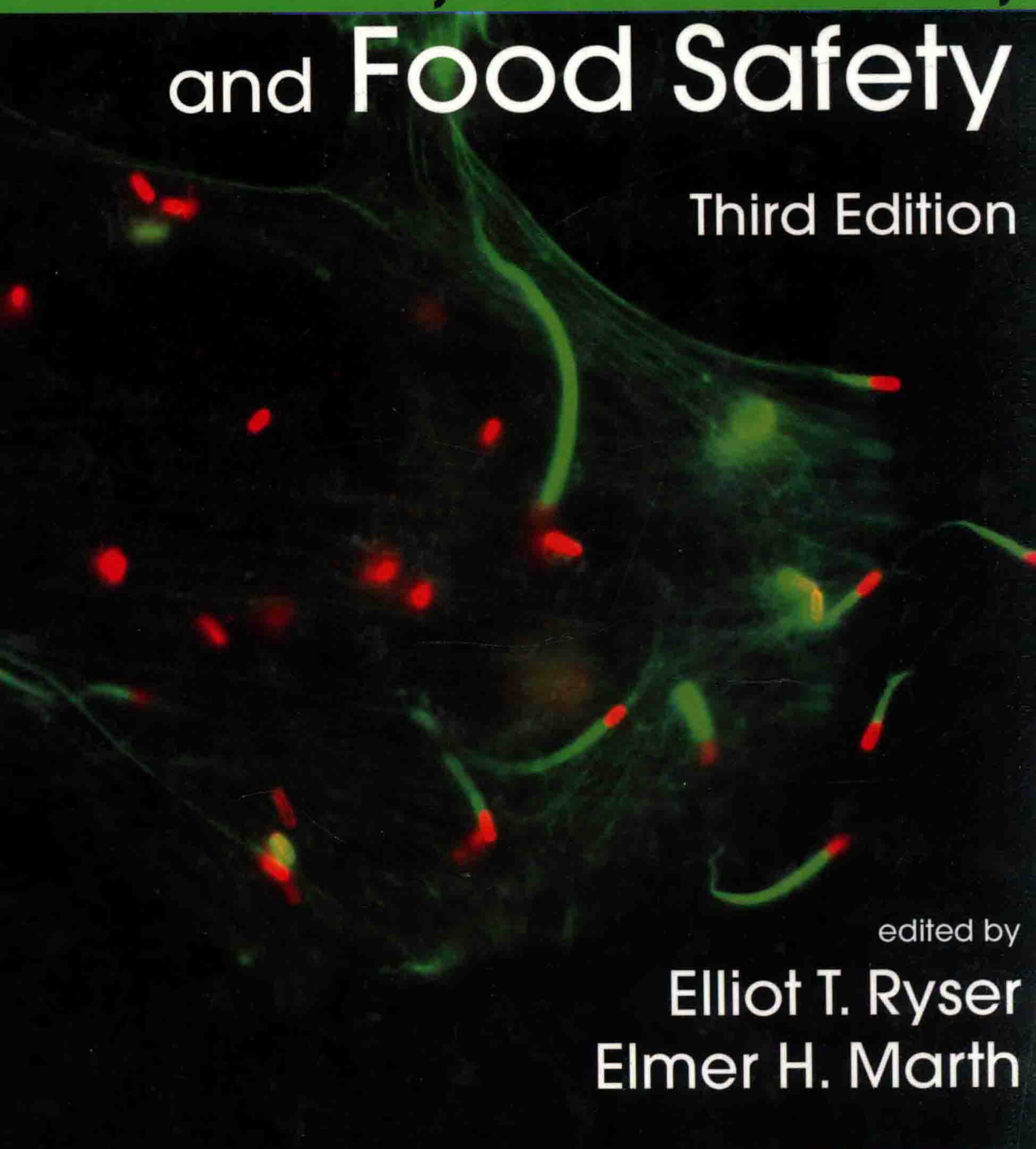
Listeria, Listeriosis, and Food Safety

Third Edition



edited by
Elliot T. Ryser
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Cover photo: An immunofluorescent image of *L. monocytogenes* (red) showing cell-to-cell spread via polymerized actin tails (green). Photo courtesy of Dr. Pascale Cossart, Institut Pasteur, Paris.

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Listeria, Listeriosis, and Food Safety

Third Edition

FOOD SCIENCE AND TECHNOLOGY

IN MEMORIAM

After conceiving the idea for a third edition of *Listeria, Listeriosis and Food Safety* in June 2002, Elmer Marth and I were in biweekly contact by phone to ensure continued progress toward its completion. This daunting project involved 33 contributors, 3 of whom in addition to myself (Robert E. Brackett, Jeffrey L. Kornacki, and Ahmed E. Yousef) earned their doctorates in the laboratory of Elmer Marth. As the book was rapidly nearing completion in Spring 2006, I was deeply saddened to learn that Elmer had become seriously ill. On June 19, 2006, Emeritus Professor Elmer H. Marth died in Madison, Wisconsin at age 78 while I was editing the chapter proofs for the book. Consequently, it is only fitting that the third edition of *Listeria, Listeriosis and Food Safety* be dedicated in memory of Dr. Elmer H. Marth who grew up on a small dairy farm in Grafton, Wisconsin to become one of the most preeminent dairy microbiologists of our time.

Elliot T. Ryser

Preface to the Third Edition

Since the second edition of *Listeria, Listeriosis and Food Safety* was published in 1999, the United States has seen a 40% decrease in the incidence of listeriosis, with the current annual rate of illness rapidly approaching the 2010 target of 2.5 cases per million population. This reduction in the rate of listeriosis would not have been possible without the combined effort of researchers, academicians, commodity organizations, and various regulatory authorities. We would like to believe that the first and second editions of our book also played a role in this outcome by providing needed information to concerned persons.

Despite considerable progress in understanding the sources, spread, control, and pathogenicity of *Listeria monocytogenes*, research on this foodborne pathogen has continued unabated, with more than 5,000 publications on *Listeria* and foodborne listeriosis appearing in the scientific literature since the second edition of this book was published. A portion of this work was fueled by a series of widely publicized outbreaks of listeriosis involving ready-to-eat meat products in the United States that began in the late 1990s. Over the last 5 years, increasing emphasis has been given to development of risk assessments that can be used to focus limited financial resources on certain high-risk foods, such as soft cheeses, ready-to-eat meats, and smoked fish, that support growth of the pathogen. Efforts ultimately have had an impact on public policies regarding allowable levels of *L. monocytogenes* in these and other foods.

The third edition of *Listeria, Listeriosis and Food Safety* again summarizes much of the newly published literature and integrates this information with earlier knowledge to present readers with a complete and current overview of foodborne listeriosis. The 17 chapters in the second edition have been retained; all are updated and expanded as appropriate. A total of 33 authors have lent their expertise to preparing this book, with new authors contributing to Chapters 1, 2, 4, 6, 7, 8, 10, 13, and 17. Sometimes these authors have collaborated with the original authors to develop the revised chapter. Two new chapters, Chapter 18 and Chapter 19, have been added to the book. Chapter 18 deals with risk assessment, cost of foodborne listeriosis outbreaks, and regulatory control of the *Listeria* problem in various countries. In Chapter 19, four experts point out specific data gaps and where, in their view, research efforts should be directed.

As was true for the earlier editions, this book will be useful to advanced undergraduate students in food science, microbiology, and public health; graduate students in these same disciplines; and practitioners in food or dairy microbiology, food or dairy science, bacteriology or microbiology, public health, epidemiology, risk assessment, meat science, animal science, and veterinary medicine. It will also be helpful to personnel in the food and dairy industries and the food service industry, and to researchers in industrial, governmental, and university laboratories.

Elliot T. Ryser

Elmer H. Marth

Preface to the Second Edition

Listeriosis and *Listeria monocytogenes* continue to be of worldwide interest to the food industry and regulatory agencies, scientists in various disciplines, and consumers of food. Such interest is prompted by the occasional appearance of *L. monocytogenes* in ready-to-eat foods, leading to the removal of these products from the marketplace. Furthermore, sporadic cases of listeriosis continue to occur and several food-associated outbreaks of the disease have occurred since the first edition of this book was published.

Scientists in several disciplines are still studying different aspects of the listeriosis problem. Their efforts have resulted in the development of much new information that has appeared in hundreds, if not thousands, of papers published since the first edition of this book was completed in 1990. This explosion of information warranted publication of a second edition.

The second edition differs markedly from the 1991 edition. Whereas we were the authors of the earlier edition, chapters in this edition have been prepared by various experts in the field. We now serve as editors, although one of us (ETR) has revised several chapters. The contributions of this edition's authors have resulted in an improved book that contains timely topics.

The chapters in the first edition have been retained; each has been revised and expanded with new information when appropriate. Two new chapters deal with typing methods and pathogenesis. Thus, this book contains 17 chapters addressing the following topics:

description of *L. monocytogenes*
occurrence and behavior of this pathogen in various natural environments
animal and human listeriosis
pathogenesis of *L. monocytogenes*
characteristics of *L. monocytogenes* important to food processors
conventional and rapid methods to isolate, detect, and identify *L. monocytogenes*
strain-specific typing of *L. monocytogenes*
foodborne listeriosis
incidence of behavior of *L. monocytogenes* in unfermented and fermented dairy products, meat, poultry (including eggs), fish and seafood, and products of plant origin
incidence and control of this pathogen within various types of food-processing facilities

This book will be useful to advanced undergraduate students, graduate students, and practitioners in food or dairy microbiology, food or dairy science, bacteriology or microbiology, public health, dietetics, meat science, poultry science, and veterinary medicine. It also will be helpful to personnel in the food and dairy industries and regulatory agencies, as well as researchers in industrial, governmental, and university laboratories.

Elliot T. Ryser

Elmer H. Marth

Preface to the First Edition

Interest in the occurrence of *Listeria* in food, particularly *Listeria monocytogenes*, escalated rapidly during the 1980s and continues unabated as a result of several major outbreaks of foodborne listeriosis. The first of these occurred during 1981 and involved consumption of contaminated coleslaw. In 1983, the reputation of the American dairy industry for producing safe products suffered when epidemiological evidence showed that 14 of 49 people in Massachusetts died after consuming pasteurized milk that was supposedly contaminated with *L. monocytogenes*. Two years later, consumption of contaminated Mexican-style cheese manufactured in California was directly linked to more than 142 cases of listeriosis, including at least 40 deaths.

Heightened public concern regarding the prevalence of *L. monocytogenes* in food prompted the United States Food and Drug Administration to initiate a series of *Listeria* surveillance programs. Subsequent discovery of this pathogen in many varieties of domestic and imported cheese, in ice cream, and in other dairy products prompted numerous product recalls, which in turn have led to staggering financial losses for the industry, including several lawsuits. These listeriosis outbreaks, together with a subsequent epidemic in Switzerland involving consumption of Vacherin Mont d'Or soft-ripened cheese and discovery of *L. monocytogenes* in raw and ready-to-eat meat, poultry, seafood, and vegetables, have underscored the need for additional information concerning foodborne listeriosis.

In 1961, Professor H. P. R. Seeliger, now retired from the University of Würzburg, published his time-honored book, *Listeriosis*. His monograph has provided scientists, veterinarians, and the medical profession with much needed information regarding *Listeria* and human and animal listeriosis, as well as pathological, bacteriological, and serological methods to diagnose this disease. However, documented cases of foodborne listeriosis were virtually unknown 30 years ago. Although much information in his book is still valid today, some of the knowledge regarding media and methods used to isolate, detect, and identify *L. monocytogenes* in clinical and, particularly, non-clinical specimens is now largely out of date.

The emergence of *L. monocytogenes* as a serious foodborne pathogen together with the virtual flood of *Listeria*-related papers that have appeared in scientific and trade journals as well as numerous conference proceedings, prompted us to review and summarize the current information so that food industry personnel, public health and regulatory officials, food microbiologists, veterinarians, and academicians have a ready source of information regarding this now fully emerged foodborne pathogen.

This book consists of 15 chapters that address the following topics:

L. monocytogenes as the causative agent of listeriosis
occurrence and survival of this pathogen in various natural environments
human and animal listeriosis
characteristics of *L. monocytogenes* important to food processors
conventional and rapid methods for isolating, detecting, and identifying *L. monocytogenes* in food
recognition of cases and outbreaks of foodborne listeriosis
incidence and behavior of *L. monocytogenes* in fermented and unfermented dairy products, meat, poultry (including eggs), seafood, and products of plant origin
incidence and control of this pathogen within various types of food-processing facilities

It is evident that major emphasis has been given to information directly applicable to food processors. Information concerning the bacterium and the disease has been admirably reviewed by Professor Seeliger and others, so our discussion of these topics should not be considered exhaustive. Thus, the first four chapters of this book supply only pertinent background information to complement our discussion of foodborne listeriosis.

Although many in the scientific community must be commended for the extraordinary progress made since 1985 toward understanding foodborne listeriosis, the continuing "explosion" of information concerning *Listeria* and foodborne listeriosis has made the 3-year task of compiling an up-to-date review of this subject quite difficult. Therefore, to produce as current a document as possible, we have included a bibliography of references that have appeared since the book was completed.

We acknowledge with gratitude the many investigators whose findings made this book necessary and possible. Special thanks go to individuals who shared unpublished information with us so that we could make the book as up to date as possible. Our thanks also go to the scientists who provided photographs or drawings; each person is acknowledged when the appropriate figure appears in the book. We thank Barbara Kamp, Pat Gustafson, Beverly Scullion, and Judy Grudzina for typing various parts of the manuscript. Illustrations were prepared by Jennifer Blitz and Suzanne Smith; their help is acknowledged and appreciated. Special thanks to Dr. Ralston B. Read, Jr., former director of the Microbiology Division of the Food and Drug Administration and now deceased, who in 1984 encouraged development of a research program on foodborne *Listeria* at the University of Wisconsin–Madison, and to Dr. Joseph A, O'Donnell, formerly with Dairy Research, Inc. and now director of the California Dairy Foods Research Center, for his early interest in and support of research on behavior of *L. monocytogenes* in dairy foods.

Research done in the Department of Food Science at the University of Wisconsin-Madison and described in this book was supported by the U.S. Food and Drug Administration; National Cheese Institute; the National Dairy Promotion and Research Board; the Wisconsin Milk Marketing Board; Kraft, Inc.; Carlin Foods; Chr. Hansen's Laboratory, Inc.; the Aristotelian University of Thessaloniki, Greece; the Cultural and Educational Bureau of the Egyptian Embassy in the United States; the Malaysian Agricultural Research and Development Institute; the Korean Professors Fund; and the College of Agricultural and Life Sciences, the Center for Dairy Research, and the Food Research Institute—all of the University of Wisconsin. We thank these agencies for their interest in and support of research on *L. monocytogenes*.

Our book is dedicated to all persons who have contributed to a better understanding of foodborne listeriosis so that control of this disease is facilitated.

Elliot T. Ryser

Elmer H. Marth

Editors

Elmer H. Marth, Ph.D., (1927–2006), a native of Jackson, Wisconsin, was emeritus professor of food science and bacteriology at the University of Wisconsin–Madison. He earned his B.S. (1950), M.S. (1952), and Ph.D. (1954) from the University of Wisconson–Madison in bacteriology with an emphasis on food and dairy bacteriology. After 3 years as instructor of bacteriology, he joined the R&D Division of Kraft Foods in Geneva, Illinois, in 1957. He rose through the ranks and in 1966 was named associate manager of the microbiology laboratory. Also in 1966, Dr. Marth returned to the University of Wisconsin–Madison as associate professor of food science with joint appointments in bacteriology and food microbiology and toxicology. He was promoted to professor in 1971 and, upon retirement in 1990, was named emeritus professor. In 1981, Dr. Marth was a visiting professor at the Swiss Federal Institute of Technology in Zürich. From 1967 to 1987, he was editor of the *Journal of Food Protection*.

At the University of Wisconsin–Madison, Dr. Marth taught courses in food sanitation, food fermentations, farm bacteriology, and writing scientific reports; he lectured in seven other courses and in five short courses. His research program included studies on food spoilage, food fermentation, and foodborne disease organisms, including *Listeria monocytogenes*. During his career, he was the author, co-author, editor, or co-editor of more than 660 scientific publications, including research papers, review papers, books, chapters in books, patents, and abstracts of papers given at meetings of professional organizations. Dr. Marth served as major professor for 32 students who received M.S. degrees and 32 students who earned Ph.D. degrees; in addition, he supervised 17 postdoctoral researchers who worked in his laboratory.

Dr. Marth was named a fellow of the Institute of Food Technologists (IFT) (1983), the International Association for Food Protection (IAFP) (1998), and the American Dairy Science Association (ADSA) (1998). He was also a member of the American Society for Microbiology and the Council of Science Editors. From the ADSA he received Pfizer (1975), Dairy Research Foundation (1980), Borden (1986), and Kraft Teaching (1988) awards. The IAFP honored him with Educator (1977), Citation (1984), Honorary Life Member (1987), and NFPA Food Safety (2000) awards. The IFT presented him with the Nicolas Appert (1987) and Babcock–Hart (1989) awards. In 2002, the Institute for Scientific Information designated Dr. Marth as a highly cited researcher, worldwide, in the agricultural sciences. The National Cheese Institute presented its highest honor, the Laureate Award, to Dr. Marth in 2004.

Elliot T. Ryser, Ph.D., a native of Milwaukee, Wisconsin, is an associate professor in the Department of Food Science and Human Nutrition and the National Food Safety and Toxicology Center at Michigan State University. He earned his B.S. (1979) in biology from Carroll College, Waukesha, Wisconsin, and his B.S. (1980) in bacteriology, and M.S. (1982) and Ph.D. (1990) in food science, from the University of Wisconsin–Madison, with an emphasis on microbial safety of food and dairy products. Following a 1-year appointment as a research scientist at Institute National de la Recherche Agronomique, Station de la Recherches Laitieres, Jouy-en-Josas, France, Dr. Ryser joined Silliker Laboratories Group, Inc. in Chicago Heights, Illinois, where he worked for 2 years as a research project manager. In 1994 he left Silliker and began his academic career as a research associate in the Department of Animal and Food Sciences at the University of Vermont, working in the laboratory of Dr. Catherine Donnelly. Dr. Ryser joined Michigan State University as an assistant professor in 1998 and was promoted to associate professor in 2004. He teaches courses on foodborne diseases, food safety, and HACCP.

Dr. Ryser's research program is focused on the incidence, survival, transfer, and eradication of *Listeria monocytogenes* and other foodborne pathogens from various foods, including dairy products. He has authored, co-authored, or co-edited more than 140 scientific publications, including research papers, review papers, books, chapters in books, patents, and abstracts of work presented at professional meetings. He has served thus far as the major professor for four Ph.D. and six M.S. students and supervised the work of four postdoctoral researchers. Dr. Ryser is a member of the International Association for Food Protection, Institute of Food Technologists, American Society for Microbiology, and American Dairy Science Association. He received the National Milk Producers Federation Richard M. Hoyt Award in 1988. In addition, he served as a scientific editor for the *Journal of Food Science* from 2000 to 2005 and is currently a scientific editor for the *Journal of Food Protection*.

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Contents

1 The Genus *Listeria* and *Listeria monocytogenes*: Phylogenetic Position, Taxonomy, and Identification

Jocelyn Rocourt and Carmen Buchrieser

CONTENTS

HISTORY

Murray, Webb, and Swann first published a description of *Listeria monocytogenes* in 1926 [112]. Several earlier reports may have described *Listeria* isolation [62,156]; the most plausible is certainly that by Hulphers [73]. However, the authors of these reports did not deposit their isolates in a permanent collection, so no subsequent investigations or comparisons with further strains were possible.

Murray and colleagues observed six cases of sudden death of young rabbits in 1924 in the animal breeding establishment of the Department of Pathology at Cambridge and many more in