



Food Additives

Second Edition
Revised and Expanded


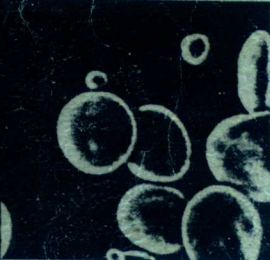
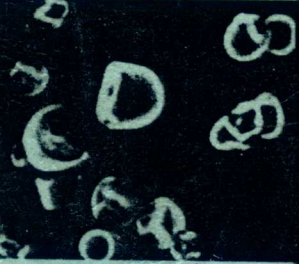
edited by

A. Larry Branen

P. Michael Davidson

Seppo Salminen

John H. Thorngate III



Food Additives

Second Edition
Revised and Expanded

edited by

A. Larry Branen
University of Idaho
Moscow, Idaho

P. Michael Davidson
University of Tennessee
Knoxville, Tennessee

Seppo Salminen
University of Turku
Turku, Finland, and
Royal Melbourne Institute of Technology
Melbourne, Australia

John H. Thorngate III
University of California
Davis, California



MARCEL DEKKER, INC.

NEW YORK • BASEL

The first edition was edited by A. Larry Branen, P. Michael Davidson, and Seppo Salminen.

ISBN: 0-8247-9343-9

This book is printed on acid-free paper.

Headquarters

Marcel Dekker, Inc.

270 Madison Avenue, New York, NY 10016

tel: 212-696-9000; fax: 212-685-4540

Eastern Hemisphere Distribution

Marcel Dekker AG

Hutgasse 4, Postfach 812, CH-4001 Basel, Switzerland

tel: 41-61-261-8482; fax: 41-61-261-8896

World Wide Web

<http://www.dekker.com>

The publisher offers discounts on this book when ordered in bulk quantities. For more information, write to Special Sales/Professional Marketing at the headquarters address above.

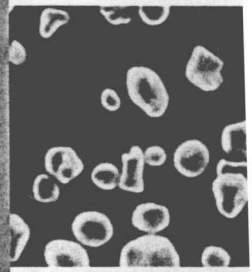
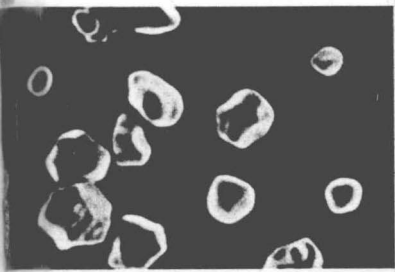
Copyright © 2002 by Marcel Dekker, Inc. All Rights Reserved.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage and retrieval system, without permission in writing from the publisher.

Current printing (last digit):

10 9 8 7 6 5 4 3 2 1

PRINTED IN THE UNITED STATES OF AMERICA



Food Additives

Second Edition
Revised and Expanded

edited by

A. Larry Branen

P. Michael Davidson

Seppo Salminen

John H. Thorngate III



Food Additives

John H. Harwig

University of Wisconsin

Salmon, Oregon

Mark Dreher

Portland, Oregon

University of Wisconsin

Salmon, Oregon

Portland, Oregon

1. 1999

2. 1999

3. 1999

FOOD SCIENCE AND TECHNOLOGY

A Series of Monographs, Textbooks, and Reference Books

EDITORIAL BOARD

Senior Editors

Owen R. Fennema University of Wisconsin–Madison

Marcus Karel Rutgers University (emeritus)

Gary W. Sanderson Universal Foods Corporation (retired)

Pieter Walstra Wageningen Agricultural University

John R. Whitaker University of California–Davis

Additives **P. Michael Davidson** University of Tennessee–Knoxville

Dairy science **James L. Steele** University of Wisconsin–Madison

Flavor chemistry and sensory analysis **John H. Thorngate III** University of California–Davis

Food engineering **Daryl B. Lund** University of Wisconsin–Madison

Health and disease **Seppo Salminen** University of Turku, Finland

Nutrition and nutraceuticals **Mark Dreher** Mead Johnson Nutritionals

Phase transition/food microstructure **Richard W. Hartel** University of Wisconsin–Madison

Processing and preservation **Gustavo V. Barbosa-Cánovas** Washington State University–Pullman

Safety and toxicology **Sanford Miller** University of Texas–Austin

1. Flavor Research: Principles and Techniques, *R. Teranishi, I. Hornstein, P. Isenberg, and E. L. Wick*
2. Principles of Enzymology for the Food Sciences, *John R. Whitaker*
3. Low-Temperature Preservation of Foods and Living Matter, *Owen R. Fennema, William D. Powrie, and Elmer H. Marth*
4. Principles of Food Science
Part I: Food Chemistry, *edited by Owen R. Fennema*
Part II: Physical Methods of Food Preservation, *Marcus Karel, Owen R. Fennema, and Daryl B. Lund*
5. Food Emulsions, *edited by Stig E. Friberg*
6. Nutritional and Safety Aspects of Food Processing, *edited by Steven R. Tanenbaum*
7. Flavor Research: Recent Advances, *edited by R. Teranishi, Robert A. Flath, and Hiroshi Sugisawa*
8. Computer-Aided Techniques in Food Technology, *edited by Israel Saguy*
9. Handbook of Tropical Foods, *edited by Harvey T. Chan*
10. Antimicrobials in Foods, *edited by Alfred Larry Branen and P. Michael Davidson*
11. Food Constituents and Food Residues: Their Chromatographic Determination, *edited by James F. Lawrence*
12. Aspartame: Physiology and Biochemistry, *edited by Lewis D. Stegink and L. J. Filer, Jr.*

13. Handbook of Vitamins: Nutritional, Biochemical, and Clinical Aspects, *edited by Lawrence J. Machlin*
14. Starch Conversion Technology, *edited by G. M. A. van Beynum and J. A. Roels*
15. Food Chemistry: Second Edition, Revised and Expanded, *edited by Owen R. Fennema*
16. Sensory Evaluation of Food: Statistical Methods and Procedures, *Michael O'Mahony*
17. Alternative Sweeteners, *edited by Lyn O'Brien Nabors and Robert C. Gelardi*
18. Citrus Fruits and Their Products: Analysis and Technology, *S. V. Ting and Russell L. Rouseff*
19. Engineering Properties of Foods, *edited by M. A. Rao and S. S. H. Rizvi*
20. Umami: A Basic Taste, *edited by Yojiro Kawamura and Morley R. Kare*
21. Food Biotechnology, *edited by Dietrich Knorr*
22. Food Texture: Instrumental and Sensory Measurement, *edited by Howard R. Moskowitz*
23. Seafoods and Fish Oils in Human Health and Disease, *John E. Kinsella*
24. Postharvest Physiology of Vegetables, *edited by J. Weichmann*
25. Handbook of Dietary Fiber: An Applied Approach, *Mark L. Dreher*
26. Food Toxicology, Parts A and B, *Jose M. Concon*
27. Modern Carbohydrate Chemistry, *Roger W. Binkley*
28. Trace Minerals in Foods, *edited by Kenneth T. Smith*
29. Protein Quality and the Effects of Processing, *edited by R. Dixon Phillips and John W. Finley*
30. Adulteration of Fruit Juice Beverages, *edited by Steven Nagy, John A. Attaway, and Martha E. Rhodes*
31. Foodborne Bacterial Pathogens, *edited by Michael P. Doyle*
32. Legumes: Chemistry, Technology, and Human Nutrition, *edited by Ruth H. Matthews*
33. Industrialization of Indigenous Fermented Foods, *edited by Keith H. Steinkraus*
34. International Food Regulation Handbook: Policy • Science • Law, *edited by Roger D. Middlekauff and Philippe Shubik*
35. Food Additives, *edited by A. Larry Branen, P. Michael Davidson, and Seppo Salminen*
36. Safety of Irradiated Foods, *J. F. Diehl*
37. Omega-3 Fatty Acids in Health and Disease, *edited by Robert S. Lees and Marcus Karel*
38. Food Emulsions: Second Edition, Revised and Expanded, *edited by Kåre Larsson and Stig E. Friberg*
39. Seafood: Effects of Technology on Nutrition, *George M. Pigott and Barbee W. Tucker*
40. Handbook of Vitamins: Second Edition, Revised and Expanded, *edited by Lawrence J. Machlin*
41. Handbook of Cereal Science and Technology, *Klaus J. Lorenz and Karel Kulp*
42. Food Processing Operations and Scale-Up, *Kenneth J. Valentas, Leon Levine, and J. Peter Clark*
43. Fish Quality Control by Computer Vision, *edited by L. F. Pau and R. Olafsson*
44. Volatile Compounds in Foods and Beverages, *edited by Henk Maarse*
45. Instrumental Methods for Quality Assurance in Foods, *edited by Daniel Y. C. Fung and Richard F. Matthews*
46. *Listeria*, Listeriosis, and Food Safety, *Elliot T. Ryser and Elmer H. Marth*
47. Acesulfame-K, *edited by D. G. Mayer and F. H. Kemper*
48. Alternative Sweeteners: Second Edition, Revised and Expanded, *edited by Lyn O'Brien Nabors and Robert C. Gelardi*
49. Food Extrusion Science and Technology, *edited by Jozef L. Kokini, Chi-Tang Ho, and Mukund V. Karwe*

50. Surimi Technology, *edited by Tyre C. Lanier and Chong M. Lee*
51. Handbook of Food Engineering, *edited by Dennis R. Heldman and Daryl B. Lund*
52. Food Analysis by HPLC, *edited by Leo M. L. Nollet*
53. Fatty Acids in Foods and Their Health Implications, *edited by Ching Kuang Chow*
54. *Clostridium botulinum*: Ecology and Control in Foods, *edited by Andreas H. W. Hauschild and Karen L. Dodds*
55. Cereals in Breadmaking: A Molecular Colloidal Approach, *Ann-Charlotte Eliasson and Kåre Larsson*
56. Low-Calorie Foods Handbook, *edited by Aaron M. Altschul*
57. Antimicrobials in Foods: Second Edition, Revised and Expanded, *edited by P. Michael Davidson and Alfred Larry Branen*
58. Lactic Acid Bacteria, *edited by Seppo Salminen and Atte von Wright*
59. Rice Science and Technology, *edited by Wayne E. Marshall and James I. Wadsworth*
60. Food Biosensor Analysis, *edited by Gabriele Wagner and George G. Guilbault*
61. Principles of Enzymology for the Food Sciences: Second Edition, *John R. Whitaker*
62. Carbohydrate Polyesters as Fat Substitutes, *edited by Casimir C. Akoh and Barry G. Swanson*
63. Engineering Properties of Foods: Second Edition, Revised and Expanded, *edited by M. A. Rao and S. S. H. Rizvi*
64. Handbook of Brewing, *edited by William A. Hardwick*
65. Analyzing Food for Nutrition Labeling and Hazardous Contaminants, *edited by Ike J. Jeon and William G. Ikins*
66. Ingredient Interactions: Effects on Food Quality, *edited by Anilkumar G. Gaonkar*
67. Food Polysaccharides and Their Applications, *edited by Alistair M. Stephen*
68. Safety of Irradiated Foods: Second Edition, Revised and Expanded, *J. F. Diehl*
69. Nutrition Labeling Handbook, *edited by Ralph Shapiro*
70. Handbook of Fruit Science and Technology: Production, Composition, Storage, and Processing, *edited by D. K. Salunkhe and S. S. Kadam*
71. Food Antioxidants: Technological, Toxicological, and Health Perspectives, *edited by D. L. Madhavi, S. S. Deshpande, and D. K. Salunkhe*
72. Freezing Effects on Food Quality, *edited by Lester E. Jeremiah*
73. Handbook of Indigenous Fermented Foods: Second Edition, Revised and Expanded, *edited by Keith H. Steinkraus*
74. Carbohydrates in Food, *edited by Ann-Charlotte Eliasson*
75. Baked Goods Freshness: Technology, Evaluation, and Inhibition of Staling, *edited by Ronald E. Hebda and Henry F. Zobel*
76. Food Chemistry: Third Edition, *edited by Owen R. Fennema*
77. Handbook of Food Analysis: Volumes 1 and 2, *edited by Leo M. L. Nollet*
78. Computerized Control Systems in the Food Industry, *edited by Gauri S. Mittal*
79. Techniques for Analyzing Food Aroma, *edited by Ray Marsili*
80. Food Proteins and Their Applications, *edited by Srinivasan Damodaran and Alain Paraf*
81. Food Emulsions: Third Edition, Revised and Expanded, *edited by Stig E. Friberg and Kåre Larsson*
82. Nonthermal Preservation of Foods, *Gustavo V. Barbosa-Cánovas, Usha R. Pothakamury, Enrique Palou, and Barry G. Swanson*
83. Milk and Dairy Product Technology, *Edgar Spreer*
84. Applied Dairy Microbiology, *edited by Elmer H. Marth and James L. Steele*
85. Lactic Acid Bacteria: Microbiology and Functional Aspects, Second Edition, Revised and Expanded, *edited by Seppo Salminen and Atte von Wright*

86. Handbook of Vegetable Science and Technology: Production, Composition, Storage, and Processing, *edited by D. K. Salunkhe and S. S. Kadam*
87. Polysaccharide Association Structures in Food, *edited by Reginald H. Walter*
88. Food Lipids: Chemistry, Nutrition, and Biotechnology, *edited by Casimir C. Akoh and David B. Min*
89. Spice Science and Technology, *Kenji Hirasa and Mitsuo Takemasa*
90. Dairy Technology: Principles of Milk Properties and Processes, *P. Walstra, T. J. Geurts, A. Noomen, A. Jellema, and M. A. J. S. van Boekel*
91. Coloring of Food, Drugs, and Cosmetics, *Gisbert Otterstätter*
92. *Listeria*, Listeriosis, and Food Safety: Second Edition, Revised and Expanded, *edited by Elliot T. Ryser and Elmer H. Marth*
93. Complex Carbohydrates in Foods, *edited by Susan Sungsoo Cho, Leon Prosky, and Mark Dreher*
94. Handbook of Food Preservation, *edited by M. Shafiur Rahman*
95. International Food Safety Handbook: Science, International Regulation, and Control, *edited by Kees van der Heijden, Maged Younes, Lawrence Fishbein, and Sanford Miller*
96. Fatty Acids in Foods and Their Health Implications: Second Edition, Revised and Expanded, *edited by Ching Kuang Chow*
97. Seafood Enzymes: Utilization and Influence on Postharvest Seafood Quality, *edited by Norman F. Haard and Benjamin K. Simpson*
98. Safe Handling of Foods, *edited by Jeffrey M. Farber and Ewen C. D. Todd*
99. Handbook of Cereal Science and Technology: Second Edition, Revised and Expanded, *edited by Karel Kulp and Joseph G. Ponte, Jr.*
100. Food Analysis by HPLC: Second Edition, Revised and Expanded, *edited by Leo M. L. Nollet*
101. Surimi and Surimi Seafood, *edited by Jae W. Park*
102. Drug Residues in Foods: Pharmacology, Food Safety, and Analysis, *Nickos A. Botsoglou and Dimitrios J. Fletouris*
103. Seafood and Freshwater Toxins: Pharmacology, Physiology, and Detection, *edited by Luis M. Botana*
104. Handbook of Nutrition and Diet, *Babasaheb B. Desai*
105. Nondestructive Food Evaluation: Techniques to Analyze Properties and Quality, *edited by Sundaram Gunasekaran*
106. Green Tea: Health Benefits and Applications, *Yukihiko Hara*
107. Food Processing Operations Modeling: Design and Analysis, *edited by Joseph Irudayaraj*
108. Wine Microbiology: Science and Technology, *Claudio Delfini and Joseph V. Formica*
109. Handbook of Microwave Technology for Food Applications, *edited by Ashim K. Datta and Ramaswamy C. Anantheswaran*
110. Applied Dairy Microbiology: Second Edition, Revised and Expanded, *edited by Elmer H. Marth and James L. Steele*
111. Transport Properties of Foods, *George D. Saravacos and Zacharias B. Maroulis*
112. Alternative Sweeteners: Third Edition, Revised and Expanded, *edited by Lyn O'Brien Nabors*
113. Handbook of Dietary Fiber, *edited by Susan Sungsoo Cho and Mark L. Dreher*
114. Control of Foodborne Microorganisms, *edited by Vijay K. Juneja and John N. Sofos*
115. Flavor, Fragrance, and Odor Analysis, *edited by Ray Marsili*
116. Food Additives: Second Edition, Revised and Expanded, *edited by Alfred Larry Branen, P. Michael Davidson, Seppo Salminen, and John H. Thorngate III*

Additional Volumes in Preparation

Characterization of Cereals and Flours: Properties, Analysis, and Applications,
edited by Gönül Kaletunç and Kenneth J. Breslauer

**Postharvest Physiology and Pathology of Vegetables: Second Edition, Revised
and Expanded, edited by Jerry A. Bartz and Jeffrey K. Brecht**

Preface to the Second Edition

In the Preface to the First Edition of *Food Additives*, we stated that food additives would “continue to play an important and essential role in food production” because of consumer demand and desire for “convenient, tasty, and nutritious foods” in an ever increasing populace. This prediction has been proven correct over the period since the first edition was published, and much has changed in food science, food safety, and food technology. Despite continued research on the toxicological effects of food additives on humans, few were restricted in the 1990s and several were actually approved for use.

In the 1990s, the food processing industry became much more global. As more processed foods were produced for export, the requirement for a working knowledge of world food additive regulations became paramount. This led to increased pressure for countries to adopt similar food additive regulations. *Codex Alimentarius* has become an important guide on food additives and a stepping-stone to improving world food marketing. Because foods are now shipped worldwide, there is a greater demand for maintenance of product quality attributes for extended periods. Food processors have had to utilize various food additives (in addition to other processing techniques, e.g., packaging) to achieve this extended shelf life. In 1990, rapid communication and information retrieval were still in their infancy. Today, the Internet as a means of communication and information retrieval concerning food additive regulations has become an important vehicle for exporters.

While there is continued pressure from consumers and consumer interest groups for the food industry to produce foods that are “preservative-free” or “additive-free,” food additives continue to play a major role in nutritional and sensory quality and safety of foods produced worldwide. In recent years, even food processors have been desirous of marketing foods with “green” labels (i.e., containing fewer additives). This has driven food processors to examine natural compounds as food additives.

When the first edition of *Food Additives* was published, terms such as probiotics, functional foods, nutraceuticals, and enteral nutrition products were essentially unknown. They are now commonplace, and food additives are playing a role in the production, maintenance, and safety of these products. Home meal replacement and refrigerated processed foods of extended durability (REPFED) have required the use of additives to maintain nutritional quality, sensory characteristics, and microbiological safety. Genetic engineering has played a role in food additives by making a few biologically derived compounds more available or less expensive. This area has great potential for growth.

In the 21st century, food additives continue to play an important role in the global food supply.

However, much still needs to be learned about existing food additives as well as potential novel food additives that exist in nature.

The original objective of *Food Additives* was to provide organized information on the various classes of intentional (i.e., added purposely for specific functions) food additives. The book included a general introduction and discussion of the chemistry and chemical analysis of the food additive class, the function and mechanism action, the application of the additive, and toxicological research and concerns. We accomplished that objective by soliciting chapters on all major groups of food additives, including antimicrobial agents, antioxidants, coloring agents, emulsifiers, enzymes, flavoring agents, flavor enhancers, miscellaneous additives, nutritional additives, pH control agents, polysaccharides, and sweeteners. Also presented in the first edition was ancillary information on food additives, including an overview along with chapters on food additive intake, hypersensitivity to additives, risks and benefits, and safety testing. The authors and editors of the first edition were selected from throughout the world to provide an international perspective. The editors wanted the book to be more than just a handbook for food additive applications. Rather, it was designed to be a treatise on these compounds that are so useful in our food supply.

In the second edition of *Food Additives*, we have striven to maintain that comprehensive approach to the subject. We again have solicited chapters on individual groups of food additives but have added several new chapters. The expanded offering includes the division of coloring agents into two chapters: synthetic food colorants (Chapter 16) and natural color additives (Chapter 17), and other new chapters on antibrowning agents (Chapter 19), commercial starches (Chapter 24), essential fatty acids (Chapter 10), fat substitutes and replacers (Chapter 11) and phosphates (Chapter 25). Another chapter (Chapter 12) discusses food additives for special dietary purposes such as in functional foods, engineering of clinical nutrition products, and probiotics.

Ancillary information has been significantly increased to reflect the interests of processors, consumer interest groups, and researchers in the many issues regarding food additives. In addition to updating the original discussions of intake assessment, risks and benefits, and hypersensitivity, several new chapters on these topics have been added. Consumer perception of food additives is discussed in Chapter 6. The role of food additives in behavior, learning, activity, and sleep of children is covered in Chapter 5. Two extremely useful chapters review food additive regulations in the European Union (Chapter 7) and the United States (Chapter 8). As in the first edition, the work is truly an international collaboration. Authors come from Europe, North America, Africa, Asia, and Australia, giving the book a global viewpoint.

In summary, we feel that the reader will see the second edition of *Food Additives* not just as an update but as an even more useful tool on the application and scientific study of food additives. It remains useful to those in universities, regulatory organizations, consumer interest groups, and food processing companies and their allied organizations. As was stated in the first edition preface, this book should provide a "basis for practical selection" of the appropriate additive for a particular food use, improve understanding of the risks and benefits of the many food additives used worldwide, aid in identification of additives requiring further research, and allow for understanding of the role of government in regulation of food additives.

Finally, we wish to express our sincerest gratitude to the chapter authors. Without their conscientious and diligent efforts, this work would not have been possible.

A. Larry Branen
P. Michael Davidson
Seppo Salminen
John H. Thorngate III

Preface to the First Edition

Food additives have been used for centuries to enhance the quality of food products. Smoke, alcohol, vinegar, oils, and spice were used more than 10,000 years ago to preserve foods. Until the time of the Industrial Revolution, these and a limited number of other chemicals were the major food additives used. The Industrial Revolution brought many changes to the food supply, including a better understanding of foods and a demand for both an increased quantity and quality. This resulted in the development of a variety of chemicals which were used to preserve, as well as enhance, the color, flavor, and texture of foods. The development of the land-grant university system in the late 1800s, and the subsequent interest in food chemistry and preservation, significantly increased the knowledge and use of food additives. With this increased technology, as well as the increased standards of living demanded by the population, additive usage in foods significantly increased in the 1950s. By the early 1960s, over 2500 different chemicals were being used in foods and in the United States the per capita consumption of these chemicals was estimated to exceed three pounds, excluding salt and sugar. The demand for new, tasty, convenient, and nutritious foods continued to increase from that time until today, and now in the United States alone, over 2500 different additives are being used to help produce over 15,000 different food items. The estimated consumption of such additives has increased from three to nine pounds per capita per year.

There has always been some concern regarding the safety of consuming the additives used in foods. Even in the early 1200s, it is reported that kings hired garglers to test the foods and several books were written in the early 1800s regarding food safety. The first real concern regarding additives, however, was expressed by Dr. Wiley when he was hired in the early 1900s as the Head of the Bureau of Chemistry of the U.S. Department of Agriculture. The work of Dr. Wiley and his so-called "poison squad" led to the first regulations to control the use of food additives. The 1906 Pure Food and Drug Act, which led to the 1938 development of the Federal Food, Drug, and Cosmetic Act, had a direct impact on additive use. Although this early legislation provided some control, implementation of these laws by the FDA was limited by the ambiguous legislative standard of "harmfulness," the fact that the burden of proof was on the FDA, and the lack of scientific knowledge of safety evaluation. Thus, the greatest legal impact on food additive use did not occur until the passage of the 1958 Food Additives Amendment. This amendment, which was followed by the 1960 Color Additives Amendment, remedied limitations of the earlier legislation by shifting the burden of proving safety to the manufacturer of the food and requiring premarketing safety data on all additives. The 1958 amendment also included the controversial "GRAS" list and Delaney Amendment, and utilized a more restrictive and less ambiguous terminology by shifting from "harmfulness" to "safety."

Passage of the 1958 legislation and increasing knowledge of toxicology in the 1960s and 1970s brought greater attention to the possible risks of additives. These concerns were enhanced by books such as Rachel Carson's *Silent Spring* and *The Chemical Feast* by James Turner. The increase of consumerism and the anti-establishment views of the 1970s led to a continuing controversy over additives among scientists, lawyers, consumer advocates, and policy makers. The legislation and controversy surrounding additives resulted in the banning of some chemicals as well as a lessened submission of new chemicals for approval. During the period from 1960 to 1980, very few chemicals were approved for use while several were banned.

A significant event in food additive safety review was the call for total review of the GRAS list by President Nixon in 1972. This review led to new regulations regarding several additives, but also led to an affirmation of the safety of several others. These studies and others provided a clearer understanding of both the risks and benefits of additives.

An event that called the greatest attention to the balance of risks and benefits of food additives was the U.S. Senate moratorium on the proposed ban of saccharin by the FDA. The moratorium was essentially the first political recognition of the importance of balancing the potential risks of an additive against its perceived benefits and allowing the customer the choice of balancing the benefits and the risks. The moratorium has continued for several years and has undoubtedly had a significant impact on the continued and proposed uses of additives.

Concern regarding the safety of additives has declined in the United States since enactment of the saccharin moratorium. This, plus a changing political trend away from consumerism and more responsible use of additives by manufacturers, has lessened the controversy regarding additives. The potential risks of additives are well recognized, but the benefits these additives play in food production, processing, and utilization are also felt to be essential to the maintenance of current food systems. With the convenient, tasty, and nutritious foods demanded, or at least desired, by consumers, and the increasing overall demand for foods as populations increase, food additives will continue to play an important and essential role in food production. There will, however, also be concern regarding the potential long-term risks associated with long-term consumption of small amounts of these chemicals and possible interactive toxicological effects. As methods improve for evaluating these toxicological effects, some additives may be banned. At the same time, this information may be used to develop safer new additives or techniques for using existing additives in a way that will lessen risk.

As we enter an age with the referendum to balance risks versus benefits, it is mandatory that a book detailing the most recent information regarding additives be made available. It is the intent of this book to provide the most up-to-date information available on a worldwide basis. Authors and the editors have been selected from throughout the world so as to bring an international perspective to this work. This is especially important since current regulations, additive use, and approaches to toxicological evaluation differ worldwide. We hope this work can serve to overcome the barriers that sometimes cause misunderstanding in the additive issue.

The book includes an overview of the use and consumption of food additives: a specific discussion of each of the major food additive categories; and information on the safety evaluation of food additives. The first two chapters provide an introduction to the food additives and current information on food additive intakes. In Chapters 3 through 14, specific information is provided on the major food additive categories. Each chapter contains a general introduction and discussion of the chemistry and chemical analysis, the function and mechanism of action, the uses and regulations governing use, and toxicological concerns of each additive category. The final three chapters provide a current view on the safety of food additive use. The first chapter in this section (Chapter 15) describes methods for safety evaluation. Hypersensitivity to additives is discussed in Chapter 16 and the final chapter provides a discussion on balancing risks and benefits of foods and food additives.

The book should be useful to those in universities, governmental organizations, consumer groups, and food companies. It should provide a basis for practical selection of additives for use in foods, for understanding the benefits and risks of the more than 2500 additives in use worldwide,

for selection of additives needing further study and research, and for understanding the role of governments in determining use of food additives. The reader is also referred to other major works on the risks and benefits of additives, including the *Handbook of Food Additives*, published several years ago by the Chemical Rubber Company.

A. Larry Branen
P. Michael Davidson
Seppo Salminen

Contributors

William E. Artz *University of Illinois, Urbana, Illinois*

A. Larry Branen *University of Idaho, Moscow, Idaho*

Jill K. Branen *University of Illinois, Urbana, Illinois*

Joan Breakey *Consulting Dietitian, Beachmere, Australia*

Christine M. Bruhn *Center for Consumer Research, Davis, California*

Helen Connell *Queensland Health, Spring Hill, Australia*

P. Michael Davidson *University of Tennessee, Knoxville, Tennessee*

Manik Desai *The Pennsylvania State University, University Park, Pennsylvania*

Stephanie Doores *The Pennsylvania State University, University Park, Pennsylvania*

Joseph D. Eifert *Nestle USA, Inc., Dublin, Ohio*

Pam Evenson *South Dakota State University, Brookings, South Dakota*

J. Bruce German *University of California, Davis, California*

John P. Godber *Albright & Wilson Canada, Ltd., Rhodia, Aubervilliers, France*

Robert J. Gordon *Givaudan Roure Inc., Dramptom, Ontario, Canada*

John M. V. Grigor *University of Lincolnshire and Humberside, Grimsby, England*

Tari Haahtela *Skin and Allergy Hospital and Helsinki University Hospital, Helsinki, Finland*

R. J. Haggerty *University of Idaho, Moscow, Idaho*

Anja Hallikainen *National Food Administration, Helsinki, Finland*

Matti Hannuksela *South Karelia Central Hospital, Lappeenranta, Finland*

Steven L. Hansen *Cargill Analytical Services, Minnetonka, Minnesota*

Kevin B. Hicks *Agricultural Research Service, U.S. Department of Agriculture, Wyndmoor, Pennsylvania*

Peter Barton Hutt *Covington & Burling, Washington, D.C.*

Wendy S. Johnson *SHS International Ltd., Liverpool, England*

Vijay K. Juneja *U.S. Department of Agriculture, Wyndmoor, Pennsylvania*

Hwee-Peng Khng *PSB Corporation Pte. Ltd., Singapore*

Arun Kilara *Arun Kilara Worldwide, Northbrook, Illinois*

David J. Kyle *Martek Biosciences Corporation, Columbia, Maryland*

Lucinda E. Lampila *Albright & Wilson Americas, Inc., Rhodia, Cranbury, New Jersey*

Yuan-Kun Lee *National University of Singapore, Singapore*

Thomas E. Luallen *Cargill, Cedar Rapids, Iowa*

Symon M. Mahungu *Egerton University, Njoro, Kenya*

Robert L. Miller *Agricultural Research Service, U.S. Department of Agriculture, Wyndmoor, Pennsylvania*

Conor Reilly *Oxford Brookes University, Oxford, England*

Seppo Salminen *University of Turku, Turku, Finland, and Royal Melbourne Institute of Technology, Melbourne, Australia*

Gerald M. Sapers *Agricultural Research Service, U.S. Department of Agriculture, Wyndmoor, Pennsylvania*

Gabriel S. Sinki *Sinki Flavor Technology, Little Falls, New Jersey*