

**HANDBOOK OF FOOD BIOENGINEERING**  
VOLUME 5

# MICROBIAL PRODUCTION OF FOOD INGREDIENTS AND ADDITIVES



Edited by  
Alina Maria Holban  
Alexandru Mihai Grumezescu





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## VOLUME 5

### MICROBIAL PRODUCTION OF FOOD INGREDIENTS AND ADDITIVES

Edited by

**Alina Maria Holban** and **Alexandru Mihai Grumezescu**

*Microbial Production of Food Ingredients and Additives*, a volume in the Handbook of Food Bioengineering series, aims to bring together the most recent approaches on the field of microbial production of food-related products and additives, focusing on current trends, actual concerns in the biotechnological field, and successful or very recent technologies. This volume introduces the reader in the amazing world of industrial microbiology and highlights the recent progress made in the field of microbial food industry. An overview regarding where we are situated in terms of microbial food synthesis and where we are heading to, can be also exploited within this book.

#### Key Features

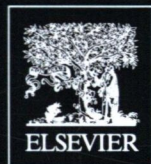
- Provides various research examples of how microbial production can improve food, empathizing on lactic acid bacteria
- Presents information on how microorganisms may be utilized to produce high quantity and quality therapeutic food ingredients used both for human and animal food
- Includes numerous applications to provide a broad perspective on the benefits of microbial production and how they are an alternative to chemical production and purification of ingredients

#### About the Editors

**Dr. Alina Maria Holban** holds a PhD in Biology and is Assistant Professor in Microbiology. She is conducting research in applied microbiology, molecular biology and nano-delivery at the Department of Microbiology and Immunology, Faculty of Biology, University of Bucharest. Her contribution on these research fields is supported by 71 international papers, 14 book chapters, 2 monographs, and 20 edited books. She also serves as Editor and Reviewer for several notable journals in the fields of nanobiomedicine and alternative antimicrobial strategies. Her current research focus is on the design of efficient antimicrobial and virulence-modulating nanoshuttles with implications in medicine, pharmacology, and food and beverage industry. Other details are available at <https://alina.amgtranscend.org/>.

**Dr. Alexandru Mihai Grumezescu** is Lecturer at the Department of Science and Engineering of Oxide Materials and Nanomaterials, in the Faculty of Applied Chemistry and Materials Science at the Politehnica University of Bucharest in Romania. He is an experienced and oft-published researcher and editor in the field of nano- and biostructures, and he is the Editor-in-Chief of four journals: *Biointerface Research in Applied Chemistry*, *Letters and Applied NanoBioScience*, *Biomaterials and Tissue Engineering Bulletin*, and *Journal of Food Bioengineering and Nanoprocessing*. He also serves as editor or guest editor for several notable journals. Dr. Grumezescu has published 170 peer-reviewed papers, 20 book chapters, 9 coauthored books, and 30 edited books. Other details are available at <http://grumezescu.com/>.

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Holiban  
Grumezescu



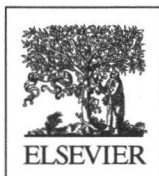
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# ***Microbial Production of Food Ingredients and Additives***

Handbook of Food Bioengineering,  
Volume 5

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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 amazing 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 for 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: Ingredient 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: Impacts of Nanoscience on the Food Industry

Volume 13: Food Quality: Balancing Health and Disease

Volume 14: Advances in Biotechnology in the 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 Material 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 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, *Ingredient 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 presented in volume 10. Highly debated topics in modern society: *Diet, Microbiome, and Health* are significantly discussed in volume 11. Volume 12 highlights the *Impacts of Nanoscience on 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 in the 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 Material 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 the 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 5: Microbial Production of Food Ingredients and Additives***

Microorganisms possess an impressive role in supporting life and ecology. These microscopic individuals may work as separate entities or multicellular specialized consortia, named biofilms, to produce numerous useful molecules. Their impact in natural processes and also current industry is so important, that life on Earth as we know it today is only possible due to the activities of microorganisms. Numerous industries have exploited the biochemical ability of microbes to synthesize, metabolize, and transform valuable substances. These properties of microorganisms support chemical industries, biotechnology, pharmaceutical industry, and nonetheless, food industry.

Most of the available food ingredients, food nutraceuticals, additives, colorants, and flavoring agents are produced by or with the help of microorganisms. Classical processes, which support current biotechnology and food industry, such as fermentation and enzyme production are exclusively based on microbial activities. They represent a resourceful source of food-related products and are responsible for many of the properties and taste of dairy products, which we daily consume.

The aim of this book was to bring together the most recent progress achieved in the field of microbial production of food-related products and additives, emphasizing the current progress, actual concerns in the biotechnological field, and success of very recent technologies. This volume introduces the reader in the amazing world of industrial microbiology and highlights the recent progress made in the field of microbial food industry. An overview regarding where we are situated in terms of microbial food synthesis and where we are heading to, can be also exploited within this book.

The volume contains 15 chapters prepared by outstanding authors from Brazil, USA, India, Spain, France, Mexico, Poland, Nigeria, Pakistan, and Turkey.

The selected manuscripts are clearly illustrated and contain accessible information for a wide audience, especially food scientists, engineers, biotechnologists, biochemists, industrial companies and also for any reader interested in learning about the most interesting and recent advances in the field of microbial production of food ingredients and additives.

Chapter 1, entitled *Microbial Production of Added-Value Ingredients: State of Art*, written by Lopes et al., describes relevant aspects of the microbial production of various ingredients, such as flavors, esters, and vitamins, and their enzymes used in food and pharmaceutical industries.

Chapter 2, *Phytase as a Diet Ingredient: From Microbial Production to Its Applications in Food and Feed Industry*, prepared by Coban and Demirci, provides an extensive review about microbial phytase production, characteristics of phytase, various phytase fermentation systems, as well as its application in food and feed industry.

In Chapter 3, *Current Trends and Future Prospective of Prebiotics as Therapeutic Food*, Biswal et al. debate the current trends and future prospects of prebiotics as therapeutic food, epitomizing cutting-edge research outcomes on prebiotic, novel sources, and their application in human health.

In Chapter 4, *Food Ingredients Synthesized by Lactic Acid Bacteria*, Zarour et al. give an overview regarding the current status of food products obtained with the help of lactic acid bacteria (LAB). The in situ production of vitamins, as well as the use of polyols synthesized by these bacteria as low-calorie sweeteners, is discussed. The dual roles of LAB exopolysaccharides to improve food texture and as component of functional food are also described, as is the contribution to the flavor of fermented food products by aroma compounds generated from citrate metabolism and amino acids catabolism by LAB. Finally, the use of LAB bacteriocins, synthesized in situ, or as additives, for food preservation is presented in this chapter.

In Chapter 5, *Microbial Diversity and Flavor Quality of Fermented Beverages*, De La Torre-González et al. revealed the main production processes and the organoleptic characteristics of the most widely consumed fermented beverages in the world, including wine and tequila, and the impact of microorganisms that are used as inoculants in the aroma and quality of these beverages.

Chapter 6, *Prebiotic and Synbiotic Foods*, written by Glibowski and Skrzypczak, discusses recent studies concerning the foods in which prebiotic substances, as well as probiotic bacteria were applied. There are many studies describing application of various prebiotics (i.e., galactooligosaccharides, soy oligosaccharides, xylooligosaccharides, pyrodextrins, isomaltooligosaccharides, or lactulose) but the most frequently investigated are fructans— inulin, fructooligosaccharides, and oligofructose. This chapter highlights that symbiotic food, which contain prebiotics and probiotics can be an alternative to traditional foods and this food can positively impact health and can prevent from severe diseases.

In Chapter 7, *Production, Use, and Prospects of Microbial Food Colorants*, Ogbodo and Ugwuanyi aim at exploring and discussing the current production protocols, as well as the prospects and challenges faced by the industry of colorants obtained through microbial activity.