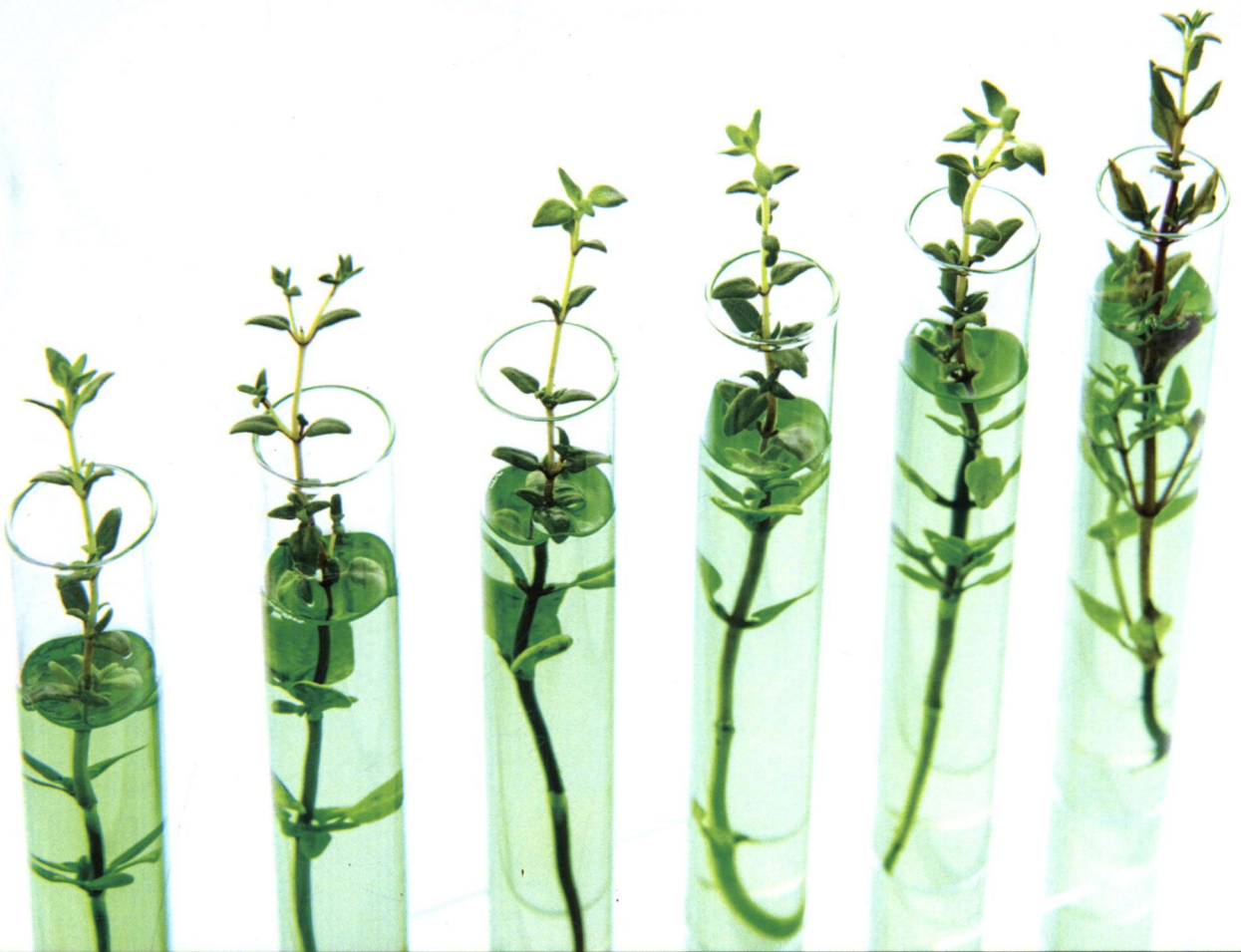


**HANDBOOK OF FOOD BIOENGINEERING**  
VOLUME 1

# FOOD BIOSYNTHESIS



Edited by  
Alexandru Mihai Grumezescu  
Alina Maria Holban





# HANDBOOK OF FOOD BIOENGINEERING

## VOLUME 1

# FOOD BIOSYNTHESIS

Edited by

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

*Food Biosynthesis*, a volume in the *Handbook of Food Bioengineering* series, aims to bring together the most recent progress in the field of food biosynthesis and processing, empathizing on current concerns and successful food biosynthetic technologies. This book reveals main biosynthesis routes, highlighting important advances made in microbial and plant biosynthesis and engineering for a better and green food industry. Also, aspects related to bioprocessing, bioproduction, and biotransformation of some products to obtain improved foods while reducing the production of chemical hazard are presented and discussed in the context of a sustainable industry.

### Key Features

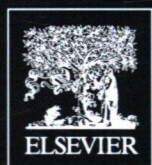
- Presents practical approaches of biosynthesis and the impact of biological origin on the field of food engineering
- Offers alternative applications to produce natural ingredients
- Includes processes and techniques to produce health-promoting foods
- Discusses the positive effects of microbial biosynthesis to enhance food safety
- Offers a variety of perspectives on biosynthesis to enable the production of future bioingredients

### About the Editors

**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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Food Engineering



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**HANDBOOK OF FOOD BIOENGINEERING**  
**FOOD BIOSYSTEMS**

Grumezeescu  
Holboan



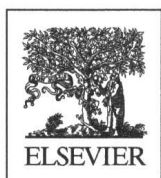
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# ***Food Biosynthesis***

Handbook of Food Bioengineering,  
Volume 1

Edited by

Alexandru Mihai Grumezescu  
Alina Maria Holban



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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: 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 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, *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 shown 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 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 1: Food Biosynthesis***

The production of food represents an intriguing domain, permanently changing and constantly posing new challenges as it becomes more versatile. The bio-, eco-, and raw-food industry is rapidly spreading across the globe and sustainable approaches in the design and production of “more natural” foods are a priority for food science. Biosynthesis is widely investigated to obtain novel and improved food ingredients that are preferred because of the green production, taste, and quality of their final food products. Moreover, biosynthesis has allowed for the production of novel food ingredients, with higher tolerabilities and nutritional values. However, the necessary time laps and costs for biosynthesis of food ingredients have usually increased, as compared to their chemical synthesis or replacements.

The aim of this volume is to bring together the most recent progress achieved in the field of food biosynthesis and processing, emphasizing the current concerns and successful food biosynthetic technologies. This volume reveals major biosynthesis routes, highlighting important advances made in microbial and plant biosynthesis and engineering for a better and greener food industry. Moreover, aspects related to bioprocessing, bioproduction, and biotransformation of some products in obtaining improved foods while reducing the production of chemical hazards are presented and discussed in the context of a sustainable industry.

The volume contains 15 chapters prepared by outstanding authors from Hungary, Portugal, Japan, India, Egypt, Iran, Brazil, USA, Mexico, and Australia.

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 food biosynthesis.

Chapter 1, entitled *Biocatalysis and Its Process Intensification in the Chemical Industry* prepared by Khan and Rathod, discusses applications and case studies of biobased synthesis in the chemical industry, with an emphasis on the food industry. Further, the authors talk about the advances in the food industry using new techniques, such as microwave- and ultrasound-related methods. The large-scale industrial production setup for enzymatic synthesis is also mentioned, with an overview of different reactor-based



systems, and the economic feasibility of enzymatic synthesis on an industrial scale and its safety aspects.

Chapter 2, *Microbial Biosynthesis: A Repertory of Vital Natural Products* prepared by Abdel-Aziz et al., discusses the many advantages of the green chemistry approach toward the synthesis of natural products by microorganisms, such as minimally processed, large-scale production, economic viability, and health safety. The chapter describes several bacterial bioactive metabolites with special features, such as their unique chemical structures and the interactions with the environment.

In Chapter 3, *Microbial Biosynthesis of Health-Promoting Food Ingredients*, Sorour et al. describe microorganisms as a treasure resource for novel healthy food ingredients and biologically active compounds due to their biodiversity and versatility. This chapter provides a recent and comprehensive overview of using bacteria, fungi, and yeasts to produce selected bioingredients, such as fructooligosaccharides, omega-3 polyunsaturated fatty acids, carotenoids, and flavonoids. Moreover, the potential use of low-cost materials as renewable feedstock that can be transformed into value-added products through microbial-catalyzed reactions is discussed, along with biosafety concerns and consumer potential risks, as a consequence of food supplementation with microbial bioingredients.

Hernández-Almanza et al. in Chapter 4, *Microbial Production of Bioactive Pigments, Oligosaccharides, and Peptides*, discuss the various microbial pathways related to the production of pigments, types and characterization, coloring properties, and their applications. This chapter emphasizes the microbial production of oligosaccharides and bioactive peptides, recent bioengineering aspects, chemical and physical characteristics, and industrial applications of such molecules.

Chapter 5, entitled *Bioprocessing of Plant-Derived Bioactive Phenolic Compounds* prepared by Holland et al., describes the bioprocessing and health and biotechnological applications of plant-derived polyphenolic compounds. The health-promoting bioactivities of plant-derived polyphenols and novel approaches for their incorporation into food products for human consumption are also discussed.

In Chapter 6, *A Review on the Impacts of Process Variables on Microbial Production of Carotenoid Pigments*, Massoud and Khosravi-Darani review different methods used for optimizing microbial cultures for increased production of carotenoids.

Fontana et al. in Chapter 7, *New Insights on Bacterial Cellulose*, describe some recent experiments aiming at blending bacterial cellulose with many other colored and tasteful bioactive food ingredients to further valorize its aspect, flavor, and taste. References to other nonfood applications of bacterial cellulose, such as the design of temporary skin substitute with wound healing, are also given.