

HANDBOOK OF FOOD BIOENGINEERING
VOLUME 2

FOOD BIOCONVERSION



Edited by
Alexandru Mihai Grumezescu
Alina Maria Holban



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Food Bioconversion, a volume in the Handbook of Food Bioengineering series, aims to integrate the most innovative and efficient biotechnological directions into a new concept regarding bioconversion of food products and waste. Types of major by-products and waste as well as their production processes and potential impact are largely dissected into this work, along with current bioconversion strategies. Also, the impact of the newly obtained products by utilizing processed food waste, on environment, health and economy is highlighted in this book. Biological methods for energy and material recovery and conversion are exemplified throughout the book, while pointing out novel methods, advantages, and current challenges.

Key Features

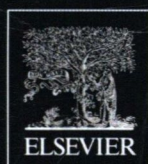
- Presents extraction techniques and biological properties of special ingredients to enhance food's functionality, that is, functional foods or nutraceuticals
- Provides detailed information on waste material recovery issues and compares different techniques to help advance research and develop new applications
- Includes research solutions of different biological treatments to produce foods with antibiotic and immunomodulatory properties, that is, probiotics, prebiotics, bacteriocins
- Explores how bioconversion technologies are essential for research outcomes to increase high-quality food production

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/>.

Dr. Alina Maria Holban holds a PhD in Biology and is an 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/>.

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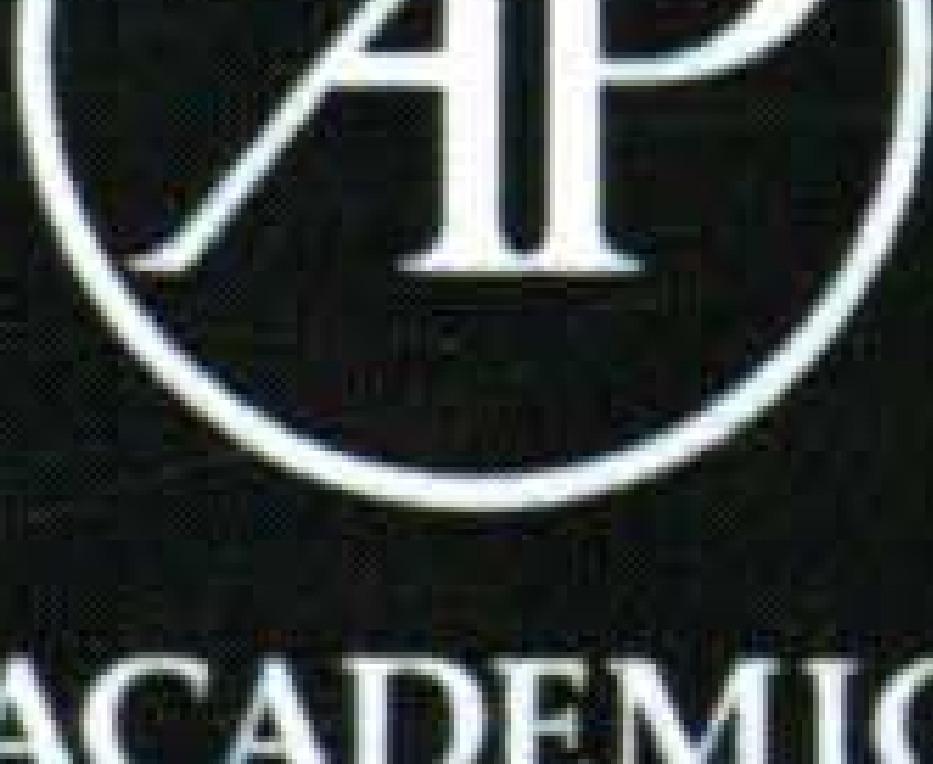
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VOLUME
2

HANDBOOK OF FOOD BIOENGINEERING

FOOD BIOENGINEERING
SCIENCE

Grumezescu
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Food Bioconversion

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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 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 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 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 2: Food Bioconversion

Modern society has caused the accumulation of immense amounts of waste and by-products. One of the main sectors responsible for such effects is the food industry. As the production sector rapidly advances because of the development of improved and innovative approaches to facilitate food design and ingredient extraction, the resulting unnecessary organic material itself represents a great industry.

In this context, bioconversion is a very productive and rapidly emerging concept, with great applications in the food industry, environmental science, and health. Bioconversion of food waste and food by-products could be widely diverse, when correlated with the innovative progress of technology in the food industry. Different instruments, methods, and completely new approaches have been developed to facilitate an efficient transformation of organic waste into a potential new resource.

This volume aims to integrate the most innovative and efficient biotechnological directions into a new concept regarding bioconversion of food products and waste. Types of major by-products and waste, as well as their production processes and potential impacts are examined in this work, along with current bioconversion strategies. The impact of the newly obtained products by utilizing processed food waste on the environment, health, and economy is highlighted. Biological methods for energy and material recovery and conversion are exemplified throughout the volume, while pointing out novel methods, advantages, and current challenges.

This volume contains 15 chapters prepared by outstanding authors from Italy, Brazil, Canada, Portugal, India, Bulgaria, Estonia, Mexico, Korea, Argentina, Spain, and South Africa.

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

Chapter 1, *Food Waste Utilization: Green Technologies for Manufacture of Valuable Products From Food Wastes and Agricultural Wastes* prepared by Narayanan et al., describes commercially adaptable, green technologies that have been successfully developed for the economical utilization of food wastes and agricultural wastes, such as

cheese whey and molasses. Valuable products (e.g., polymer-grade lactic acid and Xanthan gum) can be economically recovered from cheese whey and molasses using innovative biochemical processes and green technologies. In recent years, special emphasis has been given to mathematical modeling, simulation, and performance analysis of waste bioconversion bioreactors (e.g., biofilm-based reactors), leading to multiparameter software development.

In Chapter 2, entitled *The Importance of Microbial and Enzymatic Bioconversions of Isoflavones in Bioactive Compounds*, Lopes et al. discuss the biological activities related to the health benefits of isoflavones, highlighting that the clinical efficacy of these phenolic compounds is related to their bioconversion to flavonoid aglycones and, further, to an important bioactive metabolite called equol, which has greater biological effects than other isoflavones. In recent years interest has grown in applications to improve equol production; this chapter discusses the relevance of isoflavone bioconversion, production, and bioavailability, as well as clinical implications.

Chapter 3, *The Recovery of Energy and Materials from Food Waste by Codigestion with Sludge: Internal Environment of Digester and Methanogenic Pathway* written by Di Maria, reports the current status of knowledge about energy and material recovery from anaerobic codigestion of food waste and biowaste with sewage sludge, as well as the internal ecology of the digesters. Particular attention is paid to the implementation of this process in full-scale digesters of existing wastewater treatment plants.

Chapter 4, *Biotechnological Production of Conjugated Fatty Acids With Biological Properties* prepared by Freitas and coworkers, presents a comprehensive outlook of the biotechnological production of conjugated linoleic acid, as well as an extensive discussion of its technical issues, limitations, challenges, and potential food and nutraceutical applications based on nutritional value and biological properties.

Kalil et al. in Chapter 5, *Bioproduct Extraction From Microbial Cells by Conventional and Nonconventional Techniques*, review conventional and nonconventional techniques involved in the physicochemical production and bioconversion of bioproducts from fungi, bacteria, and microalgae, and describe their benefits and constraints. Modern techniques, such as supercritical fluid and ultrasound-assisted extraction, as well as emerging technologies, such as microwave-assisted extraction, pulsed electric fields, and organic solvent-free systems are discussed.

In Chapter 6, *Anticancer Action of Sulfated Flavonoids as Phase II Metabolites*, Sak focuses on sulfated flavonoid metabolites and their bioconversion, concentrating on their formation, structure, and different anticancer properties. It seems that the substitution of the important hydroxyl moieties by sulfate groups in a flavonoid backbone might lead to substantial alterations in biological activities of these phytochemicals.