

Contemporary Food  
Engineering Series

Da-Wen Sun, Series Editor



# Enhancing Extraction Processes in the Food Industry

EDITED BY

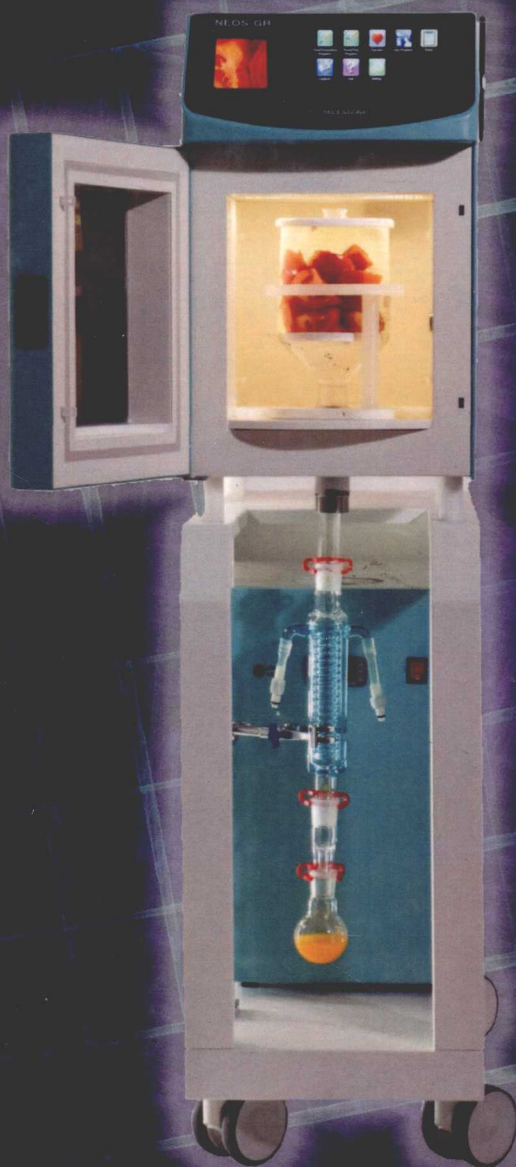
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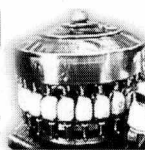


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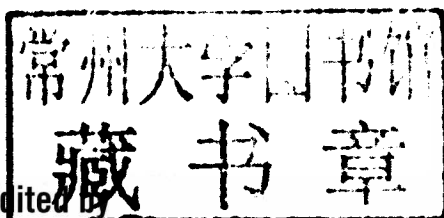


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**Nikolai Lebovka**  
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**Farid Chemat**



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# **Enhancing Extraction Processes in the Food Industry**

# Contemporary Food Engineering

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- Computational Fluid Dynamics in Food Processing, edited by Da-Wen Sun (2007)*

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# Series Preface

Food engineering is the multidisciplinary field of applied physical sciences combined with the knowledge of product properties. Food engineers provide the technological knowledge transfer essential to the cost-effective production and commercialization of food products and services. In particular, food engineers develop and design processes and equipment in order to convert raw agricultural materials and ingredients into safe, convenient, and nutritious consumer food products. However, food engineering topics are continuously undergoing changes to meet diverse consumer demands, and the subject is being rapidly developed to reflect market needs.

In the development of food engineering, one of the many challenges is to employ modern tools and knowledge, such as computational materials science and nanotechnology, to develop new products and processes. Simultaneously, improving quality, safety, and security remains a critical issue in the study of food engineering. New packaging materials and techniques are being developed to provide more protection to foods, and novel preservation technologies are emerging to enhance food security and defense. Additionally, process control and automation regularly appear among the top priorities identified in food engineering. Advanced monitoring and control systems are developed to facilitate automation and flexible food manufacturing. Furthermore, energy savings and minimization of environmental problems continue to be important issues in food engineering, and significant progress is being made in waste management, efficient utilization of energy, and reduction of effluents and emissions in food production.

The *Contemporary Food Engineering* book series, which consists of edited books, attempts to address some of the recent developments in food engineering. Advances in classical unit operations in engineering related to food manufacturing are covered as well as such topics as progress in the transport and storage of liquid and solid foods; heating, chilling, and freezing of foods; mass transfer in foods; chemical and biochemical aspects of food engineering and the use of kinetic analysis; dehydration, thermal processing, nonthermal processing, extrusion, liquid food concentration, membrane processes, and applications of membranes in food processing; shelf-life, electronic indicators in inventory management, and sustainable technologies in food processing; and packaging, cleaning, and sanitation. These books are aimed at professional food scientists, academics researching food engineering problems, and graduate-level students.

The editors of these books are leading engineers and scientists from all parts of the world. All of them were asked to present their books in such a manner as to address the market needs and pinpoint the cutting-edge technologies in food engineering. Furthermore, all contributions are written by internationally renowned experts who have both academic and professional credentials. All authors have attempted to provide critical, comprehensive, and readily accessible information on

the art and science of a relevant topic in each chapter, with reference lists for further information. Therefore, each book can serve as an essential reference source to students and researchers in universities and research institutions.

**Da-Wen Sun**  
*Series Editor*

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# Preface

Extraction has been used probably since the discovery of fire. Egyptians and Phoenicians, Jews and Arabs, Indians and Chinese, Greeks and Romans, and even Mayans and Aztecs all utilized innovative extraction and distillation for processing of perfumes or food. Nowadays, we cannot find a production line in the food industry that does not use extraction processes (e.g., maceration, solvent extraction, steam distillation or hydrodistillation, cold pressing, squeezing, etc.). With the increasing energy costs and the drive to reduce carbon dioxide emissions, food industries are under a challenge to find new technologies in order to reduce energy consumption, to meet legal requirements on emissions, product/process safety and control, and for cost reduction and increased quality as well as functionality. For example, existing extraction technologies have considerable technological and scientific bottlenecks to overcome, often requiring up to 50% of investments in a new plant and more than 70% of total process energy used in food industries. These shortcomings have led to the consideration of the use of enhanced extraction techniques, which typically require less solvent and energy, such as microwave extraction, supercritical fluid extraction, ultrasound extraction, flash distillation, and controlled pressure drop process.

Although there are a number of books that explain the innovative unit operations in food technology and describe how to conduct conventional extraction, there are few books that focus on understanding the actual instruments used in innovative and enhanced extraction. This book was prepared by a team of chemists, biochemists, chemical engineers, physicians, and food technologists who have extensive personal experience in the research of innovative extraction techniques at the laboratory and industrial scales. The book provides valuable information about the newly developed processes and methods for extraction.

The book comprises a preface, a contributors list, and 16 chapters, which take the reader through accessible descriptions of enhanced extraction techniques and their applications in food laboratory and industry. The book is addressed primarily to science graduate students, chemists, and biochemists in industry and food quality control, as well as researchers and persons who participate in continuing education and research systems.

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# Series Editor



Born in southern China, Professor Da-Wen Sun is a world authority in food engineering research and education; he is a member of the Royal Irish Academy, which is the highest academic honor. His main research activities include cooling, drying, and refrigeration processes and systems; quality and safety of food products; bioprocess simulation and optimization; and computer vision technology. His innovative studies on vacuum cooling of cooked meats, pizza quality inspection

by computer vision and edible films for shelf-life extension of fruits and vegetables have especially been widely reported in national and international media. The results of his work have especially been published in over 500 papers, including about 250 peer-reviewed journal papers. He has also edited 12 authoritative books. According to Thomson Scientific's Essential Science Indicator<sup>SM</sup>, updated as of July 1, 2010, based on data derived over a period of 10 years and 4 months (January 1, 2000, to April 30, 2010) from the ISI Web of Science, a total of 2,554 scientists are among the top 1% of the most frequently cited scientists in the category of Agricultural Sciences, and professor Sun tops the list with his ranking of 31.

Sun received his BSc honors (first class), his MSc in mechanical engineering, and his PhD in chemical engineering in China before working in various universities in Europe. He became the first Chinese national to be permanently employed in an Irish university when he was appointed as college lecturer at the National University of Ireland, Dublin (University College Dublin), in 1995, and was then continuously promoted in the shortest possible time to senior lecturer, associate professor, and full professor. He is currently the professor of food and biosystems engineering and the director of the Food Refrigeration and Computerized Food Technology Research Group at the University College Dublin (UCD).

Sun has contributed significantly to the field of food engineering as a leading educator in this field. He has trained many PhD students who have made their own contributions to the industry and academia. He has also regularly given lectures on advances in food engineering in international academic institutions and delivered keynote speeches at international conferences. As a recognized authority in food engineering, he has been conferred adjunct/visiting/consulting professorships from over 10 top universities in China, including Zhejiang University, Shanghai Jiaotong University, Harbin Institute of Technology, China Agricultural University, South China University of Technology, and Jiangnan University. In recognition of his significant contributions to food engineering worldwide and for his outstanding leadership in this field, the International Commission of Agricultural and Biosystems Engineering (CIGR) awarded him the CIGR Merit Award in 2000 and again in 2006. The Institution of Mechanical Engineers (IMechE) based in the United Kingdom named him Food Engineer of the Year in 2004. In 2008, he was awarded the CIGR Recognition Award in honor of his distinguished achievements in the top 1% of

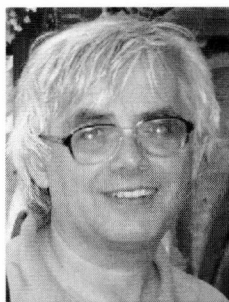
agricultural engineering scientists in the world. In 2007, he was presented with the AFST(I) Fellow Award by the Association of Food Scientists and Technologists (India), and in 2010 he was presented with the CIGR Fellow Award. The title of Fellow is the highest honor in CIGR and is conferred upon individuals who have made sustained, outstanding contributions worldwide.

Sun is a Fellow of the Institution of Agricultural Engineers and a Fellow of Engineers Ireland (the Institution of Engineers of Ireland). He has received numerous awards for teaching and research excellence, including the President's Research Fellowship and the President's Research Award of University College Dublin on two occasions. He is the editor-in-chief of *Food and Bioprocess Technology—An International Journal* (Springer) (2010 Impact Factor = 3.576, ranked at the 4th position among 126 food science and technology journals); the former editor of *Journal of Food Engineering* (Elsevier); and an editorial board member for *Journal of Food Engineering* (Elsevier), *Journal of Food Process Engineering* (Blackwell), *Sensing and Instrumentation for Food Quality and Safety* (Springer), and *Czech Journal of Food Sciences*. He is a chartered engineer.

On May 28, 2010, he was awarded membership of the Royal Irish Academy (RIA), which is the highest honor that can be attained by scholars and scientists working in Ireland, and at the 51st CIGR General Assembly held during the CIGR World Congress in Quebec City, Canada on June 13–17, 2010, he was elected incoming president of CIGR, and will become CIGR President in 2013–2014—the term of his CIGR presidency is six years, two years each for serving as incoming president, president, and past president.

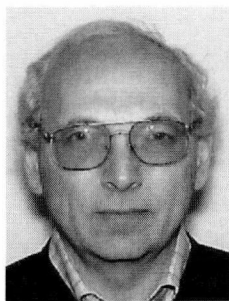
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# Editors



**Nikolai I. Lebovka** was born in Kiev, Ukraine, in 1954. He received his PhD in molecular physics from Taras Shevchenko National University of Kyiv (1986) and Dr. Habil in physics of colloids from the Biocolloid Chemistry Institute, Ukraine (1995). He is currently head of the Physical Chemistry Department of the Biocolloid Chemistry Institute and professor of physics at Taras Shevchenko National University of Kiev. He studies electric field-induced effects in biological and food materials and is also active in the fields of colloids and biocolloids, theory and applications of nanocomposites, computation physics, and theory and

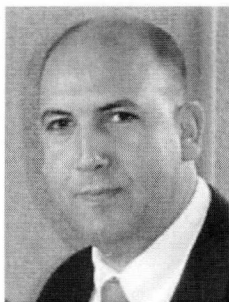
practice of percolation phenomena. He has published more than 230 papers in peer-reviewed journals and several chapters in books, and was a member of the organizing committee of several international conferences.



**Eugene Vorobiev** is a full professor at the Chemical Engineering Department and head of Laboratory for Agro-Industrial Technologies at the Université de Technologie de Compiègne (UTC), France. He received his PhD in Food Engineering (1980, Ukraine) and his Dr. Habil in Chemical Engineering (1997, France). His main research interests are focused on mass transfer phenomena, theory and practice of solid-liquid separation, and innovative food technologies (especially electrotechnologies). He has published more than 200 peer-reviewed papers and is the author of 18 patents.

He is a member of the editorial board of several journals

(*Separation and Purification Technology*, *Food Engineering Reviews*, *Filtration*) and president of the Scientific Council of IFTS ("Institut de la Filtration et des Techniques Séparatives"). He was awarded the Gold Medal of the Filtration Society (2001) and is a Laureate of the Price for the innovative technique for the environment (Ademe, 2008). He acted as a chairman of several international conferences.



**Farid Chemat** is a full professor of chemistry and director of the Laboratory for Green Extraction Techniques of Natural Products (GREEN) at the Université d'Avignon et des Pays de Vaucluse, France. Born in Blida (1968), he received his PhD (1994) in innovative process engineering from the Institut National Polytechnique de Toulouse. His main research interests are focused on innovative and sustainable extraction techniques (especially microwave, ultrasound, and green solvents) for food, pharmaceutical, and

cosmetic applications. His research activities are documented by more than 100 scientific peer-reviewed papers and 6 patents. He is coordinator of a new group named “France Eco-Extraction,” which deals with international dissemination of research and education on green extraction technologies.

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