Contemporary Food Engineering Series

Da-Wen Sun, Series Editor

High Pressure Processing of Fruit and Vegetable Products

Edited by

Milan Houška

Filipa Vinagre Marques da Silva

CRC Press

Taylor & Francis Group

High Pressure Processing of Fruit and Vegetable Products

Contemporary Food Engineering

Series Editor

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed on acid-free paper

International Standard Book Number-13: 978-1-4987-3902-3 (Hardback)

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Series Preface

CONTEMPORARY FOOD ENGINEERING

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 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, food quality improvement, safety, and security continue to be critical issues in food engineering studies. 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 processes. Furthermore, energy-saving and the minimization of environmental problems continue to be important food engineering issues, 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 Series*, consisting of edited books, attempts to address some of the recent developments in food engineering. The series covers advances in classical unit operations in engineering applied to food manufacturing as well as topics such 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 and electronic indicators in inventory management; 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 different parts of the world. All the editors were asked to present their books to address the market's needs and pinpoint cutting-edge technologies in food engineering.

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

Series Editor

Prof. Da-Wen Sun, born in southern China, is a global authority in food engineering research and education; he is a member of the Royal Irish Academy (RIA), which is the highest academic honor in Ireland; he is also a member of Academia Europaea (The Academy of Europe), one of the most prestigious academies in the world, a fellow of the International Academy of Food Science and Technology, and a fellow of International Academy of Agricultural and Biosystems Engineering. He is also the founder and editor-in-chief of *Food and Bioprocess Technology*, one of the most prestigious food science and technology journals; the series editor of "Contemporary Food Engineering" book series with already about 50 volumes published; and the founder and president of the International Academy of Agricultural and Biosystems Engineering (iAABE). In addition, he served as the president of the International Commission of Agricultural and Biosystems Engineering (CIGR), the world's largest organization in the field, in 2013–2014, where is now an honorary president. He has contributed significantly to the field of food engineering as a researcher, academic authority, and educator.

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/image processing and hyperspectral imaging technologies. His many scholarly works have become standard reference materials for researchers, especially in the areas of computer vision, computational fluid dynamics modeling, vacuum cooling, and related subjects. Results of his work have been published in over 800 papers including more than 400 peer-reviewed journal papers (Web of Science h-index = 79); among them, 31 papers have been selected by Thomson Reuters's Essential Science Indicators^{SM} as highly cited papers, ranking him no. 1 in the world in agricultural sciences (December 2015). He has also edited 14 authoritative books. According to Thomson Scientific's Essential Science Indicators^{SM}, based on data derived over a period of ten years from Web of Science, there are about 4,500 scientists who are among the top one percent of the most cited scientists in the category of Agriculture Sciences, and in the last few years, Professor Sun has consistently been ranked among the very top 10 scientists in the world (he was at the 9th position in January 2017), and has been named Highly Cited Researcher in 2015 and 2016 by Thomson Reuters.

He received a first-class BSc honors and MSc in mechanical engineering and a 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 college lecturer at the National University of Ireland, Dublin (University College Dublin, UCD), in 1995, and was then progressively promoted in the shortest possible time to senior lecturer, associate professor, and full professor. Dr. Sun is now a professor of food and biosystems engineering

and the director of the UCD Food Refrigeration and Computerized Food Technology Research Group.

As a leading educator in food engineering, Prof. Sun has trained many PhD students who have made their own contributions to the industry and academia. He has also frequently delivered lectures on advances in food engineering at academic institutions worldwide, and delivered keynote speeches at international conferences. As a recognized authority in food engineering, he has been conferred adjunct/visiting/consulting professorships from 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 contribution to food engineering worldwide and for his outstanding leadership in the field, the International Commission of Agricultural and Biosystems Engineering (CIGR) awarded him the "CIGR Merit Award" in 2000, and again in 2006, and the Institution of Mechanical Engineers based in the United Kingdom named him "Food Engineer of the Year 2004." In 2008, he was awarded the "CIGR Recognition Award" in honor of his distinguished achievements as one of the top 1% among agricultural engineering scientists in the world. In 2007, he was presented with the only "AFST(I) Fellow Award" given in that year 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 at CIGR and is conferred to individuals who have made sustained, outstanding contributions worldwide. In March 2013, he was presented with the "You Bring Charm to the World Award" by Hong Kong–based Phoenix Satellite Television with other award recipients including the 2012 Nobel Laureate in Literature, and the Chinese Astronaut Team for Shenzhou IX Spaceship. In July 2013, he received the "Frozen Food Foundation Freezing Research Award" from the International Association for Food Protection (IAFP) for his significant contributions to enhancing the field of food-freezing technologies. This is the first time that this prestigious award was presented to a scientist outside the United States. In June 2015 he was presented with the "IAEF Lifetime Achievement Award." This IAEF (International Association of Engineering and Food) award highlights the lifetime contribution of a prominent engineer in the field of food.

Editors

Dr. Milan Houska, born June 16, 1952 in Prague.

1971–1976: MSc degree in process engineering and design of chemical and food machinery
1980: PhD degree, thesis "Engineering Rheology of Thixotropic Fluids"
1980–1985: Scientific worker of Department of Physical Properties of Foods at Food Research Institute Prague (FRIP)
1985–1998: Head of Department of Physical Backgrounds of Food Processing, FRIP
1999–2015: Head of Department of Food Engineering, FRIP
2015–2017: Senior researcher
June 2017–now: Vice-director for research at FRIP

He earned his PhD degree after 3 years of studying at Department of Process Engineering at Faculty of Mechanical Engineering of the Czech Technical University in Prague. The title of the PhD thesis was "Engineering Rheology of Thixotropic Fluids." After finishing PhD studies, he started to work at FRIP at the Department of Physical Properties of Foods, where studies of texture and mechanical and thermal properties were conducted. After several years of the work in this department, he became a head of this department. After joining with the Department of Heat Processing of Foods, he started to be a leader of the joint departments with the title Department of Food Engineering.

Research activities

- Rheological and mechanical properties of foods
- Food properties database
- Modelling of thermal processes during production
- Distribution and retail and quantitative analysis of risk of growth and survival of pathogenic and spoilage microorganisms
- Food color (with coworkers)
- Influence of high pressure on foods
- Vacuum cooling of liquid and solid foods
- Enhanced speed thawing of foods

Main projects

- Coordinator of the project "Aseptic cooker AV-630."
- Coworker at the project "Aseptic filling machine ASP200/360."
- Coordinator of the previous project granted by the National Agency for Agricultural.
- Research "Development of equipment and research of influence of high pressure on nonthermal processing of foods," successfully finished in 1998.

- Coordinator of the project dealing with processing of foods that decrease the allergenic activities of apple, carrot, and celery juices.
- Coordinator of the project dealing with physical methods of treatment of wine grapes to contain more resveratrol content (UV treatment, ozonized water treatment, and storage).
- He is an active editor of the *Journal of Food Engineering*, Elsevier.

Dr. Filipa Vinagre Marques da Silva's research activity and interests are in Food Process Engineering, in particular studying the effects of new food preservation technologies such as high-pressure processing, on food safety and shelf-life, and the design of proper pasteurization processes. Her expertise in microbiology and enzymes are helpful for studying the effect of emerging food pasteurization technologies on food spoilage microbes/enzymes. The production of plant extracts and the determination of their biological activity such as antibacterial, antifungal, and insecticidal activities, is another area of research.

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1 Introduction to High-Pressure Processing of Fruit and Vegetable Products

Milan Houska and Filipa Vinagre Marques da Silva

High-pressure processing (HPP) is a cold pasteurization technology by which products, already sealed in their final package, are introduced to a vessel and subjected to a high level of isostatic pressure (300–600 MPa). As pressure is commonly transmitted by the water contained inside the HPP chamber, the technology is also referred to as high hydrostatic pressure. Both commercial HPP units with high capacity and several food products, namely of fruit origin, are marketed successfully around the world. Chapter 5 is devoted to industrial equipment available whereas Chapter 10 deals with examples of commercial fruit and vegetable products. Chapter 4 is dedicated to packaging, as prior packaging of food before HPP is mandatory in this technology.

High-pressure treatment of fruit and vegetable products opens the gate to nearly fresh products as regards the sensorial and nutritional quality of original raw materials. It has a great commercial importance and it enables consumers to find a relatively stable and safe source of nutrients, vitamins, minerals, and health effective components. Such components can play an important role as a preventive tool against the start of illnesses, namely in the elderly. It is well known that a preventive health effective diet is cheaper than "solving the consequences" by pharmaceuticals. Many fruits and vegetables are eaten raw and thus present a higher content of vitamins and other thermolabile constituents as opposed to foods that are cooked before consumption. The conventional thermal pasteurization/sterilization applied to fruit and vegetable juices not only decreases the "fresh notes" of the raw fruits/vegetables, but also generates new "cooked notes" flavors (Silva et al., 2000), often undesirable. In addition, the fruit and vegetable color, antioxidant properties, and other quality parameters can also be negatively affected by thermal treatments, as opposed to HPP (Patras et al., 2009; Silva et al., 1999; Sulaiman et al., 2017). Thus, the HPP technology allows nonthermal pasteurization of fruit juices and other beverages, namely sodas and alcoholic (e.g., beer and wine), better retaining its original organoleptic and nutritive properties (Milani and Silva, 2016) with extended shelf-life and possibly with fewer/no chemical preservatives (van Wyk and Silva, 2017). The effects of HPP technology on the quality of fruit and vegetable products, namely

nutrients and stability, health active components, and sensory aspects, were reviewed in Chapters 6 through 8.

The regulatory aspects for high-pressure treated fruit and vegetable products in different regions of the world (Europe, the United States, Asia, and Australia) are also an important topic dealt with in Chapter 3 of the book. Effects of HPP and HPP + heat on key spoilage/pathogenic microorganisms including the resistant spore form and fruit/vegetable endogenous enzymes were covered in detail in Chapters 2 and 3. Chapter 9 of this book deals with heat-assisted HPP and its effect on quality.

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2 High-Pressure Processing Effect on Microorganisms in Fruit and Vegetable Products

Filipa Vinagre Marques da Silva and Evelyn

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