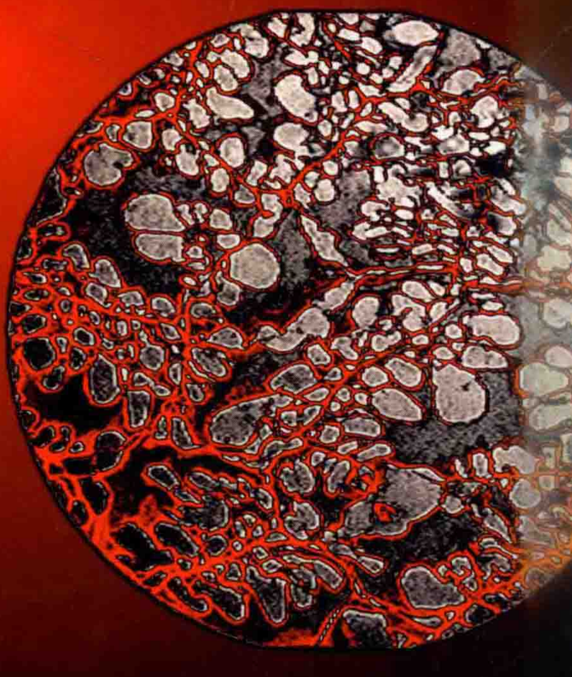
Electro-Technologies for Food Processing Series

Novel Food Processing

Effects on Rheological and Functional Properties



Edited by
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Novel Food Processing

Effects on Rheological and Functional Properties

Electro-Technologies for Food Processing Series

Series Editor

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Novel Food Processing : Effects on Rheological and Functional Properties, *edited by Jasim Ahmed, Hosahalli S. Ramaswamy, Stefan Kasapis, and Joyce I. Boye*

Series Preface

Novel Food Processing: Effects on Rheological and Functional Properties, edited by Jasim Ahmed, Hosahalli S. Ramaswamy, Stefan Kasapis, and Joyce I. Boye, is the first issue under the general umbrella of edited books in the Electro-Technologies for Food Processing Book Series involving the application of electro-technologies for various aspects of food processing, from pasteurization to sterilization, food preparation to food formulations, shelf-life extension to promoting food safety, food spoilage control to enhancing safety of foods, and from alternate to novel sources of the use of energy. Electromagnetic technologies offer unlimited potential to processing applications in foods. Industrially, electro-technologies provide unique opportunities and advantages not necessarily found in other techniques. The book series will look at each of them in detail, especially from the point of view of various industrial food processing applications. Each book in this series is expected to be devoted to a specific area of electro-technology, covering all aspects of its science and engineering, chemistry and physics, biochemistry and nutrition, quality and safety, and development and technology, both basic and applied.

Notable among the novel approaches in heating and food processing techniques are microwave and radio-frequency heating, electrical resistance or ohmic heating, induction, and infrared heating applications. Use of pulsed electric fields, high-frequency magnetic fields, electric shockwaves, pulsed light, UV radiation, and ionizing irradiation offer potential nonthermal alternatives to food processing. On a different note, these also include such separation techniques as ultrasonics, electroacoustic dewatering techniques, electrodialysis, and ion-exchange systems. Stretching it further, one can look at other electromagnetic applications in spectroscopy, near infrared (NIR), Fourier transform infrared (FTIR), and nuclear magnetic resonance (NMR) techniques finding their way into analytical and imaging concepts.

This book is special in that, rather than focusing entirely on one technology, it is focused on the rheology and functionality associated with all novel methods. The leading editor, Jasim Ahmed, has done a wonderful job of bringing together contributions from global experts focusing uniquely on structure, microstructure, rheology, and functionality issues related to the various advanced technologies. This volume has been designed to be a valuable tool to graduate students and researchers as a source of scientific information and is a useful addition to any library devoted to life sciences.

Hosahalli S. Ramaswamy
Book Series Editor

Preface

Food processing is gradually moving in a new direction, incorporating technologies from other fields and at the same time taking into account consumers' concerns about food safety, quality, and sensory attributes. The main reason for writing this book at the present time is to make available the wealth of knowledge becoming available on novel processing and its effects on food products. The concept was initiated by the leading editor (Jasim Ahmed), who intended to publish a book on the rheological characteristics of food proteins as affected by novel processing. After discussions with the second editor (Hosahalli S. Ramaswamy) and considering feedback from reviewers of the original book, it was proposed to the publisher to broaden the concept to rheology and functionality of foods. Meanwhile, the complementary expertise of the other two editors (Stefan Kasapis and Joyce I. Boye) and their meticulous input enabled the successful handling of the project.

The chapters in this book are authored by international peers who have both academic and professional credentials. The book illustrates in a very clear and concise fashion the structure–property relationship. It is intended for scientists; technologists/engineers working in the area of food processing, process equipment design, and product development; and students of food science, technology, nutrition, health science, and engineering.

The editors thank all of the contributors and, in many cases, their students and spouses for their dedicated efforts in the production of this book. We express our appreciation to our spouses and children for their understanding and encouragement during the preparation, editing of manuscripts, and constructive discussions. The leading editor (Jasim Ahmed) gratefully acknowledges the support of Dr. Sunil K. Varshney, Director of Polymer Source Inc., in the many tasks involved in editing a book in a highly demanding industrial environment. Special thanks are due to Steve Zollo of Taylor & Francis for his constant encouragement and excellent communication.

Jasim Ahmed
Hosahalli S. Ramaswamy
Stefan Kasapis
Joyce I. Boye

Editors

Dr. Jasim Ahmed has been associated with food processing teaching, research, and industry for the last 16 years in India, the Middle East, and Canada. He has both bachelor's and master's degrees in food and biochemical engineering and a PhD in food technology. He has published more than 80 peer-reviewed research papers, 15 industry-oriented technical papers, and 11 book chapters. He has served as special editor for three peer-reviewed international journals and is currently serving as one of the editors of the *International Journal of Food Properties* (Taylor & Francis). He has worked on food product development, food rheology, structure, nanocomposites, and the thermal behavior of food and biomaterials. He has extensively studied high-pressure-assisted textural modifications of protein foods and starches.

Dr. Hosahalli Ramaswamy is a professor in the Department of Food Science at McGill University, Canada. He has developed a strong research program at McGill in the area of food process engineering. His research activities include overpressure thermal processing of foods in thin profile flexible and semi-rigid containers in still and rotary autoclaves, continuous aseptic processing of particulate low acid foods, food extrusion, food quality optimization, application of microwaves for food processing and drying, evaluation of thermophysical properties of foods, food system rheology, ultra-high pressure processing, ohmic heating and the use of artificial intelligence for characterizing and modeling food processing and quality. He has to his credit more than 250 publications and several book chapters, and has edited 5 books. He has also authored a textbook on food processing. He is currently serving as editor for the *Journal of Food Engineering*.

Dr. Stefan Kasapis is a professor at RMIT University, Australia. He has an established reputation in research on conformation, interactions, and functional properties of food hydrocolloids and co-solutes. His expertise extends from the gelation properties of high-water systems to the vitrification phenomena of high-solid mixtures. He is the author of more than 100 peer-reviewed publications in reputable food science journals and seven book chapters, and the inventor of eight international patents. He serves as editor of *Food Hydrocolloids* and is a member of the editorial board of *Carbohydrate Polymers*. He organized the 9th International Hydrocolloids Conference in June 2008.

Dr. Joyce I. Boye is a research scientist with Agriculture and Agri-Food Canada. Her research in the past 15 years has been directed at developing techniques for the isolation, extraction, and characterization of proteins from both animal and plant sources. In the past ten years, Dr. Boye and her research team have done extensive work on oilseeds and pulses, working in collaboration with industries from the private sector to develop new processing techniques and products. She is the senior author of several confidential industrial reports and has a total of over 128 scientific publications/abstracts/technical presentations, including five book chapters.

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CONTENTS

The growth of novel processing technologies has now become extremely commercially important, involving many new products, industrial collaborations, and academic research groups. This book covers the present status and future trends of novel technologies alongside major lines of development in relation to rheological and functional properties of food. It is important to recognize that developments in novel food processing have mostly taken place in developed countries, however developing countries could benefit from the knowledge already generated in the field.

The advantages of novel processing technologies over conventional protocols are the retention of sensory attributes, desired texture, and improved functional properties by focusing on the promising areas of next-generation food processing. Novel technologies can be classified into two categories: electrotechnologies (pulse electric field, radio-frequency (RF) heating, microwave heating, infrared heating, ohmic heating, etc.) which make use of novel methods of heating, and nonthermal technologies (pulse-light, high hydrostatic pressure, oscillating magnetic field, irradiation, ozonization, plasma, osmotic treatment, etc.). Most of the electrotechnologies focus on novel approaches to generate heat and rely on conventional thermal mechanisms for achieving preservation and processing. Nonthermal processing technologies, on the other hand, inactivate enzymes and microorganisms, and modify the functional properties of food by alternate means without substantially increasing the product temperature.

The majority of the literature on this subject is devoted to equipment design and process optimization, in conjunction with microbial aspects and safety of various foods. There is, indeed, an urgent need to study microbial survival and destruction under the novel and alternate processing technologies to achieve food sterility or food safety. On the other hand, structural modifications and functionality of ingredients and formulations under novel processes cannot be neglected since they have a profound effect on both sensory and nutritional aspects of food. The current emphasis on health-related functional foods leading an integration of food production, processing/preservation, and nutritional aspects has led to renewed interest in the texture and functional properties of materials under novel processing technologies.

Structural and functional properties are important determinants of food quality, as perceived by consumers and required by the food industry. Rheology deals with establishing predictions of mechanical behavior based on the micro- or nanostructure of the material, e.g., the molecular size and architecture of food polymers in solution or particle size distribution in a solid suspension. Rheological measurements are essential tools in the analytical laboratory for characterizing component materials and finished products, and monitoring process conditions, as well as predicting product performance and consumer acceptance. Thus, rheological properties provide fundamental insights into the structural organization of food. For example, starch/protein dispersions converted to gel under novel processing exhibit a true viscoelastic nature (Molina, Defaye, and Ledward 2002; Ahmed et al. 2007).

In addition, the functionality of food is improved significantly with a novel processing technology like high pressure (HP), which can partially reduce allergenic proteins in rice (Kato et al. 2000), and pulse electric field, which inactivates undesirable enzymes (pectin methyl esterase [Yeom et al. 2002], polyphenol oxidase [Giner et al. 2002], and alkaline phosphatase [Castro 1994]). Frequently, the academic study of food structure is conducted in isolation from the wider commercial and consumer context. A major objective of this book, therefore, is to analyze changes in food structure at the micro- and macromolecular levels when subjected to novel processing technologies and to discuss food properties within this wider context.

The contributions culminating in the present form of the book are briefly surveyed in this opening chapter so that readers can readily obtain an overview of the book and its highlights. There are 22 chapters in total, covering most of the novel technologies. It is worth mentioning that a few of the novel processing technologies have been explored mainly for their role in preservation and processing and there is not much information on their effect on rheology/texture and/or functional properties, e.g., pulsed light or pulsed electric field (PEF), and, in these cases, the focus lies on technology rather than core content.

RF dielectric heating has been used for decades in thermal processing of nonconductive materials with industrial applications for drying of wood and tempering of frozen foods. RF is promising for many heating and drying processes but there is still a need for more readily available data related to the design of the applicators, targeted product formulations with specific dielectric properties, and control systems for the development of RF heating process applications. Selection of dielectric energy input and its combination with conventional thermal technologies may lead to products that meet and often improve the quality requirements of existing food products, hence opening the field for product development. RF heating applications are focused on in Chapter 2.

Ohmic heating is an innovative heating technique employed for thermal processing. The food is placed between two electrodes serving as an electrical resistor and an alternating electric current is passed through the circuit. The electrical resistance causes heat to be generated throughout the food matrix in a uniform and volumetric fashion. The electrical energy is directly converted into heat, causing a temperature rise, and depends largely on the electrical conductivity of the product. It is theoretically possible to properly match the electrical conductivity of solid and liquid phase of particulate fluids such that under ohmic heating the particles could heat faster than the liquid. This is a unique feature that has attracted the attention of the industry, academia, and regulatory agencies to permit ohmic heating as a potential source of treatment in aseptic processing of particulate fluids. Chapter 3 highlights the principles and applications of the technique and their influence on food rheology and functional properties.

Chapter 4 deals with the application of high electric field (HEF) to food processing, especially drying. HEF technology offers many distinctive advantages over conventional processing methods. One of the major advantages is that there is insignificant change in temperature during processing. As a result, the method can be successfully applied to any temperature-sensitive fresh material to retain flavonoids. The processing efficiency and capacity mainly depends on the voltage strength used for processing. Though interest in HEF processing is high, the technique is still in its infancy in terms of industrial exploitation.

PEF treatment of liquid foods is one of the emerging nonthermal food preservation processes. It can accomplish food preservation with short treatment times and small increases in food temperature, thus, providing an alternative to thermal pasteurization. The exposure of microbial cells to electric field induces transmembrane potential on the cell membrane, which results in electroporation and electrofusion. The generation of PEF requires a system for generating high-voltage pulses and a treatment chamber that converts the pulsed voltage into PEFs. There has been a significant development in the design of PEF systems during the last 20 years. Chapter 5 reviews the various high-voltage pulse generators and the continuous treatment chambers that have been designed and constructed by different research groups.

Ultrasound refers to energy generated by sound waves of 20,000 or more vibrations per second. High frequencies in the range of 0.1–20 MHz, pulsed operation, and low power levels (100 mW) are used for nondestructive testing (Gunasekaran and Chiyung 1994). Ultrasonic excitation is being examined for nondestructive evaluation of the internal quality and latent defects of whole fruits and vegetables in a manner similar to the use of ultrasound for viewing the developing fetus in a mother's womb (Mizrach et al. 1994). Ultrasound could be used in various applications including rheology, texture, and concentration measurements of solid or fluid foods; composition determination of eggs, meats, fruits, vegetables, and dairy products; thickness, flow level, and temperature measurements for controlling several processes; and nondestructive inspection of egg shells and food packages. Two chapters deal with the technology (Chapter 6) and applications (Chapter 7) of the subject.

Ionizing radiation (IR) was the first novel technology applied to food products to enhance shelf life, although it was not easy to convince regulatory agencies and consumers of its safety. IR offers various technological benefits by reducing food losses and improving food safety. Irradiation (1.5–7.0 kGy) applied to solid and semisolid food like meat, poultry, seafood, potatoes, and onions confers the same benefits as thermal pasteurization confers on liquids. After decades of extensive research and testing have demonstrated that IR is safe within prescribed doses, it has been permitted by all specialized agencies of the United Nations (WHO, FAO, and IAEA). Chapter 8 of this book is devoted to this area.

Ozone has a wide antimicrobial spectrum that, combined with high oxidation potential, makes it an attractive processing option for the food industry. Relatively small quantities of ozone and short contact times are sufficient for the desired antimicrobial effect as it rapidly decomposes into oxygen, leaving no toxic residues in food (Muthukumarappan, Halaweish, and Naidu 2000). The interest in ozone as an antimicrobial agent is based on its high biocidal efficacy and wide antimicrobial spectrum that is active against bacteria, fungi, viruses, protozoa, and bacterial and fungal spores (Khadre, Yousef, and Kim 2001). Ozone is 50% more effective over a wider spectrum of microorganisms than chlorine. It reacts up to 3000 times faster than chlorine with organic materials and produces no harmful decomposition products (Graham 1997). Such advantages make ozone attractive to the food industry and consequently it was declared as Generally Recognized as Safe (GRAS) for use in food processing by the U.S. Food and Drug Administration (FDA) in 1997 (Graham 1997). Chapter 9 provides details on the issue.

Most of the proteins form aggregates under many destabilizing conditions, particularly at high temperatures. Further aggregation leads to a solid-like gel of three-dimensional networks. Chapter 10 discusses protein gelation at room temperatures using a two-step process, usually referred to as cold gelation. The first step involves the formation of soluble aggregates, usually with a heat treatment. The final gelation step is commonly achieved following addition of salts or by reducing pH. Studies of cold gelation procedures in emulsions, bead and microcapsule formation, and with polysaccharide mixtures are reviewed.

There are several contributions in this book dealing with HP processing and its effect on rheology, structure, and functional properties. The first of them emphasizes the significant interest among