Contemporary Food Engineering Series

Da-Wen Sun, Series Editor

ADVANCES IN DEEP-FAT FRYING OF FOODS

Edited by
Serpil Sahin
Servet Gülüm Sumnu

CRC Press
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ADVANCES IN DEEP-FAT FRYING OF FOODS

Contemporary Food Engineering

Series Editor

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Dedication

To

Güler Özkan, Semra Şahin, Ayşe Demirezen and Ümit Burak Şahin

and

Deniz Sumnu Dindoruk

Series Editor's Preface

CONTEMPORARY FOOD ENGINEERING

Food engineering is the multidisciplinary field of applied physical sciences combined with 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 employing modern tools and knowledge, such as computational materials science and nanotechnology, to develop new products and processes. Simultaneously, improving food quality, safety, and security remain critical issues in food engineering study. 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 saving and minimization of environmental problems continue to be important food engineering issues while significant progress is being made in waste management, efficient utilization of energy, and reduction of effluents and emissions in food production.

Consisting of edited books, the *Contemporary Food Engineering* book series attempts to address some of the recent developments in food engineering. Advances in classical unit operations in engineering applied 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. The books are aimed at professional food scientists, academics researching food engineering problems, and graduate-level students.

The editors of the books are leading engineers and scientists from many parts of the world. All the editors were asked to present their books in a manner that would address the market's need and pinpoint the cutting-edge technologies in food engineering. Furthermore, all contributions are written by internationally renowned experts with 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 to be used by readers 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

Preface

Deep-fat frying is a complex process. It involves heat and mass transfer between food and the frying medium. This book explains the frying process by combining engineering principles with knowledge of biochemistry. The editors aim to provide recent references about frying that will be helpful for researchers and food processors working in the field of frying. This book will also be useful to students taking courses related to unit operations in the food industry.

The history of various fried products and general information about frying are given in the introduction. The second chapter reviews heat and mass transfer phenomena, mainly focusing on the adhesion and capillary migration of oil during the cooling period. Convective heat transfer from oil to the product, convective heat transfer coefficient during frying, coupled heat and mass transfer inside the product, and the mechanism of oil uptake will be discussed in this chapter. A series of reactions take place during frying in oil or fat that is exposed to high temperature in air and moisture. As a result, the quality of the frying oil and of the fried food is lost. The factors affecting the quality of frying oil, the main changes taking place in the frying oil, the methods used for determination of oil degradation, the antioxidants that can be used to retain the quality of frying oil, and the interactions between the food and the frying oil are given in Chapters 3 and 4.

Kinetic studies of the quality changes during frying that predict and improve the final quality of the product are summarized in Chapter 5. Moisture and oil contents, color, texture, volume, porosity and acrylamide content are considered as quality parameters.

It is important to have the physical properties data of fried foods because they affect the rate of heat and mass transfer during frying. Physical properties of food products change significantly during frying, and a change in one physical property affects the others. Variations in geometric, optic, mechanic, thermal and mass transfer properties in various foods during frying are given in Chapter 6.

Acrylamide, which is a potential carcinogen formed during processing at high temperatures, is a recent safety concern in fried products. Therefore, in Chapter 7 the mechanism of acrylamide formation and the factors to reduce its formation are discussed, and the studies related to acrylamide in frying are summarized.

It is not enough to study the changes in deep-fat frying at the macroscopic level. It is also important to examine microstructural changes in fried products. During frying, water vapor is formed due to high temperature and is transferred through the surface of the product due to pressure and concentration gradients. As a result, crust is formed and pores are developed. Pores affect oil absorption. In addition, shrinkage may be observed. In Chapter 8, microstructural changes during frying and the techniques used to study food microstructures are reviewed. The relation between the quality and microstructural changes is also discussed.

The desirable flavor formed during frying is unique. That is, it is not developed during other cooking methods. The flavors in frying oils may come from natural

compounds, processing, and/or degradation of fatty acids. Sources of flavor, development of flavor during frying, and measurement of deterioration products related to flavor are discussed in Chapter 9.

The consumption of battered and breaded foods in the frying market is increasing. Different batter formulations are employed to obtain the desired quality. In general, there is a correlation between the rheological behavior of batters and product quality. Therefore, studying rheological properties of different batter formulations will provide insights into the final fried product quality. Studies about the rheological properties of batters are given in Chapter 10, and the variations of physical properties of battered fried products (batter adhesion, color and texture) are discussed in Chapter 11. Sensory analysis of battered foods is also mentioned.

In Chapter 12, the importance of industrial frying, the evolution of the frying industry, types of fryers, criteria for fryer selection, and processes for different fried products are summarized. In addition, the terminology used in industrial frying is given.

There is much ongoing research and recent developments in frying technologies due to increasing consumer demand for low-fat and low-acrylamide products without losing product quality. In Chapter 13, the principles of vacuum, microwave and pressure frying are mentioned, and recent studies about these alternative technologies are discussed.

Serpil Sahin
Servet Gülüm Sumnu

Series Editor

Born in Southern China, Professor **Da-Wen Sun** is a world authority on food engineering research and education. His main research activities include the cooling, drying, and refrigeration processes and systems, quality and safety of food products, bioprocess simulation and optimization, and computer vision technology. Of special interest are 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 which have been widely reported in national and international media. Results of his work have been published in over 180 peer-reviewed journal papers and more than 200 conference papers.

He received first class B.Sc. Honors and M.Sc. degrees in mechanical engineering, and a Ph.D. 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 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. Sun is now professor of Food Biosystems Engineering and director of the Food Refrigeration and Computerized Food Technology Research Group in University College Dublin.

As a leading educator in food engineering, Sun has contributed significantly to the field of food engineering. He has trained many Ph.D. students, who have made their own contributions to the industry and academia. He has also, on a regular basis, given lectures on advances in food engineering in academic institutions internationally and delivered keynote speeches at international conferences. As a recognized authority in food engineering, he has been conferred adjunct/visiting/consulting professorships from ten 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 Engineering (CIGR) awarded him the CIGR Merit Award in 2000 and again in 2006 and the Institution of Mechanical Engineers (IMechE) based in the United Kingdom named him Food Engineer of the Year 2004. In 2008 he was awarded the CIGR Recognition Award for his distinguished achievements in the top one percent of agricultural engineering scientists around the world.

He is a Fellow of the Institution of Agricultural Engineers. He has also received numerous awards for teaching and research excellence, including the President's Research Fellowship, and he twice received the President's Research Award of University College Dublin. He is a member of the CIGR Executive Board and Honorary Vice-President of CIGR, editor-in-chief of *Food and Bioprocess Technology—An International Journal* (Springer), series editor of the "*Contemporary Food Engineering*" book series (CRC Press/Taylor & Francis), former editor of *Journal of Food Engineering* (Elsevier), and editorial board member for *Journal of Food Process Engineering* (Blackwell), *Sensing and Instrumentation for Food Quality and Safety* (Springer), and *Czech Journal of Food Sciences*. He is also a chartered engineer registered in the UK Engineering Council.

Editors

Serpil Sahin is a professor in the Department of Food Engineering, Middle East Technical University, Ankara, Turkey. She has authored or co-authored 45 journal articles and book chapters. She is one of the authors of *Physical Properties of Foods* (2006, Springer) and one of the editors of *Food Engineering Aspects of Baking of Sweet Goods* (Volume II in Contemporary Food Engineering Series, published by Taylor and Francis). She received BS (1989), MS (1992), and PhD (1997) degrees from the Department of Food Engineering, Middle East Technical University. Sahin was a visiting scholar in the Department of Food, Agricultural and Biological Engineering at the Ohio State University for one year (1996). She is working on food processes, especially frying, baking, separation processes, and applications of microwaves.

Servet Gülüm Sumnu is a professor in the Department of Food Engineering, Middle East Technical University, Ankara, Turkey. She has authored or co-authored 55 journal articles and book chapters. She is one of the authors of *Physical Properties of Foods* (2006, Springer) and one of the editors of *Food Engineering Aspects of Baking of Sweet Goods* (Volume II in the Contemporary Food Engineering Series, published by Taylor and Francis). She received BS (1991), MS (1994), and PhD (1997) degrees from the Department of Food Engineering, Middle East Technical University. Sumnu was a visiting scholar in the Department of Food Science and Technology at the Ohio State University for one year (1996). She is working on microwave food processes, especially microwave baking and frying. Her research also focuses on the physicochemical properties of hydrocolloids and the determination of physical properties of foods.

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