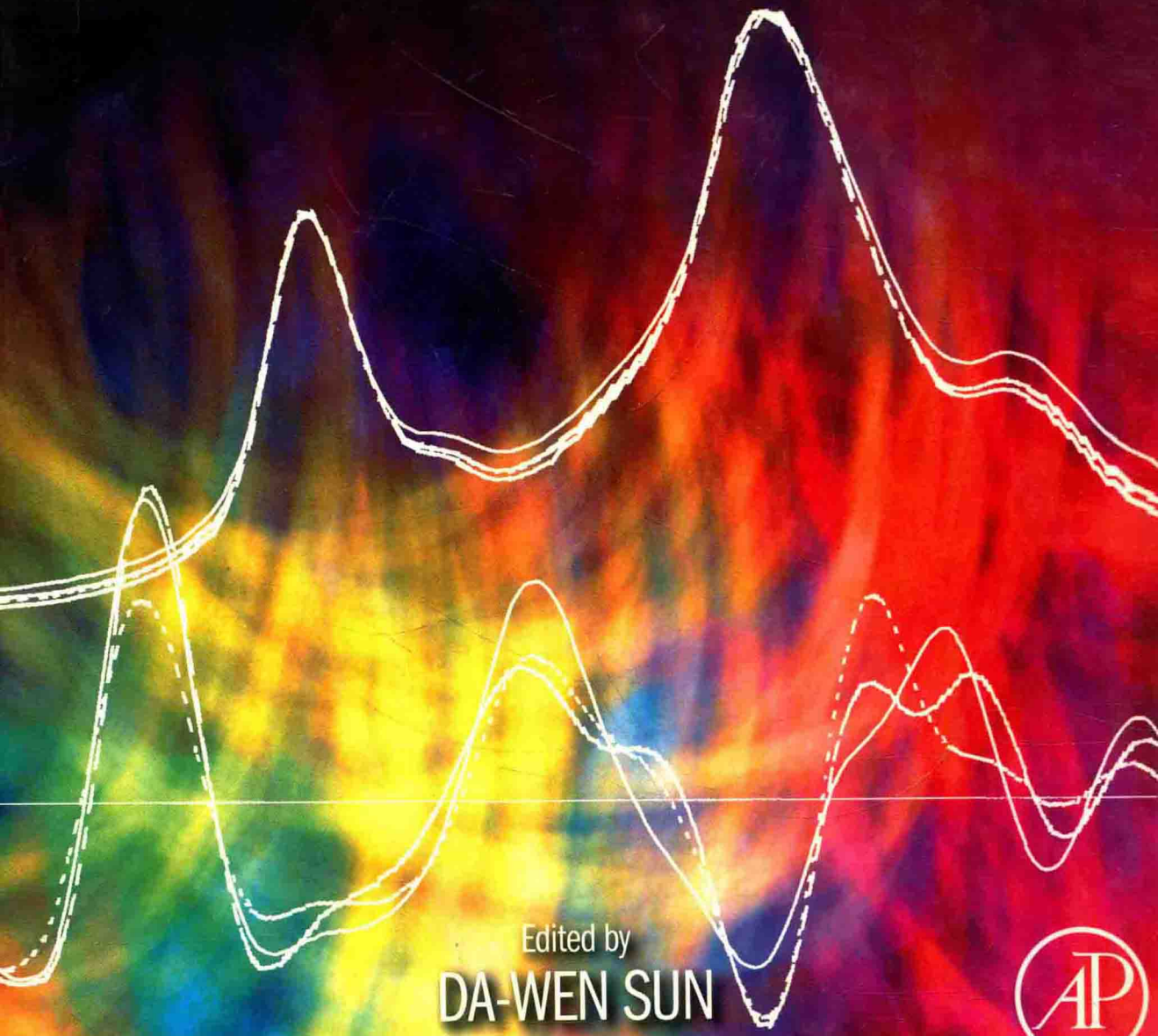
INFRARED SPECTROSCOPY FOR FOOD QUALITY ANALYSIS AND CONTROL



Edited by

DA-WEN SUN

Infrared Spectroscopy for Food Quality Analysis and Control

Edited by
Da-Wen Sun
Director of the Food Refrigeration and
Computerised Food Technology Research Group
National University of Ireland, Dublin
(University College Dublin)
Agriculture and Food Science Centre
Belfield
Dublin 4
Ireland

AMSTERDAM • BOSTON • HEIDELBERG • LONDON • NEW YORK • OXFORD
PARIS • SAN DIEGO • SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Academic Press is an imprint of Elsevier

Academic Press is an imprint of Elsevier
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA
525 B Street, Suite 1900, San Diego, CA 92101-4495, USA
32 Jamestown Road, London, NW1 7BY, UK
360 Park Avenue South, New York, NY 10010-1710, USA

First edition 2009

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-0-12-374136-3

For information on all Academic Press publications
visit our website at www.elsevierdirect.com

Typeset by Charon Tec Ltd., A Macmillan Company
www.macmillansolutions.com

Printed and bound in the United States of America

09 10 11 12 13 9 8 7 6 5 4 3 2 1

About the Editor

Born in Southern China, Professor Da-Wen Sun is a world authority in food engineering research and education. His main research activities include cooling, drying and refrigeration processes and systems, the quality and safety of food products, bioprocess simulation and optimization, and computer vision technology. In particular, his innovative studies on the vacuum cooling of cooked meats, pizza quality inspection by computer vision, and edible films for shelf-life extension of fruit and vegetables have been widely reported in the 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 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) in 1995; he was then continuously promoted in the shortest possible time to Senior Lecturer, Associate Professor and full Professor. Dr Sun is now Professor of Food and 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, Professor Sun has significantly contributed to the field of food engineering. He has trained many PhD students, who have made their own contributions to the industry and academia. He has also given lectures on advances in food engineering on a regular basis 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 by ten top universities in China, including Zhejiang University, Shanghai

Jiaotong University, Harbin Institute of Technology, China Agricultural University, South China University of Technology, 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; the Institution of Mechanical Engineers (IMechE) based in the UK named him "Food Engineer of the Year 2004", in 2008 he was awarded CIGR Recognition Award in recognition of his distinguished achievements as 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 has twice received the President's Research Award of University College Dublin. He is a member of 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 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 also a Chartered Engineer registered in the UK Engineering Council.

Contributors

Manel Alcalà Bernàrdez (Ch. 3) The University of Puerto Rico, Mayagüez, Faculty of Arts and Sciences, Department of Chemistry, Analytical and Pharmaceutical Laboratory, Mayagüez PR 00681-9019, USA

Murad A Al-Holy (Ch. 6) Department of Clinical Nutrition and Dietetics, Faculty of Allied Health Sciences, Hashemite University, Zarqa-Jordan

Josse De Baerdemaeker (Ch. 15) Division of Mechatronics, Biostatistics and Sensors (MeBioS), Department of Biosystems, K.U. Leuven, Kasteelpark Arenberg 30, B-3001, Leuven, Belgium

Davide Ballabio (Ch. 4) Milano Chemometrics and QSAR Research Group, Department of Environmental Sciences, University of Milano-Bicocca, P.zza della Scienza 1, 20126 Milano, Italy

Søren Balling Engelsen (Ch. 2) Faculty of Life Sciences, Chemometrics and Spectroscopy Group, Quality and Technology, Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark

Flip Bamelis (Ch. 15) Division of Mechatronics, Biostatistics and Sensors (MeBioS), Department of Biosystems, K.U. Leuven, Kasteelpark Arenberg 30, B-3001, Leuven, Belgium

Malgorzata Baranska (Ch. 12) Jagiellonian University, Department of Chemistry, Chemical Physics Division, 3 Ingardena str., 30–060 Krakow, Poland

Marcelo Blanco Romía (Ch. 3) University Autonomous of Barcelona, Departament de Química Àrea de Química Analítica, Entrada Nord Edifici de Ciències, Campus de la UAB, 08193 Bellaterra (Cerdanyola del Vallès), Spain

Rasmus Bro (Ch. 2) Faculty of Life Sciences, Chemometrics and Spectroscopy Group, Quality and Technology, Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark

Anna G Cavinato (Ch. 6, 13) Department of Chemistry and Biochemistry, Eastern Oregon University, One University Blvd., La Grande, OR 97850, USA

Daniel Cozzolino (Ch. 14) Australian Wine Res. Inst., Waite Rd., Urrbrae, PO Box 197, Adelaide, SA 5064, Australia

Robert G Dambergs (Ch. 14) The Australian Wine Research Institute. Waite Road, Urrbrae. PO Box 197, Adelaide, SA 5064 Australia

Bart De Ketelaere (Ch. 15) Division of Mechatronics, Biostatistics and Sensors (MeBioS), Department of Biosystems, K.U. Leuven, Kasteelpark Arenberg 30, B-3001, Leuven, Belgium

Éric Dufour (Ch. 1) UR Typicite des Produits Alimentaires, ENITA de Clermont Ferrand, Site de Marmilhat BP 35, F-63370 Lempdes, France

Colette C Fagan (Ch. 10) Biosystems Engineering, School of Agriculture, Food Science and Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland

Rahul Reddy Gangidi (Ch. 8) Spectroscopist Research Scientist, Thermo Fisher Scientific Inc., Process Instruments Division, 2026 Brewster Street, #5, St. Paul, MN 55108, USA

Yiqun Huang (Ch. 13) Department of Family, Nutrition, and Exercise Sciences, Queens College, City University of New York, 65–30 Kissena Boulevard, Flushing, NY 11367, USA

Birthe Møller Jespersen (Ch. 11) Faculty of Life Sciences, Chemometrics and Spectroscopy Group, Quality and Technology, Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark

Romdhane Karoui (Ch. 15) Unité de Recherche Typicité des Produits Alimentaires, Enita Clermont, Site de Marmilhat—BP 35, F-63370 Lempdes, France

Bart Kemps (Ch. 15) Division of Mechatronics, Biostatistics and Sensors (MeBioS), Department of Biosystems, K.U. Leuven, Kasteelpark Arenberg 30, B-3001, Leuven, Belgium

Mengshi Lin (Ch. 6) Food Science Program, Division of Food Systems & Bioengineering, 256 Stringer Wing, University of Missouri, Columbia 65211, USA

Kristof Mertens (Ch. 15) Division of Mechatronics, Biostatistics and Sensors (MeBioS), Department of Biosystems, K.U. Leuven, Kasteelpark Arenberg 30, B-3001, Leuven, Belgium

Lars Munck (Ch. 11) Faculty of Life Sciences, Chemometrics and Spectroscopy Group, Quality and Technology, Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark

Lars Nørgaard (Ch. 2) Faculty of Life Sciences, Chemometrics and Spectroscopy Group, Quality and Technology, Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark

Emiko Okazaki (Ch. 9) Food Quality Section, Division of Food Technology and Biochemistry, National Research Institute of Fisheries Science, 2–12–4 Fukuura, Kanazawa, Yokohama 236–8648, Japan

CP O'Donnell (Ch. 10) Biosystems Engineering, School of Agriculture, Food Science and Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland

Andrew Proctor (Ch. 8) Department of Food Science, 2650 N Young Ave., University of Arkansas, Fayetteville, AR 72704, USA

Barbara A Rasco (Ch. 6, 13) Department of Food Science & Human Nutrition, Washington State University, P.O. Box 646376, Pullman, WA 99164-6376, USA

Åsmund Rinnan (Ch. 2, 5) Faculty of Life Sciences, Chemometrics and Spectroscopy Group, Quality and Technology, Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark

Luis Rodriguez-Saona (Ch. 7) Department of Food Science and Technology, 110 Parker Food Science & Technology Building, Columbus OH 43210, USA

Hartwig Schulz (Ch. 12) Federal Research Centre for Cultivated Plants, Institute for Ecological Chemistry, Plant Analysis and Stored Product Protection, Erwin-Baur-Strasse 27, D-06484 Quedlinburg, Germany

Anand Subramanian (Ch. 7) Department of Food Science and Technology, The Ohio State University, 2015 Fyffe Ct, Columbus, OH 43210, USA

L Rudzik (Ch. 10) Institutsleiter, Institut für Lebensmittelqualität, LUFA Nord-West, Ammerländer Heerstr.115–117, 26129 Oldenburg, Germany

Jonas Thygesen (Ch. 2) The Royal Veterinary and Agricultural University, Chemometrics Group, Quality & Technology, Department of Food Science, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark

Roberto Todeschini (Ch. 4) Milano Chemometrics and QSAR Research Group, Department of Environmental Sciences, University of Milano-Bicocca, P.zza della Scienza 1, 20126 Milano, Italy

Musleh Uddin (Ch. 9) Food Quality Section, Division of Food Technology and Biochemistry, National Research Institute of Fisheries Science, 2–12–4 Fukuura, Kanazawa, Yokohama 236–8648, Japan

Frans van den Berg (Ch. 2, 5) Faculty of Life Sciences, Chemometrics and Spectroscopy Group, Quality and Technology, Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark

E Wüst (Ch. 10) University of Applied Scienes and Arts Hannover, Faculty of Mechanical and Bioprocess Engineering, Heisterbergallee 12, D-30453 Hannover, Germany

Preface

Infrared (IR) spectroscopy deals with the infrared part of the electromagnetic spectrum, it measures the absorption of different IR frequencies by a sample positioned in the path of an IR beam. Currently, infrared spectroscopy is one of the most common spectroscopic techniques used by the industry. With the rapid development in infrared spectroscopic instrumentation software and hardware, the application of this technique has expanded into many areas of food research. Infrared spectroscopy has become a powerful, fast and non-destructive tool for food quality analysis and control.

In order to reflect this trend of rapid technology development, it is appropriate to publish *Infrared Spectroscopy for Food Quality Analysis and Control*. The book is divided into two parts. Part I deals with principles and instruments including theory, data treatment techniques and infrared spectroscopy instruments. Part II covers its applications in quality analysis and control for various foods, for example, meat and meat products, fish and related products, vegetables, fruits, dairy products and cereals.

Infrared Spectroscopy for Food Quality Analysis and Control is written by international peers who have both academic and professional credentials, highlighting the truly international nature of the work. It aims to provide the engineer and technologist working in research, development, and operations in the food industry with critical and readily accessible information on the art and science of infrared spectroscopy technology. The book should also serve as an essential reference source to undergraduate and postgraduate students and researchers in universities and research institutions.

Contents

PART

I

Fundamentals and Instruments

PART I

Fundamentals and Instruments

1

Principles of Infrared Spectroscopy

Éric Dufour

Introduction

The development of rapid analytical methods for food products relies mainly upon two approaches: the use of physical properties of substrates as an information supply and the automation of chemical methods. Most rapid analytical methods based on the physical properties of food products are spectroscopic methods. Spectroscopy can be split into two large groups (Wilson, 1994): photonic spectroscopy, which is based on the study of the interaction of an electromagnetic wave with matter, and particle spectroscopy. The first group comprises spectroscopic methods exhibiting an analytical potential for rapid control. The second group is represented by mass spectrometry and derived methods.

All the spectroscopic methods, except mass spectrometry, can be classified according to the energy involved during measurement. Electromagnetic radiation, of which visible light forms a tiny part, exists as waves that are propagated from a source and move in a straight line if they are not reflected or refracted. The undulatory phenomenon is a magnetic field associated with an electric one. The speed of the electromagnetic wave

Infrared Spectroscopy for Food Quality Analysis and Control
ISBN: 978-0-12-374136-3