Woodhead Publishing in Food Science and Technology

The microwave processing of foods

Edited by Helmar Schubert and Marc Regier

CRC

WP

The microwave processing of foods

Edited by
Helmar Schubert and Marc Regier

CRC Press
Boca Raton Boston New York Washington, DC

WOODHEAD PUBLISHING LIMITED
Cambridge England

Published by Woodhead Publishing Limited
Abington Hall, Abington
Cambridge CB1 6AH
England
www.woodheadpublishing.com

Published in North America by CRC Press LLC
6000 Broken Sound Parkway, NW
Suite 300
Boca Raton FL 33487
USA

First published 2005, Woodhead Publishing Limited and CRC Press LLC

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

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

Woodhead Publishing Limited ISBN-13: 978-1-85573-964-2 (book)
Woodhead Publishing Limited ISBN-10: 1-85573-964-X (book)
Woodhead Publishing Limited ISBN-13: 978-1-84569-021-2 (e-book)
Woodhead Publishing Limited ISBN-10: 1-84569-021-4 (e-book)
CRC Press ISBN-10: 0-8493-3442-X
CRC Press order number: WP3442

The publishers' policy is to use permanent paper from mills that operate a sustainable forestry policy, and which has been manufactured from pulp which is processed using acid-free and elementary chlorine-free practices. Furthermore, the publisher ensures that the text paper and cover board used have met acceptable environmental accreditation standards.

Project managed by Macfarlane Production Services, Markyate, Hertfordshire
(e-mail: macfarl@aol.com)
Typeset by Godiva Publishing Services Ltd, Coventry, West Midlands
Printed by TJ International Limited, Padstow, Cornwall, England

The microwave processing of foods

Related titles from Woodhead's food science, technology and nutrition list:

Improving the thermal processing of foods (1 85573 730 2)

Thermal technologies must ensure the safety of food without compromising its quality. This important book summarises key research on both improving particular techniques and measuring their effectiveness in preserving food and enhancing its quality.

Thermal technologies in food processing (1 85573 558 X)

Thermal technologies have long been at the heart of food processing. The application of heat is both an important method of preserving foods and a means of developing texture, flavour and colour. An essential issue for food manufacturers is the effective application of thermal technologies to achieve these objectives without damaging other desirable sensory and nutritional qualities in a food product. Edited by a leading authority in the field, and with a distinguished international team of contributors, *Thermal technologies in food processing* addresses this major issue. It provides food manufacturers and researchers with an authoritative review of thermal processing and food quality.

Food preservation techniques (1 85573 530 X)

Extending the shelf-life of foods whilst maintaining safety and quality is a critical issue for the food industry. As a result there have been major developments in food preservation techniques, which are summarised in this authoritative collection. The first part of the book examines the key issue of maintaining safety as preservation methods become more varied and complex. The rest of the book looks at individual technologies and how they are combined to achieve the right balance of safety, quality and shelf-life for particular products.

Details of these books and a complete list of Woodhead's food science, technology and nutrition titles can be obtained by:

- visiting our web site at www.woodheadpublishing.com
- contacting Customer Services (email: sales@woodhead-publishing.com; fax: +44 (0) 1223 893694; tel.: +44 (0) 1223 891358 ext. 30; address: Woodhead Publishing Limited, Abington Hall, Abington, Cambridge CB1 6AH, England)

Contributor contact details

(* = main contact)

Chapters 1 and 3

Dr M. Regier* and Professor H. Schubert
Institute of Food Process Engineering
University of Karlsruhe
Kaiserstr. 12
76131 Karlsruhe
Germany

Email:
Marc.Regier@bfe.uni-karlsruhe.de
helmar.schubert@lvt.uni-karlsruhe.de

Chapter 2

Professor Juming Tang
Department of Biological Systems Engineering
Washington State University
Pullman, WA
USA 99164-6120

E-mail: jtang@mail.wsu.edu

Chapters 4 and 6

Dr V. Meda (Chapter 4)*
Department of Agriculture and Bioresource Engineering
University of Saskatchewan
57 Campus Drive
Saskatoon
SK S7N 5AJ
Canada

Email: venkatesh.meda@usask.ca

Dr V. Orsat and Professor V. Raghavan (Chapter 6)*
Bioresource Engineering
McGill University
21111 Lakeshore Drive
Ste-Anne de Bellevue
QC H9X 3V9
Canada

Email: vijaya.raghavan@mcgill.ca

Chapter 5

Professor M. S. Brewer
Department of Food Science and Human Nutrition
University of Illinois
Urbana
IL 61201
USA

Email: msbrewer@uiuc.edu

Chapter 7

Dr G. Sumnu* and Dr S. Sahin
Middle East Technical University
Food Engineering Department
06531 Ankara
Turkey

E-mail: gulum@metu.edu.tr

Chapter 8

Dr U. Erle
Nestlé Product Technology Centre
Lange Str. 21
78244 Singen
Germany

Email: ulrich.erle@rdke.nestle.com; Ulrich.Erle@rdsi.nestle.com

Chapter 9

Dr L. Dorantes-Alvarez*
Ingenieria Bioquímica Department
Escuela Nacional de Ciencias Biológicas
Instituto Politécnico Nacional
Carpio y Plan de Ayala AP 42-186
CP 11340
Mexico

Email: ldoran@ipn.mx

Dr L. Parada-Dorantes
Gastronomy Department
Universidad del Caribe
L1 M1 R78 Fraccionamiento Tabachines
Cancún
Quintana Roo
CP 77528
Mexico

Email: lparada@unicaribe.edu.mx

Chapters 10 and 12

Mr M. J. Swain* and Mr S. J. James
Food Refrigeration and Process Engineering Research Centre (FRPERC)
University of Bristol
Churchill Building
Langford
Bristol BS40 5DU
UK

Email: m.j.swain@bristol.ac.uk; steve.james@bristol.ac.uk

Chapter 11

R. F. Schiffmann
R. F. Schiffmann Associates, Inc.
149 West 88 Street
New York 10024-2401
USA

Email: microwaves@juno.com

Chapters 13 and 16

Dipl-Ing. K. Knoerzer*, Dr M. Regier and Professor H. Schubert
Institute of Food Process Engineering
University of Karlsruhe
Kaiserstr. 12
76131 Karlsruhe
Germany

Email:
kai.knoerzer@lvt.uni-karlsruhe.de
marc.regier@lvt.uni-karlsruhe.de
helmar.schubert@lvt.uni-karlsruhe.de

Chapter 14

Mr P. Püschner
Püschner GmbH and Co. KG
Microwave Power Systems
PO Box 1151
Industrial Estate Neuenkirchen
Steller Heide 14
28790 Schwanewede
Bremen
Germany
E-mail: peter@pueschner.com

Chapter 15

B. Wäppling-Raaholt and T. Ohlsson
SIK (The Swedish Institute for Food and Biotechnology)
Box 5401
SE-402 29 Göteborg
Sweden

E-mail: br@sik.se

Contents

Part I

Principles

1

Introducing microwave processing of food: principles and technologies

M. Regier and H. Schubert, University of Karlsruhe, Germany

1.1 Introduction

This chapter treats the physical background of microwaves and the corresponding physical theory but also makes some general remarks on the setup of microwave applications. It starts with the definition of the frequency covered and the corresponding wavelength range and legislative regulations, before introducing the basic equations: Maxwell's equations and those that cover the interaction between electromagnetism and matter. Starting with these basics, the wave equation and some example solutions are derived, so that the important concepts of penetration depth and power absorption, which are useful for the estimation of thermal interaction between microwaves and matter can be introduced. After covering the general setup of microwave applications including microwave sources, waveguides and applicators, the chapter is completed by useful links to further literature.

1.2 Definitions and regulatory framework

Microwaves are electromagnetic waves within a frequency band of 300 MHz to 300 GHz. In the electromagnetic spectrum (Fig. 1.1) they are embedded between the radio frequency range at lower frequencies and infrared and visible light at higher frequencies. Thus, microwaves belong to the non-ionising radiations.

The frequency f is linked by the velocity of light c to a corresponding wavelength λ by eqn 1.1:

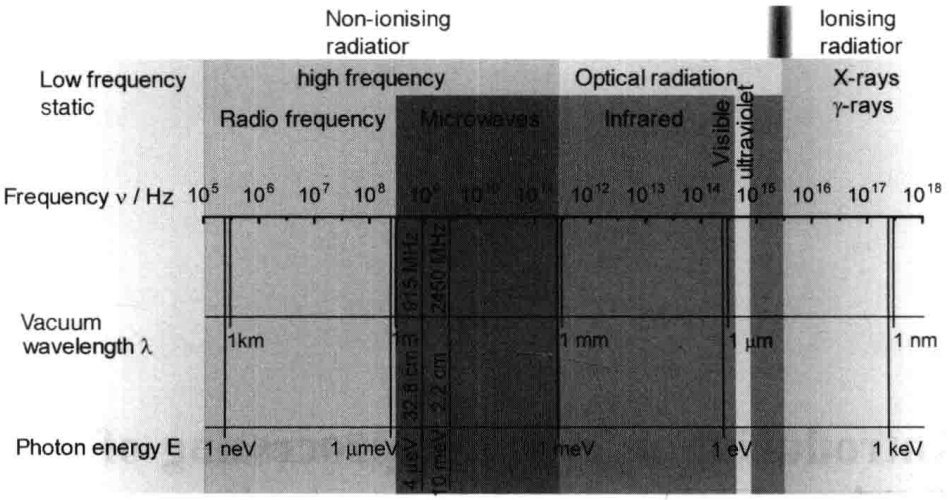

Fig. 1.1 Electromagnetic spectrum. Additionally, the two most commonly used microwave frequency bands (at 915 MHz and 2450 MHz) are sketched.

$$c = \lambda \cdot f \qquad [1.1]$$

In this case the velocity of light as well as its wavelength within matter are dependent on the material. For the speed of light in a vacuum ($c_0 \approx 3 * 10^8$ m/s) the corresponding wavelength of microwaves is between 1 m and 1 mm, so that the term 'microwave' is a little misleading. The name rather points to their wavelength within the matter, where it can indeed be in the micrometre range.

1.2.1 Regulations

As already shown in Fig. 1.1 the frequency range of microwaves adjoins the range of radio frequencies used for broadcasting. But the microwave frequency range is also used for telecommunications such as mobile phones and radar transmissions. In order to prevent interference problems, special frequency bands are reserved for industrial, scientific and medical (so-called ISM) applications, where a certain radiation level has to be tolerated by other applications such as communication devices. In the range of microwaves the ISM bands are located at 433 MHz, 915 MHz and 2450 MHz; the first is not commonly used and the second is not generally permitted in continental Europe. Outside the permitted frequency range, leakage is very restricted. Whereas 915 MHz has some considerable advantages for industrial applications, for microwave ovens at home the only frequency used is 2450 MHz.

Apart from the regulations concerning interference, there exist two types of safety regulations:

(a) the regulation concerning the maximum exposure or absorption of a human, working in a microwave environment,
(b) the regulation concerning the maximum emission or leakage of the microwave equipment.