

# Contents

*Preface*

*Contributors*

xv

## **PART I. FUNDAMENTAL PHYSICAL ASPECTS OF MICROWAVE ABSORPTION AND HEATING**

- 1. Electromagnetics: Fundamental Aspects and Numerical Modeling** **1**  
*David Dikken*
  - Introduction
  - Fundamental Electromagnetics 2
  - Analytical Modeling of Microwave Applicators 18
  - Numerical Modeling of Cavities 18
  - Application of Modeling to Microwave Heating 23
  - Conclusion 27
  - List of Symbols 27
  - References 28
  
- 2. Electromagnetics of Microwave Heating: Magnitude and Uniformity of Energy Absorption in an Oven** **33**  
*Hua Zhang and Ashim K. Datta*
  - Major Electromagnetic Issues in Microwave Heating of Foods 33

ix

## Contents

Electromagnetic Fields Inside a Domestic Microwave Oven	34
Magnitude and Uniformity of Energy Absorption: Food Factors	36
Magnitude and Uniformity of Energy Absorption: Oven Factors	54
Future Concepts and Developments in Oven Design	59
Appendix	62
References	63
<b>3. Dielectric Properties of Food Materials and Electric Field Interactions</b>	<b>69</b>
<i>Stuart O. Nelson and Ashim K. Datta</i>	
Introduction	69
Definition of Terms and Basic Principles	70
Variation of Dielectric Properties	72
Measurement Principles and Techniques	78
Dielectric Behavior of Food Materials	81
Dielectric Properties: Data Complications	106
Acknowledgments	107
List of Symbols	107
References	107
<b>4. Fundamentals of Heat and Moisture Transport for Microwaveable Food Product and Process Development</b>	<b>115</b>
<i>Ashim K. Datta</i>	
Introduction	115
Nature of Microwave Heating	116
Lambert's Law as a Simplified Description of Microwave Power Absorption	119
Heat Transport in Microwave Heating: General Description	121
Heat Transport in Microwave Heating of Solids	125
Heat Transport in Microwave Heating of Liquids	120
Effect of Changes in Temperature and Frequency on Heat Transport	132
Some Unit Operations Involving Primarily Heat Transport	133
Moisture Transport in Microwave Heating of Solid Food	141
Coupling of the Temperature and Moisture Variation of Dielectric Properties During Processing	153
Quality Improvement	158
Computer-Aided Engineering of Heat and Mass Transfer Processes	163
Acknowledgments	165
List of Symbols	165
References	166

## PART II. CHEMICAL AND BIOLOGICAL CHANGES DUE TO HEATING

- 5. Generation and Release of Food Aromas Under Microwave Heating** **173**  
*Varoujan A. Yaylayan and Deborah D. Roberts*
- Introduction 173  
 Generation of Maillard Aromas Under Microwave Heating 175  
 Aroma Release During Microwave Heating of Food Products 181  
 Development of New Products/Processes to Optimize  
 Aroma Formation and Minimize Aroma Release During  
 Microwave Processing of Food Products 184  
 References 186
- 6. Bacterial Destruction and Enzyme Inactivation During Microwave Heating** **191**  
*Ramaswamy C. Anantheswaran and Hosahalli S. Ramaswamy*
- Introduction 191  
 Kinetics of Destruction During Microwave Heating 192  
 Thermal, Nonthermal, and Microwave Enhanced Effects  
 Due to Microwave Heating 195  
 Factors Affecting Microbial Destruction During  
 Microwave Heating 196  
 Impact of Microwave Heating on Injury of Bacteria 204  
 Microwave Inactivation of Enzymes 206  
 Conclusion 209  
 References 210

## PART III. PROCESSING SYSTEMS AND INSTRUMENTATION

- 7. Consumer, Commercial, and Industrial Microwave Ovens and Heating Systems** **215**  
*Richard H. Edgar and John M. Osepchuk*
- Historical Introduction 215  
 Power Sources for Microwave Heating 226  
 Microwave Applicators and Cavities 233  
 Review of Available Oven Systems and Properties 252  
 Power and Efficiency Considerations 266  
 Uniformity Considerations 269  
 Controls and Sensors 271  
 Trends and Outlook 272  
 References 275

<b>8</b>	<b>Measurement and Instrumentation</b>	<b>279</b>
	<i>Ashim K. Datta, Henry Berek, Douglas A. Little, and Hosahalli S. Ramaswamy</i>	
	Introduction	279
	Measurement of Electric Field	280
	Point Measurement of Temperature	282
	Measurement of Surface Heating Patterns	288
	Measurement of Internal Temperature Profiles Using Magnetic Resonance Imaging	291
	Measurement of Cook or Sterilization Values (Time-Temperature History Effects)	292
	Set-Point Temperature Control in a Microwave Oven	293
	Measurement of Moisture Loss and Moisture Profiles During Microwave Heating	295
	References	296
	<b>PART IV. PROCESSES AT INDUSTRY AND HOME</b>	
<b>9</b>	<b>Microwave Processes for the Food Industry</b>	<b>299</b>
	<i>Robert F. Schiffmann</i>	
	Introduction	299
	Meat and Poultry Processing	303
	Tempering	309
	Baking	312
	Drying	320
	Pasteurization and Sterilization	325
	Future of Microwave Processing in the Food Industry	330
	Conclusion	334
	References	335
<b>10.</b>	<b>Basic Principles for Using a Home Microwave Oven</b>	<b>339</b>
	<i>Carolyn Dodson</i>	
	Introduction	339
	Cooking Patterns, Power Levels, and Temperature Correlation	340
	What Affects Microwave Cooking Time?	341
	Effects of Containers, Covers, and Shielding	344
	Various Processes at Home	346
	Cooking Various Food Types	349
	Converting Directions from Conventional Heating	350
	References	352

**PART V. PRODUCT AND PROCESS DEVELOPMENT**

<b>11. Ingredient Interactions and Product Development for Microwave Heating</b>	<b>355</b>
<i>Triveni P. Shukla and Ramaswamy C. Anantheswaran</i>	
Introduction	355
Microwave Energy	356
Microwave Oven	356
Interaction of Food Components with Microwaves	357
Food Product Design for Microwave Heating	377
Product Performance Testing	380
Advanced Technologies for Microwaveable Food	
Product Development	382
References	380
<b>12. Packaging Techniques for Microwaveable Foods</b>	<b>397</b>
<i>Timothy H. Bohrer and Richard K. Brown</i>	
Introduction	397
Passive Packages	399
Active Packages	407
Environmental Considerations	441
Some Remaining Challenges	443
Summary	444
Appendix: Patents	444
References	467
<b>PART VI. SAFETY</b>	
<b>13. Safety in Microwave Processing</b>	<b>471</b>
<i>Gregory J. Fleischman</i>	
Introduction	471
Uniformity of Thermal Treatment in Conventional and Microwave Heating	
Industrial and Commercial Production of Microbiologically Safe Foods	476
Chemical Migration	487
Operational Safety Considerations	489
Summary	494
References	494