

Contents

Preface to the 2nd Edition	xi
Editor Biography	xiii
Contributors	xv

I

HIGH PRESSURE PROCESSING

1. High-Pressure Processing of Foods: An Overview	
YANG TAO, DA-WEN SUN, EAMONN HOGAN, ALAN L. KELLY	
1.1 Introduction	3
1.2 Principles of HP Processing	3
1.3 Use of HP to Improve Food Safety and Stability	7
1.4 Effects of HP on Food Quality	12
1.5 Other Applications of HP	15
1.6 Modeling HP Processes	18
1.7 Outlook for HP Processing of Food	19
1.8 Conclusions	20
2. High-Pressure Processing of Salads and Ready Meals	
SRILATHA PANDRANGI, V.M. BALASUBRAMANIAM, YANG TAO, DA-WEN SUN	
2.1 Introduction	25
2.2 Importance of Salads and Ready Meals	25
2.3 Pressure Effects on Microorganisms	26
2.4 The Effects of Pressure on Enzyme Activity	28
2.5 The Effects of Pressure on Color	29
2.6 The Effects of Pressure on Texture	29
2.7 The Effects of Pressure on Nutrients	31
2.8 Conclusions	31
3. High-Pressure Processing of Meats and Seafood	
FRÉDÉRIQUE DURANTON, HÉLÈNE SIMONIN, CLAIRE GUYON, STÉPHANIE JUNG, MARIE DE LAMBALLERIE	
3.1 Introduction	35
3.2 HPP Effect on the Texture and Water Retention of Meat and Seafood	35
3.3 The Effect of HPP on Sensory Quality	41
3.4 The Chemical Safety of Pressure-Treated Meat Products	47
3.5 Pressure-Assisted Processes Applied to Meat and Seafood	49
3.6 Conclusions	55

4. High-Pressure Processing of Fruits and Fruit Products

SÓNIA MARÍLIA CASTRO, JORGE ALEXANDRE SARAIVA

4.1 Introduction	65
4.2 Physicochemical Parameters	66
4.3 Color	68
4.4 Texture	69
4.5 Flavor	70
4.6 Vitamins	71
4.7 Microorganisms	72
4.8 Conclusions	73

5. Microbiological Aspects of High-Pressure Processing

MONTSERRAT MOR-MUR, ROGER ESCRIU, JOSEP YUSTE

5.1 Introduction	77
5.2 Effects of High Pressure	77
5.3 Factors Affecting the Effectiveness of Treatment	80
5.4 Conclusions	87

II

PULSED ELECTRIC FIELDS PROCESSING

6. Overview of Pulsed Electric Fields Processing for Food

STEFAN TOEPFL, CLAUDIA SIEMER,
GUILLERMO SALDAÑA-NAVARRO,
VOLKER HEINZ

6.1 Introduction	93
6.2 Historical Background	93
6.3 Mechanisms of Action	94
6.4 PEF Treatment System	97
6.5 Main Processing Parameters	100
6.6 Applications	104
6.7 Conclusions	108
Nomenclature	108

7. Pulsed Electric Field Processing of Liquid Foods and Beverages

MANSEL W. GRIFFITHS, MARKUS WALKLING-RIBEIRO

7.1 Introduction	115
7.2 PEF Technology	116
7.3 Mechanisms of Microbial Inactivation	117
7.4 Equipment	119

7.5 PEF Treatment Variables	121
7.6 Target Differences	127
7.7 PEF-Based Nonthermal Hurdle Strategies	128
7.8 Specific Results on Liquid Foods	129
7.9 Process Models	136
7.10 Conclusions	137
Nomenclature	138

8. Effect of High-Intensity Electric Field Pulses on Solid Foods

STEFAN TOEPFL, CLAUDIA SIEMER, VOLKER HEINZ

8.1 Introduction	147
8.2 Principle and Analysis of Cell Disintegration by PEF	147
8.3 Effects on Solid Foods	148
8.4 Equipment and Energy Requirements	152
8.5 Conclusions	152

9. Enzymatic Inactivation by Pulsed Electric Fields

OLGA MARTÍN-BELLOSO, Á. ROBERT MARSELLÉS-FONTANET,
PEDRO ELEZ-MARTÍNEZ

9.1 Introduction	155
9.2 Mechanism of Enzyme Inactivation by PEF	155
9.3 Factors Affecting Enzyme Inactivation by PEF	156
9.4 Effects of PEF on Specific Enzymes	158
9.5 Modeling Enzymatic Inactivation by PEF	163
9.6 Enzyme Inactivation by Combining PEF with Other Hurdles	165
9.7 Enzyme Activity During Storage of PEF Processed Foods	165
9.8 Conclusions	165
Nomenclature	165

10. Food Safety Aspects of Pulsed Electric Fields

OLGA MARTÍN-BELLOSO, Á. ROBERT MARSELLÉS-FONTANET,
PEDRO ELEZ-MARTÍNEZ

10.1 Introduction	169
10.2 Microbiological Safety of PEF	170
10.3 Chemical Safety and PEFs	175
10.4 Conclusions	175
Nomenclature	176

III

OTHER NONTHERMAL PROCESSING TECHNIQUES

11. Recent Developments in Osmotic Dehydration

NAVIN K. RASTOGI, K.S.M.S. RAGHAVARAO,
K. NIRANJAN

11.1 Introduction	181
11.2 Mechanism of Osmotic Dehydration	182
11.3 Effect of Process Parameters on Mass Transfer and Structure	184
11.4 Determination of Moisture and Solid Diffusion Coefficients	188

11.5 Methods for Increasing the Rate of Mass Transfer	189
11.6 Applications of Osmotic Dehydration	195
11.7 Limitations of Osmotic Dehydration	205
11.8 Management of Osmotic Solution	205
11.9 Conclusions	206
Nomenclature	206

12. Athermal Membrane Processes for the Concentration of Liquid Foods and Natural Colors

K.S.M.S. RAGHAVARAO, M.C. MADHUSUDHAN,
A. HRISHIKESH TAVANANDI, K. NIRANJAN

12.1 Introduction	213
12.2 Existing Methods	213
12.3 Osmotic Membrane Distillation	215
12.4 Direct Osmosis	222
12.5 Membrane Modules	228
12.6 Applications	229
12.7 Integrated Membrane Processes	230
12.8 Suggestions for Future Work	232
12.9 Conclusions	233
Nomenclature	233

13. High-Intensity Pulsed Light Technology

DOMENICO CACACE, LUIGI PALMIERI

13.1 Introduction	239
13.2 Principles of PLT	239
13.3 Systems for PLT	241
13.4 Effects of PL on Microorganisms	243
13.5 Technological Aspects of PLT	245
13.6 Effects of PL on Food Quality and Components	254
13.7 Conclusions	255

14. Nonthermal Processing By Radio Frequency Electric Fields

FRANCISCO J. TRUJILLO, DAVID J. GEVEKE

14.1 Introduction	259
14.2 Radio Frequency Electric Fields Equipment	260
14.3 Modeling of Radio Frequency Electric Fields	263
14.4 RFEF Nonthermal Inactivation of Yeast	264
14.5 Bench Scale RFEF Inactivation of Bacteria and Spores	264
14.6 Pilot-Scale RFEF Inactivation of Bacteria	266
14.7 Electrical Costs	267
14.8 Conclusions	267

15. Application of Ultrasound

LARYSA PANIWNKY

15.1 Introduction	271
15.2 Fundamentals of Ultrasound	272
15.3 Ultrasound as a Food Preservation Tool	276
15.4 Ultrasound as a Processing Aid	279
15.5 Ultrasound Effects on Food Properties	286
15.6 Conclusions	288

16. Irradiation

MONIQUE LACROIX

- 16.1 Introduction 293
- 16.2 Definition of Irradiation 294
- 16.3 Gamma and X-ray Irradiation 295
- 16.4 UV Irradiation 297
- 16.5 Combined Treatments 298
- 16.6 Conclusions 307

17. New Chemical and Biochemical Hurdles

BRIJESH K. TIWARI

- 17.1 Introduction 313
- 17.2 Novel Antimicrobial Agents 313
- 17.3 Essential Oils 314
- 17.4 Antimicrobial Peptides 316
- 17.5 Novel Chemical Antimicrobial Agents 318
- 17.6 Quantification of Minimum and Noninhibitory Concentrations 320
- 17.7 Biochemical Hurdles 320
- 17.8 Conclusions 322

18. Decontamination of Foods by Cold Plasma

BRENDAN A. NIEMIRA

- 18.1 Introduction 327
- 18.2 The Chemistry of Cold Plasma 327
- 18.3 Low-Pressure Cold Plasmas 328
- 18.4 Atmospheric Pressure Cold Plasmas 330
- 18.5 Economics of Cold Plasma 332
- 18.6 Conclusions 332

19. Opportunities and Challenges in the Application of Ozone in Food Processing

B.S. PRIYANKA, NAVIN K. RASTOGI, BRIJESH K. TIWARI

- 19.1 Introduction 335
- 19.2 Physicochemical Properties 336
- 19.3 Ozonation Reactions 336
- 19.4 Generation of Ozone 337
- 19.5 Solubility of Ozone in Water 337
- 19.6 Methods for Mixing Ozone 338
- 19.7 Determination and Monitoring of Ozone 338
- 19.8 Critical Factors Affecting the Efficacy of Ozone 338
- 19.9 Application in Food Processing 339
- 19.10 Synergistic Effects of Ozone 353
- 19.11 Conclusions 354

IV**ALTERNATIVE THERMAL PROCESSING****20. Recent Developments in Microwave Heating**

SEMIN O. OZKOC, GÜLÜM SUMNU, SERPİL SAHİN

- 20.1 Introduction 361
- 20.2 Dielectric Properties of Foods 361

- 20.3 Heat and Mass Transfer in Microwave Processing 362
- 20.4 Microwave Processing of Foods 363
- 20.5 Conclusions 377
- Nomenclature 377

21. Radio-Frequency Processing

VALÉRIE ORSAT, G.S. VIJAYA RAGHAVAN

- 21.1 Introduction 385
- 21.2 Dielectric Heating 386
- 21.3 Material Properties 388
- 21.4 Adopting RF Heating 389
- 21.5 RF Heating Applications 392
- 21.6 RF Drying Applications 394
- 21.7 Conclusions 394
- Nomenclature 395

22. Ohmic Heating

ADELINE GOULLIEUX, JEAN-PIERRE PAIN

- 22.1 Introduction 399
- 22.2 Fundamentals of Ohmic Heating 400
- 22.3 Electrical Conductivity 401
- 22.4 Generic Configurations 405
- 22.5 Modeling 407
- 22.6 Treatment of Products 414
- 22.7 Conclusions 420
- Nomenclature 422

23. Combined Microwave Vacuum DryingCHRISTINE H. SCAMAN, TIMOTHY D. DURANCE,
LIANA DRUMMOND, DA-WEN SUN

- 23.1 Introduction 427
- 23.2 Microwaves 428
- 23.3 Dielectric Properties of Food 429
- 23.4 Thermal Properties of Food 430
- 23.5 Characteristics of Microwave Vacuum Drying 430
- 23.6 Combination of Microwave Vacuum with Other Processes 436
- 23.7 Equipment 437
- 23.8 Modeling of Microwave Vacuum-Drying 438
- 23.9 Microwave Freeze-Drying 439
- 23.10 Other Applications of Microwave Vacuum Processing 440
- 23.11 Commercial Potential 441
- 23.12 Conclusions 441
- Nomenclature 441

24. Recent Advances in Hybrid Drying Technologies

KIAN JON CHUA, SIAW KIANG CHOU

- 24.1 Introduction 447
- 24.2 Product Quality Degradation During Dehydration 447
- 24.3 Hybrid Drying Systems 449
- 24.4 Conclusions 457

25. Infrared Heating

ZHONGLI PAN, GRIFFITHS G. ATUNGULU, XUAN LI

- 25.1 Introduction 461
- 25.2 Fundamentals of IR Heating 461
- 25.3 Computational Modeling of IR Heating Process 464
- 25.4 Application of IR Heating for Food and Agricultural Processing 465
- 25.5 Outlook of IR Heating for Food and Agricultural Processing 471
- 25.6 Conclusions 472
- Nomenclature 472

V

INNOVATIONS IN FOOD REFRIGERATION

26. Vacuum Cooling of Foods

LIANA DRUMMOND, LIYUN ZHENG, DA-WEN SUN

- 26.1 Introduction 477
- 26.2 Vacuum Cooling Principles, Process, and Equipment 477
- 26.3 Vacuum Cooling Applications in the Food Industry 480
- 26.4 Mathematical Modeling of Vacuum-Cooling Process 486
- 26.5 Advantages and Disadvantages of Vacuum Cooling 487
- 26.6 Factors Affecting Vacuum-Cooling Process 489
- 26.7 Conclusions 491
- Nomenclature 491

27. Ultrasonic Assistance for Food Freezing

HOSSEIN KIANI, LIYUN ZHENG, DA-WEN SUN

- 27.1 Introduction 495
- 27.2 Power Ultrasound Generation and Equipment 496
- 27.3 Acoustic Effects on the Food Freezing Process 498
- 27.4 Factors Affecting Power Ultrasound Efficiency 507
- 27.5 Applications 509
- 27.6 Conclusions 511

28. High-Pressure Freezing

PEDRO D. SANZ, LAURA OTERO

- 28.1 Introduction 515
- 28.2 High Pressure for Freezing: Principles and Equipment 515
- 28.3 Types of High-Pressure Freezing Processes 517
- 28.4 Microbial and Enzymatic Inactivation after High-Pressure Freezing 524

- 28.5 Modeling High-Pressure Freezing Processes 525
- 28.6 Future Perspectives 531
- 28.7 Conclusions 532
- Nomenclature 532

29. Controlling the Freezing Process with Antifreeze Proteins

HANS RAMLØV, JOHANNES L. JOHNSEN

- 29.1 Introduction 539
- 29.2 Water as the Solvent of Life 539
- 29.3 The Physical Characteristics of Ice 540
- 29.4 Historical Review of AFP Research 544
- 29.5 Cold Tolerance in Cold-Blooded Animals 545
- 29.6 AFPs in Various Organisms 546
- 29.7 Types of AFP 547
- 29.8 Antifreeze Mechanism 550
- 29.9 Enhancement of Antifreeze Activity 553
- 29.10 The Use of AFP in Food Preservation 554
- 29.11 Physical and Chemical Characteristics of AFPs 555
- 29.12 Conclusions 556

30. Freezing Combined with Electrical and Magnetic Disturbances

EPAMEINONDAS XANTHAKIS, ALAIN LE-BAIL, MICHEL HAVET

- 30.1 Introduction 563
- 30.2 Water Properties and Freezing 563
- 30.3 Phase Changes Under Electrical Disturbances 565
- 30.4 Magnetic Fields and Phase Change 566
- 30.5 Research on Freezing Under an Electric Field 567
- 30.6 Electro and Magnetic Electric Fields or Oscillating Electric Fields 574
- 30.7 Patent Search 575
- 30.8 Conclusions 577
- Nomenclature 577

VI

MINIMAL PROCESSING

31. Minimal Processing of Fresh Fruit, Vegetables, and Juices

FRANCISCO ARTÉS, ANA ALLENDE

- 31.1 Introduction 583
- 31.2 Factors and Processing Operations that Affect the Quality of Minimally Processed Plant Foods 585
- 31.3 Emerging Technologies for Keeping the Microbial and Sensory Quality of MPFVs 589

- 31.4 Emerging Technologies for Minimally Processed
Fresh Fruit Juices 591
- 31.5 Conclusions 593

32. Minimal Processing of Ready Meals

STEPHEN JAMES, CHRISTIAN JAMES

- 32.1 Introduction 599
- 32.2 Design of Total System 601
- 32.3 Cook-Chill 602
- 32.4 Cook-Freeze 603
- 32.5 Sous-Vide 603
- 32.6 Novel and Alternative Processing Options 605
- 32.7 Conclusions 611

33. Modified Atmosphere Packaging, for Minimally Processed Foods

ROBERT W. LENCKI

- 33.1 Introduction 613
- 33.2 Properties of Packaged Food 614
- 33.3 Properties of Packaging Materials 620
- 33.4 Modified Atmosphere Packaging Design 622
- 33.5 Conclusions 624
- Nomenclature 624

Index 629