

Innovative Technologies for Food Preservation

Inactivation of Spoilage and Pathogenic
Microorganisms

Edited by

Francisco J. Barba

University of Valencia, Valencia, Spain

Anderson S. Sant'Ana

University of Campinas (UNICAMP), Campinas, SP, Brazil

Vibeke Orlie

University of Copenhagen, Frederiksberg C, Denmark

Mohamed Koubaa

Ecole Supérieure de Chimie Organique et Minérale, Compiègne, France



ACADEMIC PRESS

An imprint of Elsevier

Contents

List of Contributors

xi

Part I Introduction

1. Conventional Technologies of Food Preservation

Pedro E.D. Augusto, Beatriz M.C. Soares and Nanci Castanha

1.1 Thermal Processing	3
1.1.1 Thermal Processing Main Characteristics	4
1.1.2 Microbial Inactivation Kinetics	7
1.1.3 Process Design	10
1.2 Cooling	11
1.3 Freezing	14
1.4 Water Activity (a_w) Reduction	18
1.5 Hurdle Technology	19
1.6 Conclusions	22
References	22

2. Innovative Technologies for Food Preservation

*Francisco J. Barba, Lilia Ahrné, Epameinondas Xanthakis,
Martin G. Landerslev and Vibeke Orlien*

2.1 Introduction	25
2.2 Physical Technologies	26
2.2.1 High Hydrostatic Pressure Processing	27
2.2.2 High-Pressure Homogenization	31
2.3 Electromagnetic Technologies	34
2.3.1 Pulsed Electric Fields	34
2.3.2 Ohmic Heating	36
2.3.3 Microwaves	36
2.3.4 Radio-Frequency	37
2.3.5 UV-Light (Continuous and Pulsed)	39
2.4 Acoustic Technologies	40
2.4.1 Ultrasound	40
2.4.2 High Hydrodynamic Pressure-Shockwaves	42

2.5 Others	42
2.5.1 Membrane Filtration	42
2.5.2 Dense Phase CO ₂	45
Acknowledgments	47
References	47

3. Main Groups of Microorganisms of Relevance for Food Safety and Stability: General Aspects and Overall Description

Jose M. Lorenzo, Paulo E. Munekata, Ruben Dominguez, Mirian Pateiro, Jorge A. Saraiva and Daniel Franco

3.1 Introduction	53
3.2 Spoilage Nonspore-Forming Bacteria	54
3.2.1 <i>Brochothrix</i> spp.	55
3.2.2 <i>Carnobacterium</i> spp.	56
3.2.3 <i>Lactobacillus</i> spp.	56
3.2.4 <i>Pediococcus</i> spp.	58
3.2.5 <i>Streptococcus</i> spp.	58
3.2.6 <i>Lactococcus</i> spp.	59
3.2.7 <i>Leuconostoc</i> spp.	59
3.2.8 <i>Kurthia</i> spp.	60
3.2.9 <i>Weissella</i> spp.	60
3.3 Spoilage Spore-Forming Bacteria	60
3.3.1 Bacilli	61
3.3.2 Clostridia	63
3.4 Pathogenic Nonspore-Forming Bacteria	65
3.4.1 <i>Brucella</i> spp.	65
3.4.2 <i>Campylobacter</i> spp.	67
3.4.3 <i>Salmonella</i> spp.	68
3.4.4 <i>Yersinia</i> spp.	70
3.4.5 <i>Listeria</i> spp.	71
3.4.6 <i>Escherichia coli</i> spp.	72
3.5 Pathogenic Spore-Forming Bacteria	74
3.5.1 <i>Bacillus</i> spp.	75
3.5.2 <i>Clostridium</i> spp.	76
3.5.3 Sporulation and Germination Process and Morphology Spore	76
3.5.4 Contamination of Bacterial Spores to Food and Inactivation Methods	78
3.6 Yeasts and Molds	80
3.6.1 Yeast	80
3.6.2 Molds	82
3.7 Viruses and Parasites	85
3.7.1 Viruses	85
3.7.2 Parasites	88
3.8 Conclusion	92
References	92

Part II**Microbial Inactivation After Innovative Processing of the Main Groups of Microorganism of Relevance for Food Safety and Stability****4. Mechanisms of Microbial Inactivation by Emerging Technologies***Shahin Roohinejad, Mohamed Koubaa, Anderson S. Sant'Ana and Ralf Greiner*

4.1 Introduction	111
4.2 Inactivation Targets and Mode of Action of Emerging Technologies	112
4.2.1 Pulsed Electric Fields	112
4.2.2 Microbial Inactivation by Pulsed Electric Field	113
4.2.3 High Pressure Processing (HPP)	116
4.2.4 Ultrasounds	117
4.2.5 High Intensity Pulsed Light Technology	120
4.2.6 Microwave and Radiofrequency Electromagnetic Radiations	124
4.3 Conclusions	125
Acknowledgment	125
References	126

5. Effects of Innovative Processing Technologies on Microbial Targets Based on Food Categories: Comparing Traditional and Emerging Technologies for Food Preservation*Mehrdad Niakousari, Hadi H. Gahrue, Maryam Razmjooei, Shahin Roohinejad and Ralf Greiner*

5.1 Introduction	133
5.2 Traditional Methods of Food Preservation	134
5.3 Innovative Processing Technologies of Food Preservation	134
5.3.1 Pulsed Electric Fields	134
5.3.2 High-Pressure Processing	149
5.3.3 Ultrasounds	160
5.4 Conclusions	171
Acknowledgment	172
References	172
Further Reading	185

6. Designing, Modeling, and Optimizing Processes to Ensure Microbial Safety and Stability Through Emerging Technologies

Hassan Masood, Francisco J. Trujillo, Kai Knoerzer and Pablo Juliano

6.1 Introduction	187
6.1.1 Emerging Food Processing Technologies	187
6.1.2 Modeling and Optimization of Emerging Technologies	188
6.2 Electrical Processing	189
6.2.1 Operational Principles and Control Parameters	190
6.2.2 Microbiological Modeling	192
6.2.3 Multiphysics Models and Numerical Simulations	195
6.3 High-Pressure Processing	203
6.3.1 Operational Principles and Control Parameters	205
6.3.2 Microbiological Modeling	206
6.3.3 Multiphysics Simulations	208
6.4 Ultrasound Processing	213
6.4.1 Operational Principles and Control Parameters	213
6.4.2 Microbiological Modeling	214
6.4.3 Multiphysics Model and Numerical Simulations	215
6.5 Conclusions	219
References	220

Part III

Consumer's, Technological, Environmental and Regulatory Aspects of Application of Emerging Technologies for Food Preservation

7. Consumer Acceptance and Marketing of Foods Processed Through Emerging Technologies

María Lavilla and Elisa Gayán

7.1 Introduction	233
7.2 Global Trends of Acceptance and Trade in Foods Processed Through Emerging Technologies	234
7.3 Public Acceptance of Foods Processed Through Emerging Technologies	236
7.3.1 Brief Overview in Trends of Emerging Food Processing Technologies	236
7.3.2 Public Acceptance of Food Processed by High-Pressure Processing	237
7.3.3 Public Acceptance of Food Processed by Microwave Heating	238
7.3.4 Public Acceptance of Food Processed by Pulsed Electric Field	239
7.3.5 Public Acceptance of Food Processed by Ultraviolet Technologies	241

7.4	Market Development and Commercialization of Foods Processed Through Emerging Technologies	244
7.5	Challenges and Opportunities	245
	Acknowledgments	247
	References	247
8.	Environmental Footprint of Emerging Technologies, Regulatory and Legislative Issues	
	<i>Sónia M. Castro, Rita S. Inácio, Elisabete M.C. Alexandre, Liliana G. Fidalgo, Sofia Pereira, Patrícia Quaresma, Paulo Freitas, Paula Teixeira, Manuela Pintado, Ana M. Gomes, Carole Tonello and Jorge A. Saraiva</i>	
8.1	Introduction	255
8.2	Environmental Footprint of Emerging Technologies	256
8.3	Current Status on International Regulations	257
8.3.1	United States of America	258
8.3.2	Canada	262
8.3.3	European Union	264
8.3.4	Japan, Australia, and New Zealand	269
8.4	Concluding Remarks	272
	Acknowledgments	273
	References	273
9.	Technological Hurdles and Research Pathways on Emerging Technologies for Food Preservation	
	<i>Daniela Bermudez-Aguirre</i>	
9.1	Introduction	277
9.2	Emerging Technologies: Technological Limitations	277
9.2.1	Mechanical Processes	280
9.2.2	Electromagnetic Technologies	281
9.2.3	Acoustic Technologies	290
9.2.4	Innovative Chemical Processing Technologies	292
9.2.5	Hurdle Technology	293
9.3	Research Needs	293
9.3.1	High Hydrostatic Pressure	293
9.3.2	Pulsed Electric Fields	294
9.3.3	Ohmic Heating	294
9.3.4	Microwave	295
9.3.5	Cold Plasma	295
9.3.6	Ultraviolet	296
9.4	Challenges and Opportunities	296
9.5	Conclusions	298
	References	298
	Index	305