

# Contents

List of Contributors .....	xvii
Preface .....	xix

## **SECTION 1 PHYSICAL CHEMISTRY FUNDAMENTALS FOR FOOD PACKAGING**

---

<b>CHAPTER 1 A Review of Food Packaging Technologies and Innovations .....</b>	<b>3</b>
<i>Jung H. Han</i>	
Introduction.....	3
Developments in food processing and packaging .....	5
Food packaging technologies .....	6
Extra active functions of packaging systems.....	6
Modified atmosphere packaging .....	8
Edible films and coatings .....	8
New food-processing technologies .....	9
Future trends in food packaging.....	10
References.....	11
<b>CHAPTER 2 General Characteristics of Packaging Materials for Food System.....</b>	<b>13</b>
<i>Young Teck Kim, Byungjin Min and Kyung Won Kim</i>	
Introduction.....	13
Types and properties of packaging materials for food systems.....	14
Paper and paperboard for food packaging .....	14
Plastics for food packaging .....	18
Glass for food packaging.....	30
Metals for food packaging .....	31
Selection of packaging materials for food systems .....	31
References.....	33

<b>CHAPTER 3</b>	<b>Mass Transfer of Gas and Solute Through Packaging Materials .....</b>	<b>37</b>
<i>Jung H. Han and Martin G. Scanlon</i>		
Introduction.....	37	
General theory .....	39	
Diffusivity .....	40	
Solubility and partitioning.....	41	
Henry's law and solubility .....	41	
Convective mass transfer.....	42	
Overall mass transfer of gases and solutes .....	44	
Gaseous diffusivity and permeability.....	44	
Solute mass transfer coefficient and overall permeability .....	45	
Summary .....	46	
References.....	48	
<b>CHAPTER 4</b>	<b>Surface Chemistry of Food, Packaging, and Biopolymer Materials .....</b>	<b>51</b>
<i>Tapashi Sengupta and Jung H. Han</i>		
Introduction.....	52	
Physical chemistry of food, biopolymer materials, and packaging surfaces .....	54	
Surface tension as force and contact angle.....	54	
Surface tension as energy .....	56	
Measurement of surface energy with theoretical models .....	59	
Adhesion, cohesion and spreading .....	64	
Zisman equation and critical surface tension .....	68	
McGuire's theory and equation.....	68	
Neumann's equation .....	69	
Harmonic mean method .....	69	
Germain's method .....	70	
Special surfaces of packaging materials inspired by biomimetics .....	71	
Instrumental characterization of food, biopolymer materials, and packaging surfaces .....	74	
Goniometry or contact angle measurements .....	74	
Tensiometry .....	76	
Electrokinetic potential measurement .....	78	
Applied research .....	80	
Future trends .....	84	
References.....	84	

**CHAPTER 5 Plasticization and Polymer Morphology..... 87***Youngjae Byun and Yachuan Zhang*

Introduction.....	87
Type of plasticization .....	88
Plasticizers .....	88
Definition of plasticizers .....	88
Types of plasticizers .....	89
Application of plasticizer on packaging material .....	91
Copolymerization.....	93
Blending .....	95
Polymer morphology .....	96
Microscopic methods for studying polymer morphology .....	97
Light microscopy .....	97
Scanning electron microscopy (SEM) .....	98
Transmission electron microscopy (TEM).....	99
Atomic force microscopy (AFM).....	102
Conclusion .....	105
References.....	105

**SECTION 2 ACTIVE AND INTELLIGENT PACKAGING**

---

**CHAPTER 6 Antioxidative Packaging System ..... 111***Dong Sun Lee*

Introduction.....	111
Exclusion of oxygen .....	112
Antioxidant packaging.....	116
Controlled release in antioxidant packaging.....	123
Conclusion .....	126
References.....	126

**CHAPTER 7 Antimicrobial Packaging Systems ..... 133***Margarita Corrales, Avelina Fernández García  
and Jung H. Han*

Introduction.....	134
Antimicrobial packaging—food interactions and environmental conditions.....	135
Antimicrobial packaging systems .....	136
Metal-based micro- and nanocomposites.....	137
Copper.....	144

Zinc oxide .....	144
Titanium dioxide.....	145
Enzymes.....	145
Bacteriocins .....	147
Natural extracts.....	148
Essential oils .....	149
Allyl isothiocyanate.....	150
Anhydrides and weak organic acids.....	151
Ethylenediaminetetraacetic acid (EDTA) .....	152
Others.....	152
Imazalil .....	153
Antimicrobial macromolecules .....	153
$\epsilon$ -Polylysine.....	154
Regulation and commercialization of antimicrobial packaging .....	155
Future perspectives .....	156
References.....	158

## CHAPTER 8 Intelligent Packaging for Food Products ..... 171

*Seung Ju Lee and A.T.M Mijanur Rahman*

Introduction.....	172
Definitions and examples of active and intelligent packaging .....	173
Active packaging .....	173
Examples of active materials and articles.....	174
Intelligent packaging .....	174
Examples of intelligent packaging applications within the food industry .....	174
History of active and intelligent packaging .....	175
Global market for active, controlled, and intelligent packaging .....	175
Intelligent packaging systems .....	176
Indicators .....	176
Barcodes.....	187
Radiofrequency identification devices (RFIDs) .....	188
Sensors used in the indicators .....	192
Novel packaging for convenience users .....	197
Legal aspects of intelligent packaging.....	200
Regulation 1935/2004/EC .....	201
Regulation 450/2009/EC .....	202
Conclusion .....	202
References.....	203

## SECTION 3 EDIBLE COATING AND FILMS

---

### CHAPTER 9 Edible Films and Coatings: A Review..... 213

*Jung H. Han*

Introduction.....	214
Film composition .....	216
Film-forming materials.....	216
Plasticizers .....	222
Additives .....	223
Functions and advantages of edible films/coatings .....	224
Edibility and biodegradability .....	224
Physical and mechanical protection .....	224
Migration, permeation, and barrier functions .....	227
Convenience and quality preservation .....	228
Shelf-life extension and safety enhancement.....	229
Active substance carriers and controlled release.....	230
Non-edible product applications .....	231
Other process-aiding functions.....	233
Scientific parameters .....	233
Chemistry of film-forming materials .....	233
Film-forming mechanisms.....	234
Physical chemistry of films .....	235
Practical parameters for commercialization.....	236
Film-production processes.....	236
Feasibility of commercial system .....	238
Consumer-related issues .....	238
Regulatory issues .....	239
Edible film and coating research trends.....	240
Conclusion .....	240
References.....	241

### CHAPTER 10 Processes and Applications for Edible Coating and Film Materials from Agropolymers ..... 257

*Hyun Jin Park, Youngjae Byun, Young Teck Kim,  
W. Scott Whiteside and Ho Jae Bae*

Edible biopolymer coatings for foods.....	258
Introduction: the role of edible biopolymer coatings .....	258
How edible coatings work: controlling internal gas composition .....	259

Selecting edible coatings .....	260
Future trends .....	262
Edible biopolymer films for foods .....	263
Introduction: edible biopolymer films .....	263
Composition of edible biopolymer films and their classification.....	263
Edible biopolymer film formation mechanisms .....	264
Development of edible biopolymer films based on protein .....	265
Development of various edible biopolymer films based on polysaccharides.....	268
Development of edible biopolymer films combined with polysaccharides and protein .....	270
Functionalities of edible biopolymer film .....	270
Edible biopolymer film as active packaging materials .....	271
Current status of edible biopolymer film.....	272
References.....	272

## **CHAPTER 11 Edible Coating and Film Materials: Proteins ..... 277**

*M. Lacroix and K.D. Vu*

Introduction.....	277
Films based on milk proteins .....	282
Caseins .....	282
Whey proteins.....	283
Collagen and gelatin.....	284
Plasma proteins.....	285
Myofibrillars proteins .....	286
Egg white .....	289
Soy protein.....	289
Wheat gluten.....	291
Zein coatings and films .....	292
Protein-based nanocomposites .....	293
References.....	294

## **CHAPTER 12 Edible Coating and Film Materials: Carbohydrates ..... 305**

*Yachuan Zhang, Curtis Rempel and Derek McLaren*

Introduction.....	305
Polysaccharides and their edible coatings and films .....	306
Cellulose and derivatives.....	306
Chitosan .....	311

Pectin .....	317
Galactomannans.....	320
Conclusion .....	321
References.....	321

## **CHAPTER 13 Edible Coating and Film Materials: Lipid Bi-layers and Lipid Emulsions..... 325**

*M.B. Pérez-Gago and J.W. Rhim*

Introduction.....	325
Materials for the preparation of lipid-based edible films and coatings .....	326
Preparation of lipid-based edible films and coatings .....	330
Properties of lipid-based edible films and coatings.....	332
Properties of lipid monolayer films .....	332
Properties of bilayer films.....	332
Properties of emulsion films .....	336
Applications .....	342
Meat products .....	342
Cereal and bakery coatings .....	343
Dried fruits and nut coatings.....	343
Fresh and minimally processed fruits and vegetables .....	344
Edible packaging .....	344
Conclusion .....	345
References.....	345

## **SECTION 4 BIOPOLYMER PACKAGING**

---

### **CHAPTER 14 Bioplastics for Food Packaging: Chemistry and Physics .....** 353

*Youngjae Byun and Young Teck Kim*

Introduction.....	353
Compostable bioplastics.....	355
Polylactic acid (PLA) .....	355
Chemical structure of PLA.....	355
Physical properties of PLA .....	355
Modification of PLA and its effect on physical properties of PLA .....	357
Biodegradable polymers .....	357
Starch .....	357
Thermoplastic starch (TPS).....	358

Starch composites .....	359
Polyhydroxyalkanoates (PHAs).....	360
PHA composites .....	362
Other biodegradable plastics .....	362
Recyclable bioplastics .....	363
Bio-based PET .....	363
Bio-based PE and PP.....	364
Summary .....	364
References.....	365
<b>CHAPTER 15 Utilization of Bioplastics for Food Packaging Industry .....</b>	<b>369</b>
<i>Youngjae Byun and Young Teck Kim</i>	
Introduction.....	369
Recent research on bioplastics for food packaging applications .....	370
U.S. patent applications.....	370
Research trends in bioplastics packaging systems.....	372
Applications of bioplastics in the current market.....	375
Current and future bioplastics market.....	375
PLA market.....	378
PHA market .....	380
Starch market.....	381
Bio-based PET .....	382
Bio-based PE and PP from braskem .....	386
Compostable and hybrid resins from cereplast.....	388
Sustainability strategies from major retailers .....	388
Conclusion .....	388
References.....	389
<b>CHAPTER 16 Thermoplastic Starch.....</b>	<b>391</b>
<i>Yachuan Zhang, Curtis Rempel and Derek McLaren</i>	
Introduction.....	391
TPS Manufacturing process: casting methods and extrusion procedures .....	392
Improvements in TPS properties.....	394
Starch sources .....	395
Plasticizer.....	398
Nanoclay .....	400
Fiber .....	404
Polymer .....	404

Conclusion .....	408
References.....	408

## **CHAPTER 17 Biopolymer-Based Composite Packaging Materials with Nanoparticles..... 413**

*Jong-Whan Rhim and Young Teck Kim*

Introduction.....	414
Preparation and characterization of bio-nanocomposites .....	415
Preparation of bio-nanocomposites .....	415
Characterization of bio-nanocomposites .....	417
Properties of bio-nanocomposites .....	418
Mechanical properties.....	418
Barrier properties.....	419
Biodegradation properties.....	420
Antimicrobial properties.....	422
Other properties .....	424
Applications of bio-nanocomposites for food packaging.....	425
Rigid packaging application.....	426
Flexible packaging application.....	429
Active packaging applications .....	431
Intelligent or smart packaging applications .....	432
Nanocoatings .....	433
Other applications .....	435
Conclusion .....	435
Acknowledgements.....	436
References.....	436

## **SECTION 5 COMMERCIAL FOOD PACKAGING INNOVATIONS**

---

### **CHAPTER 18 Modified Atmosphere Packaging for Fresh Fruits and Vegetables .....** 445

*Hong Zhuang, M. Margaret Barth and Luis Cisneros-Zevallos*

Introduction.....	445
MAP for fresh and fresh-cut produce .....	446
Microperforated films.....	450
Bioplastics and biodegradable films .....	452
Active MAP (backflush and absorption) .....	454
Antimicrobial MAP systems .....	457

Intelligent MAP .....	462
Summary .....	463
References.....	464
<b>CHAPTER 19 Modified Atmosphere Packaging of Meat, Poultry and Fish .....</b>	<b>475</b>
<i>Kay Cooksey</i>	
Introduction.....	475
Background.....	476
Color .....	476
Role of gases.....	477
Poultry.....	478
Fish.....	479
Carbon monoxide .....	479
Use of argon in MAP meat .....	482
Combination of processes or additives with MAP .....	483
Antimicrobial applications with MAP .....	485
Summary .....	489
References.....	490
<b>CHAPTER 20 Microwavable Food Packaging .....</b>	<b>495</b>
<i>Marc Regier</i>	
Introduction.....	495
Microwave basics .....	496
Microwavable food packaging basics .....	501
General needs .....	501
Microwavable passive packagings .....	502
Microwavable active packagings .....	504
Regulations .....	508
Commercial examples .....	509
References.....	513
Further reading .....	514
<b>CHAPTER 21 Packaging for Nonthermal Food Processing.....</b>	<b>515</b>
<i>Sea C. Min, Howard Q. Zhang and Jung H. Han</i>	
Introduction.....	515
Nonthermal food processing .....	516
PEF.....	516
HPP .....	519
Irradiation.....	519
Pulsed light .....	520

Packaging for nonthermal food processing.....	521
PEF.....	521
HPP .....	526
Irradiation.....	528
Pulsed light .....	529
Future research .....	530
References.....	530

## **CHAPTER 22 Eco-Design for Food Packaging Innovations ..... 537**

*Su-Il Park, Dong Sung Lee and Jung.H. Han*

Introduction.....	537
Eco-design guidelines for food packaging innovation .....	539
Waste management principles.....	539
Holistic approaches for eco-design .....	540
Eco-design tools .....	541
Eco-design of food packaging harmonized with logistics..	543
References.....	546

## **CHAPTER 23 New Packaging Technologies, Materials and Formats for Fast-Moving Consumer Products ..... 549**

*Joe P. Kerry*

Growing demands of current commercial packaging systems for fast-moving consumer goods .....	549
First- and second-level packaging for application to fast-moving consumer goods.....	551
Muscle-based food products: meat, poultry, and fish.....	554
Diffusion-based TTIs.....	559
Enzymatic TTIs .....	560
Polymer-based TTIs .....	560
Non-beverage dairy-based products .....	562
Cereal-based products.....	563
Horticultural produce: fruits and vegetables.....	563
Beverages: soft, dairy-based, and alcoholic.....	565
Health, beauty, and personal care products .....	577
Other products .....	580
Conclusion .....	581
References.....	582
Index .....	585
Food Science and Technology International Series.....	601