

# Contents

<i>Preface</i>	xiii
<i>Contributors</i>	xv
<b>1 Introduction</b>	<b>1</b>
Richard Coles	
1.1 Introduction	1
1.2 Packaging developments – an historical and future perspective	3
1.3 Role of packaging for enhanced sustainability of food supply	5
1.4 Definitions and functions of packaging	9
1.5 Packaging strategy	10
1.6 Packaging design and development	10
1.6.1 The packaging design and development framework	13
1.6.2 Packaging specifications and standards	26
1.7 Conclusion	27
References	27
Websites	28
<b>2 Food Biodeterioration and Methods of Preservation</b>	<b>31</b>
Gary S. Tucker	
2.1 Introduction	31
2.2 Agents of food biodeterioration	32
2.2.1 Enzymes	32
2.2.2 Microorganisms	33
2.2.3 Non-enzymic biodeterioration	38
2.3 Food preservation methods	38
2.3.1 High temperatures	39
2.3.2 Low temperatures	47
2.3.3 Drying and water activity control	49
2.3.4 Chemical preservation	51
2.3.5 Fermentation	53
2.3.6 Modifying the atmosphere	53
2.3.7 Other techniques and developments	54
References	57
<b>3 Packaged Product Quality and Shelf Life</b>	<b>59</b>
Helen Brown, James Williams and Mark Kirwan	
3.1 Introduction	59
3.2 Factors affecting product quality and shelf life	62

3.3	Chemical/biochemical processes	63
3.3.1	Oxidation	63
3.3.2	Enzyme activity	66
3.4	Microbiological processes	67
3.4.1	Examples where packaging is key to maintaining microbiological shelf life	68
3.5	Physical and physico-chemical processes	70
3.5.1	Physical damage	70
3.5.2	Insect damage	71
3.5.3	Moisture migration	71
3.5.4	Barrier to odour pick-up	73
3.5.5	Flavour scalping	73
3.6	Migration from packaging to foods	73
3.6.1	Migration from plastic packaging	74
3.6.2	Migration from other packaging materials	77
3.6.3	Factors affecting migration from food contact materials	78
3.6.4	Packaging selection to avoid migration and packaging taints	79
3.6.5	Methods for monitoring migration	79
3.7	Conclusion	81
	References	81

#### **4 Logistical Packaging for Food Marketing Systems 85**

Diana Twede and Bruce Harte

4.1	Introduction	85
4.2	Functions of logistical packaging	86
4.2.1	Protection	86
4.2.2	Utility/productivity	87
4.2.3	Communication	88
4.3	Logistics' activity-specific and integration issues	89
4.3.1	Packaging issues in food processing	89
4.3.2	Transport issues	90
4.3.3	Warehousing issues	93
4.3.4	Retail customer service issues	94
4.3.5	Waste issues	95
4.3.6	Supply chain integration issues	96
4.4	Distribution performance testing	97
4.4.1	Shock and vibration testing	97
4.4.2	Compression testing	98
4.5	Packaging materials and systems	99
4.5.1	Corrugated fibreboard boxes	99
4.5.2	Shrink bundles	101
4.5.3	Reusable totes	101
4.5.4	Unitisation	102
4.6	Conclusion	104
	References	105
	Further reading	105

## 5 Metal Packaging

107

Bev Page, Mike Edwards and Nick May

5.1	Overview of market for metal cans	107
5.2	Container performance requirements	107
5.3	Container designs	108
5.4	Raw materials for can-making	110
5.4.1	Steel	110
5.4.2	Aluminium	111
5.4.3	How steel and aluminium are used in metal packaging	111
5.4.4	Sustainability – the infinite recycling loop of metal for packaging	112
5.5	Can-making processes	113
5.5.1	Three-piece welded cans	114
5.5.2	Two-piece single drawn and multiple drawn (DRD) cans	115
5.5.3	Two-piece drawn and wall ironed (DWI) cans	116
5.5.4	Two-piece impact extruded cans	118
5.6	End-making processes	118
5.6.1	Plain food can ends and shells for food/drink easy-open ends	118
5.6.2	Conversion of end shells into easy-open ends	119
5.6.3	Peelable membrane ends for food cans	120
5.7	Coatings, film laminates and inks	120
5.8	Processing of food and drinks in metal packages	121
5.8.1	Can reception at the packer	121
5.8.2	Filling and exhausting	122
5.8.3	Seaming	123
5.8.4	Heat processing	125
5.8.5	Post-process drying	126
5.8.6	Container handling	126
5.8.7	Storage and distribution	127
5.9	Shelf life of canned foods	127
5.9.1	Interactions between the can and its contents	128
5.9.2	The role of tin	129
5.9.3	Tin toxicity	130
5.9.4	The dissolution of tin from the can surface	130
5.9.5	Iron	131
5.9.6	Aluminium	132
5.9.7	Lacquers	132
5.10	Internal corrosion	133
5.11	Stress corrosion cracking	133
5.12	Environmental stress cracking corrosion of aluminium alloy beverage can ends	133
5.13	Sulphur staining	134
5.14	External corrosion	134
5.15	Conclusion	135
	References	135
	Further reading	135

<b>6</b>	<b>Packaging of Food in Glass Containers</b>	<b>137</b>
	Peter Grayhurst and Patrick J. Girling	
6.1	Introduction	137
6.1.1	Definition of glass	137
6.1.2	Brief history	137
6.1.3	Glass packaging	137
6.1.4	Glass containers market sectors for foods and drinks	138
6.1.5	Glass containers	138
6.2	Attributes of food packaged in glass containers	139
6.2.1	Glass pack integrity and product compatibility	141
6.2.2	Consumer acceptability	141
6.3	Glass and glass container manufacture	141
6.3.1	Melting	141
6.3.2	Container forming	141
6.3.3	Design parameters	142
6.3.4	Surface treatments	142
6.4	Closure selection	147
6.4.1	Normal Seals	148
6.4.2	Vacuum seals	148
6.4.3	Pressure seals	148
6.5	Thermal processing of glass packaged foods	148
6.6	Plastic sleeving and decorating possibilities	149
6.7	Strength in theory and practice	149
6.8	Glass pack design and specification	150
6.8.1	Concept and container design	150
6.9	Packing – due diligence in the use of glass containers	152
6.10	Environmental profile	153
6.10.1	Reuse	153
6.10.2	Recycling	154
6.10.3	Reduction – light weighting	154
6.11	Glass as a marketing tool	155
	References	155
	Further reading	156
<b>7</b>	<b>Plastics in Food Packaging</b>	<b>157</b>
	Mark J. Kirwan, Sarah Plant and John W. Strawbridge	
7.1	Introduction	157
7.1.1	Definition and background	157
7.1.2	Use of plastics in food packaging	158
7.1.3	Types of plastics used in food packaging	159
7.2	Manufacture of plastics packaging	161
7.2.1	Introduction to the manufacture of plastics packaging	161
7.2.2	Plastic film and sheet for packaging	161
7.2.3	Pack types based on use of plastic films, laminates, etc.	165
7.2.4	Rigid plastic packaging	167

7.3	Types of plastic used in packaging	170
7.3.1	Polyethylene (PE)	170
7.3.2	Polypropylene (PP)	171
7.3.3	Polyethylene Terephthalate (PET or PETE)	173
7.3.4	Polyethylene naphthalene dicarboxylate (PEN)	174
7.3.5	Polycarbonate (PC)	175
7.3.6	Ionomers	175
7.3.7	Ethylene vinyl acetate (EVA)	176
7.3.8	Polyamide (PA)	176
7.3.9	Polyvinyl chloride (PVC)	177
7.3.10	Polyvinylidene chloride (PVdC)	178
7.3.11	Polystyrene (PS)	178
7.3.12	Styrene butadiene (SB)	179
7.3.13	Acrylonitrile butadiene styrene (ABS)	179
7.3.14	Ethylene vinyl alcohol (EVOH)	179
7.3.15	Polymethyl pentene (TPX)	180
7.3.16	High nitrile polymers (HNP)	180
7.3.17	Fluoropolymers	180
7.3.18	Cellulose-based materials	181
7.3.19	Polyvinyl acetate (PVA)	182
7.4	Coating of plastic films – types and properties	182
7.4.1	Introduction to coating	182
7.4.2	Acrylic coatings	182
7.4.3	PVdC coatings	183
7.4.4	PVOH coatings	183
7.4.5	Low-temperature sealing coatings (LTSCs)	183
7.4.6	Metallising with aluminium	183
7.4.7	SiOx coatings	184
7.4.8	DLC (Diamond-like coating)	184
7.4.9	Extrusion coating with PE	184
7.5	Secondary conversion techniques	185
7.5.1	Film lamination by adhesive	185
7.5.2	Extrusion lamination	186
7.5.3	Thermal lamination	186
7.6	Printing	187
7.6.1	Introduction to the printing of plastic films	187
7.6.2	Gravure printing	187
7.6.3	Flexographic printing	188
7.6.4	Digital printing	188
7.7	Printing and labelling of rigid plastic containers	188
7.7.1	In-mould labelling	188
7.7.2	Labelling	188
7.7.3	Dry offset printing	189
7.7.4	Silk screen printing	189
7.7.5	Heat transfer printing	189
7.8	Food contact and barrier properties	189
7.8.1	The issues	189

7.8.2	Migration	190
7.8.3	Permeation	190
7.8.4	Changes in flavour	191
7.9	Sealability and closure	192
7.9.1	Introduction to sealability and closure	192
7.9.2	Heat sealing	192
7.9.3	Flat jaw sealing	192
7.9.4	Crimp jaw conditions	193
7.9.5	Impulse sealing	194
7.9.6	Hot wheel sealing	195
7.9.7	Hot air sealers	195
7.9.8	Gas flame sealers	195
7.9.9	Induction sealing	195
7.9.10	Ultrasonic sealing	195
7.9.11	Cold seal	195
7.9.12	Plastic closures for bottles, jars and tubs	196
7.9.13	Adhesive systems used with plastics	196
7.10	How to choose	196
7.11	Retort pouch	198
7.11.1	Packaging innovation	198
7.11.2	Applications	199
7.11.3	Advantages and disadvantages	200
7.11.4	Production of pouches	201
7.11.5	Filling and sealing	201
7.11.6	Processing	202
7.11.7	Process determination	203
7.11.8	Post retort handling	203
7.11.9	Outer packaging	204
7.11.10	Quality assurance	204
7.11.11	Shelf life	204
7.12	Environmental and waste management issues	205
7.12.1	Environmental benefit	205
7.12.2	Sustainable development	205
7.12.3	Resource minimisation – light weighting	205
7.12.4	Plastics manufacturing and life cycle assessment (LCA)	206
7.12.5	Plastics waste management	206
	References	209
	Further reading	210
	Websites	210
	Appendices	211

## **8 Paper and Paperboard Packaging 213**

M.J. Kirwan

8.1	Introduction	213
8.2	Paper and paperboard – fibre sources and fibre separation (pulping)	215
8.3	Paper and paperboard manufacture	217
8.3.1	Stock preparation	217

8.3.2	Sheet forming	217
8.3.3	Pressing	218
8.3.4	Drying	218
8.3.5	Coating	219
8.3.6	Reel-up	219
8.3.7	Finishing	219
8.4	Packaging papers and paperboards	219
8.4.1	Wet strength paper	220
8.4.2	Microcreping	220
8.4.3	Greaseproof	220
8.4.4	Glassine	220
8.4.5	Vegetable parchment	220
8.4.6	Tissues	220
8.4.7	Paper labels	221
8.4.8	Bag papers	221
8.4.9	Sack kraft	221
8.4.10	Impregnated papers	221
8.4.11	Laminating papers	221
8.4.12	Solid bleached board (SBB)	221
8.4.13	Solid unbleached board (SUB)	222
8.4.14	Folding boxboard (FBB)	222
8.4.15	White lined chipboard (WLC)	223
8.5	Properties of paper and paperboard	223
8.5.1	Appearance	224
8.5.2	Performance	224
8.6	Additional functional properties of paper and paperboard	225
8.6.1	Treatment during manufacture	225
8.6.2	Lamination	225
8.6.3	Plastic extrusion coating and laminating	226
8.6.4	Printing and varnishing	227
8.6.5	Post-printing roller varnishing/coating/laminating	227
8.7	Design for paper and paperboard packaging	228
8.8	Package types	228
8.8.1	Tea and coffee bags	228
8.8.2	Paper bags and wrapping paper	228
8.8.3	Sachets/pouches/overwraps	229
8.8.4	Multiwall paper sacks	229
8.8.5	Folding cartons	231
8.8.6	Liquid packaging cartons	233
8.8.7	Rigid cartons or boxes	235
8.8.8	Paper-based tubes, tubs and composite containers	235
8.8.9	Fibre drums	236
8.8.10	Corrugated fibreboard packaging	237
8.8.11	Moulded pulp containers	239
8.8.12	Labels	240
8.8.13	Sealing tapes	241
8.8.14	Cushioning materials	242
8.8.15	Cap liners (wads) and diaphragms	242

8.9	Systems	243
8.10	Environmental profile	243
8.11	Carbon footprint	247
8.11.1	Carbon sequestration in forests	247
8.11.2	Carbon stored in forest products	248
8.11.3	Greenhouse gas emissions from forest product manufacturing facilities	248
8.11.4	Greenhouse gas emissions associated with producing fibre	248
8.11.5	Greenhouse gas emissions associated with producing other raw materials/fuels	248
8.11.6	Greenhouse gas emissions associated with purchased electricity, steam and heat, and hot and cold water	248
8.11.7	Transport-related greenhouse gas emissions	249
8.11.8	Emissions associated with product use	249
8.11.9	Emissions associated with product end-of-life	249
8.11.10	Avoided emissions and offsets	249
	References	249
	Further reading	249
	Websites	250
<b>9</b>	<b>Active Packaging</b>	<b>251</b>
	B.P.F. Day and L. Potter	
9.1	Introduction	251
9.2	Oxygen scavengers	252
9.3	Carbon dioxide scavenger and emitters	254
9.4	Ethylene scavengers	255
9.5	Ethanol emitters	256
9.6	Moisture absorbers	257
9.7	Flavour/odour absorbers	258
9.8	Lactose and cholesterol removers	259
9.9	Anti-oxidant release	259
9.10	Temperature-controlled packaging	259
9.11	Regulatory issues, consumer acceptability and equipment considerations	260
9.12	Conclusion	261
	References	261
<b>10</b>	<b>Modified Atmosphere Packaging</b>	<b>263</b>
	Michael Mullan and Derek McDowell	
	Section A: Map gases packaging materials and equipment	263
10.A1	Introduction	263
10.A1.1	Historical development	264
10.A2	Gaseous environment	264
10.A2.1	Gases used in MAP	264
10.A2.2	Effect of the gaseous environment on the activity of bacteria, yeasts and moulds	265



10.A2.3	Effect of the gaseous environment on the chemical biochemical and physical properties of foods	267
10.A2.4	Physical spoilage	270
10.A3	Packaging materials	270
10.A3.1	Main plastics used in MAP	270
10.A3.2	Selection of plastic packaging materials	273
10.A4	Modified packaging atmosphere machines	276
10.A4.1	Chamber machines	277
10.A4.2	Snorkel machines	277
10.A4.3	Form-fill-seal machines	277
10.A4.4	Preformed trays	279
10.A4.5	Modification of the pack atmosphere	281
10.A4.6	Sealing	281
10.A4.7	Cutting	282
10.A4.8	Additional operations	283
10.A5	Quality assurance of map	283
10.A5.1	Heat seal integrity	285
10.A5.2	Measurement of transmission rate and permeability in packaging films	286
10.A5.3	Determination of headspace gas composition	288
Section B: Main food types		288
10.B1	Raw red meat	288
10.B2	Raw poultry	288
10.B3	Cooked, cured and processed meat products	289
10.B4	Fish and fish products	290
10.B5	Fruits and vegetables	291
10.B6	Dairy products	293
	References	293

## **11 Bioplastics 295**

Jim Song, Martin Kay and Richard Coles

11.1	Introduction	295
11.2	Definitions	297
11.2.1	Plastics based on renewable resources	297
11.2.2	Biodegradable and compostable plastics according to EN13432 or similar standards	297
11.3	Bioplastics and carbon	298
11.4	Bioplastics – overview of material types	299
11.4.1	Classification of bioplastics	299
11.4.2	Bioplastics directly extracted from biomass	300
11.4.3	Bioplastics synthesised from bio-derived monomers	305
11.4.4	Biodegradable polymers from petrochemicals	306
11.4.5	Polyesters directly produced from natural organisms	308

11.4.6	Biocomposites	308
11.5	Waste management options for bioplastics	310
11.5.1	Conventional waste management options	310
11.5.2	Biological waste treatments of bioplastics	311
11.5.3	Summary	315
11.6	Bioplastics – challenges for a growing market	316
11.7	Conclusion	317
	References	317
	Websites	319

<i>Index</i>	321
--------------	-----

*A colour plate section falls between pages 32 and 33*