

Contents

Preface — V

List of Contributors — XIII

Kiran Kumar Gali, Purabi Bhagabati and Vimal Katiyar

1	Sustainable polymers for food packaging: an introduction — 1
1.1	Types of food packaging — 1
1.1.1	Primary packaging or sales packaging — 2
1.1.2	Secondary packaging or group packaging — 3
1.1.3	Tertiary packaging or transport packaging — 3
1.2	Materials for food packaging — 3
1.2.1	Glass material — 3
1.2.2	Metals — 4
1.2.3	Paperboards — 4
1.2.4	Polymer-based food packaging — 5
1.3	Petroleum-based plastics for food packaging — 5
1.3.1	Negative impact of petroleum-based plastics in food packaging — 6
1.3.2	Importance of biobased and biodegradable plastics for food packaging — 7
1.4	Biobased plastics in food packaging — 7
1.4.1	Advantages of biobased food packaging — 8
1.4.2	Classification of biobased plastic for food packaging — 8
1.5	Differentiating biobased and biodegradable food packaging — 9
1.6	Conclusion — 11
	References — 12

Purabi Bhagabati, Umesh Bhardwaj and Vimal Katiyar

2	Biobased and biodegradable polymers for food packaging: commercial status — 15
2.1	Introduction — 15
2.2	Current scenario of food packaging — 15
2.3	Global initiatives toward biodegradable and biobased polymers — 18
	References — 21

Akhilesh Kumar Pal, Neelima Tripathi, Rahul Patwa, Tabli Ghosh, Prodyut Dhar, Medha Mili and Vimal Katiyar

3	Biobased sustainable polymers for food packaging applications — 23
3.1	Introduction — 23

3.2	Polysaccharides — 23
3.2.1	Starch — 24
3.2.2	Cellulose — 24
3.2.3	Chitosan — 28
3.2.4	Polysaccharide gums — 40
3.3	Protein-based biopolymers — 43
3.4	Protein biopolymer (silk) — 46
3.4.1	Classification of silk-based polymers — 46
3.4.2	Processing of silk — 47
3.4.3	Applications of silk — 51
3.5	Conclusions and outlook — 53
	References — 53

Arvind Gupta, Medha Mili, Tabli Ghosh and Vimal Katiyar

4	Polylactic acid for food packaging applications — 61
4.1	Introduction — 61
4.2	PLA — 61
4.3	Synthesis of PLA — 62
4.4	Properties of PLA — 63
4.5	Stereocomplex PLA — 64
4.5.1	Use of a third component to improve the stereocomplexation in PLA — 66
4.5.2	Stereocomplex PLA for food packaging — 67
4.6	Case study — 69
4.6.1	Effect of incorporating LA oligomer-g-chitosan nanofiller in PLA films — 69
4.6.2	Effect of incorporating LA-g-gum arabic nanofiller in PLA films — 70
4.6.3	Effect of polymorphic cellulose nanocrystal nanofillers on the properties of PLA-based nanocomposite films — 72
4.6.4	Effect of incorporating sucrose palmitate nanofillers in PLA films — 74
4.7	Summary — 74
	References — 75

Prodyut Dhar and Vimal Katiyar

5	Polyhydroxyalkanoates: microbially derived biodegradable polymer for food packaging applications — 79
5.1	Introduction — 79
5.2	Polyhydroxyalkanoates: different types and their physicochemical properties — 80

5.3	Polyhydroxyalkanoate-based cellulosic composites — 85
	References — 88

Surendra Singh Gaur, Tabli Ghosh and Vimal Katiyar

6 General material property requirement for food packaging applications — 93

6.1	Introduction — 93
6.2	Material properties for food packaging — 94
6.2.1	Barrier properties — 94
6.2.2	Barrier properties of biodegradable polymers — 95
6.2.3	Mechanical properties — 98
6.2.4	Thermal properties — 99
6.2.5	Morphological properties — 104
6.2.6	Optical properties — 109
6.2.7	Rheological properties — 109
6.2.8	Biodegradability — 110
6.3	Petroleum and biobased food packaging materials — 111
6.3.1	Packaging materials for milk and milk products — 111
6.3.2	Packaging materials for meat and poultry — 114
6.3.3	Packaging materials for fruits and vegetables — 115
	References — 118

Narendren Soundararajan, Shasanka Sekhar Borkotoky and Vimal Katiyar

7 Up-to-date advances of biobased and biodegradable polymers in food packaging — 127

7.1	Introduction — 127
7.2	Natural biopolymers for food packaging — 129
7.2.1	Starch-based packaging materials — 129
7.2.2	Cellulose-based packaging materials — 129
7.2.3	Chitosan- and pectin-based packaging materials — 130
7.2.4	Polyhydroxyalkanoate (PHA)-based packaging materials — 130
7.2.5	Polylactic acid (PLA)-based packaging materials — 131
7.3	Case studies: up-to-date advances in biodegradable food packaging materials — 132
7.3.1	Bionanocomposites in food packaging — 132
7.3.2	Properties of PLA bionanocomposites — 132
7.4	Biodegradable polymeric foams — 134
7.5	Development of polymeric foams — 134
7.5.1	Some potential biobased polymers for foaming — 135
7.6	Sustainable food packaging using biobased polymeric foams — 136
7.7	Processing technology for foam fabrication — 136
7.7.1	Physical/soluble foaming — 137

7.7.2	Casting and leaching —	137
7.7.3	Foaming using gases —	137
7.7.4	Thermally induced phase separation (TIPS) —	138
7.7.5	Reactive foaming —	138
7.8	Foam packaging —	138
7.9	Developments in sustainable foams —	139
	References —	140

Siddharth Mohan Bhasney, Prodyut Dhar and Vimal Katiyar

8	Polymer blends for sustainable food packaging —	145
8.1	Introduction —	145
8.2	Biopolymer —	145
8.2.1	Source and description of biobased polymers —	147
8.3	Biodegradable polymer-based blends —	147
8.3.1	PLA–PCL blends —	148
8.3.2	PLA–PBS blends —	149
8.3.3	PLA–PBAT blends —	149
8.3.4	PCL/chitin–chitosan-based blends —	150
8.3.5	Cellulose-based blends —	150
8.4	Blends of other fossil fuel-based plastics and biobased plastics —	151
8.4.1	PLA–LDPE blends —	152
8.4.2	LDPE–rice/potato starch blends —	153
8.4.3	Recycled PET/PLA–PET/chitosan-based blends —	153
8.4.4	PLA/PP blends —	154
8.4.5	PLA/polycarbonate (PC) blends —	154
8.4.6	PLA/polystyrene (PS) blends —	154
8.4.7	LDPE–starch blends —	155
8.5	Conclusion —	155
	References —	155

Narendren Soundararajan and Vimal Katiyar

9	Biobased biodegradable polymers in food packaging: regulations and legislations —	159
9.1	Introduction —	159
9.2	Nanoparticles in food packaging —	161
9.3	Experimental migration studies —	161
9.3.1	Migration studies on PLA —	161
9.3.2	Migration studies on bionanocomposites —	162
9.4	Analytical techniques used for the characterization of migrants —	164
9.4.1	Solid-phase microextraction (SPME) —	164

9.4.2	Electrospray ionization mass spectrometry (ESI-MS) —	165
9.4.3	High-performance liquid chromatography (HPLC) —	165
9.4.4	Spectroscopic and related techniques —	166
9.4.5	Nuclear magnetic resonance (NMR) —	166
9.5	Regulations due to possible migration —	167
9.6	Conclusion —	168
	References —	168

Tabli Ghosh and Vimal Katiyar

10 Edible polymer-based sustainable food packaging — 171

10.1	Introduction —	171
10.2	Edible coating —	172
10.2.1	Methods of coating —	172
10.2.2	Types of coating materials —	173
10.3	Active agents in edible coating —	174
10.3.1	Carriers of antioxidants —	175
10.3.2	Carriers of antidiabetic agents —	176
10.3.3	Carriers of anticancer agents —	176
10.3.4	Flavor enhancer —	176
10.4	Application of edible coating —	176
10.5	Properties of coating materials —	176
10.6	Case study —	177
10.6.1	Effect of edible coating on papaya fruits —	177
10.6.2	Effect of edible coating on mango fruits —	178
10.6.3	Effect of edible coating on tomato fruits —	178
10.6.4	Effect of edible coating on strawberry fruits —	178
10.7	Conclusion —	178
	References —	179

Naba Kumar Kalita, Melakuu Tesfaye, Purabi Bhagabati and Vimal Katiyar

11 Trends on end-of-life options, including recycling, reusing and composting of waste food packages — 183

11.1	Introduction —	183
11.2	Recycling of biodegradable plastics —	184
11.2.1	Mechanical recycling of bioplastics —	185
11.2.2	Chemical/biological (enzymatic) recycling —	187
11.3	Recycling of other biodegradable plastics —	189
11.3.1	Polyhydroxybutyrate (PHB) —	189
11.3.2	Polybutylene succinate (PBS) —	190
11.3.3	Cellulose acetate —	190
11.3.4	Polycaprolactone (PCL) —	190
11.4	Composting —	191

11.4.1	Difference between bioplastics and compostable plastics —	192
11.4.2	Significance of composting of biodegradable plastics —	192
11.4.3	Principles of composting —	193
11.4.4	Standards for compostability and biodegradability —	193
11.4.5	Measurement of biodegradability —	196
11.5	Challenges and future directions —	202
11.5.1	Feedstock —	202
11.5.2	Performance limitation —	202
	References —	203

Gourhari Chakraborty, Purabi Bhagabati and Vimal Katiyar

12 Authors' view point toward developments in biodegradable polymers to improve their versatility in food packaging — 207

12.1	Introduction —	207
12.2	Limitations of biodegradable polymers as food packaging material —	208
12.2.1	Material properties —	208
12.2.2	Mechanical properties —	208
12.2.3	Barrier properties —	209
12.2.4	Thermal stability —	209
12.2.5	Temperature resistance —	210
12.2.6	Processing conditions —	210
12.3	Future horizons of biodegradable polymers as a packaging material —	211
12.3.1	Composites of biodegradable polymers —	211
12.3.2	Polysaccharide-reinforced composites —	212
12.3.3	Clay-reinforced composites —	212
12.3.4	Carbon filler-reinforced composites —	212
12.3.5	Metal- and metal oxide-reinforced composites —	213
12.3.6	Coated paper for active packaging —	213
	References —	214

Index — 217