

Contents

1 Physical Properties of Beads and Their Estimation	1
1.1 Introduction	1
1.2 Bead Size and Shape	1
1.2.1 General	1
1.2.2 Size of Drops and Beads	1
1.2.3 Bead Shape	5
1.2.4 Bead Volume and Surface Area	16
1.3 Bead Density, Porosity, and Structure	18
References	22
2 Bead Formation, Strengthening, and Modification	27
2.1 Introduction	27
2.2 Entrapment	27
2.3 Single-Step Methods	28
2.3.1 Agar	28
2.3.2 Agarose	30
2.3.3 κ -Carrageenan	31
2.3.4 Alginates	33
2.3.5 Chitosan	36
2.3.6 Cellulose	37
2.3.7 Proteins	38
2.3.8 Synthetic Polymers	41
2.4 Two-Step Methods	44
2.5 Cell Immobilization by Electrostatic Method	45
References	45
3 Methods and Mathematical Models for the Drying of Polymeric Beads	53
3.1 Introduction	53
3.2 Methods for Drying Polymeric Gel Beads	54
3.2.1 General	54
3.2.2 Air-Drying	55
3.2.3 Fluidized-Bed and Microwave-Assisted Fluidized-Bed Drying	58

3.2.4	Freeze-Drying	61
3.2.5	Freeze-Dried Biological Products	63
3.3	Drying of Dosage Forms Made of Drug Dispersed in a Polymer	64
3.3.1	Mathematical Model	64
3.3.2	Numerical Model	68
3.3.3	Drying a Polymer Bead with Shrinkage	70
	References	71
4	Food and Biotechnological Applications for Polymeric	
	Beads and Carriers	75
4.1	Introduction	75
4.2	Amino Acid Production	75
4.2.1	L-Aspartic Acid	76
4.2.2	L-Alanine	77
4.2.3	L-Phenylalanine	78
4.3	Organic Acid Fermentation and Conversion	79
4.3.1	General	79
4.3.2	Citric Acid	80
4.3.3	Malic Acid	81
4.3.4	Gluconic Acid	81
4.3.5	Lactic Acid	82
4.4	Ethanol, Wine, Vinegar, Sake, and the Like	85
4.4.1	Vinegar	85
4.4.2	Soft Sake	86
4.4.3	Malolactic Fermentation	88
4.4.4	Removal of Urea from Sake and Wine by Immobilized Acid Urease	88
4.4.5	Beer Brewing Using an Immobilized Yeast Bioreactor System	89
4.5	Soy Sauce	91
4.6	The Milk Industry	92
4.6.1	Immobilization in the Milk Industry	92
4.6.2	Hydrolysis of Lactose in Milk	93
4.6.3	Antibiotic Residues in Milk	94
4.7	Miscellaneous Flavor Materials and Aroma Compounds	95
4.7.1	Biotransformation from Geraniol to Nerol	95
4.7.2	Limonin	95
4.7.3	β -Ionone	96
4.7.4	Naringin	96
4.7.5	Methyl Ketone (Blue Cheese Flavor) as a Flavor Molecule from Higher Fungi	97
4.7.6	Capsaicin	97
4.7.7	Vanillin	98
4.7.8	Japanese Seasoning	99
4.8	Miscellaneous Applications	99

4.8.1	Production of Oligosaccharides	99
4.8.2	Preservatives and Bacteriocins	100
4.8.3	Xylitol Production	101
4.8.4	Carotenoids and Leucrose	101
4.8.5	<i>cis,cis</i> -Muconic Acid (MA)	102
4.9	Various Industrial Options	102
4.9.1	Fuel Ethanol Production	102
4.9.2	Application of Gels for Separation Matrices	103
4.9.3	Bioartificial Organs	104
4.9.4	Insect Cell Immobilization	104
	References	106
5	Medicinal Applications of Hydrocolloid Beads	117
5.1	Introduction	117
5.2	Encapsulation of Cells in Hydrogels	117
5.3	Stem Cells in Bead Environments	120
5.4	Charged Hydrogel Beads as New Microcarriers for Cell Culture	122
5.5	Potential Support for Endothelial Cells	124
5.6	Vaccine Delivery	125
5.7	Crosslinked Chitosan Beads: Different Medicinal Functions	126
5.8	Mucoadhesive Beads and Their Applications	127
5.8.1	General	127
5.8.2	Eyes	128
5.8.3	Alimentary System	128
5.9	Polyelectrolyte Complexes	130
5.10	Soft Tissue Regeneration	131
	References	131
6	Dry Bead Formation, Structure, Properties, and Applications	137
6.1	Introduction	137
6.2	General Properties of Cellular Solids	137
6.3	Manufacturing Methods for Hydrocolloid Cellular Solids	138
6.3.1	Drying Bicarbonate-Containing Gels After Acid Diffusion	138
6.3.2	Cellular Solids Produced by Fermentation	140
6.3.3	Enzymatically Produced Cellular Solids	141
6.3.4	Inclusion of Oil in Cellular Solids	142
6.3.5	Porosity Control in Cellular Solids	143
6.4	Structure of Cellular Solids	144
6.5	Mechanical Properties of Cellular Solids	144
6.5.1	Compression of Cellular Solids	144
6.5.2	Models for Describing Stress–Strain Behavior	145
6.5.3	Elastic Properties of Cellular Materials	147
6.5.4	Layered Cellular Solids and Compressibility of Cellular Particulates	147
6.5.5	Acoustic Properties of Cellular Solids	148

6.6	Applications of Cellular Solids	149
6.6.1	Hydrocolloid Cellular Solids as a Carrier for Vitamins	149
6.6.2	Dried Gel Beads as Study Models and for Separation	150
6.6.3	Special Dry Beads for Water Treatment	151
6.6.4	Matrices Entrapping Hydrocolloid Cellular Beads	151
6.7	Hydrocolloid Cellular Carriers for Agricultural Uses	154
6.7.1	General	154
6.7.2	Preservation of Biocontrol Agents in a Viable Form by Dry Cellular Bead Carriers	154
6.7.3	Dry Carriers' Capacity to Protect Biocontrol Agents Against UV Light	156
6.7.4	Textural Features of Dried Hydrocolloid Beads	157
	References	158
7	Liquid-Core Beads and Their Applications in Food, Biotechnology, and Other Fields	163
7.1	Introduction	163
7.2	General	164
7.3	Soft Gelatin Capsules	164
7.4	Liquid-Core Capsules	165
7.4.1	Liquid-Core Hydrocolloid Capsules	165
7.4.2	Synthetic and Additional Liquid-Core Capsules	168
7.5	Oil-Core Hydrocolloid Capsules	171
7.6	Biotechnological Applications of Liquid-Core Capsules	174
7.6.1	Growth of Microorganisms in Liquid-Core Capsules	174
7.6.2	Activity of Enzymes Within Liquid-Core Capsules	177
7.7	Special Food Applications	178
7.7.1	Jelly-Like Foods	178
7.7.2	Fruit Products	179
7.7.3	Encapsulating Aroma and Health Compounds	179
7.7.4	Other Foods	180
7.8	Agricultural Uses of Liquid-Core Capsules	181
7.9	Environmental Uses of Liquid-Core Capsules	182
7.10	Special Applications of Liquid-Core Capsules	183
7.10.1	Stop-Smoking Aids	183
7.10.2	The Beauty Industry—Removal of Body Hair	184
7.10.3	The Paper Industry	185
	References	185
8	Beads as Drug Carriers	191
8.1	Introduction	191
8.2	Controlled Drug Release	191
8.3	Gels in Drug-Delivery Systems	192
8.4	Dual Drug-Loaded Beads	193
8.5	Drug Release from Beads	194
8.5.1	Albumin Beads	194

8.5.2	Alginate Beads	198
8.5.3	Chitosan Beads	200
8.5.4	Gelatin	205
8.5.5	Modified Starch Microspheres	206
8.5.6	Dextran Beads	207
8.5.7	Cellulose Hydrogels	209
8.5.8	Gellan Beads	210
8.5.9	Guar Beads	210
8.5.10	Pectin	211
8.5.11	Modified Poly(Vinyl Alcohol) Microspheres	213
8.5.12	Biodegradable Hydrogels Based on Polyesters	214
8.5.13	Hydrogels with Degradable Crosslinking Agents	215
8.5.14	Floating Beads	216
8.5.15	Xyloglucan Beads	217
	References	219
9	Beads and Special Applications of Polymers	
	for Agricultural Uses	231
9.1	Introduction	231
9.2	Immobilization of Plant Cell Suspensions and Single Seeds	231
9.3	Carriers for Slow Release of Bacteria that Affect Plant Growth	234
9.4	Inoculation of Seedlings and Plants with Beads Containing Fungal Inoculum	235
9.5	Joint Immobilization of Plant Growth-Promoting Bacteria and Green Microalgae	239
9.6	Cryopreservation by Encapsulation/Dehydration Technique	240
9.7	Controlled Release of Agricultural Chemicals	241
9.8	Biotechnological Applications	242
9.8.1	General	242
9.8.2	Gene-Delivery Systems Using Beads	243
9.8.3	Bioactive Bead Method for Obtaining Transgenic Plants	243
9.8.4	Synthetic Seed Technology	244
9.9	Unique Applications of Polymers	245
9.9.1	Superabsorbent Polymers	245
9.9.2	Seed Coating	246
	References	247
10	Beads for Environmental Applications	255
10.1	Introduction	255
10.2	Water Treatments	255
10.2.1	General	255
10.2.2	Wastewater Treatment by Anaerobic Fixed Bed Reactor	256
10.2.3	Wastewater Treatment Using Immobilized Microorganisms	258
10.2.4	Arsenic Removal from Water	259
10.2.5	Chitosan and Removal of Heavy Metal Ions	261

10.2.6	Water Denitrification	263
10.2.7	Anaerobic Ammonium Oxidation	265
10.3	Soil Treatments	265
10.3.1	General	265
10.3.2	Agrochemicals	265
10.3.3	Controlled Release of Pesticides into Soils	266
10.3.4	Sustained Release of a Fungicide	268
10.4	Air Pollution	268
10.4.1	General	268
10.4.2	Sampling Air	269
10.4.3	Determination of Trace Contaminants in Air by Concentration on Porous Polymer Beads	269
10.5	Miscellaneous	269
10.5.1	Biodegradation	269
10.5.2	Carbon Nanotubes	270
10.5.3	Removal by Microalgae	271
	References	272
Index	279