

Contents

Author Biography *xiii*

Preface *xv*

1	The Extraction of Alginate from Brown Seaweeds	1
1.1	Introduction	1
1.2	Global Distribution of Brown Seaweeds	2
1.3	The Extraction of Alginate from Brown Seaweeds	6
1.3.1	General Description of the Extraction Process	6
1.3.2	A Comparison of Alginic Acid Method and Calcium Alginate Method	9
1.3.3	Process Control	9
1.3.4	Key Process Parameters	10
1.3.4.1	Size Reduction of Raw Materials	10
1.3.4.2	Acid Treatment	10
1.3.4.3	Formaldehyde Treatment	12
1.3.4.4	Alkaline Extraction	12
1.3.4.5	Separation of Alginate from Insoluble Seaweed Residue	12
1.4	Ultrapure Alginate	14
1.5	Summary	15
	References	15
	Further Reading	17
2	Chemical, Physical, and Biological Properties of Alginic Materials	19
2.1	Introduction	19
2.2	The Chemical Structure of Alginic Acid	19
2.2.1	Early Studies and Basic Structural Feature	19
2.2.2	M/G Ratio and Distribution	20
2.2.3	C-5 Epimerization and Designer Alginate	21
2.2.4	Molecular Weight and Distribution	22
2.2.5	Chemical Stability	22
2.3	Physical Properties of Alginic Materials	24
2.4	Viscosity of Alginate Solutions	26
2.4.1	Effect of Molecular Weight on Solution Viscosity	26
2.4.2	Effect of Concentration on Solution Viscosity	27

2.4.3	Effect of Temperature on Solution Viscosity	28
2.4.4	Effect of Shear Rate on Solution Viscosity	28
2.4.5	Effect of Salt on Solution Viscosity	28
2.4.6	Effect of pH on Solution Viscosity	29
2.5	Polyelectrolyte Properties	29
2.6	The Ion-Exchange Properties of Alginate	29
2.7	Gelling Properties of Alginate	31
2.8	Film-Forming Properties	32
2.9	Fiber-Forming Properties	33
2.10	Bioactivities of Alginic Materials	33
2.10.1	Enzyme Inhibition Activities of Alginate	33
2.10.2	Biocompatibility and Cell Activities of Alginate	34
2.11	Summary	35
	References	35
3	Industrial Applications of Alginic Materials	39
3.1	Introduction	39
3.2	Functional Properties of Alginic Material	39
3.2.1	Alginate as a Thickening Agent	39
3.2.2	Alginate as a Gelling Agent	40
3.2.3	Alginate as a Film-Forming Agent	40
3.2.4	Alginate as a Stabilizer	41
3.2.5	Alginate for Encapsulation and Immobilization	41
3.3	Industrial Applications of Alginate	42
3.3.1	Food Ingredients	42
3.3.2	Medical and Pharmaceutical Uses	44
3.3.2.1	Dental Impression	44
3.3.2.2	Therapeutic Cell Entrapment	45
3.3.2.3	Controlled Release of Drugs	45
3.3.2.4	Alginate Oligoelectrolytes as a Mucin Polymer Network Modifier	45
3.3.2.5	Oligoguluronates as Modifiers of Cystic Fibrosis Mucus	45
3.3.3	Wound Dressings and Hemostatic Agent	46
3.3.4	Immobilization of Biocatalysts	46
3.3.5	Controlled Release of Active Agents	48
3.3.6	Textile Printing Paste	48
3.3.7	Sizing Agent for Paper	48
3.3.8	Coating for Welding Rods	49
3.3.9	Binders for Fish Feed	50
3.3.10	Biostimulants	50
3.4	Summary	50
	References	51
4	The Production of Fibers From Alginate	57
4.1	Introduction	57
4.2	The Properties of Alginate as a Fiber-Forming Polymer	58

4.3	Preparation of the Spinning Solutions	60
4.3.1	Molecular Weight of the Alginate Powder	60
4.3.2	Concentration of the Spinning Solution	61
4.3.3	Temperature of the Spinning Solution	61
4.3.4	pH of the Spinning Solution	61
4.4	The Production of Calcium Alginate Fibers	61
4.5	The Production of Calcium Sodium Alginate Fibers	65
4.6	The Production of Sodium Alginate Fibers	66
4.7	The Production of Alginic Acid Fibers	68
4.8	The Production of Zinc Alginate Fibers	69
4.9	The Production of Alginate Fibers Containing Pectin and Carboxymethyl Cellulose	69
4.10	The Production of Silver-Containing Alginate Fibers	71
4.11	The Production of Other Novel Alginate Fibers	73
4.12	Historical Development of Alginate Fibers	76
4.13	Summary	78
	References	78
5	Ion-Exchange and Gel-Forming Properties of Alginate Fibers	83
5.1	Introduction	83
5.2	Characterization Methods for Ion Exchange and Gel Forming Properties	83
5.3	Ion-Exchange Properties of Alginate Fibers	86
5.3.1	Ion-Exchange Between Calcium Alginate Fibers and Sodium Ions	86
5.3.2	Ion-Exchange Between Alginate Fibers and Zinc Ions	87
5.3.3	Ion-Exchange Between Alginate Fibers and Copper Ions	91
5.4	Gelling Properties of Alginate Fibers	94
5.5	Summary	98
	References	99
6	Applications of Alginate Fibers as Smart Woundcare Materials	101
6.1	Introduction	101
6.2	Functional Requirements of the Wound Dressings	103
6.3	Modern Advanced Wound Dressings	106
6.3.1	Chitin and Chitosan Fibers and Wound Dressings	107
6.3.2	Superabsorbent Cellulosic Fibers	108
6.3.3	Polyurethane Film and Foam	109
6.3.4	Hydrogels	110
6.3.5	Hydrocolloids	111
6.3.6	Activated Carbon	112
6.3.7	Low Adherent Dressings	113
6.3.8	Composite Wound Care Products	114
6.3.9	Antimicrobial Wound Dressings	116

- 6.3.10 Interactive Dressings 117
- 6.3.11 Tissue-Engineered “Skin Equivalents” 117
- 6.3.12 Cell-Containing Matrices 117
- 6.4 Applications of Alginate Fibers in Functional Wound Dressings 118
- 6.5 Development of Alginate Wound Dressings 119
- 6.6 Summary 121
- References 123
- Further Reading 124

7 Absorption and Interactive Properties of Alginate Wound Dressings 125

- 7.1 Introduction 125
- 7.2 Characterization Methods 126
 - 7.2.1 Test on Absorbency 126
 - 7.2.2 Fiber Calcium and Sodium Contents 127
 - 7.2.3 Gel Swelling 127
 - 7.2.4 Wet Integrity 127
 - 7.2.5 Wicking Behavior 127
 - 7.2.6 Dry and Wet Strength 128
- 7.3 Absorption of Wound Fluid by Alginate-Based Wound Dressings 128
 - 7.3.1 Absorption Mechanism of Alginate Wound Dressings 128
 - 7.3.2 Absorbency of the Various Types of Alginate Wound Dressings 129
 - 7.3.3 Fluid Retention Between Fibers and Inside Fibers 130
 - 7.3.4 A Comparison of Absorption Properties Between Alginate Felt and Rope 131
 - 7.3.5 Effect of Sterilization on the Absorption Properties of Alginate Dressings 131
 - 7.3.6 Effect of Guluronate and Mannuronate Contents 132
 - 7.3.7 Effect of Calcium and Sodium Contents 133
 - 7.3.8 Effect of Nonwoven Structures 133
 - 7.3.9 Effect of Adding CMC Into the Alginate Fibers 134
 - 7.3.10 Wicking of Fluid 135
 - 7.3.11 Dry and Wet Strength 137
- 7.4 Interactive Properties of Alginate Wound Dressings 138
 - 7.4.1 Interactive Moisture Handling Properties of Alginate Wound Dressings 138
 - 7.4.2 Biologically Interactive Properties of Alginate Wound Dressings 138
 - 7.4.3 Enzyme Inhibition Properties of Alginate Wound Dressings 139
- 7.5 Summary 142
- References 143

8 Clinical Applications of Alginate Wound Dressings 145

- 8.1 Introduction 145
- 8.2 Biocompatibility and Bioactivities of Alginate Wound Dressings 145
- 8.3 Wound Healing Mechanisms of Alginate Wound Dressings 147

- 8.4 Clinical Applications of Alginate Wound Dressings 148
 - 8.4.1 Applications of Alginate Wound Dressings in Pressure Ulcers 149
 - 8.4.2 Applications of Alginate Wound Dressings in Leg Ulcers 149
 - 8.4.3 Applications of Alginate Wound Dressings in Diabetic Foot Ulcers 151
 - 8.4.4 Applications of Alginate Wound Dressings in Burn Wounds and Donor Sites 151
 - 8.4.5 Applications of Alginate Wound Dressings as a Hemostatic Agent for Bleeding Wounds 154
 - 8.4.6 Applications of Alginate Wound Dressings in Surgical Wounds 156
 - 8.4.7 Applications of Alginate Wound Dressings in Nose Surgery 158
 - 8.4.8 Applications of Alginate Wound Dressings in Anal Fistula Surgery 159
 - 8.4.9 Applications of Alginate Wound Dressings in Cavity Wounds 160
 - 8.4.10 Applications of Alginate-Based Composite Wound Dressings 160
- 8.5 Main Properties of Alginate Wound Dressings 160
 - 8.5.1 Wound-Healing Promotion 161
 - 8.5.2 The Hemostatic Properties of Alginate Wound Dressing 162
 - 8.5.3 Pain Relief Properties of Alginate Wound Dressing 162
 - 8.5.4 The Antimicrobial Properties of Alginate Wound Dressing 163
 - 8.5.5 Alginate Wound Dressings as Cavity Filler 163
 - 8.5.6 Cost-Effectiveness of Alginate Wound Dressings 163
- 8.6 Summary 163
- References 163

9 Functional Modifications of Alginate Fibers and Wound Dressings 169

- 9.1 Introduction 169
- 9.2 Chemical Modification of Alginic Acid 169
 - 9.2.1 Chemical Modification of the Hydroxyl Groups 170
 - 9.2.1.1 Oxidation 170
 - 9.2.1.2 Reductive-Amination of Oxidized Alginate 171
 - 9.2.1.3 Sulfation 172
 - 9.2.1.4 Cyclodextrin-Linked Alginate 172
 - 9.2.1.5 Acetylation of Alginate 172
 - 9.2.1.6 Phosphorylation of Alginates 173
 - 9.2.2 Chemical Modification of the Carboxyl Groups 173
 - 9.2.2.1 Esterification 173
 - 9.2.2.2 Amidation 174
 - 9.2.3 Other Chemical Modifications 175
 - 9.2.3.1 Organic Soluble Derivative of Alginate 175
 - 9.2.3.2 Attachment of Cell Signaling Molecules 175
 - 9.2.3.3 Covalent Cross-linking of Alginates 176
 - 9.2.3.4 Graft Copolymerization of Alginates 177
- 9.3 Innovations in the Fiber-Making Process 178

9.3.1	The Production of Alginate Fibers Containing Metal Ions and Inorganic Compounds	179
9.3.2	The Production of Polyblend Fibers of Alginate and Other Polymers	180
9.3.3	The Production of Alginate Fibers Through Electrospinning	180
9.3.4	The Production of Alginate Fibers Containing Drugs	182
9.3.5	The Production of Alginate and Chitosan Composite Fibers	183
9.4	Summary	185
	References	186
10	Silver-Containing Alginate Fibers and Wound Dressings	193
10.1	Introduction	193
10.2	Antimicrobial Efficacy of Silver	194
10.3	Development of Silver-Containing Wound Dressings	195
10.4	Applications of Silver in Alginate Fibers and Wound Dressings	197
10.4.1	Types of Silver Compounds Used in Wound Dressings	197
10.4.2	Methods for Adding Silver to Wound Dressings	198
10.4.3	Examples of Silver-Containing Wound Dressings	199
10.4.3.1	Acticoat from Smith & Nephew	199
10.4.3.2	Silvercel from Johnson & Johnson	199
10.4.3.3	Aquacel Ag from ConvaTec	200
10.4.3.4	Contreet Foam from Coloplast	200
10.4.3.5	Silverlon from Argentum Medical	200
10.4.3.6	SilvaSorb from Medline	200
10.4.3.7	Urgotul SSD from Laboratoires URGO	200
10.4.3.8	Actisorb Silver 220 from Johnson & Johnson	200
10.4.3.9	Microbisan from Lendell Manufacturing Inc.	201
10.4.4	Differences Between Silver-Containing Wound Dressings	201
10.4.4.1	Different Silver Compounds	201
10.4.4.2	Different Contact Areas	202
10.4.4.3	Different Absorption Capacities	202
10.5	Preparation of Silver-Containing Alginate Fibers and Wound Dressings	203
10.5.1	The Addition of Silver Into Alginate Fibers Through Chemical Reaction	203
10.5.2	The Addition of Silver Into Alginate Fibers Through Blending	203
10.6	Release of Silver Ions from Silver-Containing Alginate Fibers	204
10.7	The Antimicrobial Effect of Silver-Containing Alginate Fibers and Wound Dressings	205
10.8	Properties and Applications of Silver-Containing Alginate Wound Dressings	206
10.8.1	Wound Healing Properties of Silver	206
10.8.2	The Release of Silver from Silver-Containing Wound Dressings	206
10.9	Test Methods for Assessing the Antimicrobial Properties of the Silver Dressing	208

- 10.9.1 Zone of Inhibition 208
- 10.9.2 Challenge Testing 208
- 10.9.3 Microbial Transmission Test 209
- 10.10 *In Vitro* and *In Vivo* Findings of the Clinical Benefits of Silver in Wound Healing 210
- 10.11 Local and Systemic Toxicity of Silver in Wound Healing 211
- 10.12 Clinical Efficacy of the Silver-Containing Dressings 212
- 10.13 Summary 213
- References 213

A Appendix A: List of Silver Containing Wound Dressings 217

B Appendix B: Answers to Commonly Asked Questions About Alginate Wound Dressings 221

- B.1 What Are Alginic Acid, Sodium Alginate, and Calcium Alginate? 221
- B.2 What Do M and G Mean With Alginate Fibers and Wound Dressings? 221
- B.3 What Are the Differences Between Alginate Wound Dressing and Calcium Alginate Wound Dressing? 222
- B.4 How Can Calcium Alginate Dressing Form Hydrogel on Contact With Wound Exudate? 223
- B.5 What Role Does Alginate Wound Dressings Play in “Moist Healing”? 223
- B.6 What Are the Main Applications of Alginate Wound Dressings? 223
- B.7 What Is the Absorption Mechanism of Alginate Wound Dressing? 226
- B.8 What Is the Reason That Calcium Alginate Fibers Do Not Gel in Pure Water? 226
- B.9 What Are the Differences Between the Absorption of Wound Exudate by Cotton Gauze and Alginate Wound Dressings? 227
- B.10 What Are the Differences Between High G and High M Alginate Fibers When They Are Applied on Exuding Wounds? 227
- B.11 Can Sodium Alginate Be Absorbed by the Body When Calcium Alginate Fibers Are Converted Into Sodium Alginate Upon Contact With Wound Exudate? 228
- B.12 Alginate Wound Dressings Are Divided Into Wet Integral and Wet Dispersible, What Does These Two Types Mean? 228
- B.13 How Can Alginate Wound Dressings Reduce Pain? 229
- B.14 Are There Any Inappropriate Consequences for the Residue Alginate Fibers Left on the Wound Surface? 229
- B.15 Are There Any Differences Between the Alginate Wound Dressings Under Different Brands? 229
- B.16 In the Manufacturing Processes, What Do Nip Rolling, Needle Punching, and Freeze Drying Mean? 230
- B.17 Can Alginate Wound Dressings Be Used in Combination With Topical Medicines Such as Anti-inflammatory Drugs Like Iodine? 230

- B.18 Can Alginate Wound Dressings Be Used on Infected Wounds? 230
- B.19 Can Alginate Wound Dressings Be Cut Into Pieces Before Being Applied to Wounds? 231
- B.20 What Should Be Done When Alginate Wound Dressings Adhere to the Wound Surface? 231
- B.21 Some Patients Experience Granulation Edema When Applied With Alginate Wound Dressings, Is This Related to the Release of Calcium Ions by the Dressing? 231
- B.22 What Are the Clinical Efficacy of Alginate Wound Dressings When Used for Pressure Sore Wounds? 231
- B.23 What Are the Clinical Efficacy of Alginate Wound Dressings When Used for Leg Ulcer Wounds? 231
- B.24 What Are the Clinical Efficacy of Alginate Wound Dressings When Used for Diabetic Foot Ulcer Wounds? 232
- B.25 What Are the Clinical Efficacy of Alginate Wound Dressings When Used for Burn Wounds? 232
- B.26 What Are the Clinical Efficacy of Alginate Wound Dressings When Used for Anal Fistula Wounds? 232
- B.27 Does Alginate Wound Dressing Possess Hemostatic Properties? 232
- B.28 Where Are the Seaweeds Used in the Production of Alginate Wound Dressings Come From? 233

Index 235