



STAFF REPORT

Global Markets for Enzymes in Industrial Applications

September 2018

BCC Research Staff

Report Code: BIO030K

Additional segmentations and data sets available upon request. Email custom@bccresearch.com

Table of Contents

Chapter 1: Introduction	1
Study Goals and Objectives.....	1
Reasons for Doing the Study.....	1
Scope of Report.....	2
Contribution of the Study and Intended Audience.....	2
Information Sources.....	3
Research Methodology	3
Geographic Breakdown.....	3
Analyst’s Credentials.....	7
BCC Custom Research	7
Related BCC Research Reports.....	7
Chapter 2: Summary and Highlights	9
Industrial Enzyme Applications.....	9
Industrial Enzyme Manufacturing	11
The Nature of Enzyme Products.....	12
Recent Developments in Enzyme Manufacturing.....	12
Chapter 3: Industrial Enzymes Overview	14
Introduction to Enzymes.....	14
Definition of Enzymes.....	14
Cofactors and Coenzymes	14
Apoenzymes	14
Prosthetic Groups.....	14
Active Site.....	14
Enzyme Characteristics.....	14
Historical Background of Industrial Enzymes.....	15
Enzyme Nomenclature.....	16
Enzyme Classification.....	16
Classification Based on the Chemical Reaction Catalyzed by the Enzyme.....	17
Industrial Enzyme Production.....	18
Microbial Production Strains	19
Enzyme Production by Microbial Fermentation	19
Submerged Fermentation	19
Solid-State Fermentation	20
Enzyme Production by Protein Engineering	20
Genetic Engineering	22
Industrial Enzyme Applications.....	22
Commonly Used Industrial Enzymes.....	22
Technical Enzymes.....	22
Enzymes in Textiles.....	22
Enzymes in the Paper and Pulp Industry.....	23
Enzymes in Household Cleaning Products	23
Enzymes in the Leather Industry.....	24
Enzymes in the Animal Feed Industry	24
Enzymes in the Food and Beverage Industry	25

Enzymes in the Starch and Sugar Industry	26
Enzymes in the Baking Industry.....	26
Enzymes in the Dairy Industry	27
Enzymes in the Brewing Industry	27
Enzymes in the Beverage Industry	27
Enzymes in the Tea and Coffee Industry	28
Enzymes in the Alcohol Industry	28
Chapter 4: Industrial Enzymes Manufacturing	30
Introduction	30
Large-Scale Fermentation of Enzymes.....	30
Organism and Enzyme Production	31
Preparation of Biological Starting Materials	31
Fermentation Media Preparation	31
Sterilization Process in Enzyme Production	32
Inoculation Process in Enzyme Production	32
Fermentation Process in Enzyme Production	32
Downstream Processing.....	33
Filtration	35
Extraction of Enzymes	35
Concentration of Enzymes	36
Formulation of the Final Enzyme Product.....	37
Recent Developments in Enzyme Manufacturing	38
Genetic Engineering	38
Enzymes from Genetically Modified Microbes	39
Chapter 5: Market Structure and Developments	42
Introduction	42
The Nature of Enzyme Products	42
Industrial Enzymes: Supply & Value Chain Analysis.....	44
Role of Supply Chain in Enzymes Industry	44
Supply Chain Becoming Part Industrial Enzymes Company Strategy.....	44
Industrial Enzymes Value Chain	44
Industrial Enzymes: Market Structure	46
Food Enzymes.....	46
Beverage Enzymes.....	47
Other Food Enzymes	48
Technical Enzymes.....	48
Biofuel Enzymes	50
Animal Feed Enzymes.....	50
Chapter 6: Market Analysis of Industrial Enzymes	53
Introduction	53
Factors Affecting the Industrial Enzyme Market	53
Market Drivers for the Industrial Enzyme	53
Market Restraints for Industrial Enzymes	54
Market Opportunities in Industrial Enzymes	55
Industrial Enzyme Market Challenges	56
Market by Type of Enzyme	56
Market Size.....	56
Food and Beverage Enzymes	57

Market Overview.....	58
Market Size.....	58
Technical Enzymes.....	59
Market Overview.....	60
Market Size.....	60
Enzymes for Animal Feed.....	61
Market Overview.....	62
Market Size.....	62
Enzymes for Biofuel Production.....	63
Market Overview.....	63
Market Size.....	64
Chapter 7: Market Breakdown by Enzyme Type	66
Introduction	66
Market Size by Enzyme Type	66
Carbohydrases	68
Market Size: Carbohydrase	69
Protease	70
Market Size: Proteases	72
Polymerases and Nucleases.....	73
Market Size: Polymerases and Nucleases	73
Lipase	74
Market Size: Lipases	75
Phytase.....	76
Market Size: Phytase	76
Other Enzymes	77
Chapter 8: Market Breakdown by Application	80
Introduction	80
Market Analysis.....	81
Market Size by Application.....	81
Food Enzymes	83
Food Enzymes by Region.....	83
Food Enzymes by Application.....	85
Other Food Enzymes	88
Technical Enzymes by Application	88
Technical Enzymes: Market Size.....	89
Textile Application.....	90
Paper and Application	90
Leather Application	91
Cleaning Application.....	91
Biofuel Enzymes	91
Biofuel Enzymes: Market Size	93
Animal Feed Enzymes	94
Animal Feed Enzymes: Market Size by Region.....	95
Other Applications	96
Enzymes in Cosmetics	96
Enzymes in Medicinal Products.....	96
Other Application: Market Size by Region	97
Chapter 9: Market Breakdown by Region	100

Introduction	100
Market Size by Region.....	100
North American Industrial Enzyme Market	101
North America: Market Size by Country	102
North America: Market Size by Enzyme Type	103
North America: Market Size by Application	105
European Industrial Enzyme Market	106
Europe: Market Size by Country.....	107
Europe: Market Size by Enzyme Type	108
Europe: Market Size by Application	109
Asia-Pacific Industrial Enzyme Market.....	110
Asia-Pacific: Market Size by Country	111
Asia-Pacific: Market Size by Enzyme Type.....	112
Asia-Pacific: Market Size by Application	114
Rest of the World	114
Rest of World: Market Size by Country	115
Rest of World: Market Size by Enzyme Type.....	116
Rest of World: Market Size by Application.....	118
Chapter 10: Regulatory Aspects of Industrial Enzymes	120
Introduction	120
Comparative Analysis of Enzymes Regulations.....	122
Identity of an Enzyme	124
Information Required for Substances with Enzymatic Properties in Canada.....	126
Enzymes in the Context of Food Regulation	126
Harmonized Regulation in the E.U.	126
JECFA Guidelines	127
Perspectives from the Industry	127
Regulation of Food Enzymes in the U.S.	128
Regulation for Animal Feed Enzymes	129
Enzymes Used in Cosmetics Products.....	130
Comparison of Regulatory Practices.....	130
Parameters for Enzyme Identification	131
Information Required for Enzymes from Genetically Modified Microbes	132
Requirements for the Production Process of Industrial Enzymes	132
Generally Recognized at Safe (GRAS) Notices.....	133
Chapter 11: Porter’s Five Forces	138
Introduction	138
Bargaining Powers of Buyers	139
Bargaining Power of Suppliers	140
Threat of New Entrants.....	141
Market Competition	143
Chapter 12: Competitive Landscape	145
Introduction	145
Share Distribution in The Global Industrial Enzyme Market.....	145
Technical Enzymes: Company Market Shares.....	145
Detergent Enzymes: Company Market Shares.....	146
Food and Beverage Enzyme: Company Market Shares.....	147
Feed Enzymes: Company Market Shares	148

Recent Developments in The Global Industrial Enzymes Market.....	149
Novozymes: Recent Developments.....	150
Associated British Foods Plc (AB Enzymes): Recent Developments.....	151
BASF Corp.: Recent Developments	152
Dyadic International: Recent Developments	152
DSM: Recent Developments.....	153
Industrial Enzymes: Mergers and Acquisitions	153
Chapter 13: Company Profiles	156
Appendix: List of Abbreviations	202
About BCC Research	205
About BCC Research.....	206
BCC Membership	206

Additional segmentations and data sets available upon request. Email custom@bccresearch.com

List of Tables

Summary Table: Global Market for Industrial Enzymes, by Application, Through 2023 (\$ Millions).....	10
Table 1 Historical Events Related to Enzymes, 1833-2016	15
Table 2 Change in Enzyme Characteristics by Protein Engineering	21
Table 3 Tools in Protein Engineering	21
Table 4 Types of Enzymes Manufactured from Genetically Modified Microorganisms.....	39
Table 5 Host Organisms Used in Enzyme Manufacturing Using Genetic Engineering Techniques	40
Table 6 Terminology Used in Enzyme Manufacturing	43
Table 7 Typical Range of Main Components of Industrial Enzymes in Enzyme Preparations	43
Table 8 Global Market for Industrial Enzymes, by Type, Through 2023 (\$ Millions).....	66
Table 9 Amylase Family.....	69
Table 10 Global Market for Carbohydrase, by Region Through 2023 (\$ Millions)	70
Table 11 Major Industrial Applications of Cysteine Proteases	71
Table 12 Global Market for Proteases, by Region, Through 2023 (\$ Millions).....	72
Table 13 Global Market for Polymerases and Nucleases, by Region, Through 2023 (\$ Millions)	73
Table 14 Global Market for Lipases, by Region Through, 2023 (\$ Millions)	75
Table 15 Global Market for Phytases, by Region, Through 2023 (\$ Millions)	76
Table 16 Global Market for Other Enzymes, by Region, Through 2023 (\$ Millions)	77
Table 17 Global Market for Industrial Enzymes, by Application, Through 2023 (\$ Millions)	81
Table 18 Global Market for Food and Beverage Enzymes, by Region, Through 2023 (\$ Millions).....	84
Table 19 Global Market for Technical Enzymes, by Region, Through 2023 (\$ Millions)	89
Table 20 Comparison of Various Works on Enzymatic Production of Biodiesel.....	92
Table 21 Global Market for Biofuel Enzymes, by Region, Through 2023 (\$ Millions)	93
Table 22 Global Market for Animal Feed Enzymes, by Region, Through 2023 (\$ Millions).....	95
Table 23 Global Market for Other Application Enzymes, by Region, Through 2023 (\$ Millions).....	97
Table 24 Global Market for Industrial Enzymes, by Region, Through 2023 (\$ Millions)	101
Table 25 North American Market for Industrial Enzymes, by Country, Through 2023 (\$ Millions)	102
Table 26 North American Market for Industrial Enzymes, by Type, Through 2023 (\$ Millions)	104
Table 27 North American Market for Industrial Enzymes, by Application, Through 2023 (\$ Millions)....	105
Table 28 European Market for Industrial Enzymes, by Country, Through 2023 (\$ Millions)	107
Table 29 European Market for Industrial Enzymes, by Type, Through 2023 (\$ Millions)	108
Table 30 European Market for Industrial Enzymes, by Application, Through 2023 (\$ Millions).....	109
Table 31 Asia-Pacific Market for Industrial Enzymes, by Country, Through 2023 (\$ Millions).....	111
Table 32 Asia-Pacific Market for Industrial Enzymes, by Type, Through 2023 (\$ Millions).....	113
Table 33 Asia-Pacific Market for Industrial Enzymes, by Application, Through 2023 (\$ Millions)	114
Table 34 Rest of World Market for Industrial Enzymes, by Country, Through 2023 (\$ Millions).....	115
Table 35 Rest of World Market for Industrial Enzymes, by Type, Through 2023 (\$ Millions).....	116
Table 36 Rest of World Market for Industrial Enzymes, by Application, Through 2023 (\$ Millions)	118
Table 37 Enzyme Preparations Approved as Food Additives Listed in 21 CFR 173	121
Table 38 Enzyme Preparation Specified in a Food Standard	121
Table 39 Enzyme Preparations Affirmed as GRAS listed in 21 CFR 184.....	122
Table 40 Legislative Framework Relevant for Notification of Industrial Enzymes	123
Table 41 Authority Responsible for the Notification of Chemicals and the Review/Assessment of the Chemical.....	123
Table 42 Definition of an Enzyme	124
Table 43 Parameters for Enzyme Identification	124
Table 44 Information Requested for Identification of a Chemical Substance.....	125

Table 45 Differentiation Between New and Existing Chemicals/Enzymes; Determination of the Equivalence of Enzymes.....	125
Table 46 Enzyme Entries in the Inventory of Ingredients Employed in Cosmetic Products	130
Table 47 Parameters for Enzyme Identification as Requested by the Canadian Authority for Notification of Technical Enzymes, and by the FDA/GRAS Guidelines for Food Enzymes	131
Table 48 Information Required for Food Enzymes from GMM	132
Table 49 Requirements on Production and Purification Process	133
Table 50 Enzymes Under GRAS Notices, 2014-2016.....	134
Table 51 New Developments in Enzymes, 2014-June 2018	150
Table 52 New Developments, by Novozymes, 2014-2017	151
Table 53 New Developments, by AB Enzymes, 2015.....	152
Table 54 New Developments, by BASF Corp., 2016-June 2018.....	152
Table 55 New Developments, by Dyadic International, 2014-Jan. 2018.....	153
Table 56 New Developments, by DSM, 2014-June 2018.....	153
Table 57 Mergers and Acquisitions of Top Industrial Enzyme Manufacturers, 2015-Sept. 2016	154
Table 58 AB Enzymes: Enzyme Product Line	158
Table 59 Adisseo: Enzyme Product Line	159
Table 60 Advanced Enzyme Technologies: Product Offerings.....	162
Table 61 Amano Enzyme, Inc.: Enzyme Product Line for Food Application	167
Table 62 Amano Enzyme, Inc.: Enzyme Product Line for Pharmaceutical Application	168
Table 63 Amano Enzyme, Inc.: Enzyme Product Line for Dietary Supplement Application	168
Table 64 Amano Enzyme, Inc.: Enzyme Product Line for Biotransformation Application.....	169
Table 65 Amano Enzyme, Inc.: Enzyme Product Line for Diagnostics Application	169
Table 66 Amicogen, Inc.: Enzyme Product Line	171
Table 67 Aum Enzymes: Enzyme Product Line	172
Table 68 BASF Corp.: Enzyme Product Line	176
Table 69 Biocatalysts Ltd.: Enzyme Product Line, by Category.....	177
Table 70 Chr. Hansen: Enzyme Product Line	184
Table 71 Direvo Industrial Biotechnology: Enzyme Product Line	185
Table 72 DowDuPont: Enzyme Product Line	187
Table 73 DSM: Enzyme Product Line	191
Table 74 GenoFocus: Enzyme Product Line	193
Table 75 Maps Enzymes Ltd.: Enzymes Products Line.....	195
Table 76 Novozymes: Enzyme Product Line	197
Table 77 Specialty Enzymes and Biotechnologies: Enzyme Product Line.....	198
Table 78 Sunson Industry Group: Enzyme Product Line.....	200
Table 79 Abbreviations Used for Enzymes in Industrial Applications.....	202

List of Figures

Summary Figure: Global Market for Industrial Enzymes, by Region, 2017-2023 (\$ Millions).....	11
Figure 1 Flowchart of a Fermentation Process	30
Figure 2 Flowchart of Downstream Processing of Enzymes	34
Figure 3 Industrial Enzymes Value Chain: Overview	45
Figure 4 Industrial Enzymes Value Chain: Timeline for Enzyme Production	45
Figure 5 Global Market for Industrial Enzyme, by Application, 2017 and 2023 (\$ Millions)	57
Figure 6 Global Market for Industrial Enzymes for Food and Beverage Applications, by Region, 2017 and 2023 (\$ Millions)	59
Figure 7 Global Market for Industrial Enzymes for Technical Applications, by Region, 2017 and 2023 (\$ Millions)	61
Figure 8 Global Market for Industrial Enzymes for Animal Feed Applications, by Region, 2017 and 2023 (\$ Millions)	63
Figure 9 Global Market for Industrial Enzymes for Biofuel Applications, by Region, 2017 and 2023 (\$ Millions)	64
Figure 10 Global Market for Industrial Enzymes, by Type, 2017-2023 (\$ Millions).....	67
Figure 11 Global Market Shares for Industrial Enzymes, by Type, 2017 (%)	68
Figure 12 Global Market Shares for Carbohydrase, by Region, 2017 (%).....	70
Figure 13 Global Market Shares of Proteases, by Region, 2017 (%).....	72
Figure 14 Global Market Shares of Polymerases and Nucleases, by Region, 2017 (%).....	74
Figure 15 Global Market Shares of Lipases, by Region, 2017 (%).....	75
Figure 16 Global Market Shares of Phytases, by Region, 2017 (%)	77
Figure 17 Global Market Shares of Other Enzymes, by Region, 2017 (%)	78
Figure 18 Global Market for Industrial Enzymes, by Application, 2017-2023 (\$ Millions)	82
Figure 19 Global Market Shares of Industrial Enzymes, by Application, 2017 (%)	83
Figure 20 Global Market Shares of Food and Beverage Enzymes, by Region, 2017 (%)	85
Figure 21 Global Market Shares of Technical Enzyme, by Region, 2017 (%).....	90
Figure 22 Global Market Shares of Biofuel Enzyme, by Region, 2017 (%).....	94
Figure 23 Global Market Shares of Animal Feed Enzyme, by Region, 2017 (%).....	96
Figure 24 Global Market Shares of Other Application, by Region, 2017 (%).....	98
Figure 25 Global Market Shares for Industrial Enzymes, by Region, 2017 (%).....	100
Figure 26 Global Market for Industrial Enzymes, by Region, 2017-2023 (\$ Millions)	101
Figure 25 North American Market Shares for Industrial Enzymes, by Country, 2017 (%).....	103
Figure 26 North American Market Shares for Industrial Enzymes, by Type, 2017 (%).....	104
Figure 27 North American Market for Industrial Enzymes, by Application, 2017-2023 (\$ Millions).....	106
Figure 28 European Market Shares for Industrial Enzymes, by Country, 2017 (%).....	107
Figure 29 European Market Shares for Industrial Enzymes, by Type, 2017 (%).....	108
Figure 30 European Market for Industrial Enzymes, by Application, 2017-2023 (\$ Millions)	110
Figure 31 Asia-Pacific Market Shares for Industrial Enzymes, by Country, 2017 (%)	112
Figure 32 Asia-Pacific Market Shares for Industrial Enzymes, by Type, 2017 (%)	113
Figure 33 Rest of World Market Shares for Industrial Enzymes, by Country, 2017 (%)	115
Figure 34 Rest of World Market Shares for Industrial Enzymes, by Type, 2017 (%)	117
Figure 35 Porter’s Five Forces: Global Industrial Enzymes	138
Figure 36 Industrial Enzymes Market, Bargaining Power of Buyers	139
Figure 37 Industrial Enzymes Market, Bargaining Power of Suppliers	140
Figure 38 Industrial Enzymes Market, Threat of New Entrants.....	141
Figure 39 Industrial Enzymes Market, Threat from Substitutes	142
Figure 40 Industrial Enzymes Market, Market Competition.....	143

Figure 41 Global Market Shares of Technical Enzymes, by Manufacturer/Supplier, 2017 (%)	146
Figure 42 Global Market Shares of Detergent Enzymes, by Manufacturer/Supplier, 2017 (%).....	147
Figure 43 Global Market Shares of Food Enzymes. by Manufacturer/Supplier, 2017 (%)	148
Figure 44 Global Market Shares of Feed Enzymes, by Manufacturer/Supplier, 2017 (%)	149
Figure 45 AB Enzymes: SWOT Analysis	157
Figure 46 AB Enzymes: Company Financials, 2013-2017 (\$ Billions).....	158
Figure 47 Advanced Enzyme Technologies: SWOT Analysis	161
Figure 48 Advanced Enzyme Technologies Ltd.: Company Financials, 2015-2017 (\$ Millions).....	162
Figure 49 Amano Enzyme, Inc.: Company Financials, 2012-2016 (\$ Millions)	166
Figure 50 Amicogen, Inc.: Company Financials, 2014-2017 (\$ Millions)	170
Figure 51 BASF Corp.: SWOT Analysis.....	174
Figure 52 BASF Corp.: Company Financials, 2013-2017 (\$ Millions)	175
Figure 53 Chr. Hansen: Company Financials, 2013-2017 (\$ Millions).....	183
Figure 54 Dow-Dupont: SWOT Analysis.....	186
Figure 55 DSM: SWOT Analysis.....	189
Figure 56 DSM: Company Financials, 2013-2017 (\$ Billions).....	190
Figure 57 Novozymes: Company Financials, 2013-2017 (\$ Billions).....	196



About BCC Research

About BCC Research

With our unparalleled 45-year history, BCC Research provides comprehensive analysis of global market sizing, forecasting and industry intelligence, covering markets where advances in science and technology are improving the quality, standard and sustainability of businesses, economies and lives.

BCC Membership

From market sizing and forecasts, to opportunity assessments and competitive analyses, our ever-expanding library gives you the data, insights and intelligence required to ensure your project is a success. Members benefit from ongoing, unlimited access to the category or collections of their choice, and most membership packages pay for themselves within two to three reports being accessed.

Did you buy this report? You may qualify to apply your purchase price towards a full membership. Call 866/285-7215 or email info@bccresearch.com to request a demo.

DISCLAIMER

The information developed in this report is intended to be as reliable as possible at the time of publication and is of a professional nature. This information does not constitute managerial, legal or accounting advice, nor should it be considered as a corporate policy guide, laboratory manual or an endorsement of any product, as much of the information is speculative in nature. BCC Research and the author assume no responsibility for any loss or damage that might result from reliance on the reported information or from its use.

ISBN: 978-1-62296-847-3
September 2018