

Contents

<i>Contributor contact details.....</i>	<i>xiii</i>
<i>Woodhead Publishing Series in Food Science, Technology and Nutrition.....</i>	<i>xviii</i>
<i>Foreword.....</i>	<i>xxvii</i>
1 Bioprocessing as a route to food ingredients: an introduction	1
<i>B. J. B. Wood, University of Strathclyde, UK</i>	
1.1 Food fermentation as an ancient technology: an overview.....	1
1.2 Solid substrate fermentations (SSF) and stirred tank reactor (STR) technology: relative industrial dominance	4
1.3 Development of bioprocessing as a route to food ingredients: the history of koji.....	10
1.4 Conclusion: food biotechnology past, present and future	12
1.5 References	15
Part I Systems biology, metabolic engineering of industrial microorganisms and fermentation technology	17
2 Systems biology methods and developments of filamentous fungi in relation to the production of food ingredients	19
<i>W. Vongsangnak, Soochow University, China and J. Nielsen, Chalmers University of Technology, Sweden</i>	

2.1	Introduction.....	19
2.2	Filamentous fungi as cell factories for food biotechnology.....	20
2.3	Systems biology of food-related filamentous fungi	23
2.4	Beyond functional genomics to metabolic modelling.....	29
2.5	Systems biology perspectives on food biotechnology and food safety	33
2.6	Acknowledgements	35
2.7	References.....	35
3	Systems biology methods and developments for <i>Saccharomyces cerevisiae</i> and other industrial yeasts in relation to the production of fermented food and food ingredients	42
	<i>V. Mapelli, C. J. Franzén and L. Olsson, Chalmers University of Technology, Sweden</i>	
3.1	Introduction.....	42
3.2	History of yeast science: it all started with food.....	43
3.3	Systems biology: possibilities and challenges in relation to food.....	44
3.4	Systems biology tools for fermented food	52
3.5	Production of flavours from yeasts	57
3.6	Food colouring: functional colours.....	62
3.7	Antioxidants.....	64
3.8	Non-conventional yeasts for food and food ingredients..	66
3.9	Conclusions	68
3.10	References	69
3.11	Appendix: glossary of the systems biology tool box	79
4	Applying systems and synthetic biology approaches to the production of food ingredients, enzymes and nutraceuticals by bacteria	81
	<i>P. A. Hoskisson, University of Strathclyde, UK</i>	
4.1	Introduction.....	81
4.2	Definition and uses of systems biology in production	82
4.3	Advantages of systems biology in the production of food ingredients, enzymes and nutraceuticals by bacteria.....	84
4.4	Production of food grade amino acids through the exploitation of systems biology and ‘omics’ approaches.....	86
4.5	Using systems approaches to develop enzymes for use in food production	90

4.6	Future trends in the application of systems and synthetic biology to food microbiology.....	91
4.7	Sources of further information.....	92
4.8	References.....	93
5	Production of foods and food components by microbial fermentation: an introduction.....	97
	<i>R. J. Seviour, La Trobe University, Australia and L. M. Harvey, M. Fazenda and B. McNeil, Strathclyde University, UK</i>	
5.1	Introduction.....	97
5.2	Food and food ingredients produced by microbial fermentation.....	99
5.3	Principles of bioreactor design and operation	101
5.4	Examples of fermentation processes used for the production of foods and foodstuffs.....	105
5.5	Dealing with fermentation waste	118
5.6	Conclusions	120
5.7	References.....	121
6	Fermentation monitoring and control of microbial cultures for food ingredient manufacture	125
	<i>B. McNeil and L. M. Harvey, Strathclyde University, UK, N. J. Rowan, Athlone Institute of Technology, Ireland and I. Giavasis, Technological Educational Institute of Larissa, Greece</i>	
6.1	Introduction.....	125
6.2	Monitoring bioprocesses for food fermentation: an overview	127
6.3	On line bioprocess monitoring for food fermentation....	130
6.4	Spectrometric monitoring of fermentation.....	133
6.5	Future trends.....	139
6.6	Sources of further information and advice.....	140
6.7	References.....	141
7	Industrial enzyme production for the food and beverage industries: process scale up and scale down	144
	<i>S. M. Stocks Novozymes A/S, Denmark</i>	
7.1	Introduction.....	144
7.2	Difficulties of the scale up approach	147
7.3	Consequences of changing scale	154
7.4	Further complexities when changing scale	161
7.5	Future trends and scale	167
7.6	Conclusion: scale up is scale down.....	168
7.7	Acknowledgements	169
7.8	References.....	169

Part II Use of microorganisms for the production of natural molecules for use in foods	173
8 Microbial production of food flavours.....	175
<i>Y. Waché, AgroSup Dijon, France</i>	
8.1 Introduction.....	175
8.2 Production of flavours by microorganisms in their classical environment	176
8.3 Microorganisms for biotechnological flavour production: first generation of biotechnological flavour compounds	181
8.4 New attempts to produce flavour compounds when precursors are unavailable	183
8.5 Analysing natural flavours in food.....	185
8.6 Conclusion and future trends	187
8.7 Sources of further information and advice	189
8.8 References.....	190
9 Microbial production of carotenoids	194
<i>S. Sanchez, B. Ruiz and R. Rodríguez-Sanoja, Universidad Nacional Autónoma de México, Mexico, DF and L. B. Flores-Cotera, Cinvestav-IPN, Mexico, DF</i>	
9.1 Introduction.....	194
9.2 Microbial sources of carotenoids	196
9.3 Main biosynthetic pathways used for carotenoid production	197
9.4 Regulation of carotenoid production	205
9.5 Genetic improvement of carotenoid production	209
9.6 Fermentation conditions.....	213
9.7 Commercially significant carotenoids.....	218
9.8 Conclusion.....	222
9.9 Acknowledgements	223
9.10 References.....	223
10 Microbial production of flavonoids and terpenoids	234
<i>H. Dvora and M. A. G. Koffas, Rensselaer Polytechnic Institute, USA</i>	
10.1 Introduction.....	234
10.2 Overview of flavonoids and terpenoids.....	235
10.3 Current and emerging techniques in microbial production of flavonoids and terpenoids	243
10.4 Future trends.....	255
10.5 References.....	256

11	Microbial production of enzymes used in food applications	262
	<i>K. Hellmuth, Chr Hansen Nienburg GmbH, Germany</i>	
	<i>and J. M. van den Brink, Chr Hansen A/S, Innovation, Denmark</i>	
11.1	Introduction: microbial production of food enzymes.....	262
11.2	Requirements of a good food enzyme	264
11.3	Limitations of enzyme use in food applications	265
11.4	Enzymes currently used in the food industry.....	266
11.5	Good production strain criteria for the food industry.....	271
11.6	Production processes.....	272
11.7	Examples of heterologous enzyme production	276
11.8	Regulatory aspects of food enzymes	281
11.9	References	283
12	Microbial production of organic acids for use in food.....	288
	<i>M. Sauer, D. Mattanovich, and H. Marx, University of</i>	
	<i>Natural Resources and Life Sciences (BOKU Wien-VIBT), Austria</i>	
12.1	Introduction.....	288
12.2	From filamentous fungi to genetically engineered bacteria and yeasts	289
12.3	Gluconic acid production	289
12.4	Oxidative branch of the citric acid cycle.....	293
12.5	Reductive branch of the citric acid cycle	306
12.6	Kojic acid	310
12.7	Conclusions	311
12.8	Future trends.....	312
12.9	Sources of further information and advice	313
12.10	References	314
13	Production of viable probiotic cells.....	321
	<i>F. Grattepanche and C. Lacroix, ETH Zürich, Switzerland</i>	
13.1	Introduction.....	321
13.2	Biomass production.....	322
13.3	Fermentation technologies.....	327
13.4	Downstream processing of probiotic biomass.....	331
13.5	Storage of frozen and dried probiotic concentrates	337
13.6	Microencapsulation	339
13.7	Exploitation of adaptive stress response of bacteria.....	341
13.8	Conclusion	343
13.9	References	343
14	Microbial production of bacteriocins for use in foods.....	353
	<i>D. G. Burke, P. D. Cotter, R. P. Ross, Teagasc Food Research Centre,</i>	
	<i>Ireland and C. Hill, University College Cork, Ireland</i>	
14.1	Introduction.....	353
14.2	<i>In situ</i> production of bacteriocins in food.....	355

14.3	<i>Ex situ</i> production of bacteriocins	361
14.4	Improvement of bacteriocinogenic bacteria	371
14.5	Conclusions	373
14.6	Acknowledgements	374
14.7	References	374
15	Microbial production of amino acids and their derivatives for use in foods, nutraceuticals and medications	385
	<i>H. Suzuki, Kyoto Institute of Technology, Japan</i>	
15.1	Introduction.....	385
15.2	Microbial production of amino acids.....	386
15.3	Amino acid derivatives of interest.....	392
15.4	Short peptides	397
15.5	Future trends in amino acid production	405
15.6	Sources of further information and advice	406
15.7	References	407
16	Production of microbial polysaccharides for use in food	413
	<i>I. Giavasis, Technological Educational Institute of Larissa, Greece</i>	
16.1	Introduction.....	413
16.2	Types, sources and applications of microbial polysaccharides	414
16.3	Production of microbial polysaccharides	430
16.4	Properties and structure–function relationships	443
16.5	Future trends.....	453
16.6	References	454
17	Microbial production of xylitol and other polyols.....	469
	<i>T. Granström and M. Leisola, Aalto University, Finland</i>	
17.1	Introduction.....	469
17.2	History of sugars and sugar alcohols.....	470
17.3	Physiological effects of sugar alcohols	472
17.4	Biochemistry of sugar alcohol metabolism.....	475
17.5	Biotechnological production strategies	480
17.6	Future trends.....	488
17.7	References	489
18	Microbial production of prebiotic oligosaccharides	494
	<i>T.-H. Nguyen and D. Haltrich, University of Natural Resources and Life Sciences (BOKU Wien), Austria</i>	
18.1	Introduction.....	494
18.2	Microbial production of prebiotic oligosaccharides	496
18.3	Future trends.....	512
18.4	Conclusions	518
18.5	References	518

19 Microbial production of polyunsaturated fatty acids as nutraceuticals	531
<i>C. Ralledge, University of Hull, UK</i>	
19.1 Introduction.....	532
19.2 Production of microbial oils.....	534
19.3 Gamma-linolenic acid (GLA, 18:3 <i>n</i> -6).....	538
19.4 Docosahexaenoic acid (DHA, 22:6 <i>n</i> -3)	540
19.5 Arachidonic acid (ARA, 20:4 <i>n</i> -6).....	544
19.6 Eicosapentaenoic acid (EPA, 20:5 <i>n</i> -3).....	545
19.7 PUFA oils from photosynthetically-grown microalgae....	550
19.8 Safety.....	552
19.9 References	555
20 Microalgae as sources of food ingredients and nutraceuticals.....	559
<i>B. Klein and R. Buchholz, Friedrich-Alexander Universität of Erlangen-Nürnberg, Germany</i>	
20.1 Introduction.....	559
20.2 Microalgae and cyanobacteria and their potential as food supplements.....	560
20.3 Risks of microalgal products	566
20.4 Conclusion	566
20.5 References	566
21 Microbial production of vitamins.....	571
<i>R. Ledesma-Amaro, M.A. Santos, A. Jiménez and J. L. Revuelta, University of Salamanca, Spain</i>	
21.1 Introduction.....	571
21.2 Fat-soluble vitamins	572
21.3 Water-soluble vitamins.....	577
21.4 Future trends.....	588
21.5 References	589
Index.....	595