Contents

Wo	List of contributors Woodhead Publishing Series in Food Science, Technology and Nutrition Preface		xi xiii xxvii	
1	The	use of natural antimicrobials in food: an overview	1	
	P.M.	Davidson, H. Bozkurt Cekmer, E.A. Monu, C. Techathuvanan		
	1.1	Introduction	1	
	1.2	Types of natural antimicrobials: animal sources	3	
	1.3	Types of natural antimicrobials: plant sources	6	
	1.4	Types of natural antimicrobials: microbial sources	9	
	1.5	Challenges to application of natural antimicrobials to foods	12	
	1.6	Application of natural antimicrobials	16	
	1.7	Conclusions	18	
		References	19	
Pa	rt Or	ne Types	29	
2	Plan	t extracts as antimicrobials in food products: types	31	
	R. G	yawali, S.A. Hayek, S.A. Ibrahim		
	2.1	Introduction	31	
	2.2	Herbs, spices, and plant extracts as antimicrobials	32	
	2.3	Essential oils	37	
	2.4	Plant extracts in combination with minerals	38	
	2.5	Conclusion	40	
		Acknowledgment	40	
		References	41	
3		t extracts as antimicrobials in food products: mechanisms		
		ction, extraction methods, and applications	49	
		yawali, S.A. Hayek, S.A. Ibrahim		
		Introduction	49	
	3.2	1	50	
	3.3	Plant extracts and antibiotic resistance	53	
	3.4	Extraction methods to maximize antimicrobial properties	54	

i Contents

	3.5	Response of Gram-positive and Gram-negative bacteria	
		to plant extracts	57
	3.6	Applications of plant extracts in food products	58
	3.7	Conclusion	62
		Acknowledgment	62
		References	62
4	Bact	teriophages as antimicrobials in food products: history,	
		ogy and application	69
	Н. А	nany, L.Y. Brovko, T. El-Arabi, M.W. Griffiths	
	4.1	Introduction	69
	4.2	Research into bacteriophages	70
	4.3	Biology of bacteriophages	71
	4.4	Bacteriophages as biocontrol agents in food	74
	4.5	The use of phage endolysins as biocontrol agents in food	80
	4.6	Combining bacteriophages with other preservation techniques	
		to enhance food safety	82
		References	83
5	Bact	teriophages as antimicrobials in food products: applications	
_		nst particular pathogens	89
	_	nany, L.Y. Brovko, T. El-Arabi, M.W. Griffiths	0,
	5.1	Introduction	89
	5.2	Bacteriophages to control Gram-negative food-borne	0,
	5.2	pathogens	90
	5.3	Bacteriophages to control Gram-positive food-borne	, ,
	0.0	pathogens	99
	5.4	Conclusion and future trends	105
	5.1	References	106
6	Log	tic acid bacteria (LAB) as antimicrobials in food products: types	
U		mechanisms of action	117
		O'Bryan, P.G. Crandall, S.C. Ricke, J.B. Ndahetuye	117
		Introduction	117
		Characteristics of lactic acid bacteria (LAB)	117
		Carbohydrate metabolism in LAB	118
		Effects of culture preparation and storage techniques on LAB	119
	6.5	Antimicrobial compounds produced by LAB: organic acids,	117
	0.5	diacetyl, and hydrogen peroxide	124
	6.6	Antimicrobial compounds produced by LAB: bacteriocins	124
	6.7	Conclusions	120
	0.7	Acknowledgments	129
		References	129
		References	エムフ

Contents

7		tic acid bacteria (LAB) as antimicrobials in food products: ytical methods and applications	137
		O'Bryan, P.G. Crandall, S.C. Ricke, J.B. Ndahetuye	107
	7.1	Introduction	137
	7.2	Screening lactic acid bacteria (LAB) for antimicrobial activity	137
	7.3	Regulatory framework governing the use of LAB in food	141
	7.4	Methods for using LAB as biopreservatives in food	142
	7.5	Use of LAB in the biopreservation of particular food	
		products and as a biosanitizer	144
	7.6	Conclusions	147
		Acknowledgments	147
		References	148
8	Chit	osan as an antimicrobial in food products	153
		ivanovic, R.H. Davis, D.A. Golden	
	8.1	Introduction	153
	8.2	Overview of antimicrobial activity of chitosan	154
	8.3	Mechanism of action	154
	8.4	Effects of molecular structure	164
	8.5	Effects of environmental conditions	169
	8.6	Current applications and future trends	172
		References	173
Pa	rt Tw	vo Processing	183
9	Eval	luating natural antimicrobials for use in food products	185
	D.O.	Ukuku, S. Mukhopadhyay, V. Juneja, K. Rajkowski	
	9.1	Introduction	185
	9.2	The advantages of using antimicrobials in food preservation	185
	9.3	The use of natural antimicrobials in food preservation	186
	9.4	Combining antimicrobials with other preservation techniques	188
	9.5	Factors affecting the biocidal activity of natural antimicrobials	191
	9.6	The regulation of natural antimicrobials	198
	9.7	Conclusion	201
		References	202
10		sical and chemical methods for food preservation using	
		ral antimicrobials	211
		arry-Ryan	• • •
	10.1		211
		Physical application of natural antimicrobials	211
	10.2	• 11	211
	10.3	Chemical application of natural antimicrobials	218
	10.3 10.4	Chemical application of natural antimicrobials Biological application of natural antimicrobials	218 221
	10.3 10.4 10.5	Chemical application of natural antimicrobials Biological application of natural antimicrobials Commercial natural antimicrobials	218 221 223
	10.3 10.4	Chemical application of natural antimicrobials Biological application of natural antimicrobials Commercial natural antimicrobials	218 221

viii Contents

11	Nano	structured and nanoencapsulated natural antimicrobials	
11		se in food products	229
		andelli, T.M. Taylor	>
	11.1	Introduction	229
		Natural food antimicrobials	230
		Nanostructures for antimicrobial delivery	233
	11.4	Methods for characterization of nanostructures	242
	11.5	Food applications of nanostructured antimicrobial systems	249
	11.6	Conclusions and future trends	251
	11.0	References	252
12	Mode	elling the effects of natural antimicrobials as food	
	-	rvatives	259
		Iaiswal, S. Jaiswal	
	12.1		259
	12.2	Antimicrobial susceptibility assessment	260
	12.3	Mathematical modelling in food preservation	261
	12.4	Types of models	261
	12.5	Model development	268
	12.6	Modelling the effects of natural antimicrobial agents	271
	12.7	Conclusion and future trends	278
		References	279
D	.4 TIL		
	t Thr	ee Using natural antimicrobials in particular	205
foo	as		285
13	Using	natural antimicrobials to enhance the safety and quality	
	_	sh and processed fruits and vegetables: types of antimicrobials	287
		Alvarez, M. del R. Moreira, S.I. Roura, J.F. Ayala-Zavala,	
		González-Aguilar	
		Introduction	287
	13.2	Fresh and processed fruits and vegetables: advances	
		and challenges	288
	13.3	Natural antimicrobials used in assuring the safety and quality	
		of fresh and processed fruits and vegetables: antimicrobials	
		from plant essential oils	291
	13.4	Antimicrobials from plants: aldehydes and methyl jasmonate	299
	13.5	Antimicrobials from plants: phenolic compounds and	
		isothiocyanates	300
	13.6	Chitosan is not from plant origin	303
	13.7	Natural antimicrobials of microbial origin:	
			204
		lactic acid bacteria (LAB) and bacteriocins	304
	13.8	lactic acid bacteria (LAB) and bacteriocins Conclusion and future trends	304

Contents ix

14	of fres	natural antimicrobials to enhance the safety and quality sh and processed fruits and vegetables: application	215
		ques and quality issues	315
		Alvarez, M. del R. Moreira, S.I. Roura, J.F. Ayala-Zavala, González-Aguilar	
	14.1	Introduction	315
	14.1	Techniques for applying natural antimicrobials to fruits	313
	14.2	and vegetables: key issues	315
	14.3	Encapsulation of natural antimicrobials	316
	14.3	Edible films and coatings enriched with natural antimicrobials	318
	14.5	Antioxidant properties of natural antimicrobials	319
	14.5	Plant antimicrobials as flavoring compounds	322
	14.7	Conclusion and future trends	323
	14.7	References	323
		References	323
15	Using	natural antimicrobials to enhance the safety	
	and q	uality of milk	327
	<i>M.C. I</i>	Pina-Pérez, D. Rodrigo, A. Martinez	
	15.1	Introduction	327
	15.2	Enhancing the safety and quality of milk-based beverages	
		using natural antimicrobials: milk	328
	15.3	Enhancing the safety and quality of infant milk formulas	
		using natural antimicrobials	334
	15.4	Enhancing the safety and quality of egg-milk beverages	
		using natural antimicrobials	337
	15.5	Conclusion and future trends	340
		References	340
16	Using	natural antimicrobials to enhance the safety	
	_	uality of fruit- and vegetable-based beverages	347
		Pina-Pérez, D. Rodrigo, A. Martinez	
	16.1	Introduction	347
	16.2	Enhancing the safety and quality of fruit- and	
	10.2	vegetable-based beverages using natural antimicrobials	348
	16.3	Melon and watermelon juices	348
	16.4	Orange and orange-based juices	350
	16.5	Grape juices	353
	16.6	Apple and pear juices	354
	16.7	Dark fruit juices	355
	16.8	Tomato juices	357
	16.9	Other vegetable beverages	358
		Conclusion and future trends	358
	10.10	References	359

Contents	

and quality of alcoholic and other beverages M.C. Pina-Pérez, D. Rodrigo, A. Martinez	365
9	
17.1 Introduction	365
17.2 Alcoholic beverages	365
17.3 Wine	366
17.4 Beer	366
17.5 Apple cider	367
17.6 Hot drinks	368
17.7 Conclusion and future trends	371
References	371
18 Using natural antimicrobials to enhance the safety	
and quality of poultry	375
M. Singh, J. Smith, M. Bailey	
18.1 Introduction	375
18.2 Food safety and its role in food quality	375
18.3 Pre-harvest use of natural antimicrobials	377
18.4 Antimicrobials for use on poultry products	380
18.5 Conclusion and future trends	392
References	393