

Contents

List of Figures	xiii
List of Tables	xv
Preface.....	xvii
Acknowledgments	xix
Author biographies.....	xxi
Chapter 1 Introduction	1
1.1 The evolution of preservation with organic acids: From stone age to space age.....	1
1.1.1 More than a century of preservation with organic acids.....	1
1.1.2 Toward preservative-free food	2
1.2 Unrivaled advantages	3
1.3 Economic implications: “Safer food, better business”	3
1.4 Legislative issues in food production.....	6
1.5 Problems in an “organic world”	7
1.5.1 Nutrition and consumer perceptions	9
1.5.2 Pesticides.....	9
1.5.3 Mycotoxins.....	10
1.5.4 Food safety control measures	10
1.5.5 Seeking alternatives	10
1.6 New and emerging pathogens	11
1.6.1 Introduction.....	11
1.6.2 Foodstuffs implicated	11
1.6.3 Laboratory methodologies	12
1.6.4 Epidemiology	12
1.6.5 A review of emerging organisms.....	13
1.6.5.1 Bacteria	13
1.6.5.2 Fungi.....	14
1.6.5.3 Viruses.....	15
1.6.5.4 Protozoa.....	15
References	15

Chapter 2 Nature and composition of organic acids	21
2.1 General characterization	21
2.2 Structural description	23
2.3 An overview of individual organic acids and their applications	25
2.3.1 Acetic acid.....	25
2.3.2 Ascorbic acid	26
2.3.3 Benzoic acid.....	26
2.3.4 Cinnamic acid	28
2.3.5 Citric acid.....	29
2.3.6 Formic acid	30
2.3.7 Fumaric acid	31
2.3.8 Gluconic acid	32
2.3.9 Lactic acid	33
2.3.10 Malic acid.....	35
2.3.11 Propionic acid.....	36
2.3.12 Sorbic acid.....	37
2.3.13 Succinic acid	39
2.3.14 Tartaric acid.....	39
2.3.15 Other acids.....	40
2.4 General applications.....	41
2.5 Food products naturally containing organic acids.....	42
2.5.1 Fruit	42
2.5.2 Juices	43
2.5.3 Wine and vinegar	43
2.5.4 Dairy	44
2.5.5 Coffee.....	44
2.5.6 Bakery products.....	44
2.5.7 Honey	44
References	44
Chapter 3 Application of organic acids in food preservation	51
3.1 Introduction.....	51
3.2 Foodstuffs.....	51
3.2.1 Meat	51
3.2.1.1 Cured meat.....	52
3.2.1.2 Poultry	52
3.2.1.3 Seafood	52
3.2.2 Acidic foods.....	53
3.2.3 Confectionery	53
3.2.4 Fruits and vegetables	53
3.2.5 Fruit juices.....	53
3.2.6 Salads.....	54
3.2.7 Vegetables	54

Contents

3.2.8	Dairy	54
3.2.9	Soft drinks	55
3.2.10	Sport drinks.....	55
3.2.11	Animal feed.....	55
3.3	Industrial applications	55
3.3.1	Labeling.....	55
3.3.2	Vacuum packaging	56
3.3.3	Meat	56
3.3.4	Processed meats	58
3.3.5	Seafood.....	59
3.3.6	Poultry	59
3.3.7	Dipping/spraying.....	60
3.3.8	Acidified foods.....	60
3.4	Salts of organic acids	60
3.4.1	Potassium sorbate	61
3.4.2	Sodium benzoate	63
3.4.3	Sodium lactate.....	64
3.4.4	Other.....	64
3.5	Organic acid combinations	64
3.5.1	Combinations in general	65
3.5.2	Salt combinations.....	66
3.5.2.1	Possible adverse effects	66
3.5.3	Aromatic compounds.....	67
3.5.4	Ethanol	67
3.5.5	Irradiation	67
3.5.6	Emulsifiers	68
3.5.7	Spices	68
3.5.8	Liquid smoke.....	68
3.6	Considerations in the selection of organic acids.....	69
3.6.1	Sensory properties.....	69
3.6.2	Color stability	69
3.6.3	Flavor.....	69
3.6.4	Carcass decontamination	70
3.6.5	Chemical stability	70
3.7	Organic acids in antimicrobial packaging.....	70
3.7.1	Antimicrobial films	70
3.7.2	Active packaging	71
3.7.3	Edible films.....	72
3.7.4	Modified atmosphere packaging (MAP).....	73
3.8	Organic acids in animal feed preservation.....	73
3.8.1	The essence of preserving feed.....	73
3.8.2	The postantibiotic era.....	74
3.8.3	Chicken feed.....	75
3.8.4	In combination with heat treatment	75

3.8.5	Propionic acid in feed	76
3.8.6	Organic acids in animal nutrition.....	77
3.9	Concentrations	77
3.9.1	Pressure toward decreased concentrations	77
3.9.2	Concentrations effective against common pathogens.....	78
3.9.3	Daily consumption of organic acids	78
3.9.4	Legislation	79
3.10	A review of current methodologies	79
3.11	Recommended applications	80
3.11.1	Carcasses.....	80
3.11.2	Processed meats.....	80
3.12	Control of common pathogens	81
3.12.1	Chickens.....	81
3.12.2	Fruit	82
3.12.3	Vegetables	82
3.13	Organic acids as additives in chilled foods	82
3.14	Marinating.....	83
	References	84
	Chapter 4 Microbial organic acid producers.....	97
4.1	Introduction.....	97
4.2	Predominant antimicrobial substances produced by LAB	99
4.2.1	Lactic acid	99
4.2.2	Bacteriocins.....	101
4.3	Principles of lactic acid fermentation.....	101
4.4	Other applications of LAB.....	105
4.5	Genetic and bioinformatic characterization of LAB.....	105
4.6	Acetic acid bacteria (AAB).....	106
4.6.1	Acetic acid (vinegar) production	106
4.6.2	Microorganisms involved in the production of vinegar	106
4.6.2.1	Acetobacter and yeasts.....	106
4.6.3	Industrial importance—essential versus undesirable	108
4.6.4	Glucose, acid, and ethanol tolerance.....	108
4.7	Susceptibility of and resistance to organic acids	109
4.8	Other organisms	110
4.8.1	Fungi.....	110
4.8.2	Other bacteria.....	111
	References	112
	Chapter 5 Mechanisms of microbial inhibition.....	117
5.1	Introduction.....	117
5.2	Activity of organic acids.....	118
5.3	Physiological actions of organic acids	119

Contents

5.3.1	Introduction.....	119
5.3.2	Bacterial membrane disruption.....	121
5.3.3	Accumulation of toxic anions	121
5.3.4	Inhibition of essential metabolic reactions	122
5.3.5	Stress on intracellular pH homeostasis	122
5.4	Factors that influence organic acid activity	123
5.4.1	Number of undissociated organic acids that enter the bacterial cell.....	124
5.4.2	Acidity constant (pK_a value).....	124
5.4.3	Water activity (a_w)	125
5.4.4	Temperature	125
5.4.5	Production of H_2O_2	126
5.5	The role of pH.....	126
5.6	Antibacterial action.....	128
5.7	Antifungal action.....	129
5.8	Antiviral action	131
5.9	Acidified foods.....	131
5.10	Comparing effectiveness of organic acids with inorganic acids	133
5.11	Spectra of inhibition.....	134
5.12	Improving effectiveness	134
5.13	(Physical) factors that will enhance effectiveness.....	136
5.13.1	Ozone.....	136
5.13.2	Ultrasound.....	136
5.13.3	Ionizing radiation	136
5.13.4	Heat treatment	137
5.13.5	Steam washing	137
5.13.6	Vacuum	138
5.13.7	Freezing.....	138
5.13.8	Storage temperature	138
5.13.9	Do interactions exist?	138
5.13.10	Buffering	139
5.14	Comparisons among organic acids.....	139
	References	142
	Chapter 6 Problems associated with organic acid preservation	151
6.1	Adverse effects on humans and animals.....	151
6.1.1	Chemical reactions in humans ("allergies")	151
6.1.2	Organic acids as pro-oxidants	152
6.2	Adverse effects on foodstuffs	153
6.3	Protective effects on microorganisms	153
6.4	Sensorial effects and consumer perception.....	154
6.5	Recommended daily intake	154
6.6	Odors and palatability	155

6.7 Cost	156
6.8 Application methods	156
6.9 Oxidation	158
6.10 Ineffectiveness	158
6.11 Influence on tolerance to other stresses	159
References	159
Chapter 7 Large-scale organic acid production	165
7.1 Introduction	165
7.2 Naturally occurring weak organic acids	165
7.3 Microbial physiology and organic acids	165
7.4 Substrates and yields	168
7.5 Industrial fermentation	170
7.5.1 Monopolar	171
7.5.2 Bipolar	171
7.6 Organic acid demand	173
7.7 Lactic acid production	174
7.7.1 Factors affecting production of lactic acid	176
7.8 Citric acid production	177
References	180
Chapter 8 Resistance to organic acids	185
8.1 Introduction	185
8.2 Intrinsic (natural) resistance	185
8.2.1 Bacteria	186
8.2.2 Fungi	187
8.3 Development of resistance	188
8.4 Inducible resistance	189
8.5 Mechanisms of resistance	191
8.5.1 Bacteria	191
8.5.2 Fungi	193
8.6 Transmission of resistance	196
8.7 Extent of the situation	196
8.8 <i>E. coli</i> O157:H7	197
8.9 Protective effects of organic acids	198
8.10 Possible advantages of organic acid resistance	198
8.11 Industry strategies	198
8.11.1 Targets	199
References	199
Chapter 9 Acid tolerance	205
9.1 Introduction	205
9.2 Delineating the difference among acid adaptation, acid tolerance, and acid resistance	205

Contents

9.3	Role of organic acids in tolerance	206
9.4	Acid tolerance of gastrointestinal pathogens	208
9.5	Cross-resistance to secondary stresses.....	210
9.6	Mechanisms of acid tolerance development.....	210
9.6.1	Passive homeostasis	212
9.6.2	Active pH homeostasis	212
9.7	Known acid-tolerant organisms	213
9.8	Development of acid tolerance.....	215
9.9	Implications of acid tolerance	216
9.10	Contribution of acidic foodstuffs	217
9.11	Analytical procedures.....	217
9.12	Interacting mechanisms	218
9.13	Control strategies.....	218
	References	219
	Chapter 10 Modeling organic acid activity	225
10.1	Introduction.....	225
10.2	Genomics	227
10.3	Growth models in defined systems	229
10.4	Different predictive models	230
10.4.1	Partial least squares regression (PLS).....	231
10.4.2	Stoichiometric models.....	231
10.5	Predictive indices for organic acids	232
10.6	Toward improving on existing models	233
10.7	Significance of modeling	236
	References	238
	Chapter 11 Legislative aspects	243
11.1	Introduction.....	243
11.2	Differences in regulatory authorities.....	243
11.3	Application guidelines for organic acid preservation.....	245
11.4	The role of general food safety regulations	248
11.5	Codex Alimentarius Commission.....	250
11.6	Proposed amendments	251
11.7	Role of government and parastatals	253
11.8	Feed preservation	254
11.9	Commercial trials	255
	References	255
	Chapter 12 Incidental and natural organic acid occurrence.....	261
12.1	Introduction.....	261
12.2	Honey	261
12.3	Sourdough	261
12.4	Berries.....	262

12.5 Wine.....	262
12.6 Coffee.....	264
12.7 Vinegar.....	264
12.8 Acid foods.....	264
12.9 Kombucha.....	264
12.10 Edible films.....	265
12.11 Summary	265
References	268
Chapter 13 Biopreservation	271
13.1 Introduction.....	271
13.2 LAB and biopreservation.....	272
13.3 Other organisms implicated in biopreservation.....	274
13.4 New technologies and applications	275
13.5 Consumer acceptance	276
13.6 Organic acids and probiotics	276
References	277
Chapter 14 Novel applications for organic acids.....	281
14.1 Emerging challenges.....	281
14.2 Consumer satisfaction.....	281
14.3 Optimizing organic acid application in animal feed	282
14.4 Preservative combinations	283
14.5 Antimicrobial packaging.....	283
14.5.1 Factors for the design of antimicrobial film or packaging	284
14.6 Optimizing commercial trials	285
14.7 New possibilities in minimally processed foods.....	285
14.8 Alternatives to washing techniques	286
14.9 Alternative application regimes	286
14.10 Recognizing the need in RTE foods.....	288
References	289
Chapter 15 Detection of organic acids.....	293
15.1 Introduction.....	293
15.2 Traditional detection methods.....	293
15.3 Contemporary methods.....	295
15.4 The importance of effective detection	299
15.5 Detection in specific foodstuffs	302
15.6 Characteristics of detected organic acids.....	303
15.7 Comparing sample preparation techniques	303
References	304
Index	307