

SOCIETY OF DAIRY TECHNOLOGY

# Dairy Powders and Concentrated Products

EDITED BY

A. Y. TAMIME



WILEY-BLACKWELL



# Contents

<i>Preface to the Technical Series</i>	xv
<i>Preface</i>	xvii
<i>Contributors</i>	xxi
<b>1 Chemistry of Milk – Role of Constituents in Evaporation and Drying</b>	<b>1</b>
H.C. DEETH AND J. HARTANTO	
1.1 Introduction	1
1.2 Chemical components of liquid, concentrated and dried milk products	1
1.2.1 Protein	1
1.2.2 Fat	6
1.2.3 Carbohydrate	8
1.2.4 Minerals	9
1.2.5 Water	11
1.2.6 Air	11
1.3 Surface composition of powders	12
1.4 Quality issues	14
1.4.1 Heat stability	14
1.4.2 Fouling	18
1.4.3 Age thickening	19
1.4.4 Maillard reactions	19
1.4.5 Oxidation	20
1.5 Conclusions	22
References	22
<b>2 Current Legislation on Concentrated and Dried Milk Products</b>	<b>28</b>
M. HICKEY	
2.1 Introduction	28
2.2 European Union legislation	31
2.2.1 Access to EU legislation	31
2.2.2 Vertical-legislation on concentrated and dried milk products	31
2.2.3 Horizontal-hygiene and food safety requirements	41
2.2.4 Horizontal-food additives legislation	45
2.2.5 Horizontal-labelling requirements for foods	52
2.2.6 Horizontal-packaging legislation	53

2.3	United Kingdom legislation	54
2.3.1	Legislative basis	54
2.3.2	Background	54
2.3.3	Present legislation on composition	56
2.3.4	Present legislation on hygiene	58
2.3.5	The Dairy UK Code of Practice for HTST pasteurisation	58
2.4	Irish legislation	59
2.4.1	Introduction	59
2.4.2	Present legislation on hygiene	60
2.4.3	Present legislation on specific products	60
2.5	United States legislation	61
2.5.1	Introduction and background to US legislation	61
2.5.2	The 'Code of Federal Regulations'	63
2.5.3	Hygiene requirements for milk and certain milk products	64
2.5.4	US standards of identity and labelling	66
2.5.5	The USDA specifications and grading schemes for certain milk products	71
2.5.6	Food additives in US legislation	72
2.6	Legislation in Australia and New Zealand	73
2.6.1	Introduction	73
2.6.2	The 'Joint Food Standards Code'	73
2.6.3	New Zealand-specific legislation	74
2.7	The international perspective—Codex Alimentarius	75
2.7.1	What is Codex Alimentarius?	75
2.7.2	Codex Alimentarius Commission membership and structure	76
2.7.3	Codex Alimentarius standards	76
2.7.4	Codex Alimentarius—general standards	79
2.7.5	Codex Alimentarius standards for concentrated and dried milks	84
2.8	Private standards and specifications	87
2.9	Conclusions and possible future developments	88
	References	88
<b>3</b>	<b>Technology of Evaporators, Membrane Processing and Dryers</b>	<b>99</b>
	M. CARIĆ, J.C. AKKERMAN, S. MILANOVIĆ, S.E. KENTISH AND A.Y. TAMIME	
3.1	Introduction	99
3.2	Evaporators	100
3.2.1	Principles of evaporation	100
3.2.2	Evaporation techniques and systems	101
3.2.3	Plant design of evaporator configuration	104
3.2.4	Heat economy in evaporator installation	104
3.2.5	Cleaning of evaporators	105
3.2.6	Evaporation versus membrane filtration	106

3.3	Membrane filtration technology	108
3.3.1	Principles of membrane filtration	108
3.3.2	Membrane filtration techniques and systems	112
3.3.3	Membrane filtration configurations	114
3.3.4	Heat economy in membrane filtration	115
3.3.5	Application of membrane filtration in the dairy industry	115
3.3.6	Cleaning of membrane filtration systems	116
3.4	Spray drying technology	123
3.4.1	Principles of spray drying	123
3.4.2	Spray drying techniques and systems	127
3.4.3	Plant design of spray drying configuration	130
3.4.4	Heat economy of spray drying	132
3.4.5	Cleaning of dryers	133
3.5	Conclusions	142
	References	143
4	<b>Production of Evaporated Milk, Sweetened Condensed Milk and ‘Dulce de Leche’</b>	149
	M.N. OLIVEIRA, A.L.B. PENNA AND H. GARCIA NEVAREZ	
4.1	Background	149
4.2	Evaporated milk	151
4.2.1	Introduction	151
4.2.2	Evaporated milk production	154
4.2.3	Product properties	154
4.3	Sweetened condensed milk	156
4.3.1	Introduction	156
4.3.2	Production stages	156
4.4	‘Dulce de leche’	158
4.4.1	Background	158
4.4.2	‘Dulce de leche’ production	160
4.4.3	Product properties	164
4.4.4	Rheological parameters	165
4.4.5	Results of a research on ‘dulce de leche’ using the UF process	166
4.5	Conclusions	176
	References	177
5	<b>Dried Milk Products</b>	180
	M. SKANDERBY, V. WESTERGAARD, A. PARTRIDGE AND D.D. MUIR	
5.1	Introduction	180
5.2	Definitions	180
5.2.1	Composition	180
5.2.2	Heat classification	182
5.2.3	Dispersion properties	182

5.3	Microbial quality	182
5.3.1	Raw milk	182
5.3.2	Effects of milk processing	186
5.4	Functionality and certain technical aspects	189
5.4.1	Heat treatment	189
5.4.2	Whey protein denaturation	191
5.4.3	Agglomeration and instantisation	194
5.5	Specific processes	203
5.5.1	Ordinary milk powders	203
5.5.2	Instant milk powders	204
5.5.3	Other types of milk powders	209
5.6	Quality assessment	212
5.6.1	Introduction	212
5.6.2	Milk	212
5.6.3	Concentrate	215
5.6.4	Powder	216
5.7	Conclusions	233
	References	233

## 6 Casein and Related Products 235

H.S. ROLLEMA AND D.D. MUIR

6.1	Introduction	235
6.2	Products—definitions and structure	236
6.2.1	Acid casein	236
6.2.2	Caseinates	236
6.2.3	Phosphocasein	237
6.2.4	Rennet casein	237
6.2.5	Co-precipitate	238
6.2.6	Milk protein concentrates and isolates	238
6.2.7	Isolated and enriched casein fractions	238
6.2.8	Casein fragments	239
6.3	Methods of manufacture	240
6.3.1	Introduction	240
6.3.2	Acid casein—conventional treatment	241
6.3.3	Rennet casein	243
6.3.4	Caseinate	243
6.3.5	Co-precipitate	244
6.3.6	Acid casein—supercritical fluid processing	244
6.3.7	Fractionation of casein	245
6.3.8	Total milk protein	247
6.3.9	Casein-derived peptides	247
6.4	Functionality	249
6.4.1	Solubility	249
6.4.2	Heat and alcohol stability	249
6.4.3	Viscosity	249

6.4.4	Formation of protein-stabilised emulsions	249
6.4.5	Functionality of peptides derived from casein	250
6.5	Quality control	250
	References	252
<b>7</b>	<b>Dried Whey, Whey Proteins, Lactose and Lactose Derivative Products</b>	<b>255</b>
	P. JELEN	
7.1	Introduction	255
7.2	Types and composition of raw whey and main whey-based powders	255
7.2.1	Standard and modified whey powders	256
7.2.2	Whey protein	256
7.2.3	Lactose and modified lactose products	257
7.2.4	Other whey-based powdered products	259
7.3	Unit operations in the production of concentrated and dried whey and whey-based products	259
7.4	Technological complexities in the production and storage of whey-based products	261
7.4.1	Heat sensitivity of whey protein	261
7.4.2	Low solubility and hygroscopicity of lactose	262
7.4.3	Content of lactic acid	262
7.4.4	Propensity for non-enzymatic Maillard browning reaction	263
7.4.5	Foam formation and its potential detrimental effects during drying	263
7.4.6	Free moisture in lactose powders	263
7.5	Modified whey-based products and their uses	264
7.6	Future trends	264
7.7	Sources of further information	265
	References	266
<b>8</b>	<b>Specialised and Novel Powders</b>	<b>268</b>
	P. HAVEA, A.J. BALDWIN AND A.J. CARR	
8.1	Introduction	268
8.2	Principles	268
8.2.1	Moisture content	268
8.2.2	Carbohydrate content	269
8.2.3	High-fat content	269
8.2.4	Oxidation	269
8.2.5	Processing control	270
8.2.6	Particle solubility	270
8.3	Coffee whitener powders	270
8.3.1	Chemical composition	270
8.3.2	Manufacturing process	271
8.3.3	Functional properties	271
8.3.4	Recent developments	272

8.4	Novel whey products	273
8.4.1	Whey protein in nutraceutical applications	273
8.4.2	Heat-denatured whey protein	274
8.4.3	Cold gelling WPCs	276
8.4.4	Co-precipitation of whey protein with casein	277
8.5	Milk mineral	278
8.6	Cheese powder	280
8.7	Hydrolysates	280
8.8	Cream powders	284
8.8.1	Why dried cream powders?	284
8.8.2	Emulsion stability	284
8.8.3	Processing of cream powders	285
8.8.4	Physicochemical properties of dairy cream powders	286
8.9	Concluding remarks	287
	References	288

## **9 Infant Formulae – Powders and Liquids** 294

D.-H. MONTAGNE, P. VAN DAEL, M. SKANDERBY  
AND W. HUGELSHOFER

9.1	Introduction	294
9.2	Historical background	294
9.3	Definition and classification of infant formula	296
9.4	An overview of the world market of infant formulae	297
9.4.1	Annual production figures	297
9.4.2	Worldwide manufacturers of infant formulae	299
9.5	Regulations governing infant formulae	301
9.5.1	General background	301
9.5.2	Cultural and religious aspects	301
9.5.3	Labelling	302
9.5.4	Procedures for placing infant food product on the market	303
9.6	Essential composition	303
9.6.1	Introduction	303
9.6.2	Proteins	305
9.6.3	Lipids	309
9.6.4	Carbohydrates	309
9.6.5	Minerals	310
9.6.6	Vitamins	311
9.7	Food safety	311
9.7.1	Food additives	311
9.7.2	Hygiene and microbiological standards	311
9.8	Raw materials/ingredients	312
9.8.1	General aspects	312
9.8.2	Milk	312
9.8.3	Oils	313
9.8.4	Carbohydrates	313

9.9	Manufacture of dried infant formulae (powders)	313
9.9.1	Introduction	313
9.9.2	The 'wet mix' processing line	314
9.9.3	Preparation of the mix	316
9.9.4	Evaporation	316
9.9.5	Spray drying	317
9.9.6	Hygiene and production time between CIP cleaning	318
9.9.7	Structure of the powder	318
9.9.8	Drying parameters	319
9.9.9	Finished powder conveying system	320
9.9.10	Microbiological examination	320
9.10	Manufacture of liquid infant formulae (Ready-To-Feed and concentrates)	321
9.10.1	Dissolving of ingredients	321
9.10.2	First stage of standardisation	321
9.10.3	Oils and fat addition	321
9.10.4	First heat treatment and fat emulsification	323
9.10.5	Second stage of standardisation	323
9.10.6	Final conditioning	323
9.10.7	Retort sterilisation	323
9.10.8	UHT sterilisation and aseptic processing	324
9.10.9	Intermediate aseptic storage	325
9.10.10	Aseptic filling machines and packaging materials	325
9.10.11	Microbiological examination	326
9.11	Conclusion	327
	References	328
<b>10</b>	<b>Process Control in Evaporation and Drying</b>	<b>332</b>
	C.G. BLOORE AND D.J. O'CALLAGHAN	
10.1	Background	332
10.2	Control technology	333
10.3	Measurement technology	334
10.4	Actuator technology	335
10.5	Communication technology	335
10.6	Control philosophies	336
10.7	Process dynamics	337
10.8	Evaporator control	337
10.8.1	Feed flow rate	337
10.8.2	Pre-heat temperature	337
10.8.3	Energy input	337
10.8.4	Condenser water flow rate	338
10.8.5	Level of total solids in the concentrate	338
10.8.6	Modelling approaches for evaporator control	340
10.8.7	Control of evaporator cleaning systems	341

10.9	Spray dryer control	341
10.9.1	Controlling the evaporative demand	341
10.9.2	Controlling the energy input	342
10.9.3	Controlling powder moisture content	342
10.9.4	Concentrate flow rate in disc atomising dryers	342
10.9.5	Concentrate flow rate in nozzle atomising dryers	343
10.9.6	Inlet air flow rate	343
10.9.7	Air-flow stability in spray dryers	343
10.9.8	Inlet air temperature	344
10.9.9	Chamber pressure	344
10.9.10	Outlet temperature in dryers without static fluid beds	344
10.9.11	Outlet temperature in spray dryers with integrated fluid beds	345
10.9.12	'Dummy' outlet temperature	346
10.9.13	Moisture control	347
10.9.14	A model-predictive approach to the control of a spray dryer	347
10.9.15	The influence of the protein content of the powder	347
10.9.16	Cleaning system control in spray drying	348
10.10	Conclusion	349
	References	349

## 11 Hazards in Drying 351

C.G. BLOORE AND D.J. O'CALLAGHAN

11.1	Background	351
11.2	Combustion	351
11.2.1	Smouldering combustion	352
11.2.2	Flaming combustion	352
11.2.3	Deflagrations	352
11.2.4	Detonations	353
11.2.5	Secondary explosions	353
11.3	Dust characteristics	353
11.3.1	Combustibility/explosibility	353
11.3.2	Upper and lower explosive limits	353
11.3.3	Minimum ignition temperature	354
11.3.4	Minimum ignition energy	354
11.3.5	Maximum explosion pressure and the rate of pressure rise	355
11.3.6	Particle size	356
11.3.7	Moisture content	356
11.4	Ignition sources	356
11.4.1	Flames	356
11.4.2	Hot surfaces	357
11.4.3	Mechanical friction	358
11.4.4	Impact sparks	358
11.4.5	Electrical sparks	359
11.4.6	Electrostatic discharge sparks	359

11.4.7	Hot work	359
11.4.8	Self-ignition	360
11.5	Hazards of dust explosions	362
11.6	Fire detection	362
11.6.1	Fast-acting temperature sensors	362
11.6.2	Infra-red optical detectors	362
11.6.3	Carbon monoxide detectors	363
11.6.4	Pressure sensors	363
11.6.5	Operator observation	364
11.7	Explosion suppression	364
11.7.1	Dry powder suppression	364
11.7.2	Chlorinated fluorocarbon compounds	365
11.7.3	Pressurised hot water	365
11.8	Explosion venting	365
11.8.1	Venting principles	365
11.8.2	Vent ducts	366
11.8.3	Vent doors and panels	366
11.9	Containment	367
11.10	Isolation	367
11.11	Inerting	367
11.12	Fire fighting	367
11.13	Conclusion	368
	References	368