

Woodhead Publishing in Food Science and Technology

*Food processing
technology*

Principles and practice

Second edition

P J Fellows



WOODHEAD PUBLISHING LIMITED

Contents

Acknowledgements	xvii
Glossary	xix
List of symbols	xxvii
List of acronyms	xxx
Introduction	1
The food industry today	1
About this book	3
Note on the second edition	4
PART I BASIC PRINCIPLES	7
1 Properties of foods and processing theory	9
1.1 Properties of liquids, solids and gases	9
1.1.1 Density and specific gravity	10
1.1.2 Viscosity	13
1.1.3 Surface activity	14
1.1.4 Rheology and texture	16
1.2 Material transfer	18
1.3 Fluid flow	21
1.3.1 Fluid flow through fluidised beds	26
1.4 Heat transfer	26
1.4.1 Energy balances	27
1.4.2 Mechanisms of heat transfer	27
1.4.3 Sources of heat and methods of application to foods	37
1.4.4 Energy conservation	38
1.4.5 Effect of heat on micro-organisms	40
1.4.6 Effect of heat on nutritional and sensory characteristics	43
1.5 Water activity	44
1.5.1 Effect of a_w on foods	47
1.6 Effects of processing on sensory characteristics of foods	48

viii Contents

1.6.1	Texture	49
1.6.2	Taste, flavour and aroma	49
1.6.3	Colour	50
1.7	Effects of processing on nutritional properties	50
1.8	Food safety, good manufacturing practice and quality assurance ...	52
1.8.1	HACCP	55
1.8.2	Hurdle technology	57
1.9	Acknowledgements	59
1.10	References	59
2	Process control	63
2.1	Automatic control	64
2.1.1	Sensors	65
2.1.2	Controllers	70
2.2	Computer-based systems	72
2.2.1	Programmable logic controllers (PLCs)	72
2.2.2	Types of control systems	74
2.2.3	Software developments	75
2.2.4	Neural networks	77
2.3	Acknowledgements	78
2.4	References	78
PART II	AMBIENT-TEMPERATURE PROCESSING	81
3	Raw material preparation	83
3.1	Cleaning	83
3.1.1	Wet cleaning	84
3.1.2	Dry cleaning	85
3.1.3	Removing contaminants and foreign bodies	85
3.2	Sorting	87
3.2.1	Shape and size sorting	88
3.2.2	Colour sorting	92
3.2.3	Weight sorting	93
3.3	Grading	95
3.4	Peeling	95
3.4.1	Flash steam peeling	95
3.4.2	Knife peeling	96
3.4.3	Abrasion peeling	96
3.4.4	Caustic peeling	96
3.4.5	Flame peeling	96
3.5	Acknowledgements	97
3.6	References	97
4	Size reduction	98
4.1	Size reduction of solid foods	99
4.1.1	Theory	99
4.1.2	Equipment	102
4.1.3	Effect on foods	108

4.2	Size reduction in liquid foods (emulsification and homogenisation)	110
4.2.1	Theory	110
4.2.2	Equipment	112
4.2.3	Effect on foods	114
4.3	Acknowledgements	116
*4.4	References	116
5	Mixing and forming	118
5.1	Mixing	118
5.1.1	Theory of solids mixing	119
5.1.2	Theory of liquids mixing	122
5.1.3	Equipment	125
5.1.4	Effect on foods	132
5.2	Forming	132
5.2.1	Bread moulders	134
5.2.2	Pie and biscuit formers	134
5.2.3	Confectionery moulders	138
5.3	Acknowledgements	139
5.4	References	139
6	Separation and concentration of food components	140
6.1	Centrifugation	141
6.1.1	Theory	141
6.1.2	Equipment	142
6.2	Filtration	146
6.2.1	Theory	146
6.2.2	Equipment	149
6.3	Expression	150
6.3.1	Theory	150
6.3.2	Equipment	151
6.4	Extraction using solvents	153
6.4.1	Theory	153
6.4.2	Equipment	155
6.5	Membrane concentration (hyperfiltration and ultrafiltration)	157
6.5.1	Theory	162
6.5.2	Equipment	164
6.6	Effect on foods	167
6.7	Acknowledgements	168
6.8	References	168
7	Fermentation and enzyme technology	170
7.1	Fermentation	171
7.1.1	Theory	171
7.1.2	Types of food fermentations	174
7.1.3	Equipment	183
7.1.4	Effect on foods	184
7.2	Enzyme technology	184
7.2.1	Enzyme production from micro-organisms	186
7.2.2	Application of enzymes in food processing	187

x Contents

7.3	Acknowledgements	193
7.4	References	193
8	Irradiation	196
8.1	Theory	198
8.2	Equipment	199
8.2.1	Measurement of radiation dose	200
8.2.2	Dose distribution	200
8.3	Effect on micro-organisms	200
8.4	Applications	201
8.4.1	Sterilisation (or 'radappertisation')	202
8.4.2	Reduction of pathogens (or 'radicidation')	202
8.4.3	Prolonging shelf life (or 'radurisation')	202
8.4.4	Control of ripening	203
8.4.5	Disinfestation	203
8.4.6	Inhibition of sprouting	203
8.5	Effect on foods	203
8.5.1	Induced radioactivity	203
8.5.2	Radiolytic products	204
8.5.3	Nutritional and sensory value	204
8.6	Effect on packaging	205
8.7	Detection of irradiated foods	205
8.7.1	Physical methods	206
8.7.2	Chemical methods	207
8.7.3	Biological methods	207
8.8	Acknowledgement	208
8.9	References	208
9	Processing using electric fields, high hydrostatic pressure, light or ultrasound	210
9.1	Pulsed electric field processing	211
9.1.1	Theory	215
9.1.2	Equipment	216
9.2	High pressure processing	216
9.2.1	Theory	217
9.2.2	Processing and equipment	218
9.2.3	Effect on micro-organisms, enzymes and food components	221
9.3	Processing using pulsed light	222
9.3.1	Theory	222
9.3.2	Equipment and operation	223
9.3.3	Effect on micro-organisms and foods	223
9.4	Processing using ultrasound	224
9.4.1	Theory	224
9.4.2	Application to processing	225
9.5	Other methods	226
9.6	References	226

PART III PROCESSING BY APPLICATION OF HEAT	229
A. Heat processing using steam or water	231
10 Blanching	233
10.1 Theory	233
10.2 Equipment	234
10.2.1 Steam blanchers	235
10.2.2 Hot-water blanchers	236
10.3 Effect on foods	238
10.3.1 Nutrients	238
10.3.2 Colour and flavour	239
10.3.3 Texture	239
10.4 Acknowledgement	239
10.5 References	240
11 Pasteurisation	241
11.1 Theory	241
11.2 Equipment	242
11.2.1 Pasteurisation of packaged foods	242
11.2.2 Pasteurisation of unpackaged liquids	244
11.3 Effect on foods	248
11.3.1 Colour, flavour and aroma	248
11.3.2 Vitamin loss	248
11.4 Acknowledgements	249
11.5 References	249
12 Heat sterilisation	250
12.1 In-container sterilisation	250
12.1.1 Theory	250
12.1.2 Retorting (heat processing)	261
12.1.3 Equipment	262
12.2 Ultra high-temperature (UHT)/aseptic processes	264
12.2.1 Theory	264
12.2.2 Processing	267
12.2.3 Equipment	268
12.3 Effect on foods	273
12.3.1 Colour	273
12.3.2 Flavour and aroma	273
12.3.3 Texture or viscosity	274
12.3.4 Nutritive value	275
12.4 Acknowledgements	275
12.5 References	276
13 Evaporation and distillation	278
13.1 Evaporation	278
13.1.1 Theory	278
13.1.2 Equipment	285
13.2 Effect on foods	290

13.3	Distillation	291
13.4	Acknowledgements	293
13.5	References	293
14	Extrusion	294
14.1	Theory	296
14.4.1	Rheological properties of the food	296
14.1.2	Operating characteristics	297
14.2	Equipment	299
14.2.1	Single-screw extruders	299
14.2.2	Twin-screw extruders	300
14.2.3	Ancillary equipment	302
14.3	Applications	304
14.3.1	Cold extrusion	304
14.3.2	Extrusion cooking	304
14.4	Effect on foods	307
14.4.1	Sensory characteristics	307
14.4.2	Nutritional value	307
14.5	Acknowledgements	307
14.6	References	308
B.	Heat processing using hot air	309
15	Dehydration	311
15.1	Theory	311
15.1.1	Drying using heated air	313
15.1.2	Drying using heated surfaces	321
15.2	Equipment	323
15.2.1	Hot-air driers	323
15.2.2	Heated-surface (or contact) driers	331
15.3	Effect on foods	334
15.3.1	Texture	335
15.3.2	Flavour and aroma	336
15.3.3	Colour	337
15.3.4	Nutritional value	338
15.4	Rehydration	339
15.5	Acknowledgements	339
15.6	References	339
16	Baking and roasting	341
16.1	Theory	341
16.2	Equipment	343
16.2.1	Direct heating ovens	343
16.2.2	Indirect heating ovens	343
16.2.3	Batch ovens	345
16.2.4	Continuous and semi-continuous ovens	345
16.3	Effect on foods	348
16.3.1	Texture	348
16.3.2	Flavour, aroma and colour	349

16.3.3	Nutritional value	350
16.4	Acknowledgements	352
16.5	References	352
C. Heat processing using hot oils		353
17	Frying	355
17.1	Theory	355
17.1.1	Shallow (or contact) frying	356
17.1.2	Deep-fat frying	357
17.2	Equipment	358
17.3	Effect on foods	360
17.3.1	Effect of heat on oil	360
17.3.2	Effect of heat on fried foods	361
17.4	Acknowledgements	362
17.5	References	362
D. Heat processing by direct and radiated energy		363
18	Dielectric, ohmic and infrared heating	365
18.1	Dielectric heating	366
18.1.1	Theory	366
18.1.2	Equipment	369
18.1.3	Applications	370
18.1.4	Effect on foods	373
18.2	Ohmic heating	373
18.2.1	Theory	374
18.2.2	Equipment and applications	377
18.3	Infrared heating	380
18.3.1	Theory	380
18.3.2	Equipment	382
18.3.3	Effect on foods	383
18.4	Acknowledgements	383
18.5	References	383
PART IV PROCESSING BY THE REMOVAL OF HEAT		385
19	Chilling	387
19.1	Theory	388
19.1.1	Fresh foods	388
19.1.2	Processed foods	392
19.1.3	Cook-chill systems	395
19.2	Equipment	396
19.2.1	Mechanical refrigerators	396
19.2.2	Cryogenic chilling	399
19.3	Chill storage	400
19.3.1	Control of storage conditions	400

xiv Contents

19.4	Effect on foods	402
19.5	Acknowledgements	403
19.6	References	403
20	Controlled- or modified-atmosphere storage and packaging	406
20.1	Modified- and controlled-atmosphere storage (MAS and CAS)	407
20.2	Modified-atmosphere packaging	409
20.2.1	MAP for fresh foods	409
20.2.2	MAP for processed foods	411
20.2.3	Packaging materials for MAP	413
20.2.4	Active packaging systems	413
20.3	Acknowledgement	416
20.4	References	416
21	Freezing	418
21.1	Theory	419
21.1.1	Ice crystal formation	420
21.1.2	Solute concentration	421
21.1.3	Volume changes	422
21.1.4	Calculation of freezing time	423
21.2	Equipment	425
21.2.1	Cooled-air freezers	425
21.2.2	Cooled-liquid freezers	427
21.2.3	Cooled-surface freezers	429
21.2.4	Cryogenic freezers	430
21.3	Changes in foods	432
21.3.1	Effect of freezing	432
21.3.2	Effects of frozen storage	433
21.3.3	Thawing	438
21.4	Acknowledgements	439
21.5	References	439
22	Freeze drying and freeze concentration	441
22.1	Freeze drying (lyophilisation)	441
22.1.1	Theory	442
22.1.2	Equipment	446
22.1.3	Effect on foods	448
22.2	Freeze concentration	449
22.2.1	Theory	449
22.2.2	Equipment	450
22.3	Acknowledgements	450
22.4	References	451
PART V	POST-PROCESSING OPERATIONS	453
23	Coating or enrobing	455
23.1	Coating materials	455
23.1.1	Batters, powders and breadcrumbs	456

23.1.2	Chocolate and compound coatings	456
23.2	Enrobers	458
23.3	Dusting or breading	459
23.4	Pan coating	459
23.4.1	Hard coatings	460
23.4.2	Soft coatings	460
23.4.3	Chocolate coating	460
23.5	Acknowledgements	461
23.6	References	461
24	Packaging	462
24.1	Theory	466
24.1.1	Light	466
24.1.2	Heat	467
24.1.3	Moisture and gases	467
24.1.4	Micro-organisms, insects, animals and soils	471
24.1.5	Mechanical strength	472
24.2	Types of packaging materials	474
24.2.1	Textiles and wood	474
24.2.2	Metal	474
24.2.3	Glass	478
24.2.4	Flexible films	481
24.2.5	Rigid and semi-rigid plastic containers	487
24.2.6	Paper and board	490
24.2.7	Combined packaging systems	496
24.2.8	Active packaging technologies	497
24.3	Printing	498
24.3.1	Bar codes and other markings	499
24.4	Interactions between packaging and foods	501
24.5	Environmental considerations	502
24.5.1	Packaging costs	503
24.5.2	Manufacture of packaging materials	503
24.5.3	Distribution of packaging materials and ingredients for food production	505
24.5.4	Distribution to retailers and consumers	506
24.5.5	Consumer recycling	506
24.6	Acknowledgements	507
24.7	References	508
25	Filling and sealing of containers	511
25.1	Rigid and semi-rigid containers	511
25.1.1	Filling	512
25.1.2	Sealing	513
25.2	Flexible containers	519
25.3	Types of sealer	519
25.3.1	Form-fill-seal (FFS) equipment	521
25.4	Shrink-wrapping and stretch-wrapping	524
25.5	Tamper-evident packaging	525
25.6	Labelling	526

xvi Contents

25.7	Checkweighing	527
25.8	Metal detection	527
25.9	Acknowledgements	528
25.10	References	528
26	Materials handling, storage and distribution	530
26.1	Materials handling	531
26.1.1	Handling equipment for raw materials and ingredients	532
26.1.2	Handling equipment for processing	532
26.2	Waste management and disposal	540
26.3	Storage	542
26.4	Distribution	544
26.5	Acknowledgements	547
26.7	References	547
Appendices		
A	Vitamins in foods	549
B	Nutritional and functional roles of minerals in foods	551
C	EU permitted food additives	554
D	Units and dimensions	560
Index		563