

FOOD HYGIENE, MICROBIOLOGY AND HACCP

Third edition

S.J. Forsythe and P.R. Hayes

Suranaree University of Technology



31051000501399



AN ASPEN PUBLICATION

Contents

Preface to the Third Edition	xii
Preface to the Second Edition	xiv
Preface to the First Edition	xvi
1 Fundamental Principles of Microbiology	1
1.1 Introduction	1
1.2 Characteristics of Bacteria	2
1.2.1 Shape and size	2
1.2.2 Reproduction	2
1.2.3 Bacterial structure	2
1.2.4 Gram reaction	3
1.3 Types of Bacteria Important in Foods	4
1.3.1 Gram negative bacteria	4
1.3.2 Gram positive bacteria	7
1.4 Characteristics of Fungi	8
1.4.1 Moulds	8
1.4.2 Yeasts	11
1.5 Characteristics of Viruses and Prions	11
1.6 The Growth Curve of Bacteria	14
1.7 Factors Influencing Bacterial Growth	15
1.7.1 Nutrients	15
1.7.2 Temperature	16
1.7.3 Moisture	17
1.7.4 Oxygen	18
1.7.5 Hydrogen ion concentration (pH)	19
1.7.6 Inhibitory substances	20
Bibliography	20
References	20
2 Food Poisoning and Other Food-borne Hazards	21
2.1 Introduction	21
2.2 Incidence of Food Poisoning	21
2.2.1 The bacteria responsible	23
2.2.2 Type of food	23
2.3 Bacterial Food Poisoning	24
2.3.1 Salmonellas ✓	24
2.3.2 Enteritis due to <i>Campylobacter</i> spp	32
2.3.3 <i>Staphylococcus aureus</i> ✓	36
2.3.4 <i>Bacillus cereus</i> ✓	39
2.3.5 <i>Vibrio parahaemolyticus</i> ✓	42
2.3.6 Botulism	44
2.3.7 Listeriosis	49
2.3.8 <i>Clostridium perfringens</i> ✓	54
2.3.9 <i>Escherichia coli</i> ✓	57
2.3.10 Miscellaneous bacterial food poisoning and new variant CJD	59

2.4	Mycotoxicoeses	63
2.4.1	Aflatoxins	64
2.4.2	Miscellaneous mycotoxins	67
2.5	Virus Food Poisoning	68
2.5.1	Small round structured viruses (SRSV)	69
2.5.2	Infective hepatitis	69
2.5.3	Rotaviruses	69
2.5.4	Bovine spongiform encephalopathy and new variant CJD	70
2.5.5	General control measures	70
2.6	Animal Toxins and Parasitic Infections	70
2.6.1	Animals that are naturally toxic to man	70
2.6.2	Secondary toxicity	71
2.6.3	Parasitic infections	73
2.7	Poisonous Plants	76
2.8	Chemical Poisoning	77
	Bibliography	79
	References	79
3	Food Spoilage	86
3.1	Introduction	86
3.2	Spoilage of Fresh Meats	87
3.2.1	Contamination of tissues by microorganisms	87
3.2.2	Control of microbial growth	88
3.2.3	Effect of storage temperature	90
3.2.4	Chemical changes produced by bacteria in chilled meats	93
3.3	Spoilage of Cured Meats	94
3.3.1	Curing agents	94
3.3.2	The curing process	95
3.3.3	The microbiology and spoilage of bacon and ham	95
3.4	Spoilage of Vacuum-Packed Meats	98
3.4.1	Types of packaging materials	98
3.4.2	Influence of packaging materials on the microbiological flora	98
3.4.3	Spoilage of packed fresh meats	99
3.4.4	Spoilage of vacuum-packed bacon	101
3.4.5	Modified atmospheric packaging	102
3.4.6	Sous vide	103
3.5	Spoilage of Poultry	103
3.5.1	Effects of processing on the microbiological flora	103
3.5.2	Spoilage of chickens held at chill temperatures	105
3.6	Spoilage of Fish and Shellfish	106
3.6.1	Bacteriology of the newly caught fish	106
3.6.2	The effect of initial processing and storage in ice on board ship	106
3.6.3	The effect of handling ashore	108
3.6.4	Chemical changes induced by bacteria in fish	108
3.6.5	Salted fish	109
3.6.6	Smoked fish	110
3.6.7	Packaged fish	111
3.6.8	Shellfish	111
3.7	Dairy Products	112
3.7.1	Milk	112
3.7.2	Butter	115
3.7.3	Cheese	116
3.7.4	Yoghurt	117
3.8	Eggs and Egg Products	118
3.8.1	The chicken's egg and its spoilage	118
3.8.2	Egg products	119
3.9	Vegetables and Fruits	120
3.9.1	Spoilage by fungi	120

	3.9.2 Spoilage by bacteria	121
	3.9.3 Control of microbial spoilage	122
3.10	Cereal Based Products	123
3.11	Beer	124
3.12	Wine	125
3.13	Sauerkraut	125
3.14	Canned Foods	125
	3.14.1 Leaker spoilage	126
	3.14.2 Spoilage due to inadequate heat treatment	129
3.15	Frozen Foods	133
	3.15.1 Influence of sub-zero temperatures on microorganisms	133
	3.15.2 Factors affecting viability of microorganisms during freezing	133
	3.15.3 Effect of cold storage	134
	3.15.4 Freezing injury to cells	135
	3.15.5 Thawed foods and their spoilage	135
3.16	Dehydrated Foods	136
	3.16.1 Methods of drying	136
	3.16.2 Influence of drying and freeze drying on microorganisms	137
	3.16.3 Storage stability of dried foods	137
	3.16.4 Rehydration	138
	3.16.5 Intermediate moisture foods	138
3.17	Irradiated Foods	138
	3.17.1 Types of radiation	138
	3.17.2 Effect of radiation on microorganisms	139
	3.17.3 High dose applicatons	140
	3.17.4 Low dose applications and the spoilage of foods so treated	141
	Bibliography	143
	References	143
4	Microbiological Examining Methods	150
4.1	The Rational of Microbiological Testing	150
4.2	Sampling	150
	4.2.1 Sampling plan	150
	4.2.2 The representative sample	151
	4.2.3 Sampling techniques	153
	4.2.4 Treatment of sample	154
	4.2.5 Examination methods	154
4.3	Microbiological Test Procedures	156
	4.3.1 Total viable count	156
	4.3.2 Viable but nonculturable bacteria	158
4.4	Conventional Methods	158
	4.4.1 Indicator organisms	158
	4.4.2 Food poisoning bacteria	161
	4.4.3 Food spoilage organisms	168
	4.4.4 Canned foods	170
	4.4.5 Frozen and dehydrated food	171
4.5	Rapid Detection Techniques	171
	4.5.1 Separation and concentration techniques	172
	4.5.2 Impedance microbiology	177
	4.5.3 Enzyme immunoassays and latex agglutination tests	180
	4.5.4 Nucleic acid probes and PCR	182
	4.5.5 ATP bioluminescence techniques and hygiene monitoring	185
	4.5.6 <i>Lux</i> gene technology	188
	4.5.7 Flow cytometry	189
	4.5.8 Miscellaneous tests	190
4.6	Microbiological Criteria and Specifications	190
	Bibliography	191
	References	192

5	Factory Design and Construction	203
5.1	The Factory Site	203
5.2	General Design Principles and Structural Techniques	204
5.2.1	Roofing and lighting	205
5.3	Construction of Ceilings, Walls and Floors	207
5.3.1	Ceilings and overhead fittings	207
5.3.2	Walls	208
5.3.3	Floors and drains	210
5.4	Ventilation and Air Conditioning	211
5.5	Noise and Vibration	214
	Bibliography	214
6	Factory Layout	215
6.1	Handling of Food Materials	215
6.1.1	Work flow patterns and plant layout	216
6.2	Layout and Integration of Different Work Areas	217
6.2.1	Raw materials: reception	217
6.2.2	Raw materials: storage	218
6.2.3	Processing area	220
6.2.4	Finished product storage	221
6.2.5	Employee service and welfare areas	221
6.2.6	Offices and general administration buildings	227
6.2.7	Laboratories	227
6.2.8	Machine maintenance and storage areas	228
6.2.9	Integration of the principal areas of work	228
	Bibliography	231
	Reference	231
7	Design of Food Processing Equipment	232
7.1	Introduction	232
7.2	Legislation	233
7.3	Construction Materials	236
7.3.1	General requirements	236
7.3.2	Stainless steel	237
7.3.3	Corrosion of stainless steel	237
7.3.4	Iron and mild steel	238
7.3.5	Copper and its alloys	238
7.3.6	Miscellaneous metals	239
7.3.7	Plastics	239
7.3.8	Rubber, glass and wood	240
7.3.9	Antimicrobial worksurfaces	241
7.4	Growth 'Pockets'	241
7.5	Ease of Dismantling and Re-assembly of Equipment	243
7.6	Accessibility and the Supporting Framework	244
7.7	External Surfaces	245
7.8	Design Features for Individual Items of Equipment	246
7.8.1	Tanks, vats, etc	246
7.8.2	Pumps	249
7.8.3	Valves	250
7.8.4	Pipes	256
7.8.5	Steam and air lines	259
7.8.6	Motors	259
7.8.7	Size reduction equipment	261
7.8.8	Mixers	262
7.8.9	Forming and assembly equipment	263

7.8.10	Mechanical separators	263
7.8.11	Equipment transferring solid foods	264
7.8.12	Heating equipment	269
7.8.13	Safety	273
	Bibliography	274
	References	274
8	HACCP and Product Quality	276
8.1	HACCP and Quality Schemes	276
8.2	Origins of HACCP	277
8.3	Objectives of HACCP	277
8.4	The Seven Principles of HACCP	278
8.4.1	Principle 1	279
8.4.2	Principle 2	279
8.4.3	Principle 3	279
8.4.4	Principle 4	279
8.4.5	Principle 5	280
8.4.6	Principle 6	281
8.4.7	Principle 7	281
8.5	HACCP-like Implementation	281
8.6	Generic HACCP	281
8.6.1	CCP for refrigerated foods	282
8.6.2	CCP for whole young chickens	282
8.7	Principle 1 – Hazard Analysis	282
8.7.1	Microbial hazards	284
8.7.2	Extrinsic parameters	287
8.8	Principle 2 – Critical Control Points	290
8.8.1	The CCP decision tree	290
8.8.2	Trends in CCP implementation	291
8.9	Critical Limits	292
8.9.1	Critical limits during a cooking process	292
8.10	ATP-bioluminescence and HACCP Monitoring	294
8.11	End-product Testing and Microbiological Criteria	294
8.11.1	Verification	294
8.11.2	Record keeping	295
8.11.3	Dairy industry	295
8.11.4	Meat industry	296
8.11.5	Seafoods industry	297
8.11.6	Catering, cooked–chilled foods, sous-vide	298
8.12	Problems of Implementation	300
8.13	HACCP and Predictive Microbiology	302
8.14	Risk Assessment	304
8.15	Quality Assurance and Quality Control	304
8.16	Raw Material Control	307
8.16.1	Inspection	307
8.16.2	Ambient temperature storage	307
8.16.3	Chill storage	308
8.16.4	Deep frozen storage	309
8.16.5	Storage zones	309
8.17	Process Control	309
8.17.1	Process temperature/time relationships	310
8.17.2	Design of and critical points in pork pie processing	312
8.17.3	Waste materials	314
8.17.4	Maintenance of processing lines	315
8.18	Packaging	315
8.18.1	Required properties of packaging materials	315
8.18.2	Main types of packaging materials and containers	316

8.18.3	Microbiological aspects of packaging materials	316
8.18.4	Storage of packaging materials	317
8.19	Finished Product Storage	317
8.20	Transport and Distribution	318
8.21	Total Quality Management and Longitudinal Integrated Safety Assurance	320
	Bibliography	321
	References	322
9	Cleaning and Disinfection: Methods	327
9.1	Introduction	327
9.2	Definitions	327
9.3	Types of Soil	328
9.4	Removal of Gross Soil	329
9.5	Detergents	330
9.5.1	Desirable properties	330
9.5.2	Classifications of detergents	331
9.5.3	Detergent formulation	338
9.5.4	Factors affecting efficiency of detergents	339
9.6	Chemical Disinfectants	340
9.6.1	Desirable properties	340
9.6.2	Classification of disinfectants	341
9.6.3	Evaluation of disinfectants	347
9.7	Use of Heat	352
9.7.1	Steam	352
9.7.2	Hot water	352
9.8	Dry Cleaning	353
9.9	Cleaning-in-Place (CIP)	353
9.9.1	CIP systems	353
9.9.2	Spraying devices	354
9.9.3	Benefits of CIP	357
9.10	Mechanical Aids for Cleaning	357
9.10.1	Pressurized steam	357
9.10.2	Hydraulic devices	358
9.10.3	Compressed air	358
9.10.4	Ultrasonics	358
9.10.5	Portable cleaning machines	359
9.10.6	Fixed cleaning systems	360
9.11	Foam Cleaning	360
9.12	Cleaning Small Equipment	360
9.13	Paper and Fabric Wipers	362
	Bibliography	362
	References	362
10	Cleaning and Disinfection: Practical Application	364
10.1	Aims	364
10.2	Cleaning Schedules	365
10.3	Biofilms	366
10.4	Use of Labour	366
10.5	The Role of Management	368
10.6	Miscellaneous Problems Encountered	369
10.7	Assessment of Cleaning Efficiency	370
	Bibliography	371
	References	371

11	Hygiene and Training of Personnel	372
11.1	Hand Washing and Care of the Hands	372
11.1.1	Personal hygiene	373
11.1.2	Bactericidal soaps and creams	373
11.1.3	Use of gloves	374
11.2	Practices, Good and Bad	374
11.2.1	Clothing and jewellery	375
11.2.2	Hair	375
11.2.3	Other bad practices	375
11.3	Health Supervision	376
11.3.1	Pre-employment medical examination	376
11.3.2	Health monitoring of employees	376
11.4	Induction and In-Service Training	377
	Bibliography	379
	References	379
12	World-wide Food Safety Programmes and Legislation	380
12.1	World-wide Food Safety Programmes	380
12.1.1	World-wide food poisoning outbreaks	380
12.1.2	Salm-Net	382
12.1.3	Antibiotic resistance	383
12.2	Legislation	384
12.3	Food Legislation Within the European Community	385
12.3.1	The legislative process	385
12.3.2	Microbiological criteria for foods	386
12.3.3	Examples of EC food legislation	388
12.4	International Food Standards	403
12.4.1	International implementation of HACCP concept	404
12.5	Food Hygiene and Safety Legislation in the UK	405
12.5.1	The Food Safety Act (1990)	405
12.5.2	Codes of Practice	406
12.5.3	Food Safety (General Food Hygiene) 1995	406
12.5.4	Food Safety (Temperature) Regulations 1995	408
12.5.5	Dairy Products (Hygiene) Regulations 1995	410
12.5.6	Food Standards Agency	410
12.5.7	Ice-Cream (Heat Treatment) Regulations (1959); Liquid Egg (Pasteurization) Regulations (1963)	411
12.6	Food Legislation In Some European Countries	412
12.6.1	France	412
12.6.2	Italy	413
12.6.3	Germany	415
12.6.4	Netherlands	417
12.6.5	Food Hygiene Directive (93/43/EEC) implementation	418
12.7	Food Legislation in the USA	418
12.7.1	The GMP regulations	420
12.7.2	Regulations concerning specific foods	421
12.7.3	Microbiological standards in the USA	426
12.8	Food Legislation in Japan and Korea	427
12.8.1	Microbiological Standards in Japan and Korea	428
12.9	Concluding Remarks	428
	Bibliography	430
	References	430
	Index	434