

# *Contents*

## **Chapter 1 The Scope of Food Microbiology**

1.1	Micro-organisms and Food	2
1.1.1	Food Spoilage/Preservation	2
1.1.2	Food Safety	4
1.1.3	Fermentation	4
1.2	Microbiological Quality Assurance	4

## **Chapter 2 Micro-organisms and Food Materials**

2.1	Diversity of Habitat	5
2.2	Micro-organisms in the Atmosphere	6
2.2.1	Airborne Bacteria	7
2.2.2	Airborne Fungi	8
2.3	Micro-organisms of Soil	11
2.4	Micro-organisms of Water	13
2.5	Micro-organisms of Plants	15
2.6	Micro-organisms of Animal Origin	18
2.6.1	The Skin	18
2.6.2	The Nose and Throat	19
2.7	Conclusions	19

## **Chapter 3 Factors Affecting the Growth and Survival of Micro-organisms in Foods**

3.1	Microbial Growth	20
3.2	Intrinsic Factors (Substrate Limitations)	23
3.2.1	Nutrient Content	23
3.2.2	pH and Buffering Capacity	24
3.2.3	Redox Potential, $E_h$	28

3.2.4	Antimicrobial Barriers and Constituents	32
3.2.5	Water Activity	36
3.3	Extrinsic Factors (Environmental Limitations)	45
3.3.1	Relative Humidity	45
3.3.2	Temperature	46
3.3.3	Gaseous Atmosphere	48
3.4	Implicit Factors	49
3.5	Predictive Food Microbiology	52

## Chapter 4 The Microbiology of Food Preservation

4.1	Heat Processing	63
4.1.1	Pasteurization and Appertization	63
4.1.2	Quantifying the Thermal Death of Micro-organisms: D and z Values	66
4.1.3	Heat Sensitivity of Micro-organisms	68
4.1.4	Describing a Heat Process	72
4.1.5	Spoilage of Canned Foods	77
4.1.6	Aseptic Packaging	80
4.2	Irradiation	81
4.2.1	Microwave Radiation	82
4.2.2	UV Radiation	83
4.2.3	Ionizing Radiation	85
4.3	High-Pressure Processing–Pascalization	90
4.4	Low-Temperature Storage–Chilling and Freezing	92
4.4.1	Chill Storage	93
4.4.2	Freezing	96
4.5	Chemical Preservatives	98
4.5.1	Organic Acids and Esters	99
4.5.2	Nitrite	102
4.5.3	Sulfur Dioxide	106
4.5.4	Natamycin	107
4.5.5	'Natural' Food Preservatives	107
4.6	Modification of Atmosphere	108
4.7	Control of Water Activity	112
4.8	Compartmentalization	115

## Chapter 5 Microbiology of Primary Food Commodities

5.1	What is Spoilage?	119
5.2	Milk	121
5.2.1	Composition	121
5.2.2	Microflora of Raw Milk	123

5.2.3	Heat Treatment of Milk	127
5.2.4	Milk Products	130
5.3	Meat	131
5.3.1	Structure and Composition	132
5.3.2	The Microbiology of Primary Processing	134
5.3.3	Spoilage of Fresh Meat	136
5.4	Fish	139
5.4.1	Structure and Composition	140
5.4.2	The Microbiology of Primary Processing	140
5.4.3	Crustaceans and Molluscs	141
5.4.4	Spoilage of Fresh Fish	142
5.5	Plant Products	145
5.5.1	Cereals	147
5.5.2	Preservation of High-moisture Cereals	149
5.5.3	Pulses, Nuts and Oilseeds	149
5.5.4	Fruits and Fruit Products	151
5.5.5	Vegetables and Vegetable Products	153

## Chapter 6 Food Microbiology and Public Health

6.1	Food Hazards	158
6.2	Significance of Foodborne Disease	160
6.3	Incidence of Foodborne Illness	165
6.4	Risk Factors Associated with Foodborne Illness	169
6.5	The Changing Scene and Emerging Pathogens	171
6.6	The Site of Foodborne Illness. The Alimentary Tract: Its Function and Microflora	172
6.7	The Pathogenesis of Diarrhoeal Disease	176

## Chapter 7 Bacterial Agents of Foodborne Illness

7.1	<i>Aeromonas hydrophila</i>	182
7.1.1	Introduction	182
7.1.2	The Organism and its Characteristics	183
7.1.3	Pathogenesis and Clinical Features	184
7.1.4	Isolation and Identification	184
7.1.5	Association with Foods	184
7.2	<i>Bacillus cereus</i> and other <i>Bacillus</i> Species	185
7.2.1	Introduction	185
7.2.2	The Organism and its Characteristics	186
7.2.3	Pathogenesis and Clinical Features	186
7.2.4	Isolation and Identification	188
7.2.5	Association with Foods	189

7.3	<b><i>Brucella</i></b>	190
	7.3.1 Introduction	190
	7.3.2 The Organism and its Characteristics	191
	7.3.3 Pathogenesis and Clinical Features	191
	7.3.4 Isolation and Identification	191
	7.3.5 Association with Foods	192
7.4	<b><i>Campylobacter</i></b>	192
	7.4.1 Introduction	192
	7.4.2 The Organism and its Characteristics	193
	7.4.3 Pathogenesis and Clinical Features	194
	7.4.4 Isolation and Identification	195
	7.4.5 Association with Foods	196
7.5	<b><i>Clostridium botulinum</i></b>	198
	7.5.1 Introduction	198
	7.5.2 The Organism and its Characteristics	199
	7.5.3 Pathogenesis and Clinical Features	202
	7.5.4 Isolation and Identification	205
	7.5.5 Association with Foods	205
7.6	<b><i>Clostridium perfringens</i></b>	209
	7.6.1 Introduction	209
	7.6.2 The Organism and its Characteristics	211
	7.6.3 Pathogenesis and Clinical Features	211
	7.6.4 Isolation and Identification	212
	7.6.5 Association with Foods	213
7.7	<b><i>Enterobacter sakazakii</i></b>	214
	7.7.1 Introduction	214
	7.7.2 The Organism and its Characteristics	214
	7.7.3 Pathogenesis and Clinical Features	215
	7.7.4 Isolation and Identification	215
	7.7.5 Association with Foods	215
7.8	<b><i>Escherichia coli</i></b>	216
	7.8.1 Introduction	216
	7.8.2 The Organism and its Characteristics	217
	7.8.3 Pathogenesis and Clinical Features	218
	7.8.4 Isolation and Identification	222
	7.8.5 Association with Foods	223
7.9	<b><i>Listeria monocytogenes</i></b>	224
	7.9.1 Introduction	224
	7.9.2 The Organism and its Characteristics	226
	7.9.3 Pathogenesis and Clinical Features	227
	7.9.4 Isolation and Identification	228
	7.9.5 Association with Foods	229
7.10	<b><i>Mycobacterium</i> species</b>	231
	7.10.1 Introduction	231
	7.10.2 The Organism and its Characteristics	232
	7.10.3 Pathogenesis and Clinical Features	232

7.10.4	Isolation and Identification	233
7.10.5	Association with Foods	233
7.11	<i>Plesiomonas shigelloides</i>	234
7.11.1	Introduction	234
7.11.2	The Organism and its Characteristics	234
7.11.3	Pathogenesis and Clinical Features	235
7.11.4	Isolation and Identification	235
7.11.5	Association with Foods	235
7.12	<i>Salmonella</i>	235
7.12.1	Introduction	235
7.12.2	The Organism and its Characteristics	237
7.12.3	Pathogenesis and Clinical Features	238
7.12.4	Isolation and Identification	241
7.12.5	Association with Foods	244
7.13	<i>Shigella</i>	249
7.13.1	Introduction	249
7.13.2	The Organism and its Characteristics	250
7.13.3	Pathogenesis and Clinical Features	250
7.13.4	Isolation and Identification	251
7.13.5	Association with Foods	251
7.14	<i>Staphylococcus aureus</i>	252
7.14.1	Introduction	252
7.14.2	The Organism and its Characteristics	252
7.14.3	Pathogenesis and Clinical Features	254
7.14.4	Isolation and Identification	255
7.14.5	Association with Foods	256
7.15	<i>Vibrio</i>	257
7.15.1	Introduction	257
7.15.2	The Organisms and their Characteristics	259
7.15.3	Pathogenesis and Clinical Features	260
7.15.4	Isolation and Identification	261
7.15.5	Association with Foods	262
7.16	<i>Yersinia enterocolitica</i>	262
7.16.1	Introduction	262
7.16.2	The Organism and its Characteristics	263
7.16.3	Pathogenesis and Clinical Features	265
7.16.4	Isolation and Identification	266
7.16.5	Association with Foods	266
7.17	Scombrototoxic Fish Poisoning	267
7.18	Conclusion	268

## Chapter 8 Non-bacterial Agents of Foodborne Illness

8.1	Helminths and Nematodes	270
8.1.1	Platyhelminths: Liver Flukes and Tapeworms	270
8.1.2	Roundworms	272

8.2	Protozoa	274
8.2.1	<i>Giardia lamblia</i>	275
8.2.2	<i>Entamoeba histolytica</i>	276
8.2.3	Sporozoid Protozoa	276
8.3	Toxigenic Algae	277
8.3.1	Dinoflagellate Toxins	277
8.3.2	Cyanobacterial Toxins	279
8.3.3	Toxic Diatoms	279
8.4	Toxigenic Fungi	280
8.4.1	Mycotoxins and Mycophagy	281
8.4.2	Mycotoxins of <i>Aspergillus</i>	282
8.4.3	Mycotoxins of <i>Penicillium</i>	290
8.4.4	Mycotoxins of <i>Fusarium</i>	292
8.4.5	Mycotoxins of Other Fungi	297
8.5	Foodborne Viruses	300
8.5.1	Polio	301
8.5.2	Hepatitis A and E	301
8.5.3	Gastroenteritis Viruses	303
8.5.4	Sources of Food Contamination	304
8.5.5	Control	306
8.6	Spongiform Encephalopathies	307

## Chapter 9 Fermented and Microbial Foods

9.1	Introduction	310
9.2	Yeasts	312
9.3	Lactic acid Bacteria	314
9.4	Activities of Lactic Acid Bacteria in Foods	317
9.4.1	Antimicrobial Activity of Lactic Acid Bacteria	317
9.4.2	Health-promoting Effects of Lactic Acid Bacteria-Probiotics	320
9.4.3	The Malo-lactic Fermentation	322
9.5	Fermented Milks	323
9.5.1	Yoghurt	323
9.5.2	Other Fermented Milks	327
9.6	Cheese	330
9.7	Fermented Vegetables	336
9.7.1	Sauerkraut and Kimchi	336
9.7.2	Olives	340
9.7.3	Cucumbers	341
9.8	Fermented Meats	343
9.9	Fermented Fish	346
9.10	Beer	348
9.11	Vinegar	356
9.12	Mould Fermentations	362

9.12.1	Tempeh	362
9.12.2	Soy Sauce and Rice Wine	365
9.12.3	Mycoprotein	368
9.13	Conclusion	369

## **Chapter 10 Methods for the Microbiological Examination of Foods**

10.1	Indicator Organisms	370
10.2	Direct Examination	373
10.3	Cultural Techniques	374
10.4	Enumeration Methods	377
10.4.1	Plate Counts	377
10.4.2	Most Probable Number Counts	380
10.5	Alternative Methods	381
10.5.1	Dye-reduction Tests	382
10.5.2	Electrical Methods	382
10.5.3	ATP Determination	386
10.6	Rapid Methods for The Detection of Specific Organisms and Toxins	388
10.6.1	Immunological Methods	388
10.6.2	DNA/RNA Methodology	389
10.6.3	Subtyping	393
10.7	Laboratory Accreditation	394

## **Chapter 11 Controlling the Microbiological Quality of Foods**

11.1	Quality and Criteria	396
11.2	Sampling Schemes	399
11.2.1	Two-class Attributes Plans	399
11.2.2	Three-class Attributes Plans	402
11.2.3	Choosing a Plan Stringency	405
11.2.4	Variables Acceptance Sampling	407
11.3	Quality Control using Microbiological Criteria	410
11.4	Control at Source	412
11.4.1	Training	412
11.4.2	Facilities and Operations	413
11.4.3	Equipment	415
11.4.4	Cleaning and Disinfection	418
11.5	Codes of Good Manufacturing Practice	425
11.6	The Hazard Analysis and Critical Control Point (HACCP) Concept	425
11.6.1	Hazard Analysis	428
11.6.2	Identification of Critical Control Points (CCPs)	429

11.6.3	Establishment of CCP Critical Limits	429
11.6.4	Monitoring Procedures for CCPs	431
11.6.5	Protocols for CCP Deviations	431
11.6.6	Verification	432
11.6.7	Record Keeping	432
11.7	Quality Systems: BS 5750 and ISO 9000 Series	434
11.8	Risk Analysis	436
 <b>Chapter 12 Further Reading</b>		 440
 <b>Subject Index</b>		 447