

# Seafood Processing

Technology, Quality and Safety

Edited by

**Ioannis S. Boziaris**

*School of Agricultural Sciences, University of Thessaly, Volos, Greece*

**WILEY** Blackwell

# Contents

<b>About the <i>IFST Advances in Food Science</i> Book Series</b>	<b>xiii</b>
<b>List of Contributors</b>	<b>xv</b>
<b>Preface</b>	<b>xix</b>
<b>1 Introduction to Seafood Processing – Assuring Quality and Safety of Seafood</b>	<b>1</b>
<i>Ioannis S. Bozaris</i>	
1.1 Introduction	1
1.2 Seafood spoilage	2
1.3 Seafood hazards	2
1.4 Getting the optimum quality of the raw material	3
1.4.1 Pre-mortem handling	3
1.4.2 Post-mortem handling	4
1.5 Seafood processing	4
1.6 Quality, safety and authenticity assurance	6
1.7 Future trends	6
References	7
<b>Part I Processing Technologies</b>	<b>9</b>
<b>2 Shellfish Handling and Primary Processing</b>	<b>11</b>
<i>Yi-Cheng Su and Chengchu Liu</i>	
2.1 Introduction	11
2.1.1 Health hazards associated with molluscan shellfish	11
2.2 Shellfish harvesting	13
2.2.1 Growing area	13
2.2.2 Water quality	17
2.3 Bivalve shellfish handling	18
2.3.1 Temperature control	18
2.3.2 Transportation and storage	19
2.3.3 Retail handling	20
2.4 Shellfish primary processing	21
2.4.1 Shucking	21

2.4.2	Packing	22
2.4.3	Post-harvest processes	22
2.5	Bivalve shellfish depuration	23
2.5.1	Factors affecting depuration	24
2.5.2	Facilities	25
2.5.3	Water disinfection	25
2.6	Shellfish labelling	27
2.7	Conclusion	27
	Acknowledgements	28
	References	28
<b>3</b>	<b>Chilling and Freezing of Fish</b>	<b>33</b>
	<i>Flemming Jessen, Jette Nielsen and Erling Larsen</i>	
3.1	Introduction	33
3.2	Post-mortem changes at chilled storage temperatures	34
3.2.1	Rigor mortis	34
3.2.2	Protein changes	36
3.2.3	Lipid changes	36
3.2.4	Microbial changes	37
3.3	Effect of freezing temperatures on quality-related processes	37
3.3.1	The freezing process	37
3.3.2	Frozen storage temperatures	40
3.4	Fresh fish chain	41
3.4.1	Handling and processing on board fish vessels	42
3.4.2	Landing, sorting and first sale	44
3.4.3	Transport and wholesaler/central storage	45
3.4.4	Super-chilling	46
3.5	Frozen fish chain	46
3.5.1	Freezing systems	47
3.5.2	Frozen storage	51
3.5.3	Thawing	52
3.5.4	Storage life	53
3.6	Legislation	54
3.7	Recommendations	54
	References	55
<b>4</b>	<b>Heat Processing of Fish</b>	<b>61</b>
	<i>Dagbjørn Skipnes</i>	
4.1	Introduction	61
4.2	Basic principles	61
4.3	Best available technology for thermal processing of fish	62
4.4	Quality changes during heat treatment of fish	63
4.4.1	Process design effects on product quality	68
4.4.2	Biochemical changes during heating	69
4.4.3	Cook loss	71
4.4.4	Water holding capacity	73
4.4.5	Texture and colour changes	74
	Acknowledgement	75
	References	75

---

<b>5</b>	<b>Irradiation of Fish and Seafood</b>	<b>83</b>
	<i>Ioannis S. Arvanitoyannis and Persefoni Tserkezou</i>	
5.1	Introduction	83
5.2	Quality of irradiated fish and fishery products and shelf life extension	84
5.2.1	Fish	84
5.2.2	Shellfish, crustaceans and molluscs	89
5.3	Microflora of irradiated fish and fishery products	101
5.3.1	Fish	101
5.3.2	Shellfish, crustaceans and molluscs	106
5.4	Conclusions	120
	References	120
<b>6</b>	<b>Preservation of Fish by Curing</b>	<b>129</b>
	<i>Sigurjon Arason, Minh Van Nguyen, Kristin A. Thorarinsdottir and Gudjon Thorkelsson</i>	
6.1	Introduction	129
6.2	Salting	130
6.2.1	Salting methods	130
6.2.2	Processes for salted fish products	132
6.2.3	Changes in fish muscle during salting	134
6.2.4	Heavily salted fish products	138
6.3	Marinating	143
6.3.1	Introduction	143
6.3.2	Marinating methods	143
6.3.3	Ingredients used in marinating	145
6.3.4	Factors affecting the quality of marinated products	145
6.3.5	Changes in fish muscle during marinating	146
6.3.6	Storage of marinated fish products	146
6.4	Smoking	146
6.4.1	Introduction	146
6.4.2	Smoking method	147
6.4.3	Changes in fish muscle during smoking	148
6.4.4	Factors affecting the quality of smoked fish products	149
6.4.5	Packaging and storage of smoked fish products	151
	References	151
<b>7</b>	<b>Drying of Fish</b>	<b>161</b>
	<i>Minh Van Nguyen, Sigurjon Arason and Trygve Magne Eikevik</i>	
7.1	Introduction	161
7.2	Principles of drying	161
7.2.1	Mass and heat transfer during drying	161
7.2.2	Drying kinetics	162
7.2.3	Water activity	163
7.3	Drying methods	163
7.3.1	Sun drying	163
7.3.2	Solar drying	164
7.3.3	Heat pump drying	164
7.3.4	Freeze-drying	165
7.3.5	Osmotic dehydration	166

7.4	Changes in fish muscle during drying	166
7.4.1	Changes in chemical properties of fish muscle	166
7.4.2	Changes in physical properties of fish muscle	167
7.4.3	Effect of drying on the nutritional properties of fish	169
7.5	Packing and storage of dried fish products	169
	References	170
<b>8</b>	<b>Fish Fermentation</b>	<b>177</b>
	<i>Somboon Tanasupawat and Wonnop Visessanguan</i>	
8.1	Definition of the term fermentation in food technology	177
8.2	Fermented foods worldwide	178
8.3	Lactic acid fermentation	179
8.4	Traditional salt/fish fermentation	180
8.4.1	Classification of fermented fish	181
8.4.2	World fermented fish products	182
8.5	Future trends in fish fermentation technology	197
	References	199
<b>9</b>	<b>Frozen Surimi and Surimi-based Products</b>	<b>209</b>
	<i>Emiko Okazaki and Ikuo Kimura</i>	
9.1	Fish material for frozen surimi	209
9.2	Principles and process of frozen surimi production	209
9.2.1	Fish material	210
9.2.2	Washing and scaling of fish	210
9.2.3	Sorting of fish	212
9.2.4	Filleting of fish	212
9.2.5	Mechanical separation of fish	212
9.2.6	Leaching	212
9.2.7	Refining	217
9.2.8	Dewatering	218
9.2.9	Blending of cryoprotectants	218
9.2.10	Freezing	218
9.2.11	Frozen storage and transport	218
9.3	Characteristics of fish material and manufacturing technology	219
9.3.1	Surimi from dark-fleshed fatty fish species	219
9.3.2	Surimi production from fish species with high protease activity in the muscle	222
9.4	Denaturation of fish protein by freezing and its prevention	223
9.4.1	Stability of fish protein	224
9.4.2	Substances promoting protein denaturation during frozen storage	224
9.4.3	Cryoprotectants and their mechanism of action	226
9.4.4	Effects of polyphosphates	228
9.5	Evaluation of surimi quality	228
9.6	Surimi-based products	231
9.6.1	The production of surimi-based products in the world	231
9.6.2	General processing techniques of surimi-based products	231
9.6.3	Recent technological changes in the production of surimi-based products	231
9.7	Future prospective	232
	References	233

---

<b>10 Packaging of Fish and Fishery Products</b>	<b>237</b>
<i>Bert Nosedá, An Vermeulen, Peter Ragaert and Frank Devlieghere</i>	
10.1 Introduction	237
10.2 MAP principles and importance for packaging fresh fish	238
10.2.1 Principles of MAP	238
10.2.2 Importance of MAP	240
10.3 Non-microbial effects of MAP	242
10.3.1 Effect on sensorial quality	242
10.3.2 Effect on oxidative rancidity	242
10.4 Effects of MAP on fish spoilage	243
10.4.1 Effect of MAP on the spoilage microbiota	243
10.4.2 Effect of MAP on the spoilage mechanism	246
10.5 Effects of MAP on the microbial safety of fish products	248
10.5.1 <i>Listeria monocytogenes</i>	249
10.5.2 <i>Clostridium botulinum</i>	249
10.6 Application of MAP on fish and fishery products	250
10.6.1 Fresh fish	251
10.6.2 Fresh crustaceans	252
10.6.3 Fresh molluscs	252
10.6.4 Smoked fish products	253
10.7 Packaging materials and future developments	253
10.7.1 Barrier materials	254
10.7.2 Active and intelligent packaging	254
10.7.3 New resources for packaging materials	255
References	255
<b>11 Fish Waste Management</b>	<b>263</b>
<i>Ioannis S. Arvanitoyannis and Persefoni Tserkezou</i>	
11.1 Introduction	263
11.2 Treatment methods	265
11.2.1 Hydrolysis	265
11.2.2 Bioremediation	266
11.2.3 Anaerobic treatment	269
11.2.4 Filtration/screening	270
11.2.5 Miscellaneous/multifunctional methods	272
11.3 Uses of fish waste	291
11.3.1 Animal feed	291
11.3.2 Biodiesel/biogas	292
11.3.3 Natural pigments	292
11.3.4 Food industry/cosmetics	293
11.3.5 Waste management	294
11.3.6 Miscellaneous uses	296
11.4 Inputs and outputs in fisheries	296
References	304
Electronic Sources	309
<b>12 Fish Processing Installations: Sustainable Operation</b>	<b>311</b>
<i>George M. Hall and Sevim Köse</i>	
12.1 Introduction	311
12.1.1 Defining sustainability	311

12.1.2	Sustainability criteria	312
12.1.3	Climate change	312
12.2	Assessment tools	313
12.2.1	Carbon footprinting	313
12.2.2	Life cycle assessment	314
12.2.3	Supply chain	318
12.3	Process operations	319
12.3.1	Introduction	319
12.3.2	Pre-processing	319
12.3.3	Canning	319
12.3.4	Smoking	322
12.3.5	Freezing and chilling	324
12.3.6	Surimi production	327
12.3.7	Fish meal and fish oil	329
12.3.8	Fermented products	332
12.4	Production efficiency	333
12.4.1	Introduction	333
12.4.2	Cleaner production	333
12.4.3	Management approaches	334
12.5	On-board processing	334
12.5.1	Introduction	334
12.5.2	Advantages and disadvantages	334
12.5.3	Sustainability aspects	336
12.5.4	Plant design	337
12.6	Conclusions	338
	References	339
<b>13</b>	<b>Value-added Seafood</b>	<b>343</b>
	<i>Michael Morrissey and Christina DeWitt</i>	
13.1	Introduction	343
13.2	Value-added product development	344
13.3	Market-driven	345
13.4	Values-driven	347
13.5	Health-driven	348
13.6	Resource-driven	350
13.7	Technology-driven	350
13.8	Conclusions	354
	References	354
<b>Part II</b>	<b>Quality and Safety Issues</b>	<b>359</b>
<b>14</b>	<b>Seafood Quality Assessment</b>	<b>361</b>
	<i>Jörg Oehlenschläger</i>	
14.1	Why is quality assessment of aquatic animals multifarious and complex?	361
14.2	Fish composition	362
14.2.1	Introduction	362
14.2.2	Categories of fish species	363
14.2.3	Fish muscle	364
14.2.4	Nutritional composition	364

---

14.3	Fish freshness	365
14.3.1	What is fish freshness and how can it be defined?	365
14.3.2	Freshness and quality relationship	366
14.3.3	Some indicators for the freshness determination of fish	366
14.4	Sensory methods	367
14.4.1	EU quality grading scheme	368
14.4.2	The Torry scheme for cooked fillets	368
14.4.3	Quality Index Method	368
14.5	Chemical methods	370
14.5.1	Traditional methods as TVB-N, TMAO, TMA, DMA	370
14.5.2	Biogenic amines	372
14.5.3	K-value	373
14.6	Physical methods	374
14.6.1	pH	374
14.6.2	Eye fluid refractive index	374
14.7	Instrumental methods and automation	374
14.7.1	Fischtester and Torrymeter	375
14.7.2	VIS/NIR spectroscopy	375
14.7.3	Electronic nose	376
14.7.4	Colour measurement	377
14.7.5	Texture measurement	378
14.7.6	NMR (Nuclear Magnetic Resonance)	378
14.8	Imaging technologies and machine vision	380
14.9	Conclusion	380
	References	381

## **15 Microbiological Examination of Seafood** **387**

*Ioannis S. Bozaris and Foteini F. Parlapani*

15.1	Introduction	387
15.2	Seafood microbiology	388
15.2.1	Indigenous microbiota	388
15.2.2	Contamination (exogenous) microbiota	388
15.2.3	Spoilage microbiota	388
15.2.4	Pathogenic microorganisms	389
15.3	Microbiological parameters of seafood analysis	389
15.4	Microbiological analysis using conventional culture techniques	392
15.4.1	Enumeration of total viable counts	392
15.4.2	Determination of spoilage microorganisms	395
15.4.3	Hygienic indicators	396
15.4.4	Pathogen detection	397
15.5	Microbiological examination using indirect rapid methods	399
15.5.1	Determination of bacterial ATP	399
15.5.2	Electrical methods	400
15.5.3	Other indirect methods	400
15.6	Microscopy based rapid methods	401
15.6.1	Direct Epifluorescence Filter Technique (DEFT)	401
15.6.2	Fluorescent <i>In Situ</i> Hybridization (FISH)	401
15.6.3	Flow cytometry	401
15.7	Immuno-based techniques	402
15.8	Molecular methods for microbial determination	402
15.8.1	Exploration of fish and seafood microbiota	402



15.8.2	Detection and quantification of microorganisms	407
15.9	Conclusions	408
	References	408
<b>16</b>	<b>Fish and Seafood Authenticity – Species Identification</b>	<b>419</b>
	<i>Fátima C. Lago, Mercedes Alonso, Juan M. Vieites and Montserrat Espiñeira</i>	
16.1	Molecular techniques applied to seafood authentication	419
16.1.1	Molecular markers	420
16.1.2	Reference Material (RM) and Tissue Banks (TBs)	421
16.1.3	Databases (DBs)	421
16.2	Molecular techniques based on protein analysis	423
16.2.1	Electrophoretic techniques	423
16.2.2	High-Performance Liquid Chromatography (HPLC)	428
16.2.3	Immunological techniques	429
16.2.4	Limitations of fish species identification techniques based on analysis of proteins	430
16.3	Molecular techniques based on DNA analysis	430
16.3.1	PCR (Polymerase Chain Reaction)	431
16.3.2	Polymerase Chain Reaction–Restriction Fragment Length Polymorphism (PCR–RFLP)	431
16.3.3	Real-Time PCR (RT-PCR)	432
16.3.4	Forensically Informative Nucleotide Sequencing (FINS)	435
16.3.5	Other methodologies for fish species identification	437
16.3.6	Accredited assays as a quality seal	439
	References	440
<b>17</b>	<b>Assuring Safety of Seafood – Risk Assessment</b>	<b>453</b>
	<i>John Sumner, Catherine McLeod and Tom Ross</i>	
17.1	Introduction	453
17.2	Differentiating risk from hazard	454
17.3	Hazards, risks and food safety risk assessment	456
17.4	Hazard Identification/Risk Profile	458
17.5	Exposure assessment	459
17.6	Hazard Characterization	462
17.7	Risk Characterization	465
17.7.1	Methods for risk characterization	465
17.8	Qualitative Risk Assessment	466
17.9	Semi-quantitative Risk Assessment	466
17.10	Quantitative Risk Assessment	468
17.11	Reality check	468
17.12	Uncertainty and variability	469
17.13	Data gaps	470
17.14	Risk management approaches	470
17.14.1	Case study 1: <i>Vibrio parahaemolyticus</i> in oysters consumed raw	471
17.14.2	Case study 2: <i>L. monocytogenes</i> in cooked crustaceans	472
17.14.3	Case study 3: Zero tolerance and the precautionary principle	472
17.15	Final thoughts	473
	References	474
	<b>Index</b>	<b>479</b>