## Contents

*Preface*  
*Contributors*

1 **Introduction: Challenges to the Fish-Processing Industry in a Resource-Starved World**  
George M. Hall  
1.1 Introduction  
1.1.1 Defining sustainability  
1.1.2 Sustainable development concepts for FPI  
1.2 Sustainability tools  
1.2.1 Carbon footprinting  
1.2.2 Carbon labelling  
1.2.3 Life cycle assessment  
1.2.4 The supply chain  
1.3 Climate change  
1.4 The capture fishery  
1.4.1 Current production levels  
1.4.2 Future trends and fisheries management  
1.5 Contribution of aquaculture  
1.5.1 Current production levels  
1.5.2 Future trends  
1.5.3 Barriers to increased production  
1.6 Industrial fish production  
1.6.1 Current levels  
1.6.2 Future trends  
1.6.3 Redefining ‘industrial species’  
1.7 Implications for the processing industry  
1.7.1 Efficiency in processing  
1.7.2 Food security and trade  
1.7.3 Introducing new food species  
1.7.4 Post-harvest losses  
1.7.5 Environmental impact of fish processing  
1.8 Conclusion: sustainability in the fish-processing industry  
References

---

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>xi</td>
</tr>
<tr>
<td>xii</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>19</td>
</tr>
<tr>
<td>19</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td>23</td>
</tr>
<tr>
<td>24</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>26</td>
</tr>
<tr>
<td>27</td>
</tr>
<tr>
<td>28</td>
</tr>
</tbody>
</table>
## Contents

### 2 Canning Fish and Fish Products

George M. Hall

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Principles of canning</td>
<td>30</td>
</tr>
<tr>
<td>2.1.1 Thermal destruction of fish-borne bacteria</td>
<td>30</td>
</tr>
<tr>
<td>2.1.2 Quality criteria for thermally processed fish</td>
<td>34</td>
</tr>
<tr>
<td>2.2 Packaging materials</td>
<td>34</td>
</tr>
<tr>
<td>2.2.1 Glass jars</td>
<td>35</td>
</tr>
<tr>
<td>2.2.2 Rigid metal containers</td>
<td>35</td>
</tr>
<tr>
<td>2.2.3 Rigid plastic containers</td>
<td>37</td>
</tr>
<tr>
<td>2.2.4 Flexible containers (pouches)</td>
<td>37</td>
</tr>
<tr>
<td>2.2.5 Environmental issues related to packaging materials</td>
<td>37</td>
</tr>
<tr>
<td>2.3 Processing operations</td>
<td>39</td>
</tr>
<tr>
<td>2.3.1 Pre-processing operations</td>
<td>40</td>
</tr>
<tr>
<td>2.3.2 Heat-processing operations</td>
<td>44</td>
</tr>
<tr>
<td>2.3.3 Post-processing operations</td>
<td>46</td>
</tr>
<tr>
<td>2.3.4 Environmental issues and process optimization</td>
<td>46</td>
</tr>
<tr>
<td>2.4 Canning of specific species</td>
<td>47</td>
</tr>
<tr>
<td>2.4.1 Small pelagics</td>
<td>48</td>
</tr>
<tr>
<td>2.4.2 Tuna and mackerel</td>
<td>48</td>
</tr>
<tr>
<td>2.4.3 Crustacea</td>
<td>48</td>
</tr>
<tr>
<td>2.5 Conclusions</td>
<td>48</td>
</tr>
<tr>
<td>References</td>
<td>49</td>
</tr>
</tbody>
</table>

### 3 Preservation by Curing (Drying, Salting and Smoking)

George M. Hall

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Basic relationships</td>
<td>51</td>
</tr>
<tr>
<td>3.1.1 Water activity and spoilage</td>
<td>51</td>
</tr>
<tr>
<td>3.1.2 Product quality</td>
<td>53</td>
</tr>
<tr>
<td>3.2 Drying</td>
<td>53</td>
</tr>
<tr>
<td>3.2.1 Air- or contact drying</td>
<td>53</td>
</tr>
<tr>
<td>3.2.2 Improving the efficiency of drying</td>
<td>55</td>
</tr>
<tr>
<td>3.3 Salting</td>
<td>55</td>
</tr>
<tr>
<td>3.3.1 Wet and dry salting</td>
<td>55</td>
</tr>
<tr>
<td>3.3.2 Quality aspects</td>
<td>56</td>
</tr>
<tr>
<td>3.4 Smoking</td>
<td>57</td>
</tr>
<tr>
<td>3.4.1 The preservative effect</td>
<td>57</td>
</tr>
<tr>
<td>3.4.2 Quality aspects</td>
<td>57</td>
</tr>
<tr>
<td>3.4.3 Smoking systems and equipment</td>
<td>58</td>
</tr>
<tr>
<td>3.4.4 Traditional systems</td>
<td>59</td>
</tr>
<tr>
<td>3.4.5 Fuel wood for traditional fish smoking</td>
<td>62</td>
</tr>
<tr>
<td>3.5 Post-harvest losses in fish smoking</td>
<td>65</td>
</tr>
<tr>
<td>3.5.1 Sustainable livelihoods approach</td>
<td>67</td>
</tr>
<tr>
<td>3.5.2 Assessing post-harvest fisheries losses</td>
<td>70</td>
</tr>
<tr>
<td>3.6 Sustainability issues</td>
<td>74</td>
</tr>
<tr>
<td>References</td>
<td>75</td>
</tr>
</tbody>
</table>
# Freezing and Chilling of Fish and Fish Products

George M. Hall

## 4.1 Introduction

- **4.1.1** Freezing time calculations
- **4.1.2** Effect of freezing on micro-organisms and parasites
- **4.1.3** Physico-chemical effects during freezing
- **4.1.4** Temperature modelling in fish transportation

## 4.2 Freezing systems

- **4.2.1** The refrigeration cycle
- **4.2.2** Classification of freezers
- **4.2.3** Air-blast freezers
- **4.2.4** Immersion freezers
- **4.2.5** Plate freezers
- **4.2.6** Cryogenic freezers

## 4.3 Environmental impact of freezing operations

- **4.3.1** Energy efficiency of freezing systems
- **4.3.2** Cold storage systems
- **4.3.3** Refrigerants and cryogens
- **4.3.4** New refrigeration techniques
- **4.3.5** Environmental impact of freezer/cold storage buildings

## 4.4 Life cycle assessment and the supply chain

## References

## 5 Surimi and Fish Mince Products

George M. Hall

## 5.1 Introduction

- **5.1.1** Fish muscle proteins
- **5.1.2** Important protein properties in surimi processing
- **5.1.3** Appropriate species for surimi production
- **5.1.4** Surimi quality and sustainability

## 5.2 The surimi process

- **5.2.1** Basic process elements
- **5.2.2** Energy consumption
- **5.2.3** Water consumption
- **5.2.4** By-product development

## 5.3 Fish mince processing

## References

## 6 Sustainability Impacts of Fish-Processing Operations

George M. Hall

## 6.1 Introduction

## 6.2 Sustainability issues

- **6.2.1** Sustainability and legislation
- **6.2.2** Energy
- **6.2.3** Water
6.2.4 Effluents 120
6.2.5 By-product development 120
6.3 Individual processes 121
6.4 Life cycle assessment 123
  6.4.1 Background 123
  6.4.2 Application to fish-processing operations 125
  6.4.3 Development of LCA for fishing activity 127
6.5 Supply chain analysis 129
6.6 Cleaner production 131
6.7 Processing in a changing world 134
  References 135

7 Sustainability of Fermented Fish Products 138
S. Kose and George M. Hall
7.1 Introduction 138
7.2 Principles of the fermentation process 139
  7.2.1 Metabolic activity of LAB 139
  7.2.2 The genera of LAB 140
  7.2.3 Other issues relating to fermentation process 140
  7.2.4 Inhibitory effects of LAB 141
7.3 Definition and classification of fermented fish products 142
  7.3.1 Definition 142
  7.3.2 Classification 143
7.4 Types of fermented fish products 146
  7.4.1 European products 146
  7.4.2 South-East Asian products 147
  7.4.3 Fermented fish products of Africa 150
7.5 Quality and standards of fermented fish products 151
  7.5.1 Salting procedures 152
  7.5.2 Micro-organisms 152
  7.5.3 Fish enzymes 153
  7.5.4 Temperature during fermentation 153
  7.5.5 Nutritional issues 153
  7.5.6 Flavour 154
  7.5.7 Presence of lipids 154
  7.5.8 Colour 154
  7.5.9 Other characteristics 155
7.6 Safety issues related to fermented fish products 155
  7.6.1 Pathogenic bacteria 156
  7.6.2 Parasites 158
  7.6.3 Histamine and other biogenic amines 158
7.7 Conclusions 163
  Acknowledgements 163
  References 163

8 On-board Fish Processing 167
S. Kose
8.1 Introduction 167
Contents

8.2 On-board processing
  8.2.1 Types of plants processing at sea 168
  8.2.2 Tenders 171
  8.2.3 History of on-board processing 172
  8.2.4 Species and products processed at sea 173
8.3 Advantages of on-board processing 174
8.4 Quality issues related to on-board processing 175
  8.4.1 Introduction to quality issues for fisheries products 175
  8.4.2 Receiving and handling raw materials 176
  8.4.3 Quality issues during processing 187
  8.4.4 Quality issues during storage and transport 202
8.5 Sustainable issues 203
Acknowledgements 203
References 204

9 Fishmeal Production and Sustainability 207
George M. Hall
9.1 Introduction 207
  9.1.1 Fishmeal production 207
  9.1.2 Conversion efficiency of fishmeal and fish oil 210
  9.1.3 Nutritional value of fishmeal and fish oil 212
9.2 The fishmeal process 215
  9.2.1 Raw material unloading 216
  9.2.2 The cooker 217
  9.2.3 The press 218
  9.2.4 The decanter 218
  9.2.5 Separators and purifiers 219
  9.2.6 Evaporators 219
  9.2.7 The drier 220
  9.2.8 Post-production operations 220
  9.2.9 Conclusions 221
9.3 Sustainability issues 221
  9.3.1 Energy 222
  9.3.2 Water 222
  9.3.3 Effluents 222
  9.3.4 By-products 223
  9.3.5 Cleaner production 223
  9.3.6 Life cycle assessment of the fishmeal and fish oil process 224
9.4 Alternatives to fishmeal 226
  9.4.1 Fish silage 227
  9.4.2 Fish protein hydrolysates 229
  9.4.3 Plant-based alternatives to fishmeal 231
9.5 Conclusions 232
References 233

10 Utilization of Fish Processing By-products for Bioactive Compounds 236
K. Shirai and J. C. Ramirez-Ramirez
10.1 Introduction 236
## Contents

10.2 Raw material chemical composition ................................................................. 236  
10.3 Protein hydrolysates and peptides ................................................................. 237  
  10.3.1 General aspects and production ............................................................... 237  
  10.3.2 FPH composition and use as food ingredient ............................................. 240  
  10.3.3 FPH and peptide applications ................................................................. 240  
  10.3.4 Therapeutic and health-promoting properties .......................................... 243  
10.4 Collagen and gelatin ......................................................................................... 244  
  10.4.1 Extraction conditions of fish collagens and gelatins ................................. 246  
  10.4.2 Functional properties .............................................................................. 248  
  10.4.3 Therapeutic properties ............................................................................ 249  
10.5 Omega-3 polyunsaturated fatty acid in fish ...................................................... 250  
  10.5.1 Composition ............................................................................................ 250  
  10.5.2 Extraction ............................................................................................... 255  
  10.5.3 Therapeutic properties ............................................................................ 256  
10.6 Concluding remarks ....................................................................................... 258  
  Acknowledgements ............................................................................................ 258  
  References ........................................................................................................ 258  

11 Life Cycle Assessment of Bulk Packaging Used to Transport Fresh Fish Products: Case Study 266  
K. S. Williams  
11.1 Introduction .................................................................................................... 266  
  11.1.1 Background to UK waste and sustainability .............................................. 267  
11.2 UK fishing industry ....................................................................................... 268  
  11.2.1 Transportation of fish products ............................................................... 269  
  11.2.2 Packaging of fish .................................................................................... 270  
  11.2.3 Types of packaging ................................................................................. 271  
11.3 Life cycle assessment .................................................................................... 275  
  11.3.1 Methodology .......................................................................................... 275  
11.4 Case study: Rainbow Seafood – EPS and PP fish boxes ................................. 276  
  11.4.1 Company profile ..................................................................................... 276  
  11.4.2 Context of the study ............................................................................... 277  
  11.4.3 Methodology .......................................................................................... 278  
11.5 System design ............................................................................................... 278  
11.6 Data acquisition ............................................................................................ 280  
11.7 Life cycle inventory ....................................................................................... 280  
11.8 Life cycle impact assessment ........................................................................ 281  
11.9 Results and recommendations ...................................................................... 282  
11.10 Conclusions ................................................................................................ 282  
  Acknowledgement ............................................................................................. 285  
  References ........................................................................................................ 285  

Index 289