

Chilled foods

A comprehensive guide

Second edition

Edited by Mike Stringer and Colin Dennis

Chilled foods

A comprehensive guide

Second edition

Edited by
Mike Stringer and Colin Dennis



CRC Press

Boca Raton Boston New York Washington, DC

WOODHEAD PUBLISHING LIMITED

Cambridge England

Published by Woodhead Publishing Limited, Abington Hall, Abington
Cambridge CB1 6AH, England
www.woodhead-publishing.com

Published in North and South America by CRC Press LLC, 2000 Corporate Blvd, NW
Boca Raton FL 33431, USA

First edition 1992, Ellis Horwood Ltd
Second edition 2000, Woodhead Publishing Limited and CRC Press LLC
© 2000, Woodhead Publishing Limited
The authors have asserted their moral rights.

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. Reasonable efforts have been made to publish reliable data and information, but the authors and the publishers cannot assume responsibility for the validity of all materials. Neither the authors nor the publishers, nor anyone else associated with this publication, shall be liable for any loss, damage or liability directly or indirectly caused or alleged to be caused by this book.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming and recording, or by any information storage or retrieval system, without permission in writing from the publishers.

The consent of Woodhead Publishing Limited and CRC Press does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from Woodhead Publishing Limited or CRC Press for such copying.

Trademark notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library.

Library of Congress Cataloging in Publication Data
A catalog record for this book is available from the Library of Congress.

Woodhead Publishing Limited ISBN 1 85573 499 0
CRC Press ISBN 0-8493-0856-9
CRC Press order number: WP0856

Cover design by The ColourStudio
Project managed by Macfarlane Production Services, Markyate, Hertfordshire
Typeset by MHL Typesetting Limited, Coventry, Warwickshire
Printed by TJ International, Padstow, Cornwall, England

Chilled foods

A comprehensive guide

Second edition

Edited by Mike Stringer and Colin Dennis



WOODHEAD PUBLISHING LIMITED

058825

Related titles from the Science, Technology and Nutrition list:

Mastering Food Safety (ISBN: 1 85233 412 3)

Edited by Christopher I. Kennedy

Maintaining quality throughout the food chain is a key issue for the food industry. This book provides a comprehensive overview of the quality factors at each stage of the food chain, from production to consumption. It identifies the key quality parameters of production and distribution as well as describing the technical aspects of food safety and quality control. It is an invaluable resource for food technologists, scientists and retailers.

Chilled foods

Second edition

A Y Tamplin and R E Robinson

In the first edition this book quickly established itself as the standard reference in its field for both industry and academia. The second edition is 40% longer than the first and includes revised and updated sections on 'cold storage', 'cold chain', 'cold distribution' and 'cold retailing'. It also includes new chapters on 'cold storage', 'cold chain', 'cold distribution' and 'cold retailing'. The book covers the latest developments in mechanisation and automation and the implementation of HACCP.

Food processing - Principles and Practice Second Edition (ISBN: 1 85233 522 4)

P J Fellows

The first edition of this book was widely regarded as the standard text for many food science and technology courses. The book has been completely revised and updated to reflect the latest developments in the food industry. It includes new chapters on 'cold storage', 'cold chain', 'cold distribution' and 'cold retailing'. The book covers the latest developments in mechanisation and automation and the implementation of HACCP.

... a well written and authoritative review of food processing technology - the essential reference for food technologists, food scientists and food industry managers. Details of these books and a complete list of food science and technology books and nutrition titles can be obtained by:

- visiting our web site at www.woodhead-publishing.com
- contacting Customer Services (e-mail: custserv@woodhead-publishing.com fax: +44 (0)1223 893300 or by post to Woodhead Publishing Ltd, Abingdon Hall, Abingdon, Cambridge CB1 6AH, England)

If you would like to receive information on forthcoming titles in this area, please send your address details to: Francis Taylor, address tel and fax as above, e-mail: order@woodhead-publishing.com

Cambridge England



Related titles from Woodhead's food science, technology and nutrition list:

Managing frozen foods (ISBN: 1 85573 412 5)

Edited by Christopher J Kennedy

Maintaining quality throughout the food chain is a key issue for the frozen food industry. This book provides a unique overview of the whole supply chain and key quality factors at each stage in the production, distribution and retail of frozen foods. It identifies the key quality parameters in production and distribution as well as describing the technology and working practices necessary to attain these standards. It is an invaluable resource for manufacturers, distributors and retailers.

Yoghurt – Science and technology Second Edition (ISBN: 1 85573 399 4)

A Y Tamime and R K Robinson

In its first edition this book quickly established itself as the standard reference in its field for both industry professionals and those involved in research. This completely revised and updated second edition is 40% longer than the first and includes developments such as the new 'bio-yoghurts' as well as all other recent changes and technological developments in the industry including: the production of strained yoghurt by ultrafiltration, the latest developments in mechanisation and automation and the implementation of HACCP.

Food processing – Principles and practice Second Edition (ISBN: 1 85573 533 4)

P J Fellows

The first edition of *Food processing and technology* was quickly adopted as the standard text by many food science and technology courses. The publication of a completely revised and updated new edition is set to confirm the position of this textbook as the best single-volume introduction to food manufacturing technologies available.

'... a well written and authoritative review of food processing technology – the essential reference for food technologists and students alike.' *Food Trade Review*

Details of these books and a complete list of Woodhead's food science, technology and nutrition titles can be obtained by:

- visiting our web site at www.woodhead-publishing.com
- contacting Customer Services (e-mail: sales@woodhead-publishing.com; fax: +44 (0)1223 893694; tel.: +44 (0)1223 891358 ext. 30; address: Woodhead Publishing Ltd, Abington Hall, Abington, Cambridge CB1 6AH, England)

If you would like to receive information on forthcoming titles in this area, please send your address details to: Francis Dodds (address, tel. and fax as above; e-mail: francisd@woodhead-publishing.com). Please confirm which subject areas you are interested in.

Preface

During the last 40 years, consumer choice has been transformed by developments in the production, distribution and retailing of food, which with improvements in the design and equipment of the domestic kitchen have facilitated a major change in our lifestyle.

Perhaps the most striking development is the marketing of a wide and expanding range of chilled perishable foods. Convenience, easy preparation and the 'fresh' and 'healthy' image and an extensive choice of different culinary tastes are attractive features. Many products are made by industrial processes using technology which has no parallel in the domestic kitchen. Others, notably cooked ready meals of all kinds, require skills, time and patience to prepare. These developments have occurred by the application of technology to the production, packaging, distribution and retailing of food.

The integrity and safety of chilled foods is multifactorial. Care is required at every stage in the food chain, from primary production of raw materials, through manufacture, distribution, retail and consumer use.

This book provides a comprehensive guide to the many important aspects necessary to provide the consumer with safe, high quality products, and includes recent developments in legislation. Since the introduction of the first coordinated chilled distribution chain in the late 1960s, substantial developments have occurred in the refrigeration equipment available and in the temperature monitoring and control systems.

Product, process and packaging developments which have occurred over the last 20 years have resulted in chilled foods representing a larger and increasing proportion of weekly purchases for home consumption as well as in institutional and service catering. Their safety and reliability have resulted from the application of scientific principles of food technology and depend on a series of

safety factors in their preparation, processing, distribution and retail sale. The overriding requirement is for the reliable 'chill chain' to control the temperature at every stage from the final process of production to the moment of purchase and absence of abuse by the consumer. Hygienic preparation and production areas are a further essential requirement for chilled food manufacture. This has resulted from a greater understanding and awareness of hygienic design of equipment and buildings, together with appropriate cleaning and sanitation regimes. Developments in methods of detection of microorganisms have greatly assisted in improving approaches to hygiene practices and monitoring the microbiological status of raw materials and finished products.

The establishment of the shelf-life of chilled foods requires a full appreciation of the microbiological, chemical, physical and biochemical aspects which influence the sensory acceptability of products. These factors are discussed in relation to the safety and quality of products, together with methods of determining shelf life of such products. The importance of the application of HACCP as part of quality management systems in the production and distribution of chilled foods brings together the many aspects of chilled foods which are covered in this book.

Further developments in processing and packaging technology will undoubtedly contribute to the continued development and innovation in the chilled food sector. High pressure processing, electric-field sterilisation and active and intelligent packaging all offer potential in this respect.

As editors, we have between us over 35 years experience in chilled food science and technology. Our contacts with the contributing authors have been built up over these years. They all have wide research and industrial experience and are recognised experts in their fields. We consider ourselves fortunate to have secured their cooperation in providing a major and unique contribution to the scientific and technical understanding of the chilled food market.

We are grateful to all the authors for applying themselves so diligently to give the best of their knowledge and skills.

Mike Stringer
Colin Dennis

Contributors

Introduction

Professor Colin Dennis and Dr Mike Stringer
Campden & Chorleywood Food Research Association
Chipping Campden GL55 6LD
Tel: +44 (0)1386 842001 (CD)
+44 (0)1386 842003 (MS)
Fax: +44 (0)1386 842100
E-mail: c.dennis@campden.co.uk
m.stringer@campden.co.uk

Chapter 1

L. Bedford
Campden & Chorleywood Food Research Association
Chipping Campden GL55 6LD
Tel: +44 (0)1386 842013
Fax: +44 (0)1386 842100
E-mail: l.bedford@campden.co.uk

Chapter 2

Dr Ralph Early
Harper Adams University College
Newport TF10 8NB
Tel: +44 (0)1952 820280
Fax: +44 (0)1952 814783
E-mail: rearly@harper-adams.ac.uk

Chapter 3

Dr Steve James
Food Refrigeration & Process Engineering Research Centre
University of Bristol
Churchill Building
Langford
Bristol BS18 7DY
Tel: +44 (0)117 928 9239
Fax: +44 (0)117 928 9314
E-mail: steve.james@bristol.ac.uk

Chapter 4

Mr Robert D. Heap MBE
Cambridge Refrigeration Technology
140 Newmarket Road
Cambridge CB5 8HE

Tel: +44 (0)1223 365101
Fax: +44 (0)1223 461522
E-mail: crt@crtech.demon.co.uk

Chapter 5

Dr Mark Woolfe
Food Labelling, Standards and Consumer
Protection Division
Food Standards Agency
PO Box 31037
Ergon House
London SW1P 3WG
Tel: +44 (0)20 7238 6168
Fax: +44 (0)20 7238 6763
E-mail:
mark.woolfe@foodstandards.gsi.gov.uk

Chapter 6

Dr Brian P F Day
Campden & Chorleywood Food Research
Association
Chipping Campden GL55 6LD
Tel: +44 (0)1386 842082
Fax: +44 (0)1386 842100
E-mail: b.day@campden.co.uk

Chapter 7

Dr Steven Walker and Dr Gail Betts
Campden & Chorleywood Food Research
Association
Chipping Campden GL55 6LD
Tel: +44 (0)1386 842011 (SW)
+44 (0)1386 842071 (GB)
Fax: +44 (0)1386 842100
E-mail: s.walker@campden.co.uk
g.betts@campden.co.uk

Chapter 8

Dr Roy Betts
Campden & Chorleywood Food Research
Association
Chipping Campden GL55 6LD
Tel: +44 (0)1386 842075
Fax: +44 (0)1386 842100
E-mail: r.betts@campden.co.uk

Chapter 9

Dr Helen Brown and M. N. Hall
Campden & Chorleywood Food Research
Association
Chipping Campden GL55 6LD
Tel: +44 (0)1386 842016 (HB)
+44 (0)1386 842014 (MNH)
Fax: +44 (0)1386 842100
E-mail: h.brown@campden.co.uk
m.hall@campden.co.uk

Chapter 10

Dr Linda Everis and Dr Gail Betts
Campden & Chorleywood Food Research
Association
Chipping Campden GL55 6LD
Tel: +44 (0)1386 842063 (LE)
+44 (0)1386 842071 (GB)
Fax: +44 (0)1386 842100
E-mail: l.everis@campden.co.uk
g.betts@campden.co.uk

Chapter 11

Professor Martyn Brown
Microbiology Department
Unilever Research
Colworth Laboratory
Colworth House
Sharnbrook
Bedford MK44 1LQ
Tel: +44 (0)1234 222351
Fax: +44 (0)1234 222277
E-mail: martyn.brown@unilever.com

Chapter 12

Dr Stephane Durand
HP Foods Ltd

E-mail:
Stephane_DURAND@hpfoods.com

Chapter 13

Dr John Holah and R. H. Thorpe
Campden & Chorleywood Food Research
Association
Chipping Campden GL55 6LD

Tel: +44 (0)1386 842041
Fax: +44 (0)1386 842100
E-mail: j.holah@campden.co.uk

Chapter 14

Dr John Holah
Campden & Chorleywood Food Research
Association
Chipping Campden GL55 6LD

Tel: +44 (0)1386 842041
Fax: +44 (0)1386 842100
E-mail: j.holah@campden.co.uk

Chapter 15

Dr David Rose
Campden & Chorleywood Food Research
Association
Chipping Campden GL55 6LD

Tel: +44 (0)1386 842088
Fax: +44 (0)1386 842100
E-mail: d.rose@campden.co.uk

Chapter 16

Ms Kaarin Goodburn
11 Yewfield Road
London NW10 9TD

Tel: +44 (0) 20 8451 0503
Fax: +44 (0) 20 8459 8061
E-mail: kgoodburn@bigfoot.com

Contents

Preface	xi
List of contributors	xiii

Introduction: the chilled foods market 1

C. Dennis and M. Stringer, Campden and Chorleywood Food Research Association

I.1 Definition	1
I.2 Drivers in the chilled food sector	3
I.3 Overall market size	6
I.4 Individual categories within the chilled food sector	12
I.5 Conclusion	15
I.6 References	16

Part I Raw materials

1 Raw material selection: fruit and vegetables 19

L. Bedford, Campden and Chorleywood Food Research Association

1.1 Introduction	19
1.2 Criteria for selection	20
1.3 Specifications	28
1.4 New trends in raw material production	30
1.5 New trends in plant breeding	31
1.6 Conclusion	32
1.7 Sources of further information and advice	33
1.8 References	33

2 Raw material selection: dairy ingredients	37
<i>L. R. Early, Harper Adams University College</i>	
2.1 Introduction	37
2.2 Milk composition	37
2.3 Functional approach	38
2.4 Sensory properties	39
2.5 Microbiological criteria for milk products	41
2.6 Chilled dairy products and milk-based ingredients used in chilled foods	41
2.7 Chilled desserts	52
2.8 Ready meals	53
2.9 Maximising quality in processing	53
2.10 Food safety issues	55
2.11 Future trends	57
2.12 References	58
3 Raw material selection: meat and poultry	63
<i>S. J. James, Food Refrigeration and Process Engineering Research Centre</i>	
3.1 Introduction	63
3.2 The influence of the live animal	65
3.3 Pre- and post-slaughter handling	69
3.4 Conclusions	72
3.5 References	73
Part II Technologies and processes	
4 The refrigeration of chilled foods	79
<i>R. D. Heap, Cambridge Refrigeration Technology</i>	
4.1 Introduction	79
4.2 Principles of refrigeration	81
4.3 Safety and quality issues	81
4.4 Refrigerant fluids and the environment	82
4.5 Chilled foods and refrigeration	83
4.6 Chilling	84
4.7 Chilling equipment	85
4.8 Chilled storage	87
4.9 Refrigerated transport	90
4.10 Refrigerated display cabinets	94
4.11 Regulations and legislation	96
4.12 Sources of further information	97
4.13 References	97

5 Temperature monitoring and measurement	99
<i>M. Wolfe, Food Standards Agency, London</i>	
5.1 Introduction	99
5.2 Importance of temperature monitoring	101
5.3 Principles of temperature monitoring	102
5.4 Temperature monitoring in practice	105
5.5 Equipment for temperature monitoring	116
5.6 Temperature and time-temperature indicators	126
5.7 Temperature modelling and control	130
5.8 Further reading	131
5.9 References	131
6 Chilled food packaging	135
<i>B. P. F. Day, Campden and Chorleywood Food Research Association</i>	
6.1 Introduction	135
6.2 Requirements of chilled food packaging materials	135
6.3 Chilled food packaging materials	136
6.4 Packaging techniques for chilled food	139
6.5 Future trends	147
6.6 Sources of further information	149
6.7 References	149
Part III Microbiological and non-microbiological hazards	
7 Chilled foods microbiology	153
<i>S. J. Walker and G. Betts, Campden and Chorleywood Food Research Association</i>	
7.1 Introduction	153
7.2 Why chill?	154
7.3 Classification of growth	154
7.4 The impact of microbial growth	156
7.5 Factors affecting the microflora of chilled foods	157
7.6 Spoilage microorganisms	162
7.7 Pathogenic microorganisms	167
7.8 Temperature control	173
7.9 Predictive microbiology	174
7.10 Conclusions	178
7.11 References	179
8 Conventional and rapid analytical microbiology	187
<i>R. P. Betts, Campden and Chorleywood Food Research Association</i>	
8.1 Introduction	187
8.2 Sampling	188
8.3 Conventional microbiological techniques	188
8.4 Rapid and automated methods	191

8.5	Microbiological methods – the future	214
8.6	References and further reading	214
9	Non-microbial factors affecting quality and safety	225
	<i>H. M. Brown and M. H. Hall, Campden and Chorleywood Food Research Association</i>	
9.1	Introduction	225
9.2	Characteristics of chemical reactions	226
9.3	Chemical reactions of significance in chilled foods	226
9.4	Characteristics of biochemical reactions	231
9.5	Biochemical reactions of significance in chilled foods	233
9.6	Characteristics of physico-chemical reactions	238
9.7	Physico-chemical reactions of significance in chilled foods	238
9.8	Non-microbiological safety issues of significance in chilled foods	243
9.9	Conclusions	248
9.10	References	248
Part IV	Safety and quality issues	
10	Shelf-life determination and challenge testing	259
	<i>G. Betts and L. Everis, Campden and Chorleywood Food Research Association</i>	
10.1	Introduction	259
10.2	Factors affecting shelf-life	260
10.3	Modelling shelf-life	268
10.4	Determination of product shelf-life	270
10.5	Maximising shelf-life	278
10.6	Challenge testing	279
10.7	Future trends	283
10.8	References	283
11	Microbiological hazards and safe process design	287
	<i>M. H. Brown, Unilever Research, Sharnbrook</i>	
11.1	Introduction	287
11.2	Definitions	290
11.3	Microbiological hazards	304
11.4	Risk classes	307
11.5	Safe process design 1: equipment and processes	308
11.6	Safe process design 2: manufacturing areas	316
11.7	Safe process design 3: unit operations for decontaminated products	323
11.8	Control systems	328
11.9	Conclusions	332
11.10	References	333

12 Quality and consumer acceptability	341
<i>S. R. P. R. Durand, HP Foods Ltd</i>	
12.1 Introduction	341
12.2 What defines sensory quality?	342
12.3 Sensory evaluation techniques	344
12.4 Determining consumer acceptability	349
12.5 Future trends and conclusion	351
12.6 References	352
13 The hygienic design of chilled foods plant	355
<i>J. Holah and R. H. Thorpe, Campden and Chorleywood Food Research Association</i>	
13.1 Introduction	355
13.2 Segregation of work zones	357
13.3 High-risk barrier technology	363
13.4 Hygienic construction	380
13.5 Equipment	389
13.6 Conclusion	394
13.7 References	394
14 Cleaning and disinfection	397
<i>J. Holah, Campden and Chorleywood Food Research Association</i>	
14.1 Introduction	397
14.2 Sanitation principles	398
14.3 Sanitation chemicals	402
14.4 Sanitation methodology	409
14.5 Sanitation procedures	414
14.6 Evaluation of effectiveness	416
14.7 Management responsibilities	421
14.8 References	423
15 Total quality management	429
<i>D. J. Rose, Campden and Chorleywood Food Research Association</i>	
15.1 Introduction	429
15.2 The scope of a quality system	433
15.3 Developing a quality system	435
15.4 Implementation	442
15.5 Performance measuring and auditing	446
15.6 Benefits	448
15.7 Future trends	449
15.8 References and further reading	450
16 Legislation	451
<i>K. Goodburn, Chilled Food Association</i>	
16.1 Introduction	451

x Contents

16.2	Food law is reactive	451
16.3	Food laws and international trade	452
16.4	Chilled foods are... ..	453
16.5	Approaches to legislation	454
16.6	Codex	455
16.7	ATP	457
16.8	Canada	458
16.9	European Union	458
16.10	Australia/New Zealand	461
16.11	France	462
16.12	The Netherlands	463
16.13	United Kingdom	464
16.14	United States	465
16.15	Summary	468
16.16	References and further reading	468
Index		474