

ELLIS HORWOOD-PUBLISHERS

FUNDAMENTALS OF FOOD CHEMISTRY

W. Heimann



FUNDAMENTALS OF FOOD CHEMISTRY

Dr.-Ing. WERNER HEIMANN
Professor and Director of the
Institute of Food Chemistry
University of Karlsruhe

Translator
CHLOE MORTON, M.A., F.I.L.

Translation Editors
Professor I. MORTON and Dr. R. SCOTT



ELLIS HORWOOD LIMITED
Publishers · Chichester

AVI PUBLISHING COMPANY
West Port, Connecticut, USA

First published in 1980 by

ELLIS HORWOOD LIMITED

Market Cross House, Cooper Street, Chichester, West Sussex, PO19 1EB, England

The publisher's colophon is reproduced from James Gillison's drawing of the ancient Market Cross, Chichester.

Distributors:

Australia, New Zealand, South-east Asia:

Jacaranda-Wiley Ltd., Jacaranda Press,

JOHN WILEY & SONS INC.,

G.P.O. Box 859, Brisbane, Queensland 40001, Australia.

Europe, Africa:

JOHN WILEY & SONS LIMITED

Baffins Lane, Chichester, West Sussex, England.

The Americas, Japan, The Phillipines:

AVI PUBLISHING COMPANY

250 Post Road East, Westport, Connecticut 06880, U.S.A.

British Library Cataloguing in Publication Data

Heimann, Werner

Fundamentals of food chemistry. —

(Ellis Horwood series in food science and technology).

1. Food — Composition

I. Title

641.1 TX531 79-41651

ISBN 0-85312-115-X (Ellis Horwood Ltd., Publishers, Library Edition)

ISBN 0-87055-356-9 (AVI Publishing Company)

Typeset in Press Roman by Ellis Horwood Ltd.

Printed in Great Britain by Fakenham Press Ltd.

COPYRIGHT NOTICE

© Ellis Horwood Limited 1980

All Rights Reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the permission of Ellis Horwood Limited, Market Cross House, Cooper Street, Chichester, West Sussex, England.

Table of Contents

Foreword.....	13
Introduction.....	15
PART 1: NUTRITION	
Chapter 1.....	19
PART 2: THE CHEMISTRY OF FOOD	
Chapter 2 Constituents of food	23
Chapter 3 Protein materials.....	27
3.1 Amino acids.....	28
Reactions of amino acids	31
Reactions of the carboxyl groups	32
Reactions of the amino groups.....	32
Classification of amino acids	33
The most important amino acids	34
Composition of important amino acids	34
Acyclic amino acids.....	34
Monoaminomonocarboxylic acids.....	34
Monoaminodicarboxylic acids	35
Diaminomonocarboxylic acids.....	35
Hydroxyamino acids	42
Amino acids containing sulphur	43
Cyclic amino acids.....	43

Table of Contents

Aromatic series	44
Heterocyclic series	44
Essential amino acids	44
Separation and determination of amino acids	46
Physical and chemical methods	46
Microbiological determination of amino acids	47
3.2 Proteins	47
Constitution of proteins	47
Protein sources and biological value	53
Potential protein sources for the future	54
Physico-chemical properties of proteins	55
Classification of proteins	57
Simple proteins	58
Globulins	58
Albumins	58
Protamines	58
Histones	58
Gliadins	59
Glutelins	59
Skeletal proteins	59
Compound proteins	60
Phosphoproteins	61
Nucleoproteins	61
Glycoproteins	63
Chromoproteins	64
Symplexes	64
Behaviour of proteins during food processing	66
Reactions for the presence and determination of proteins	67
Precipitation reactions	67
Precipitation reactions accompanied by denaturation	67
Precipitation reactions not involving denaturation	68
Colour reactions	68
Serological distinction of proteins	70
Quantitative determination of proteins	70
Chapter 4 Fats and associated substances (lipids)	73
4.1 Classification of fats	75
4.2 Building blocks of fats (natural fatty acids)	76
Saturated fatty acids	76
Unsaturated fatty acids	78
Fatty acids with one double bond: monoenoic acids	79
Fatty acids with two or more double bonds: dienoic, trienoic and polyenoic acids	81

Table of Contents

7

Dienoic acids	81
Trienoic acids	82
Polyenoic acids	83
Branched chain fatty acids	83
Hydroxy- and keto- fatty acids	84
Polymerised fatty acids and epoxy fatty acids	84
Commercial production of fatty acids	85
4.3 Chemical composition of fats.	86
Triglycerides.	86
Nomenclature of the glycerides	87
Mono- and diglycerides.	88
4.4 Properties of fats.	89
4.5 Production of fats	93
Technical processing of vegetable fats	93
Pressing procedure.	94
Extraction process.	95
Processing of animal fats.	97
Fat production by microbiological synthesis.	98
4.6 Refining of edible fats	98
4.7 Hardening of fats.	104
Hardening of fats by hydrogenation	104
Interesterification	105
Fractionation processes	109
4.8 Deterioration of fats	109
Chemical changes in fats	109
Hydrolytic reactions	110
Oxidative (desmolytic) reactions	110
Biochemical and microbiological changes in fats	113
Biochemical and microbial fat hydrolysis	113
Biochemical and microbiological-oxidative (desmolytic) breakdown.	114
4.9 Precautions in the storage of fats	115
Natural antioxidants	116
Synthetic antioxidants	117
4.10 Accompanying materials of fats (lipids)	118
Phosphatides (glycero-phosphatides)	118
Lipochromes and lipovitamins	122
Carotenoids	123
Chlorophyll	124
Lipovitamins	125
Sterols.	125
Hydrocarbons.	127

Chapter 5 Carbohydrates	129
5.1 Monosaccharides	130
Configuration and classification of sugars	130
Optical activity of sugars	131
General properties and reactions of sugars	135
Reactions of the reducing group	135
Action of alkalies	137
Action of acids	139
Oxidation of monosaccharides	140
Reduction of monosaccharides	142
Reactions of the hydroxyl group	142
Mutarotation and conformation	143
Individual monosaccharides	147
Pentoses	147
Hexoses	148
D-Glucose	149
D-galactose	150
D-mannose	150
D-fructose	151
L-sorbose	152
Derivatives of the monosaccharides	152
Desoxysugars	152
Sugars with branched chains	153
Aminosugars	153
Sugar alcohols	154
Uronic acids	156
Glycosides	157
5.2 Oligosaccharides	160
Disaccharides	160
Non-reducing disaccharides	162
Sucrose or saccharose	162
Trehalose (mycose)	164
Reducing disaccharides	165
Maltose or malt sugar	165
Isomaltose, cellobiose and gentiobiose	166
Lactose (milk sugar, sand sugar)	167
Meliobiose	168
Trisaccharides	168
Raffinose	168
Melezitose	169
Gentianose	170
Higher oligosaccharides	170
Non-reducing oligosaccharides	170

Table of Contents

9

Oligosaccharides of milk	170
Chemical methods of separation	172
5.3 Polymeric saccharides or polysaccharides	172
Classification of polysaccharides	174
Homoglycans from sugars (group a)	174
Glucans	174
Starch	174
Glycogen	179
Cellulose	180
Other glucans	182
Fructans (fructosans)	183
Inulin group	183
Cereal fructans	183
Laevans	183
Other homoglycans	183
Chitin	184
Mannans	184
Galactans	184
Heteroglycans from sugars (group b)	185
Glucomannoglycan	185
Galactomannoglycan	185
Hemicelluloses	185
Homo- and heteroglycans which contain uronic acid (groups c, d and e)	185
Plant gums and plant mucilages	186
Pectins	186
Gelling	189
Alginates	192
Mucopolysaccharides	193
Hyaluronic acid	193
Chondroitin sulphuric acids	194
Dermatan sulphate	194
Heparin	194
Chapter 6 Minerals and trace elements	195
Chapter 7 Vitamins	197
7.1 Classification and nomenclature of vitamins	199
7.2 Analysis of vitamins	200
7.3 Fat-soluble vitamins	201
Vitamin A	201
D-vitamins	203
E vitamins (tocopherols)	205

K vitamins	208
'Vitamin F'	209
7.4 Water-soluble vitamins	209
The B vitamin group	209
Vitamin B ₁ (thiamin, aneurin)	209
Vitamin B ₂ (riboflavin, lactoflavin)	212
Niacin (nicotinic acid, nicotinic acid amide, vitamin PP)	214
Vitamin B ₆ group (pyridoxin)	217
Pantothenic acid	219
Folic acid group	220
Biotin	221
The vitamin B ₁₂ group (cobalamin)	222
Vitamin C (L(+)) ascorbic acid)	223
7.5 Other active dietary compounds	229
Myo-inositol	230
'Vitamin P'	230
Choline	232
7.6 Vitamin content of some foods	232
7.7 Vitamin requirements	233
7.8 Influence of storage and preparation on the vitamin content of food	233
Chapter 8 Enzymes	237
8.1 Chemical and catalytic nature of enzymes	238
8.2 Enzymes as catalysts	240
8.3 Enzyme specificity	244
8.4 Enzyme kinetics	245
Factors which influence reaction rate	245
Effect of substrate concentration	245
Effect of enzyme concentration	246
Effect of temperature	248
Effect of pH	249
Specific enzyme activators	250
Enzyme inhibitors	250
8.5 Classification and nomenclature of enzymes	251
8.6 Individual enzymes	252
Oxidoreductases	252
Phenoloxidases	253
Ascorbic acid oxidases	254
Aldehydodehydrase	255
Glucose oxidases	255
Peroxidase	255
Catalase	256

Table of Contents

11

Dehydrogenases	256
Transferases	257
Hydrolases	259
Ester hydrolases	259
Lipases	259
Pectin esterases (pectases)	259
Phosphoric acid ester hydrolases (phosphatases)	259
Phospholipases	260
Glycosidohydrolases	260
Amylases	261
Cellulases	261
Pectinases	261
Oligo- and simple saccharides	262
Peptide hydrolases	262
Lyases	264
Isomerasers	264
Ligases	265
8.7 Enzymes in food technology	265
Enzyme preparations from plants	266
Enzyme preparations from animal tissues	267
Enzyme preparations from microorganisms	268
8.8 Enzymes in food analysis	269
Determination of enzyme activity	269
Enzymatic determination of individual compounds	270
 PART 3: FOOD AND MAN	
Chapter 9 Nutrient requirements	273
9.1 Energy requirement of man and energy value of food	273
9.2 Protein requirement	275
9.3 Importance of fats	276
9.4 Importance of carbohydrates	277
Chapter 10 Nutrient content of foods	279
Chapter 11 Food digestion	283
Chapter 12 Behaviour of foods during preparation and cooking	287
cooking processes	288
Chapter 13 Preservation of food	291
13.1 Physical processes	292
Cooling and freezing processes	292
Sterilisation and pasteurisation (heat preservation)	297

Table of Contents

Drying of foods.	298
Drying processes	303
Sterility by filtration	306
Irradiation procedures	307
Energy rich rays	307
UV irradiation	308
Infrared irradiation	308
High frequency heating.	309
Storage under gas pressure.	310
13.2 Preservation by processing.	310
Salting and pickling	310
Smoking	311
Acidification	312
Alcoholic preservation	312
Sugar preservation	312
13.3 Chemical additives in food preservation.	313
Additives and foreign materials	313
Classification	315
Chemical preservatives	317
Preservative action	318
Important preservatives	321
Literature for further study.	327
Index	335

FUNDAMENTALS OF FOOD CHEMISTRY



ELLIS HORWOOD SERIES IN FOOD SCIENCE AND TECHNOLOGY

This publishing programme provides an organised coverage on food science for professional technologists, research workers, and students in universities and polytechnics.

Series Editors:

Professor I. D. Morton, Head of Food Science, Queen Elizabeth College,
University of London;

Dr R. Scott, formerly Reading University

Dr R. Osner, Sheffield City Polytechnic

FUNDAMENTALS OF FOOD CHEMISTRY

W. Heimann, Director, Institute for Food Chemistry, University
of Karlsruhe, Germany

HYGIENIC DESIGN AND OPERATION OF FOOD PLANT

Edited by R. Jowitt, National College of Food Technology,
University of Reading

HANDBOOK OF DOMESTIC ENGINEERING

D. Kirk and A. Milson, Sheffield City Polytechnic

PRINCIPLES OF DESIGN AND OPERATION OF CATERING EQUIPMENT

A. Milson and D. Kirk, Sheffield City Polytechnic

FUNDAMENTALS OF FOOD CHEMISTRY

Dr.-Ing. WERNER HEIMANN
Professor and Director of the
Institute of Food Chemistry
University of Karlsruhe

Translator
CHLOE MORTON, M.A., F.I.L.

Translation Editors
Professor I. MORTON and Dr. R. SCOTT



ELLIS HORWOOD LIMITED
Publishers · Chichester

AVI PUBLISHING COMPANY
West Port, Connecticut, USA

First published in 1980 by

ELLIS HORWOOD LIMITED

Market Cross House, Cooper Street, Chichester, West Sussex, PO19 1EB, England

The publisher's colophon is reproduced from James Gillison's drawing of the ancient Market Cross, Chichester.

Distributors:

Australia, New Zealand, South-east Asia:

Jacaranda-Wiley Ltd., Jacaranda Press,

JOHN WILEY & SONS INC.,

G.P.O. Box 859, Brisbane, Queensland 40001, Australia.

Europe, Africa:

JOHN WILEY & SONS LIMITED

Baffins Lane, Chichester, West Sussex, England.

The Americas, Japan, The Phillipines:

AVI PUBLISHING COMPANY

250 Post Road East, Westport, Connecticut 06880, U.S.A.

British Library Cataloguing in Publication Data

Heimann, Werner

Fundamentals of food chemistry. —

(Ellis Horwood series in food science and technology).

1. Food — Composition

I. Title

641.1 TX531 79-41651

ISBN 0-85312-115-X (Ellis Horwood Ltd., Publishers, Library Edition)

ISBN 0-87055-356-9 (AVI Publishing Company)

Typeset in Press Roman by Ellis Horwood Ltd.

Printed in Great Britain by Fakenham Press Ltd.

COPYRIGHT NOTICE

© Ellis Horwood Limited 1980

All Rights Reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the permission of Ellis Horwood Limited, Market Cross House, Cooper Street, Chichester, West Sussex, England.

Table of Contents

Foreword.....	13
Introduction.....	15
PART 1: NUTRITION	
Chapter 1.....	19
PART 2: THE CHEMISTRY OF FOOD	
Chapter 2 Constituents of food	23
 Chapter 3 Protein materials.....	27
3.1 Amino acids.....	28
Reactions of amino acids	31
Reactions of the carboxyl groups	32
Reactions of the amino groups.....	32
Classification of amino acids	33
The most important amino acids	34
Composition of important amino acids	
Acyclic amino acids.....	34
Monoaminomonocarboxylic acids.....	34
Monoaminodicarboxylic acids	35
Diaminomonocarboxylic acids.....	35
Hydroxyamino acids	42
Amino acids containing sulphur	43
Cyclic amino acids.....	43

Table of Contents

Aromatic series	44
Heterocyclic series	44
Essential amino acids	44
Separation and determination of amino acids	46
Physical and chemical methods	46
Microbiological determination of amino acids	47
3.2 Proteins	47
Constitution of proteins	47
Protein sources and biological value	53
Potential protein sources for the future	54
Physico-chemical properties of proteins	55
Classification of proteins	57
Simple proteins	58
Globulins	58
Albumins	58
Protamines	58
Histones	58
Gliadins	59
Glutelins	59
Skeletal proteins	59
Compound proteins	60
Phosphoproteins	61
Nucleoproteins	61
Glycoproteins	63
Chromoproteins	64
Symplexes	64
Behaviour of proteins during food processing	66
Reactions for the presence and determination of proteins	67
Precipitation reactions	67
Precipitation reactions accompanied by denaturation	67
Precipitation reactions not involving denaturation	68
Colour reactions	68
Serological distinction of proteins	70
Quantitative determination of proteins	70
Chapter 4 Fats and associated substances (lipids)	73
4.1 Classification of fats	75
4.2 Building blocks of fats (natural fatty acids)	76
Saturated fatty acids	76
Unsaturated fatty acids	78
Fatty acids with one double bond: monoenoic acids	79
Fatty acids with two or more double bonds: dienoic, trienoic and polyenoic acids	81