Dietary Sugars
Chemistry, Analysis, Function and Effects

Edited by

Victor R Preedy
School of Medicine, King's College London, UK

RSC Publishing
## Contents

**Dietary Sugars in Context**

**Chapter 1  Sugars in Honey**  
*Sevgi Kolaylı, Laïd Boukraa, Hüseyin Şahin and Fatiha Abdellah*

1.1 Introduction 3
1.2 Main Sugars 4
  - 1.2.1 Monosaccharides 4
  - 1.2.2 Disaccharides 5
  - 1.2.3 Oligosaccharides 6
1.3 Adulteration of Honey 8
1.4 Crystallization of Honey 8
1.5 Is Honey Sweeter than Sugar? 9
1.6 Honey Sugars and Health 9
  - 1.6.1 Honey and Blood Glucose Level 9
  - 1.6.2 Honey as an Anti-infective Agent 10
  - 1.6.3 Honey as a Prebiotic 10
Summary Points 11
Key Facts 12
Definition of Words and Terms 12
List of Abbreviations 13
References 13

**Chapter 2  Sugars and Dental Caries**  
*Anna Haukioja and Merja Laine*

2.1 Dental Caries 16
  - 2.1.1 Dental Caries and Erosion 16
  - 2.1.2 Dental Plaque in Caries 17
  - 2.1.3 Saliva Protects Oral Tissues 18

Food and Nutritional Components in Focus No. 3  
Dietary Sugars: Chemistry, Analysis, Function and Effects  
Edited by Victor R Preedy  
© The Royal Society of Chemistry 2012  
Published by the Royal Society of Chemistry, www.rsc.org  
vii
2.2 The Influence of Sugars in Diet on Caries Risk
2.3 The Relation between Different Sugars and Dental Health
  2.3.1 Sugar Polymers
  2.3.2 Disaccharides
  2.3.3 Monosaccharides
  2.3.4 Sugar Alcohols
Summary Points
Key Facts
Definitions of Words and Terms
References

Chapter 3 Whole Body Glucose Metabolism
Jørgen Jensen and Jesper Franch
3.1 Introduction
3.2 Glucose Transport
  3.2.1 Glucose Transporters
3.3 Metabolism of Glucose
  3.3.1 Glycogen Synthesis
  3.3.2 Glycolysis
  3.3.3 Alternative Routes of Glucose Metabolism
3.4 Glucose and the Mitochondria
  3.4.1 The Krebs Cycle
  3.4.2 De Novo Lipid Synthesis
3.5 Regulation of Whole Body Glucose Metabolism
  3.5.1 Glucose Metabolism after Meals
  3.5.2 Glucose Metabolism in the Post-absorptive Phase
  3.5.3 Glucose Metabolism During Exercise
  3.5.4 Type 2 Diabetes
Summary Points
Key Facts
Definitions of Words and Terms
Acknowledgements
References

Chapter 4 Medical Implications of Dietary Simple Sugars and Complex Carbohydrates, Glycemic Index and Glycemic Load
Mary Downes Gastrich and Michelle Wien
4.1 Introduction
4.2 Purpose of this Review
4.3 Results
4.4 The Relationship Between the Quality and Quantity of Dietary CHO and Differing Medical Implications 50

4.4.1 Dietary CHO and Metabolic Syndrome/CVD Risk Factors 50

4.4.2 Dietary CHO and T2DM/Insulin Resistance 65

4.4.3 Dietary CHO and Cancer Risks 65

4.4.4 Dietary CHOs and Other Medical Conditions 66

4.5 Gender Differences in Trials of the Effects of Dietary CHO and Various Medical Implications 66

4.5.1 Trends in Gender Differences in Dietary CHO and Metabolic Syndrome and CVD 66

4.5.2 Trends in Gender Differences in Dietary CHO and Insulin Resistance/T2DM 66

4.5.3 Trends in Gender Differences in Dietary CHO and Cancers 67

4.5.4 Trends in Gender Differences in Dietary CHO and Other Medical Conditions 67

4.6 Conclusions 68

4.7 Discussion 68

Summary Points 69

Key Facts 70

Definitions 70

List of Abbreviations 71

References 71

Chemistry and Biochemistry

Chapter 5 Glucose Chemistry 77

Bilal Ahmad Malik and Mohammed Benaissa

5.1 Introduction 77

5.2 Structure 79

5.3 Chemical Reactions with Glucose 80

5.4 The Configuration of Glucose 82

5.5 Mutarotation of Glucose 83

Summary Points 83

Definitions of Words and Terms 84

List of Abbreviations 84

References 85

Chapter 6 Galactose Chemistry 86

Fabio Vieira dos Santos, Vanessa Jaqueline da Silva Vieira dos Santos, Juliana Pereira Lyon and Leonardo Marmo Moreira

6.1 Introduction 86

6.2 Chemical Classification of D-Galactose 88
Chapter 7  Maltose Chemistry and Biochemistry  
Robert R. Crow, Sanath Kumar and Manuel F. Varela

7.1 Introduction 101 
7.2 The Metabolism of Maltose 101 
7.2.1 Maltose and Glycolysis 103 
7.2.2 Enzymes Involved in Maltose Metabolism 103 
7.3 Maltose Transport Systems 105 
7.3.1 Passive Transport and Channels for Maltose 105 
7.3.2 Primary Active Transporters for Maltose 105 
7.3.3 Secondary Active Transporters for Maltose 106 
7.3.4 Group Translocation Transport Systems for Maltose 107 
7.4 Mutations that Confer Maltose Transport in other Sugar Transporters 107 
7.4.1 The Lactose Permease of E. coli and Maltose 108 
7.4.2 The Melibiose Permease of Enterobacter cloacae and Maltose 109 
7.4.3 The Raffinose Permease of E. coli and Maltose 109 
Summary Points 110 
Key Facts of Maltose Chemistry and Biochemistry 110 
Definition of Words and Terms 111 
List of Abbreviations 111 
References 112 

Chapter 8  Fructose Chemistry  
David J Timson

8.1 Introduction: Structure and Stereochemistry 115 
8.2 Chemical Reactions of Fructose 117 
8.2.1 Oxidation and Reduction 118 
8.2.2 Modifications of the Hydroxyl Groups: Acetylation and Methylation 118
### Chapter 10 Lactose Chemistry

*Lee D. Hansen and Jennifer B. Nielsen*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1 Introduction</td>
<td>150</td>
</tr>
<tr>
<td>10.2 Crystal Structures and Properties</td>
<td>151</td>
</tr>
<tr>
<td>10.3 Reactions of Lactose</td>
<td>153</td>
</tr>
<tr>
<td>10.3.1 Hydrolysis and Transglycosylation</td>
<td>153</td>
</tr>
<tr>
<td>10.3.2 Isomerization</td>
<td>155</td>
</tr>
<tr>
<td>10.3.3 Maillard Reaction</td>
<td>156</td>
</tr>
<tr>
<td>10.3.4 Fermentation</td>
<td>159</td>
</tr>
<tr>
<td>10.4 Disposal</td>
<td>159</td>
</tr>
<tr>
<td>Summary Points</td>
<td>160</td>
</tr>
<tr>
<td>Key Facts</td>
<td>160</td>
</tr>
<tr>
<td>Definition of Words and Terms</td>
<td>161</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>161</td>
</tr>
<tr>
<td>References</td>
<td>162</td>
</tr>
</tbody>
</table>

### Chapter 11 Characterization of Sugars, Cyclitols and Galactosyl Cyclitols in Seeds by GC

*Ralph L. Obendorf, Marcin Horbowicz and Leslaw Bernard Lahuta*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.1 Introduction</td>
<td>167</td>
</tr>
<tr>
<td>11.2 Water-soluble Carbohydrates in Seeds</td>
<td>168</td>
</tr>
<tr>
<td>11.2.1 Extraction of Water-soluble Carbohydrates from Seeds</td>
<td>173</td>
</tr>
<tr>
<td>11.2.2 Natural Sources of Standards not Commercially Available</td>
<td>176</td>
</tr>
<tr>
<td>11.2.3 Identification of Compounds Forming Unknown Peaks</td>
<td>177</td>
</tr>
<tr>
<td>11.3 GC Analysis of Water-soluble Carbohydrates</td>
<td>177</td>
</tr>
<tr>
<td>11.4 Species Differences in Water-soluble Carbohydrates</td>
<td>178</td>
</tr>
<tr>
<td>11.5 Conclusions</td>
<td>180</td>
</tr>
<tr>
<td>Summary Points</td>
<td>181</td>
</tr>
<tr>
<td>Key Facts</td>
<td>181</td>
</tr>
<tr>
<td>Definitions of Words and Terms</td>
<td>182</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>183</td>
</tr>
<tr>
<td>References</td>
<td>183</td>
</tr>
</tbody>
</table>
Chapter 12 Dietary Sugars: TLC Screening of Sugars in Urine and Blood Samples

Jose Ramón Alonso-Fernández and Vinood B. Patel

12.1 Introduction 186
12.2 Forerunners of TLC Methods 187
12.3 Early TLC Methods 189
12.4 Galactosaemia Studies 190
12.5 Oligosaccharides 191
12.6 A TLC Procedure for Screening for Sugars in Blood and Urine 193
   12.6.1 Sample Collection 193
   12.6.2 Concentration of Samples 194
   12.6.3 Loading Samples onto the TLC Plate 195
   12.6.4 The TLC Cell 196
   12.6.5 Procedure 196
   12.6.6 Differential Diagnosis of Galactosaemias 198

Summary Points 203
Key Facts 203
Definitions of Words and Terms 204
List of Abbreviations 204
Acknowledgements 205
References 205

Chapter 13 Analysis of Dietary Sugars in Beverages by Gas Chromatography

O. Hernández-Hernández, F.J. Moreno and M.L. Sanz

13.1 Introduction 208
13.2 Beer 210
   13.2.1 Determination of Monomeric Composition 211
   13.2.2 Determination of Glycosidic-Linkages of Arabinoxylans 211
13.3 Wines 214
   13.3.1 Low Molecular Weight Carbohydrates (LMWC) 214
   13.3.2 Polysaccharides 216
13.4 Spirit Drinks 218
13.5 Juices 219
13.6 Soft Drinks 220
13.7 Hot Drinks 222
13.8 Conclusions 222
Summary Points 223
Key Facts 223
Definitions of Words and Terms 224
Abbreviations 226
References 226
Chapter 14 UV Spectrophotometry Method for Dietary Sugars
Ana C. A. Veloso, Ligia R. Rodrigues, Luis G. Dias and António M. Peres

14.1 Introduction 229
14.2 Dietary Sugars 230
  14.2.1 Physicochemical Properties 231
  14.2.2 Physiological Effects 232
  14.2.3 Methodology for Dietary Carbohydrates Analysis 232
14.3 UV-Vis Spectrophotometric Methods for Dietary Sugars 234
  14.3.1 Derivative Spectroscopy and Chemometric Analysis 234
  14.3.2 UV-Vis Spectrophotometry for Indirect Sugar Analysis 238
  14.3.3 UV Spectrophotometry for Direct Sugar Analysis in Controlled Multicomponent Samples 239
14.4 Conclusions and Future Prospects 245
Summary Points 245
Key Facts 245
Definitions of Key Terms 246
List of Abbreviations 246
References 246

Chapter 15 Extraction and Quantification of Sugars and Fructans from Vegetable Matter
Katherine Cools and Leon A. Terry

15.1 Introduction 249
  15.1.1 Structure of Sugars and Fructans 249
  15.1.2 Biosynthesis 250
  15.1.3 Distribution of Sugars and Fructans 252
  15.1.4 Sugar and Fructan Measurement 253
15.2 Sugar and Fructan Extraction 253
15.3 Quantification 259
  15.3.1 Quantification of Total Sugars and Fructans 259
  15.3.2 Quantification using High Pressure Liquid Chromatography 260
  15.3.3 Quantification using Anion Exchange Chromatography 260
  15.3.4 Gas Chromatography 261
  15.3.5 Detectors 261
15.4 Conclusions 262
Chapter 16 Determination of Dietary Sugars by Ion Chromatography and Electrochemical Detection: a Focus on Galactose, Glucose, Fructose and Sucrose

Donatella Nardiello, Carmen Palermo, Maurizio Quinto and Diego Centonze

16.1 Analysis of Carbohydrates: Historical Background 269
16.2 Analysis of Carbohydrates by Ion Chromatography and Electrochemical Detection 270
16.2.1 Chromatographic Separation of Galactose, Glucose, Fructose and Sucrose by HPAEC 270
16.2.2 Pulsed Amperometric Detection: Triple Step PAD Waveform for Galactose, Glucose, Fructose and Sucrose 272
16.2.3 Constant Potential Amperometric Detection of Carbohydrates at Modified Electrodes 275

Summary Points 280
Key Facts of the Analytical Methods for the Determination of Carbohydrates 281
Key Facts of Anion Exchange Chromatography Separations of Carbohydrates 281
Key Facts of the Electrochemical Detection of Carbohydrates 281
Definitions of Words and Terms 282
List of Abbreviations 283

Chapter 17 Assay of Glucose Using Near Infrared (NIR) Spectroscopy

Mohammed Benaissa, Amneh Mbaideen and Bilal Ahmad Malik

17.1 Introduction 286
17.2 Beer Lambert’s Law 288
17.3 Multivariate Calibration Methods 288
17.3.1 Multiple Linear Regression (MLR) 289
17.3.2 Principle Component Analysis (PCA) 290
17.3.3 Principal Component Regression (PCR) 291
17.3.4 Partial Least Square Regression (PLS) 292
17.3.5 Performance Comparison 294
17.4 Pre-processing Techniques 294
  17.4.1 Mean Centering of a Data Matrix 295
  17.4.2 Smoothing 296
  17.4.3 Derivative 298
  17.4.4 Digital Bandpass Filtering (DBPF) 300
17.5 The Potential of Advanced Digital Signal Processing Techniques 301
17.6 Examples of Application of NIR Spectroscopy in the Analysis of Glucose in Food Items 301
17.7 Conclusion 302
Summary Points 302
Key Facts about NIR Spectroscopy 303
Definitions 303
List of Abbreviations 304
References 304

Chapter 18 A New Liquid Chromatographic-Mass Spectrometric Method to Assess Glucose Kinetics In Vivo Using $^{13}$C$_6$ D-glucose as a Tracer 307

_David S. Millington, Haoyue Zhang, Cris A. Slentz and William E. Kraus_

18.1 Background 307
18.2 Summary of Procedures and Methods 309
  18.2.1 The Labeled IVGTT Protocol 309
  18.2.2 The HGO Infusion Protocol 309
  18.2.3 Sample Preparation and Analysis by Mass Spectrometry 309
  18.2.4 IVGTT: Estimation of $^{13}$C$_6$ Glucose Concentration 310
  18.2.5 HGO: Estimation of Fasting HGO 311
18.3 Results 311
  18.3.1 IVGTT Results 311
  18.3.2 HGO Results 314
18.4 Discussion and Future Direction 315
Summary Points 317
Key Facts of Glucose Metabolism 317
Key Facts of Liquid Chromatography and Mass Spectrometry 318
Definitions and Explanations of Key Terms 318
List of Abbreviations 320
Acknowledgements 320
References 320
Chapter 19 Self Monitoring of Blood Glucose (SMBG)

Tomomi Fujisawa

19.1 Background 323
19.2 Blood Samples/Skin Puncture Site 324
19.3 Monitoring Device and Strips 324
    19.3.1 Glucose Readings Monitored by SMBG 325
    19.3.2 Accuracy of SMBG Results 325
    19.3.3 Enzyme/co-enzyme and Clinical Attention to SMBG 326
19.4 Puncture Device and Lancets/Needles for SMBG 327
19.5 Choice of SMBG Systems 327
19.6 Procedures for SMBG 328
19.7 Clinical Significance of SMBG 329
    19.7.1 Clinical Benefit of SMBG in Glycemic Control in Insulin-treated Subjects 329
    19.7.2 Clinical Benefit of SMBG on Glycemic Control in Non-insulin-treated Subjects 330
    19.7.3 Cost-effectiveness of SMBG 334
    19.7.4 Effects of SMBG on Psychological Distress 335
19.8 Future Perspectives of SMBG 335
Summary Points 336
Key Facts of Self Monitoring of Blood Glucose (SMBG) 337
Definitions of Words and Terms 337
List of Abbreviations 338
References 338

Chapter 20 The Glucose Oxidase-Peroxidase Assay for Glucose

Mary Beth Hall

20.1 Introduction 340
20.2 Chemistry 341
20.3 Factors Affecting Method Performance 341
    20.3.1 Volumetric Additions and Precision 342
    20.3.2 Adherence to Protocol 342
    20.3.3 Enzyme Activity and Purity 342
    20.3.4 Stability of Absorbance 343
    20.3.5 Nonlinear Equation Describes Standard Curve 343
    20.3.6 Interference 348
20.4 A Glucose Oxidase-Peroxidase Method for Glucose Determination 350
    20.4.1 Preparation of and Considerations on Use of Glucose Standard Solutions 350
Chapter 21 Glucose Biosensors
Azila Abdul-Aziz

21.1 Introduction 358
21.2 Requirements for Glucose Analysis in Food 359
21.3 Glucose Transduction Technologies 361
   21.3.1 Electrochemical Glucose Biosensors 361
   21.3.2 Optical Glucose Biosensors 365
   21.3.3 Instrumentation 367
21.4 Commercialization Activities 369
21.5 Concluding Remarks 370
Summary Points 371
Key Facts 371
Definitions of Words and Terms 372
List of Abbreviations 373
References 373

Chapter 22 Assay Galactose by Biosensors
Martin Ming-fat Choi and Han-chih Hencher Lee

22.1 General Review of Biosensors 376
22.2 Types of Biosensors 377
   22.2.1 Transducers: Electrochemical and Optical 377
   22.2.2 Enzyme Immobilization Techniques 378
22.3 Development of Galactose Biosensors 380
   22.3.1 Principles 381
   22.3.2 Methodology 382
   22.3.3 Advantages and Disadvantages 386
22.4 Applications of Biosensors in Galactose Assay 387
22.5 Conclusion 388
22.6 Future Trends 388
Chapter 23 Combined Assays for Lactose and Galactose by Enzymatic Reactions

Nissim Silanikove and Fira Shapiro

23.1 Introduction 395
23.2 Methodology for the Determination of Lactose and Galactose 396
23.3 Principles of the Simultaneous Determination of Lactose and Galactose in Dairy Products by Enzymatic Reactions 396
23.4 Simplification of the Colorimetric Assay by Replacing NAD with Thio-NAD 398
23.5 The Challenge of Quantifying Metabolites in Milk and Dairy Products 398
23.6 Fluorometry Coupling to Formation of Chromophore and Enzymatic Cycling as a Solution for the Determination of Lactose and Galactose in Milk and Dairy Products 399
23.7 Conclusions 401
Summary Points 402
Key Facts 402
References 403

Chapter 24 Food Sources and Analytical Approaches for Maltose Determination

Elvira M. S. M. Gaspar, João F. Lopes, Daniel Gyamfi and Inês S. Nunes

24.1 Introduction 405
24.2 Food Carbohydrates 406
24.2.1 Relevance of Dietary Carbohydrates and Food Sugars 408
24.2.2 Maltose 410
24.2.3 Food Sources 410
24.2.4 Metabolism and Effects 411
24.3 Analytical Approaches 413
24.3.1 Non-chromatographic Methodologies 413
24.3.2 Chromatographic Methodologies 415
24.4 Conclusions 419
Summary Points 420
Chapter 25 Determination of Maltose in Food Samples by High-temperature Liquid Chromatography Coupled to ICP-AES
Amanda Terol, Soledad Prats, Salvador Maestre and José Luis Todoli

25.1 Maltose Chemical Properties and their Importance in the Food Industry
25.2 Analytical Methods for the Determination of Maltose in Food Samples
   25.2.1 Sample Preparation
   25.2.2 Determination of Maltose in Food Samples
25.3 What is High-temperature Liquid Chromatography?
   25.3.1 General Advantages and Characteristics of HTLC
   25.3.2 Special Instrumentation
25.4 Inductively Coupled Plasma Atomic Emission Spectrometry for the Determination of Sugars in Food
25.5 HTLC-ICP Hyphenation
25.6 Comparison of HTLC-ICP-AES Hyphenation with the Techniques Commonly used for the Determination of Maltose
25.7 Conclusion

Chapter 26 Analysis of Maltose and Lactose by U-HPLC-ESI-MS/MS
Luca Valgimigli, Simone Gabbanini and Riccardo Matera

26.1 Introduction
26.2 Method Description and Discussion
   26.2.1 Chromatography
   26.2.2 Mass Spectrometry
   26.2.3 Method Validation
Chapter 27 Assays of Fructose in Experimental Nutrition

Keiichiro Sugimoto, Hiroshi Inui and Toshikazu Yamanouchi

27.1 Introduction 464
27.2 Physiological Significance 465
27.3 Sample Treatment 466
27.4 Determination of Fructose Concentration 467
  27.4.1 Chemical Method 467
  27.4.2 Enzymatic Method 467
  27.4.3 HPLC Methods 469
  27.4.4 GC/MS Methods 473
27.5 Applications 475
  27.5.1 Sucrose Tolerance Test in Rats 475
  27.5.2 Fructose Tolerance Test in Mice 476
  27.5.3 Sucrose Tolerance Test in Humans 476
  27.5.4 Evaluation of Inhibitive Activity on Fructose Absorption in the Caco-2 Cell Line 477
Summary Points 478
Key Facts of Diabetes and Blood Fructose Levels 479
Definitions of Words and Terms 479
List of Abbreviations 480
References 481

Chapter 28 Amperometric Detection for Simultaneous Assays of Glucose and Fructose

Mithran Somasundrum and Werasak Surareungchai

28.1 Introduction 484
28.2 Principles of Voltammetry 485
28.3 Experimental Details 486
  28.3.1 Electrochemical Cells 486
  28.3.2 Electrodes 487
  28.3.3 Electrolyte 488
Chapter 28 Types of Voltammetry

28.4 Types of Voltammetry
28.4.1 Fixed Potential – Potential Step
28.4.2 Fixed Potential – Amperometry
28.4.3 Potential Ramp
28.5 Passivation in Voltammetry
28.6 Electrochemistry of Glucose and Fructose
28.7 Pulsed Amperometric Detection (PAD)
28.8 Simultaneous Detection of Glucose and Fructose

Summary Points
Key Facts of Voltammetry
Definitions of Words and Terms
List of Abbreviations
Acknowledgements
References

Chapter 29 Sucrose Determination by Raman Spectroscopy

29.1 Introduction
29.2 Vibrational Spectroscopy
29.2.1 Raman Spectroscopy
29.2.2 Raman Spectroscopy Applied to the Characterisation of Foods and Drugs in Biological Systems
29.2.3 Raman Spectroscopy Applied to the Characterisation of Saccharides
29.2.4 Raman Spectroscopy Applied to the Characterisation of Sucrose
29.2.5 Quantitative Analysis of Sucrose by Raman Spectroscopy
29.2.6 Physico-Chemical Analysis of Sucrose by Raman Spectroscopy
29.3 Conclusions
Summary Points
Key Facts of Raman Spectroscopy
Definitions of Words and Terms
List of Abbreviations
References

Chapter 30 Analysis of Sucrose from Sugar Beet
J. Mitchell McGrath and Karen K. Fugate

30.1 Introduction
| Contents |
|-------------------|------------------|
| 30.2 Extraction for Measurement | 529 |
| 30.3 Analytical Methods |
| 30.3.1 Historical Perspective | 529 |
| 30.3.2 Refractometry | 530 |
| 30.3.3 Polarimetry | 531 |
| 30.3.4 Enzyme-based Spectroscopic Assays | 532 |
| 30.3.5 Gas Chromatography (GC) | 534 |
| 30.3.6 High-performance Liquid Chromatography (HPLC) | 534 |
| 30.3.7 Near-infrared Spectroscopy (NIR) | 535 |
| 30.3.8 Other Methods | 537 |
| 30.4 Future Trends | 539 |
| Summary Points | 539 |
| Key Facts | 540 |
| Definitions of Words and Terms | 541 |
| List of Abbreviations | 542 |
| Acknowledgements | 542 |
| References | 543 |

**Function and Effects**

**Chapter 31 Lactose in Milk and Dairy Products: A Focus on Biosensors**

*Felipe Conzuelo, A. Julio Reviejo and José M. Pingarrón*

| 31.1 Introduction | 549 |
| 31.2 Lactose Analysis |
| 31.2.1 Enzyme Reactions Involved in Lactose Determination | 550 |
| 31.2.2 Biosensors for Lactose Determination | 552 |
| 31.3 Concluding Remarks | 564 |
| Summary Points | 564 |
| Key Facts | 565 |
| Definitions of Words and Terms | 565 |
| List of Abbreviations | 566 |
| References | 567 |

**Chapter 32 Analysis of Human Milk Lactose**

*David S Newburg, Ceng Chen and Gherman Wiederschain*

| 32.1 Introduction | 570 |
| 32.1.1 Biological Importance of Lactose Analysis in Human Milk | 570 |
| 32.1.2 Techniques for Lactose Analysis in Human Milk | 572 |
| 32.2 Methods of Analysis |
| 32.2.1 Gravimetric and Chemical | 573 |
Chapter 33 Sweetened Beverages and Added Sugars in Obesity

Odilia I. Bermudez

33.1 Introduction
33.2 Simple Sugars as Dietary Components
33.3 Sugar-sweetened Beverages
   33.3.1 Sugar-sweetened Beverages
33.4 Trends in the Intake of Sweetened Beverages
33.5 Obesity as a World Epidemic
   33.5.1 Concepts and Definitions of Obesity
   33.5.2 The Worldwide Epidemic of Obesity
33.6 Sweetened Beverages and Added Sugars and Obesity
33.7 Final Remarks and Future Perspectives
Summary Points
Key Facts of Obesity and Intake of Sugar Sweetened Beverages
Key Facts of the US National Health and Nutrition Examination Survey (NHANES)
Definitions of Words and Terms
List of Abbreviations
References

Chapter 34 Maternal Glucose and Offspring Child BMI

Andrea Deierlein

34.1 Introduction
34.2 Anthropometric Outcomes in Early Infancy
34.3 Anthropometric Outcomes in Early Childhood
   34.3.1 Anthropometric Outcomes at 1–2 Years
   34.3.2 Anthropometric Outcomes in Early Childhood
   34.3.3 Other Outcomes in Childhood
34.4 Limitations of Studies and Gaps in our Understanding
   34.4.1 Role of Maternal Prepregnancy Obesity
Chapter 35 Dextrose in Total Parenteral Nutrition
Karen C. McCowen

35.1 Introduction
35.2 Metabolic Response to Injury
35.3 Route of Feeding in ICU Patients - TPN
   Versus Enteral
35.4 Hyperglycemia
   35.4.1 Dextrose Infusion Rates
   35.4.2 Effects of Hyperglycemia Induced by TPN on Clinical Outcome
   35.4.3 Effect of Hyperglycemia to Promote Infections
35.5 Hyperglycemia-induced Muscle Catabolism
   35.5.1 Intensive Insulin Therapy in Patients Receiving Nutrition Support in the ICU
   35.5.2 Glycemic Lability
   35.5.3 Hypocaloric TPN
   35.5.4 Insulin in TPN
35.6 Complications Associated with Dextrose Infusions in Parenteral Nutrition
   35.6.1 Liver Dysfunction
   35.6.2 Respiratory Insufficiency
   35.6.3 Essential Fatty Acid Deficiency (EFAD)
   35.6.4 Refeeding Syndrome
35.7 Conclusions and Recommendations
Summary Points
Key Facts
Definitions of Words and Terms
List of Abbreviations
References

Chapter 36 The Intestinal Transport of Galactose
Maria Jesús Rodriguez Yoldi

36.1 Galactose
36.2 SGLT1 and GLUT2, D-Galactose Intestinal Transporters
  36.2.1 Functional Disorders of SGLT1
36.3 Factors Involved in Galactose Intestinal Transport
  36.3.1 Proteins
  36.3.2 Hormones
  36.3.3 Stress and Glucocorticoids
  36.3.4 Diet
  36.3.5 Heavy Metals
  36.3.6 Infection
Summary Points
Key Facts
Definitions of Words and Terms
List of Abbreviations
Acknowledgements
References

Chapter 37 Galactose and Galactose Tracers in Metabolic Studies
Ana Francisca Soares and John Griffith Jones

37.1 Overview of Galactose in Nutrition and Health
  37.1.1 Principal Metabolic Fate of Galactose
  37.1.2 Minor Metabolic Fates of Galactose: Galactitol and Galactonate
  37.1.3 Endogenous Galactose Production
37.2 Galactose Tracers as Probes of Hepatic Metabolic Fluxes
  37.2.1 Oxidative and Non-oxidative Disposal of Galactose
  37.2.2 Galactose Flux into UDPG
  37.2.3 Measuring UDPG Flux with Galactose Tracers
  37.2.4 Measuring Transaldolase Exchange Activity with Galactose Tracers
37.3 Integration of Galactose and Glucose Metabolic Flux Measurements
  37.3.1 $^{13}$C-isotopomer Analysis of Galactose and Glucose Metabolism
  37.3.2 Galactose and Glucose Metabolism by $^2$H$_2$O
Summary Points
Key Facts of Hepatic Galactose Metabolism
Definitions of Words and Terms
List of Abbreviations
References
Chapter 38 D-Galactose, Dietary Sugars and Modeling Neurological Aging
Kodeeswaran Parameshwaran, Michael H. Irwin, Kosta Steliou and Carl A. Pinkert

38.1 Introduction
38.1.1 Human Intake of Dietary Sugars
38.1.2 Brain Energy Metabolism: Energy Requirements and Glucose Metabolism in Health, Disease, and Aging
38.1.3 Mouse Models of Glucose Metabolism and Neurological Aging

38.2 D-Galactose
38.2.1 D-Galactose as Dietary Sugar and Modifications in Metabolism
38.2.2 Chronic D-galactose Administration of Oxidative Stress in Rodents
38.2.3 D-Galactose and Neurological Aging

38.3 Fructose Metabolism and Brain Aging
Summary Points
Key Facts
Definitions of Words and Terms
List of Abbreviations
References

Chapter 39 Maltose Preference: Studies in Outbreed Weanling Rats
Yoko Horikawa and Nanaya Tamaki

39.1 Introduction
39.2 Maltose Preference with a Single Diet Method
39.3 Maltose Preference by Selection from Suc, Glc and Fru with a Two-choice Method
39.4 Maltose Preference by Selection from Dex, Mal and Glc with a Three-choice Method
39.5 Increased Maltose Preference in Rats Fed a Low-protein Diet
39.6 Maltose Preference in Zn-deficient Rats
Summary Points
Key Facts
Definitions of Words and Terms
List of Abbreviations
References
## Chapter 40 Maltose and Other Sugars in Beer

*Ginés Navarro, Nuria Vela and Simón Navarro*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.1 Introduction</td>
<td>700</td>
</tr>
<tr>
<td>40.2 Barley: Taxonomy, Cultivation and Uses</td>
<td>701</td>
</tr>
<tr>
<td>40.2.1 Structure of the Barley Grain and Composition</td>
<td>701</td>
</tr>
<tr>
<td>40.3 Malting Process and Enzyme Development</td>
<td>705</td>
</tr>
<tr>
<td>40.4 Effect of Mashing and Boiling on the Sugar Content</td>
<td>707</td>
</tr>
<tr>
<td>40.5 Consumption of Sugars During Primary Fermentation</td>
<td>708</td>
</tr>
<tr>
<td>40.6 Factors Affecting Stuck and Sluggish Fermentation</td>
<td>713</td>
</tr>
<tr>
<td>40.7 Sugar Content in Finished Beer</td>
<td>715</td>
</tr>
<tr>
<td>Summary Points</td>
<td>716</td>
</tr>
<tr>
<td>Key Facts</td>
<td>717</td>
</tr>
<tr>
<td>Definitions of Words and Terms</td>
<td>718</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>718</td>
</tr>
<tr>
<td>References</td>
<td>719</td>
</tr>
</tbody>
</table>

## Chapter 41 Fructose Absorption and Enteric Metabolism

*Kate Witkowska and Chris Cheeseman*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>41.1 Sources of Fructose in the Human Diet</td>
<td>722</td>
</tr>
<tr>
<td>41.2 Intestinal Absorption Mechanisms</td>
<td>722</td>
</tr>
<tr>
<td>41.2.1 Site of Fructose Absorption</td>
<td>722</td>
</tr>
<tr>
<td>41.2.2 Absorption of Free Fructose</td>
<td>723</td>
</tr>
<tr>
<td>41.2.3 GLUT5 (SLC2A5)</td>
<td>724</td>
</tr>
<tr>
<td>41.2.4 GLUT2</td>
<td>724</td>
</tr>
<tr>
<td>41.2.5 Putative Fructose Transporters</td>
<td>724</td>
</tr>
<tr>
<td>41.2.6 Intestinal Metabolism of Fructose</td>
<td>725</td>
</tr>
<tr>
<td>41.2.7 Release of Fructose and Metabolites into the Circulation</td>
<td>725</td>
</tr>
<tr>
<td>41.2.8 Regulation of Fructose Uptake During a Meal</td>
<td>725</td>
</tr>
<tr>
<td>41.2.9 Adaptation to Altered Dietary Intake of Hexoses</td>
<td>726</td>
</tr>
<tr>
<td>41.2.10 Fructose Malabsorption and Development</td>
<td>727</td>
</tr>
<tr>
<td>Summary Points</td>
<td>729</td>
</tr>
<tr>
<td>Key Facts of Fructose Absorption and Enteric Metabolism</td>
<td>729</td>
</tr>
<tr>
<td>Definition of Words and Terms</td>
<td>729</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>731</td>
</tr>
<tr>
<td>References</td>
<td>731</td>
</tr>
</tbody>
</table>
Chapter 44 High Sucrose Diet and Antioxidant Defense
Kamal A. Amin, G. M. Safwat and Rajaventhan Srirajaskanthan

44.1 Introduction
44.1.1 Overview of Sucrose
44.1.2 Sucrose Function, Oxidant/Antioxidant Qualities and its Body Health Effects
44.1.3 High Sucrose Diet, Antioxidant and Oxidative Stress Marker

44.2 Conclusion
Summary Points
Key Facts
Definitions of Words and Terms
List of Abbreviations
References

Chapter 45 Sugars in the Diet of Young Children
Erkkola Maijaliisa, Ruottinen Soile and Virtanen Suvi M

45.1 Introduction
45.2 Dietary Guidelines and Assessment of Intake
45.2.1 Dietary Guidelines for Sugar Intake
45.2.2 Dietary Assessment of Sugar Intake in Children
45.3 Sugar Sources and Intake in Children
45.3.1 Dietary Sources of Sugars
45.3.2 Sugar Intake in Children
45.3.3 Socioeconomic Determinants of Sugar Intake in Children
45.4 Sugar Intake and Quality of Diet
45.5 Associations Between Sugar Intake and Health in Children

Summary Points
Key Facts of Sugars in the Diet of Young Children
Definitions of Words and Terms
List of Abbreviations
References

Chapter 46 Lactose: Uses in Industry and Biomedical Importance
Lactose a Functional Disaccharide
Byong Lee and Andrew Szilagyi

46.1 Introduction
46.2 Industrial Uses of Lactose
Contents

46.2.1 Biochemical Description of Lactose 807
46.2.2 Analysis of Lactose 808
46.2.3 Food Uses of Lactose 808
46.2.4 Bioactive Lactose Derived Products 809
46.2.5 Pharmaceutical Uses of Lactose 812
46.3 Biomedical Significance of Lactose 812
46.3.1 Digestion of Lactose 812
46.3.2 Lactose Intolerance 813
46.3.3 Impact of Lactose and Digestion Status on Different Diseases 813
46.3.4 Gene Food Interaction 814
46.3.5 Prediction of Disease Risk by Population Proportion of LP/LNP Status 815
Summary Points 816
Key Facts: Lactose a Functional Disaccharide: Uses in Industry and Biomedical Importance 816
Key Facts: Biomedical Importance of Lactose 816
Definitions of Words and Terms 817
List of Abbreviations 817
References 818

Chapter 47 Technology and Biotechnology of Lactose Contained in Raw Food Materials 821
Magdalini Soupioni, Maria Kanellaki and Loulouda A. Bosnea

41.1 Introduction 821
47.2 Chemical Properties of Lactose 822
47.2.1 Biosynthesis of Lactose 824
47.3 Recovery of Lactose - Lactose Products and Derivatives 824
47.4 Fermentation of Lactose 825
47.4.1 Lactic Acid Fermentation 827
47.4.2 Alcoholic Fermentation 828
47.4.3 Propionic Acid Fermentation 829
47.4.4 Butyric Acid Fermentation 830
47.4.5 Production of Aroma Substances 830
47.5 Products from Fermentation-based Modifications of Lactose 830
47.5.1 Fermentation of Lactose to Ethanol 832
47.6 Fermentation of Lactose by Kefir 833
47.7 Bio-surfactants 834
47.8 Biogas 835
Summary Points 835
Chapter 48  Lactose Intolerance and the Consumption of Dairy Foods  842

Jeanette N. Keith and Ravi Chhatrala

48.1 Introduction  842
48.2 Clinical Significance of Lactase Non-persistence  843
  48.2.1 Lactose Digestion  843
  48.2.2 Lactase Deficiency  843
  48.2.3 Lactose Maldigestion  845
48.3 Lactose Intolerance  846
  48.3.1 Clinical Definition of LI  846
  48.3.2 Prevalence of LI  846
  48.3.3 Clinical Assessment  847
48.4 Clinical Implications of LI  848
  48.4.1 Health Consequences of Dairy Avoidance  848
  48.4.2 Impact on Public Health  850
48.5 Clinical Management of LI  851
  48.5.1 From Bench to Bedside  851
  48.5.2 Specific Dietary Strategies  851
Summary Points  853
Key Facts  854
Definitions of Words and Terms  854
List of Abbreviations  854
References  855

Subject Index  858