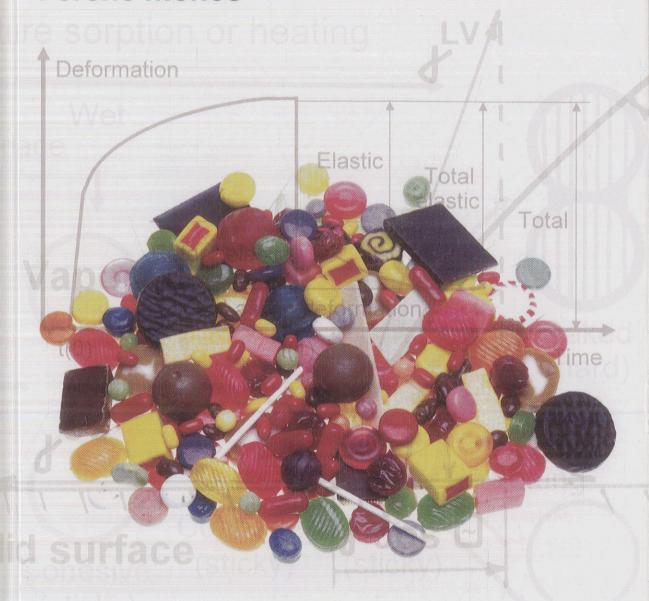
Confectionery and Chocolate Engineering

Principles and Applications

Ferenc Mohos



Contents

| Acknow | Acknowledgements | | |
|--------|------------------|--|----|
| Part I | Theo | retical introduction | 1 |
| Chapte | r 1 Pı | rinciples of food engineering | 3 |
| 1.1 | Introdu | ction | 3 |
| | 1.1.1 | The peculiarities of food engineering | 3 |
| | 1.1.2 | The hierarchical and semi-hierarchical structure of materials | 5 |
| | 1.1.3 | Application of the Damköhler equations in food engineering | 6 |
| 1.2 | The Da | mköhler equations | 6 |
| 1.3 | Investig | ation of the Damköhler equations by means of | |
| | similari | ty theory | 8 |
| | 1.3.1 | Dimensionless numbers | 8 |
| | 1.3.2 | Degrees of freedom of an operational unit | 11 |
| | 1.3.3 | Polynomials as solutions of the Damköhler equations | 12 |
| 1.4 | Analogi | ies | 13 |
| | 1.4.1 | The Reynolds analogy | 13 |
| | 1.4.2 | <i></i> | 15 |
| | 1.4.3 | Similarity and analogy | 16 |
| 1.5 | | ional analysis | 16 |
| 1.6 | The Bu | ckingham Π theorem | 17 |
| Furthe | r reading | | 18 |
| Chapte | er 2 C | haracterization of substances used in the confectionery industry | 19 |
| 2.1 | Qualita | tive characterization of substances | 19 |
| | 2.1.1 | Principle of characterization | 19 |
| | 2.1.2 | v 1 | 20 |
| | 2.1.3 | Classification of confectionery products according to their | |
| | | characteristic phase conditions | 27 |
| | 2.1.4 | Phase transitions – a bridge between sugar sweets and chocolate | 28 |
| 2.2 | | tative characterization of confectionery products | 29 |
| | 2.2.1 | Composition of chocolates and compounds | 29 |
| | 2.2.2 | Composition of sugar confectionery | 35 |
| | 2.2.3 | Composition of biscuits, crackers and wafers | 43 |
| 2.3 | | ation of recipes | 45 |
| | 2.3.1 | Recipes and net/gross material consumption | 45 |
| | 2.3.2 | Planning of material consumption | 48 |

| Chapte | r 3 Eng | gineering properties of foods | 52 |
|--------|----------------|--|------------------|
| 3.1 | Introduc | tion | 53 |
| 3.2 | Density | | 53 |
| | 3.2.1 | Solids and powdered solids | 54 |
| | 3.2.2 | Particle density | 54 |
| | 3.2.3 | Bulk density and porosity | 55 |
| | 3.2.4 | Loose bulk density | 55 |
| | 3.2.5 | Dispersions of various kinds, and solutions | 56 |
| 3.3 | | ental functions of thermodynamics | 56 |
| | 3.3.1 | Internal energy | 56 |
| | 3.3.2 | Enthalpy | 58 |
| | 3.3.3 | Specific heat capacity calculations | 58 |
| 3.4 | | eat and heat of reaction | 62 |
| | 3.4.1 | Latent heat and free enthalpy | 62 |
| | 3.4.2 | Phase transitions | 63 |
| 3.5 | | conductivity | 66 |
| | 3.5.1 | First Fourier equation | 66 |
| | 3.5.2 | Heterogeneous materials | 67 |
| | 3.5.3 | Liquid foods | 67 |
| | 3.5.4 | Liquids containing suspended particles | 68 |
| | 3.5.5 | Gases | 68 |
| 3.6 | | diffusivity and Prandtl number | 69 |
| | 3.6.1 | Second Fourier equation | 69 |
| | 3.6.2 | Liquids and gases | 69 |
| | 3.6.3 | Prandtl number | 70 |
| 3.7 | | fusivity and Schmidt number | 71 |
| | 3.7.1 | Law of mass diffusion (Fick's first law) | 71 |
| | 3.7.2 | Mutual mass diffusion | 72 |
| | 3.7.3 | Mass diffusion in liquids | 72 |
| | 3.7.4 | Temperature dependence of diffusion | 73 |
| | 3.7.5 | Mass diffusion in complex solid foodstuffs | 74 |
| 2.0 | 3.7.6 | Schmidt number | 75 |
| 3.8 | | c properties | 76 |
| | 3.8.1 | Radio frequency and microwave heating | 76 |
| | 3.8.2 | Power absorption – the Lambert–Beer law | 77 7 2 |
| | 3.8.3 | Microwave and radio frequency generators | 78 |
| 2.0 | 3.8.4 | Analytical applications | 81 |
| 3.9 | | l conductivity | 81 |
| | 3.9.1 | Ohm's law | 81 |
| | 3.9.2 | Electrical conductivity of metals and electrolytes; the | 02 |
| | 202 | Wiedemann-Franz law and Faraday's law | 82 |
| | 3.9.3 3.9.4 | Electrical conductivity of materials used in confectionery | 83 |
| 3.10 | | Ohmic heating technology | 83 |
| 3.10 | | absorption properties characteristics of food powders | 85 86 |
| 3.11 | 3.11.1 | Classification of food powders | 86 86 |
| | 3.11.2 | Surface activity | 86 87 |
| | 3.11.3 | Effect of moisture content and anticaking agents | |
| | J.11.3 | Effect of moisture content and anticaking agents | 87 |

| | 3.11.4 | Mechanical strength, dust formation and explosibility index | 88 |
|--------|------------|---|-----|
| | 3.11.5 | Compressibility | 89 |
| | 3.11.6 | Angle of repose | 91 |
| | 3.11.7 | Flowability | 91 |
| | 3.11.8 | Caking | 92 |
| | 3.11.9 | Effect of anticaking agents | 95 |
| D 41 | 3.11.10 | Segregation | 95 |
| Furthe | er reading | | 96 |
| Chapte | er 4 Th | e rheology of foods and sweets | 97 |
| 4.1 | _ | y: its importance in the confectionery industry | 98 |
| 4.2 | Stress ar | nd strain | 98 |
| | 4.2.1 | Stress tensor | 98 |
| | 4.2.2 | | 100 |
| | 4.2.3 | | 103 |
| | 4.2.4 | Constitutive equations | 104 |
| 4.3 | Solid be | | 105 |
| | 4.3.1 | Rigid body | 105 |
| | 4.3.2 | Elastic body (or Hookean body/model) | 105 |
| | 4.3.3 | Linear elastic and nonlinear elastic materials | 107 |
| | 4.3.4 | Texture of chocolate | 108 |
| 4.4 | Fluid be | | 109 |
| | 4.4.1 | Ideal fluids and Pascal bodies | 109 |
| | 4.4.2 | | 109 |
| | 4.4.3 | 2.174123.4764.67 | 126 |
| | | Viscoelastic functions | 132 |
| | | Oscillatory testing | 141 |
| | 4.4.6 | Electrorheology | 144 |
| 4.5 | | y of solutions | 144 |
| 4.6 | , | y of emulsions | 146 |
| | | Viscosity of dilute emulsions | 146 |
| | | Viscosity of concentrated emulsions | 147 |
| 4.5 | 4.6.3 | Rheological properties of flocculated emulsions | 148 |
| 4.7 | | y of suspensions | 149 |
| 4.8 | - | gical properties of gels | 151 |
| | 4.8.1 | * | 151 |
| | 4.8.2 | Scaling behaviour of the elastic properties of colloidal gels | 152 |
| | 4.8.3 | Classification of gels with respect to the nature of the | |
| | 1.0.5 | structural elements | 153 |
| 4.9 | Rheolog | gical properties of sweets | 156 |
| | 4.9.1 | Chocolate mass | 156 |
| | 4.9.2 | Truffle mass | 162 |
| | 4.9.3 | Praline mass | 163 |
| | 4.9.4 | Fondant mass | 163 |
| | 4.9.5 | Dessert masses | 164 |
| | 4.9.6 | Nut brittle (croquante) masses | 165 |
| | 4.9.7 | Whipped masses | 166 |

| 2 | 4.10 | Rheolog | gical properties of wheat flour doughs | 166 |
|---|--------|----------------|---|------------|
| | | 4.10.1 | Complex rheological models for describing food systems | 166 |
| | | 4.10.2 | Special testing methods for the rheological study of doughs | 170 |
| | | 4.10.3 | Studies of the consistency of dough | 172 |
| J | Furthe | er reading | y > | 175 |
| (| Chapte | er 5 In | troduction to food colloids | 176 |
| | 5.1 | | loidal state | 177 |
| | | 5.1.1 | Colloids in the confectionery industry | 177 |
| | | 5.1.2 | The colloidal region | 177 |
| | | 5.1.3 | The various types of colloidal systems | 179 |
| | 5.2 | | ion of colloids | 179 |
| | | 5.2.1 | Microphases | 179 |
| | | 5.2.2 | Macromolecules | 180 |
| | | 5.2.3 | Micelles | 180 |
| | | 5.2.4 | Disperse (or non-cohesive) and cohesive systems | 180 |
| | | 5.2.5 | Energy conditions for colloid formation | 181 |
| | 5.3 | - | ties of macromolecular colloids | 182 |
| | | 5.3.1 | Structural types | 182 |
| | | 5.3.2 | Interactions between dissolved macromolecules | 184 |
| | | 5.3.3 | Structural changes in solid polymers | 184 |
| | 5.4 | - | ties of colloids of association | 188 188 |
| | | 5.4.1 | Types of colloids of association | 100 |
| | | 5.4.2 | Parameters influencing the structure of micelles and the | 190 |
| | c c | D | value of $c_{\rm M}$ | 190 |
| | 5.5 | - | ties of interfaces | 190 |
| | | 5.5.1 | Boundary layer and surface energy Formation of boundary layer: adsorption | 190 |
| | | 5.5.2 | Dependence of interfacial energy on surface morphology | 191 |
| | | 5.5.3 | Phenomena when phases are in contact | 193 |
| | | 5.5.4 5.5.5 | Adsorption on the free surface of a liquid | 196 |
| | 5.6 | | cal properties of interfaces | 198 |
| | 5.0 | 5.6.1 | The electric double layer and electrokinetic phenomena | 198 |
| | | 5.6.2 | Structure of the electric double layer | 199 |
| | 5.7 | | of colloidal stability: the DLVO theory | 200 |
| | 5.8 | | ty and changes of colloids and coarse dispersions | 203 |
| | 5.0 | | Stability of emulsions | 203 |
| | | 5.8.2 | Two-phase emulsions | 205 |
| | | 5.8.3 | Three-phase emulsions | 205 |
| | | 5.8.4 | Two liquid phases plus a solid phase | 205 |
| | | 5.8.5 | Emulsifying properties of food proteins | 207 |
| | | 5.8.6 | Emulsion droplet size data and the kinetics of emulsification | 207 |
| | | 5.8.7 | Bancroft's rule for the type of emulsion | 209 |
| | | 5.8.8 | HLB value and stabilization of emulsions | 210 |
| | | 5.8.9 | Emulsifiers used in the confectionery industry | 211 |
| | 5.9 | | ion instability | 212 |
| | | 5.9.1 | Mechanisms of destabilization | 212 |
| | | 5.9.2 | Flocculation | 213 |
| | | 5.9.3 | Sedimentation (creaming) | 215 |
| | | | | |

| | 5.9.4 | Coalescence | 219 |
|--------|------------|---|-----|
| | 5.9.5 | Ostwald ripening in emulsions | 220 |
| 5.10 | Phase in | nversion | 221 |
| 5.11 | Foams | | 222 |
| | 5.11.1 | Transient and metastable (permanent) foams | 222 |
| | 5.11.2 | Expansion ratio and dispersity | 224 |
| | 5.11.3 | Disproportionation | 225 |
| | 5.11.4 | Foam stability: coefficient of stability and lifetime histogram | 229 |
| | 5.11.5 | Stability of polyhedral foams | 230 |
| | 5.11.6 | Thinning of foam films and foam drainage | 230 |
| | 5.11.7 | Methods of improving foam stability | 231 |
| Furth | er reading | | 233 |
| | u Di | | 225 |
| Part 1 | | ical operations | 235 |
| Chapt | | omminution | 237 |
| 6.1 | _ | s during size reduction | 238 |
| | 6.1.1 | Comminution of non-cellular and cellular substances | 238 |
| | 6.1.2 | Grinding and crushing | 238 |
| | 6.1.3 | Dry and wet grinding | 239 |
| 6.2 | | er's 'surface' theory | 239 |
| 6.3 | | 'volume' theory | 240 |
| 6.4 | | rd, or Bond, theory | 241 |
| 6.5 | | requirement for comminution | 241 |
| | 6.5.1 | Work index | 241 |
| | 6.5.2 | Differential equation for the energy requirement for | |
| | | comminution | 241 |
| 6.6 | | size distribution of ground products | 242 |
| | 6.6.1 | Particle size | 242 |
| | 6.6.2 | Screening | 243 |
| | 6.6.3 | Sedimentation analysis | 245 |
| | 6.6.4 | Electrical-sensing-zone method of particle size distribution | |
| | | determination (Coulter method) | 245 |
| 6.7 | | e size distributions | 245 |
| | 6.7.1 | Rosin-Rammler (RR) distribution | 245 |
| | 6.7.2 | Normal distribution (Gaussian distribution, N distribution) | 246 |
| | 6.7.3 | Log-normal (LN) distribution (Kolmogorov distribution) | 246 |
| | 6.7.4 | Gates-Gaudin-Schumann (GGS) distribution | 247 |
| 6.8 | | s of grinding | 247 |
| 6.9 | | nution by five-roll refiners | 248 |
| | 6.9.1 | Effect of a five-roll refiner on particles | 248 |
| | 6.9.2 | Volume and mass flow in a five-roll refiner | 251 |
| 6.10 | | ng by a melangeur | 253 |
| 6.11 | | inution by a stirred ball mill | 256 |
| | 6.11.1 | Kinetics of comminution in a stirred ball mill | 257 |
| | 6.11.2 | Power requirement of a stirred ball mill | 257 |
| | 6.11.3 | Residence time distribution in a stirred ball mill | 259 |
| Furth | ıer readin | g | 261 |

| Chapt | er 7 M | ixing/kneading | 263 |
|-------|------------|--|-------------|
| 7.1 | | al solutions to the problem of mixing | 263 |
| 7.2 | | haracteristics of a stirrer | 264 |
| 7.3 | • | time characteristics of a stirrer | 266 |
| 7.4 | | ntative shear rate and viscosity for mixing | 266 |
| 7.5 | | tion of the Reynolds number for mixing | 266 |
| 7.6 | | of powders | 267 |
| 7.0 | 7.6.1 | | 267 |
| | 7.6.2 | Scaling up of agitated centrifugal mixers | 271 |
| | 7.6.3 | Mixing time for powders | 272 |
| | 7.6.4 | Power consumption | 273 |
| 7.7 | | of fluids of high viscosity | 274 |
| | | of finds of high viscosity f impeller speed on heat and mass transfer | 275 |
| 7.8 | | Heat transfer | 275 |
| | 7.8.1 | | 275 |
| 7.0 | 7.8.2 | Mass transfer | 276 |
| 7.9 | | by blade mixers | 277 |
| 7.10 | Mixing | | 277 |
| 7.11 | - | of two liquids | 278 |
| Furth | er reading | 5 | 210 |
| Chap | ter 8 Se | plutions | 27 9 |
| 8.1 | | tion of aqueous solutions of carbohydrates | 279 |
| 0.2 | 8.1.1 | Mass balance | 279 |
| | 8.1.2 | Parameters characterizing carbohydrate solutions | 280 |
| 8.2 | | ity of sucrose in water | 282 |
| 0.2 | 8.2.1 | Solubility number of sucrose | 282 |
| 8.3 | | us solutions of sucrose and glucose syrup | 283 |
| 0.5 | 8.3.1 | Syrup ratio | 283 |
| 8.4 | | us sucrose solutions containing invert sugar | 285 |
| 8.5 | Solubil | ity of sucrose in the presence of starch syrup and invert sugar | 285 |
| 8.6 | | dissolution | 286 |
| | ner readin | | 288 |
| ruiti | iei icaum | 8 | - * - |
| Chap | | vaporation | 289 |
| 9.1 | | tical background – Raoult's law | 289 |
| 9.2 | Boiling | point of sucrose/water solutions at atmospheric pressure | 291 |
| 9.3 | | ation of a modification of Raoult's law to calculate the boiling | |
| | point c | f carbohydrate/water solutions at decreased pressure | 291 |
| | 9.3.1 | Sucrose/water solutions | 291 |
| | 9.3.2 | Dextrose/water solutions | 292 |
| | 9.3.3 | Starch syrup/water solutions | 292 |
| | 9.3.4 | Invert sugar solutions | 292 |
| | 9.3.5 | Approximate formulae for the elevation of the boiling point of | |
| | | aqueous sugar solutions | 292 |
| 9.4 | Vapou | r pressure formulae for carbohydrate/water solutions | 295 |
| | 9.4.1 | Vapour pressure formulae | 295 |
| | 9.4.2 | Antoine's rule | 297 |
| | 9.4.3 | Trouton's rule | 299 |

| 301 |
|-------------------------------------|
| 302 |
| points of sucrose solutions 303 |
| ess for chewy candy 304 |
| 305 |
| 307 |
| 307 |
| 309 |
| 310 |
| 310 |
| 310 |
| 311 |
| For crystallization 312 |
| rated solution 313 |
| 315 |
| 317 |
| 318 |
| 319 |
| 322 |
| h rate 323 |
| the hydrodynamic conditions 324 |
| ture based on the diffusion |
| 326 |
| 329 |
| 329 |
| e growth and crystal thickening 330 |
| 333 |
| 334 |
| 345 |
| 346 |
| 346 |
| 346 |
| 346 |
| 347 |
| lance 347 |
| 349 |
| lization 350 |
| 350 |
| ect of temperature or |
| 351 |
| 351 |
| r structure of fat melts 351 |
| 351 |
| 352 |
| 353 |
| ry, differential thermal analysis |
| ods 354 |
| fit it |

| 10.8 | Crystalli | zation of glycerol esters: Polymorphism | 355 |
|-------|------------|--|-----|
| 10.9 | | zation of cocoa butter | 359 |
| | 10.9.1 | Polymorphism of cocoa butter | 359 |
| | 10.9.2 | Tempering of cocoa butter and chocolate mass | 360 |
| | 10.9.3 | Shaping (moulding) and cooling of cocoa butter and chocolate | 365 |
| | 10.9.4 | Sugar blooming and dew point temperature | 367 |
| | 10.9.5 | Crystallization during storage of chocolate products | 368 |
| | 10.9.6 | Bloom inhibition | 370 |
| | 10.9.7 | Tempering of cocoa powder | 371 |
| 10.10 | | ization of fat masses | 371 |
| | 10.10.1 | Fat masses and their applications | 371 |
| | 10.10.2 | Cocoa butter equivalents and improvers | 372 |
| | 10.10.3 | Fats for compounds and coatings | 374 |
| | 10.10.4 | • | 376 |
| | 10.10.5 | • | 378 |
| | | Filling fats | 379 |
| | 10.10.7 | - | 381 |
| 10.11 | | ization of confectionery fats with a high trans-fat portion | 382 |
| | 10.11.1 | Coating fats and coatings | 383 |
| | 10.11.2 | | 383 |
| | 10.11.3 | Future trends in the manufacture of trans-free special | |
| | | confectionery fats | 384 |
| 10.12 | Modelli | ng of chocolate cooling processes and tempering | 385 |
| | 10.12.1 | | 385 |
| | 10.12.2 | Modelling the temperature distribution in cooling chocolate | |
| | | moulds | 386 |
| | 10.12.3 | Modelling of chocolate tempering process | 390 |
| Furth | er reading | 5 | 392 |
| Chapt | er 11 Ge | elling, emulsifying, stabilizing and foam formation | 394 |
| 11.1 | | olloids used in confectionery | 395 |
| 11.2 | Agar | · | 395 |
| | 11.2.1 | Isolation of agar | 395 |
| | 11.2.2 | Types of agar | 396 |
| | 11,2.3 | Solution properties | 396 |
| | 11.2.4 | Gel properties | 397 |
| | 11.2.5 | Setting point of sol and melting point of gel | 398 |
| | 11.2.6 | Syneresis of an agar gel | 398 |
| | 11.2.7 | Technology of manufacturing agar gels | 399 |
| 11.3 | Alginate | es | 400 |
| | 11.3.1 | Isolation and structure of alginates | 400 |
| | 11.3.2 | Mechanism of gelation | 401 |
| | 11.3.3 | Preparation of a gel | 401 |
| | 11.3.4 | Fields of application | 402 |
| 11.4 | Carrage | | 402 |
| | 11.4.1 | Isolation and structure of carrageenans | 402 |
| | 11.4.2 | Solution properties | 403 |
| | | | |

| | 11.4.3 | Depolymerization of carrageenan | 404 |
|--------|------------|--|-----|
| | 11.4.4 | Gel formation and hysteresis | 405 |
| | 11.4.5 | Setting temperature and syneresis | 405 |
| | 11.4.6 | Specific interactions | 405 |
| | 11.4.7 | Utilization | 406 |
| 11.5 | Furcellar | | 407 |
| 11.6 | Gum ara | | 407 |
| | | | 408 |
| 11.7 | Gum tra | = | 408 |
| 11.8 | Guaran | | 409 |
| 11.9 | Locust b | ean gum | 409 |
| 11.10 | Pectin | Total discount of a source of the stime | 409 |
| | 11.10.1 | Isolation and composition of pectin | |
| | 11.10.2 | High-methoxyl (HM) pectins | 410 |
| | 11.10.3 | Low-methoxyl (LM) pectins | 411 |
| | 11.10.4 | Low-methoxyl (LM) amidated pectins | 411 |
| | 11.10.5 | Gelling mechanisms | 411 |
| | 11.10.6 | Technology of manufacturing pectin jellies | 412 |
| 11.11 | Starch | | 413 |
| | 11.11.1 | Occurrence and composition of starch | 413 |
| | 11.11.2 | Modified starches | 414 |
| | 11.11.3 | Utilization in the confectionery industry | 414 |
| 11.12 | Xanthan | gum | 416 |
| 11.13 | Gelatin | | 416 |
| | 11.13.1 | Occurrence and composition of gelatin | 416 |
| | 11.13.2 | Solubility | 417 |
| | 11.13.3 | Gel formation | 417 |
| | 11.13.4 | Viscosity | 418 |
| | 11.13.5 | Amphoteric properties | 418 |
| | 11.13.6 | Surface-active/protective-colloid properties and utilization | 419 |
| | 11.13.7 | Methods of dissolution | 420 |
| | 11.13.8 | Stability of gelatin solutions | 421 |
| | 11.13.9 | Confectionery applications | 421 |
| 11.14 | Egg prot | teins | 422 |
| | 11.14.1 | Fields of application | 422 |
| | 11.14.2 | Structure | 422 |
| | 11.14.3 | Egg-white gels | 423 |
| | 11.14.4 | Egg-white foams | 424 |
| | 11.14.5 | Egg-yolk gels | 424 |
| | 11.14.6 | Whole-egg gcls | 425 |
| 11.15 | Foam fo | | 425 |
| | 11.15.1 | Fields of application | 425 |
| | 11.15.2 | Velocity of bubble rise | 426 |
| | 11.15.3 | Whipping | 429 |
| | 11.15.4 | Continuous industrial aeration | 430 |
| | 11.15.5 | Industrial foaming methods | 432 |
| | 11.15.6 | In situ generation of foam | 432 |
| Furthe | er reading | • | 433 |
| | , reading | | |

| Chapt | er 12 Tra | ansport | 434 |
|-----------------|--------------------|---|-----|
| 12.1 | Types of transport | | |
| 12.2 | Calculat | ion of flow rate of non-Newtonian fluids | 434 |
| 12.3 | Transpo | rting dessert masses in long pipes | 436 |
| 12.4 | Changes | in pipe direction | 437 |
| 12.5 | Laminar | unsteady flow | 438 |
| 12.6 | Transpo | rt of flour and sugar by air flow | 438 |
| | | Physical parameters of air | 438 |
| | 12.6.2 | Air flow in a tube | 438 |
| | 12.6.3 | Flow properties of transported powders | 439 |
| | 12.6.4 | Power requirement of air flow | 441 |
| | 12.6.5 | Measurement of a pneumatic system | 442 |
| Further reading | | | |
| Chapt | er 13 Pro | essin <i>o</i> | 445 |
| 13.1 | | ions of pressing in the confectionery industry | 445 |
| 13.2 | | of pressing | 445 |
| 13.3 | | quor pressing | 448 |
| | er reading | | 449 |
| - | | | |
| _ | er 14 Ex | | 451 |
| 14.1 | | rough a converging die | 451 |
| | 14.1.1 | Theoretical principles of the dimensioning of extruders | 451 |
| | | Pressure loss in the shaping of pastes | 455 |
| | | Design of converging die | 456 |
| 14.2 | | used for shaping confectionery pastes | 459 |
| | 14.2.1 | Screw feeders | 459 |
| | | Cog-wheel feeders | 460 |
| | 14.2.3 | Screw mixers and extruders | 461 |
| 14.3 | | n cooking | 464 |
| 14. 4 | Roller e | | 465 |
| | | Roller extrusion of biscuit doughs | 465 |
| | 14.4.2 | Feeding by roller extrusion | 467 |
| Furth | er reading | | 467 |
| Chapt | er 15 Pa | rticle agglomeration: Instantization | |
| - | | d tabletting | 469 |
| 15.1 | Theoreti | cal background | 469 |
| | 15.1.1 | Processes resulting from particle agglomeration | 469 |
| | 15.1.2 | Solidity of a granule | 472 |
| | 15.1.3 | Capillary attractive forces in the case of liquid bridges | 472 |
| | 15.1.4 | Capillary attractive forces in the case of no liquid bridges | 473 |
| | 15.1.5 | Solidity of a granule in the case of dry granulation | 474 |
| | 15.1.6 | Water sorption properties of particles | 475 |
| | 15.1.7 | Effect of electrostatic forces on the solidity of a granule | 477 |
| | 15.1.8 | Effect of crystal bridges on the solidity of a granule | 478 |
| | 15.1.9 | Comparison of the various attractive forces affecting granulation | 479 |
| | 15.1.10 | Effect of surface roughness on the attractive forces | 479 |

| 15.2 | Process | es of agglomeration | 481 |
|--------|------------|---|-----|
| | 15.2.1 | Agglomeration in the confectionery industry | 481 |
| | 15.2.2 | Agglomeration from liquid phase | 481 |
| | 15.2.3 | Agglomeration of powders: Tabletting or dry granulation | 482 |
| 15.3 | Granul | ation by fluidization | 482 |
| | 15.3.1 | Instantization by granulation: Wetting of particles | 482 |
| | 15.3.2 | Processes of fluidization | 483 |
| 15.4 | Tablett | ing | 484 |
| | 15.4.1 | Tablets as sweets | 484 |
| | 15.4.2 | Types of tabletting | 485 |
| | 15.4.3 | Compression, consolidation and compaction | 486 |
| | 15.4.4 | Characteristics of the compaction process | 488 |
| | 15.4.5 | Quality properties of tablets | 492 |
| Furth | er reading | g | 492 |
| Part I | II Chen | nical and complex operations: Stability of sweets | 493 |
| Chapt | er 16 C | hemical operations (inversion and caramelization), ripening and | |
| тг | | omplex operations | 495 |
| 16.1 | Inversion | | 495 |
| | 16.1.1 | Hydrolysis of sucrose by the effect of acids | 495 |
| | 16.1.2 | A specific type of acidic inversion: Inversion by cream of | .,, |
| | 1911. | tartar | 498 |
| | 16.1.3 | Enzymatic inversion | 499 |
| 16.2 | | elization | 502 |
| 10.2 | 16.2.1 | Maillard reaction | 502 |
| | 16.2.2 | Sugar melting | 504 |
| 16.3 | | ation of cocoa material | 505 |
| | 16.3.1 | Purposes and methods of alkalization | 505 |
| | 16.3.2 | German process | 506 |
| 16.4 | Ripenir | <u>-</u> | 507 |
| 10.1 | 16,4.1 | Ripening processes of diffusion | 507 |
| | 16.4.2 | Chemical and enzymatic reactions during ripening | 509 |
| 16.5 | | ex operations | 510 |
| 10.5 | 16.5.1 | Complexity of the operations used in the confectionery | 510 |
| | 10.5.1 | industry | 510 |
| | 16.5.2 | Conching | 510 |
| | 16.5.3 | New trends in the manufacture of chocolate | 521 |
| | 16.5.4 | Modelling the structure of dough | 522 |
| Furth | er readin | | 523 |
| Chant | ter 17 W | Vater activity, shelf life and storage | 525 |
| 17.1 | Water | | 525 |
| | 17.1.1 | Definition of water activity | 525 |
| | 17.1.2 | Adsorption/desorption of water | 527 |
| | 17.1.2 | Measurement of water activity | 527 |
| | 17.1.4 | Factors lowering water activity | 533 |
| | 17.1.5 | Sorption isotherms | 534 |
| | | | |

| | 17.1.6 | Hygroscopicity of confectionery products | 535 |
|--------|-------------------|---|------------|
| | 17.1.7 | Calculation of equilibrium relative humidity of | |
| | | confectionery products | 538 |
| 17.2 | | e and storage | 541 |
| | 17.2.1 | Definition of shelf life | 541 |
| | 17.2.2 | Role of light and atmospheric oxygen | 541 |
| | 17.2.3 | Role of temperature | 541 |
| | 17.2.4 | Role of water activity | 541 |
| | 17.2.5 | · · · · · · · · · · · · · · · · · · · | 542 |
| | 17.2.6 | Concept of mould-free shelf life | 542 |
| 17.3 | _ | scheduling | 547 |
| Furthe | er reading | | 548 |
| Chante | er 18 St | ability of food systems | 550 |
| 18.1 | | n use of the concept of food stability | 550 |
| 18.2 | | theories: types of stability | 550 |
| 10.2 | 18.2.1 | Orbital stability and Lyapunov stability | 550 |
| | 18.2.2 | Asymptotic and marginal (or Lyapunov) stability | 551 |
| | | Local and global stability | 552 |
| 18.3 | | e as a case of marginal stability | 552 |
| 18.4 | | matrix of a food system | 553 |
| | | Linear models | 553 |
| | 18.4.2 | | 554 |
| | | | |
| Part I | V Appe | ndices | 555 |
| Appen | dix 1 Da | ata on engineering properties of materials used and made by the | |
| | co | nfectionery industry | 557 |
| A1.1 | Carboh | ydrates | 557 |
| A1.2 | Oils and | l fats | 566 |
| A1.3 | Raw ma | aterials, semi-finished products and finished products | 567 |
| Annon | dix 2 So | olutions of sucrose, corn syrup and other monosaccharides and | |
| Appen | | saccharides | 579 |
| | | | |
| | | rvey of fluid models | 582 |
| A3.1 | | position method for calculation of flow rate of | 500 |
| | | ical models | 582 |
| | A3.1.1 | Principle of the decomposition method | 582 |
| | A3.1.2 | Bingham model | 583 |
| | A3.1.3 | Casson model $(n = 1/2)$ | 585 |
| | A3.1.4 | Peek, McLean and Williamson model | 586 |
| | A3.1.5 | Reiner-Philippoff model | 587 |
| | A3.1.6 | Reiner model Rehinowitzeh, Fisanschitze Staigen and One model | 587 |
| | A3.1.7 | Rabinowitsch, Eisenschitz, Steiger and Ory model | 588 589 |
| | A3.1.8 A3.1.9 | Oldroyd model | 590 |
| | A3.1.9 A3.1.10 | Weissenberg model Ellis model | 590 591 |
| | C 1. I. IV | TAIRS HIVARD | -ファエ |

| | | Meter model | 591 |
|-----------------|--|--|-----|
| | A3.1.12 | Herschel-Bulkley-Porst-Markowitsch-Houwink (HBPMH) | |
| | | (or generalized Ostwald-deWaele) model | 592 |
| | | Ostwald-de Waele model | 594 |
| | | Williamson model | 595 |
| A3.2 | Calculation of the friction coefficient ξ of non-Newtonian fluids in the | | |
| | laminar region | | 596 |
| A3.3 | | ization of the Casson model | 597 |
| | A3.3.1 | Theoretical background to the exponent <i>n</i> | 597 |
| | A3.3.2 Theoretical foundation of the Bingham model | | 598 |
| A3.4 | Determination of the exponent n of the flow curve of a generalized | | |
| | Casson fluid | | 598 |
| A3.5 | Dependence of shear rate on the exponent n in the case of a | | |
| | generalized Casson fluid | | 600 |
| A3.6 | | ion of the flow rate for a generalized Casson fluid | 601 |
| A3.7 | | | 603 |
| Furth | er reading | | 605 |
| | dix 4 Fra | actals | 606 |
| A4.1 | | r forms – fractal geometry | 606 |
| A4.2 | Box-cou | nting dimension | 606 |
| A4.3 | 3 Particle-counting method | | 607 |
| A4.4 | 4 Fractal backbone dimension | | 608 |
| Further reading | | | 608 |
| Appen | dix 5 Int | roduction to structure theory | 609 |
| A5.1 | General | features of structure theory | 609 |
| A5.2 | Attribut | es and structure: A qualitative description | 610 |
| A5.3 | | nical structures | 611 |
| A5.4 | Structur | e of measures: A quantitative description | 611 |
| A5.5 | | ns of conservation and balance | 612 |
| A5.6 | Algebra | ic structure of chemical changes | 614 |
| A5.7 | | mological triangle: External technological structure | 614 |
| A5.8 | | ed substantial fragments | 615 |
| Appen | ndix 6 Te | chnological lay-outs | 617 |
| | Further reading | | |
| Refere | ences | | 630 |
| Index | | | 668 |