

---

11.3	Presentation of viscosity measurements, 278
11.4	Single point flow measurement, 279
11.4.1	Gallenkamp torsion viscometer, 280
11.4.2	MacMichael viscometer, 281
11.5	Rotational viscometers, 282
11.6	Vibrational viscometers, 285
11.7	Oscillatory rheometers, 285
11.8	Sample preparation and measurement procedures, 286
11.8.1	Sample preparation, 286
11.8.2	Checking the viscometer, 287
11.8.3	Preconditioning, 287
11.8.4	Shear rate range, 288
11.8.5	Holding time at the maximum shear rate, 288
11.8.6	Hysteresis, 288
11.8.7	Overall measurement time, 288
11.9	Factors affecting the flow properties of chocolate, 289
11.9.1	Fat content, 289
11.9.2	Particle size distribution, 290
11.9.3	Surface active agents (emulsifiers), 291
11.9.4	Conching, 294
11.9.5	Moisture, 295
11.10	Advanced methods to characterise chocolate flow behaviour, 295
	Conclusions, 296
	Acknowledgements, 296
	References, 296
<b>12</b>	<b>Bulk chocolate handling, 298</b>
	<i>John H. Walker</i>
12.1	Introduction, 298
12.2	Viscosity and viscometry, 298
12.2.1	What is viscosity?, 298
12.2.2	Laminar and turbulent flow, 300
12.3	Pump sizes, 301
12.3.1	Power, 301
12.3.2	Speed, 301
12.4	General criteria for choosing a pump, 301
12.5	Types of pump, 302
12.5.1	Gear pumps, 302
12.5.2	Sliding vane pump, 303
12.5.3	Lobe and rotary piston pumps, 303
12.5.4	Screw pump, 304
12.5.5	Pawl pumps, 305
12.5.6	Progressive cavity pump, 305
12.5.7	Positive displacement piston and diaphragm pumps, 306

- 12.6 Pipeline pigging, 307
- 12.7 Storage of liquid chocolate, 308
- 12.8 Jacketed pipe work, 309
  - 12.8.1 Corrosion of stainless steel, 310
- 12.9 Valves, 311
  - 12.9.1 Plug cock valve, 311
  - 12.9.2 Butterfly valve, 311
  - 12.9.3 Ball valve, 311
- 12.10 Contamination removal, 312
  - 12.10.1 Magnets, 312
  - 12.10.2 Sieving, 312

Conclusions, 313

Acknowledgements, 313

### **13** Tempering, 314

*Erich J. Windhab*

- 13.1 Introduction, 314
- 13.2 Physics of cocoa butter crystallisation, 315
- 13.3 Chocolate tempering technology, 316
- 13.4 Measurement of temper and its related characteristics, 318
  - 13.4.1 Tempermeters, 319
  - 13.4.2 Differential scanning calorimetry, 321
  - 13.4.3 Thermorheometry, 322
  - 13.4.4 Nuclear magnetic resonance, 323
- 13.5 Tempering processes, 323
  - 13.5.1 The principle of conventional continuous chocolate “stir/shear-tempering”, 324
  - 13.5.2 Impact of temperature/temperature control, 324
  - 13.5.3 Impact of shear, 326
  - 13.5.4 Importance of residence time distribution, 330
  - 13.5.5 “Recipe factors” influencing tempering quality, 331
- 13.6 Types of tempering machine, 331
  - 13.6.1 Chocolate tempering kettles, 331
  - 13.6.2 Types of continuous industrial tempering machines, 332
  - 13.6.3 Continuous industrial seed-tempering, 341
- 13.7 Properties of CBCS tempered chocolate, 346
  - 13.7.1 Pre-crystallised liquid state, 346
  - 13.7.2 Semi-solid and solid state, 348
  - 13.7.3 Industrial process layouts, 350
- 13.8 Other methods of tempering, 352

Conclusion, 352

Acknowledgements, 353

References and further reading, 353

Appendix: Machinery manufacturers, 355