

chocolate's rheological and calorimetric characteristics, will be the key drivers for ongoing and future improvements in the tempering of confectionery.

## Acknowledgements

The author would like to thank Mr. R.B. Nelson who gave an outline input to this book chapter on tempering and particularly for the overview of industrial tempering machines for more than a decade, by his contributions about tempering in the 2nd and 3rd editions of this book, and Konstantinos Paggios and Dr. Yuantong Zeng for updating the final sections on seed tempering.

Furthermore I would like to thank the "ETH Industrial Committee on CHOColate TEChnology" (ETHIC-CHOTEC), the Swiss Federal Institute of Technology, Zürich (ETH) and in particular the Swiss Committee for Technology and Innovation (CTI) as well as the CHOCOSUISSE and its Swiss Cocoa and Chocolate Foundation for their great support of numerous projects, without which many of contributions to this article could have not been made.

## References and further reading

- Beckett, S. T. (1995) *Industrial Chocolate Manufacture and Use*, Kluwer Academic, Dordrecht.
- Bolliger, S., Zeng, Y. T., Windhab, E. J. (1999) In-line measurement of tempered cocoa butter and chocolate by means of near-infrared spectroscopy. *Journal of the American Oil Chemists Society*, **76**(6), 659–667.
- Bolliger, S., Breitschuh, B., Stranzinger, M., Wagner, T., Windhab, E. J. (1998) Comparison of precrystallization of chocolate. *Journal of Food Engineering*, **35**(3), 281–297.
- Borochovitch, R. (2004) *Processes for Preparation of Polymorphic Form II of Sertraline Hydrochloride*, United States Patent Application 20040030190, A1.
- Braun, P., Zeng, Y., Windhab, E. J. (2006) Selective pre-crystallization – a revolutionary process, *Food Review Journal*, **2006**(Aug.), 28–33.
- Breitschuh, B., Drost, M., Windhab, E. J. (1999) Process development for continuous crystallization and separation of fat crystal suspensions. *Chemical Engineering and Technology*, **21**(5), 425–428.
- Breitschuh, B., Windhab, E. J. (1998) Parameters influencing cocrystallization and polymorphism in milk fat. *Journal of the American Oil Chemists Society*, **75**(8), 897–904.
- Breitschuh, B., Windhab, E. J. (1996) Direct measurement of thermal fat crystal properties for milk-fat fractionation. *Journal of the American Oil Chemists Society*, **73**(11), 1603–1610.
- Cebula, D., Dilley, K., Smith, K. (1991) Continuous tempering studies on model confectionery systems, *Manufacturing Confectioner*, **1991**, 131–136.
- Cebula, D. J., Ziegleder, G. (1993) *Fettig Wissenschaft/Technologie*, **95**, 340.
- Dieffenbacher, A. (1986) Fat fractionation, Nestec S.A., United States Patent 4 594 194.
- Dimick, P. S., Manning, D. M. (1987) Thermal and compositional properties of cocoa butter during static crystallization, *Journal of the American Oil Chemists Society*, **64**(12), 1663–1669.
- Duck, W. (1963) The measurement of unstable fat in finished chocolate. *Manufacturing Confectioner*, **1963**(Nov.), p. 822.
- Eriksson, K. et al. (2003) *Process for the Crystallization of Non-Sucrose Substances*. United States Patent Application 20030131784, A1.

- Kleinert, J. (1980) *Review for Chocolate Confectionery and Bakery*, **1980**(March), 19–24.
- Koyano, T., Hachiya, I., Arishima, T., Sagi, N., Sato, K. (1991) Polymorphism of POS. II. Kinetics of melt crystallization. *Journal of the American Oil Chemists Society* **68**(10), 716–718.
- Koyano, T., Hachiya, I., Sato, K. (1990) Fat polymorphism and crystal seeding effects on fat bloom stability of dark chocolate. *Food Structure*, **9**, 231–240.
- Lovegreen, N. V., Gray, M. S., Feuge, R. O. (1976) Solidification of cocoa butter, *Journal of the American Oil Chemists Society*, **53**(3), 108–112.
- Mehrle, Y., Padar, S., Windhab, E. J. (2006) Crystallisation behaviour of cocoa butter under shear, *Annual Meeting of the Swiss Group of Rheology*, Fribourg.
- Mehrle, Y., Padar, S., Windhab, E. J. (2007) New insight into cocoa butter polymorph transformation under chocolate processing conditions using an “in-line SAXS” technique, *2nd Biannual Meeting of the Swiss ETH-Industry Working Group on Chocolate Technology*, ETH Zürich.
- Metin, M., Hartel, R. (1998) Thermal analysis of isothermal crystallisation kinetics in blends of cocoa butter with milk fat or milk fat fractions, *Journal of American Oil and Chemistry Society*, **75**(11), 1617–1624.
- Mitsuhashi, H. (1989) *Crystalline Alpha-Maltose*, United States Patent **4 816 445**.
- Nelson, R. B. (1999) Tempering. In: *Industrial Chocolate Manufacture and Use* (ed. S. T. Beckett), Blackwell, Oxford, pp. 231–258.
- Ouriev, B., Windhab, E. J. (2007) *Method for Determining Rheological Parameters of a Fluid*, United States Patent **7 228 728**.
- Padar, S., Windhab, E. (2007) Verfestigung vorkristallisierter Schokolade bei Verarbeitungstemperatur, *1st Biannual Meeting 2007 of the ETH-Industry Working Group on Chocolate Technology*, ETH Zürich.
- Padar, S., Mehrle, Y., Windhab, E. J. (2005) Impact of shear stress on crystal polymorphism and agglomerate structures in chocolate suspension systems. *Annual European Rheology Conference*, Grenoble.
- Pate, D. R. (1983) *Process for Continuous Fluidization of Shortening*, SCM Corporation, United States Patent **4 391 838**.
- Sato, K., Arishima, T., Wang, Z. H., Ojima, K., Sagi, N., Mori, H. (1989) Polymorphism of POP and SOS. I. Occurrence and polymorphic transformation. *Journal of the American Oil Chemists Society*, **66**(5), 664–674.
- Sato, K., Arishima, T., Wang, Z. H., Ojima, K., Sagi, N., Mori, H. (1989) Polymorphism of POP and SOS. II. Kinetics of melt crystallization. *Journal of the American Oil Chemists Society*, **66**(5), 675–679.
- Vaeck, S. V. (1960) Cacao and fat bloom, *14th PMCA Production Conference*, Pennsylvania.
- Van Mechelen, J. B., Peschar, R., Schenk, H. (2006a) Structures of mono-unsaturated triacylglycerols. I. The  $\beta 1$  polymorph, *Acta Crystallographia*, **B62**, 1121–1130.
- Van Mechelen, J. B., Peschar, R., Schenk, H. (2006b) Structures of mono-unsaturated triacylglycerols. II. The  $\beta 2$  polymorph, *Acta Crystallographia*, **B62**, 1131–1138.
- Wille, R. L., Lutton E. S. (1966) Polymorphism of cocoa butter. *Journal of the American Oil Chemists Society*, **43**(8), 491–496.
- Windhab, E. J. (1986) Fettcrystallisation unter Druck und Scherung, *ZDS Fettsymposium*, Solingen.
- Windhab, E. J. (1999) New developments in crystallization processing. *Journal of Thermal Analysis and Calorimetry*, **57**, 171–180.
- Windhab, E. J. (2003) Die Hochscher-Impfkristallisation/von der grundlagenbasierten Prozessidee zum neuen Produktionskonzept, *Chemie Ingenieur Technik*, **75**(8), 1168–1169.
- Windhab, E. J., Zeng, Y. (1997) *Verfahren zur Herstellung von Fettschmelze basierten Impfkristallsuspensionen*. World Patent WO 00/72695.
- Windhab, E. J., Zeng, Y. (1998) Hochscher- und Animpfkristallisation von Schokolade, *International ZDS Symposium Schoko-Technik*.
- Windhab, E. J., Zeng, Y. (1999); *Method of Producing Seed Crystal Suspensions Based on Melted Fat*, European Patent EP00A1, World Patent WO00A1.