Application note

Studying the tempering process of chocolate to understand the effect of the cooling rate on its quality

Chocolate sales are growing worldwide, and a variety of tastes and textures have been developed to meet customers' requirements. The tempering process, which refers to a controlled melting and cooling of chocolate to obtain the right crystal form (form V)[1], is essential when designing chocolate products, as it determines the quality of the chocolate. Well-tempered chocolate has a shiny gloss, good texture, and a smooth mouthfeel. Badly tempered chocolate is chalky, grainy, and chewy. Additionally, it often has an unattractive appearance owing to "fat bloom". The cooling rate, especially, plays a crucial role in the tempering process[1]. It is usually studied using differential scanning calorimetry (DSC), measuring the effective heat capacity of chocolate cooled at different rates. However, this approach cannot characterise rapid shifts of the cooling rate[1].

The MultiScan MS20 from DataPhysics Instruments is a compact and versatile measuring device for optical stability and aging analyses. It provides the possibility to study tempering processess of chocolate easily and conveniently. In this application note, we study the effects of different cooling rates on the tempering process and its impact on chocolate quality using an MS20.

Fig. 1: The quality of chocolate is depending on the tempering process.

Keywords: MultiScan 20 ▪ Stability Analysis ▪ Chocolate ▪ Melting & Tempering Process ▪ Cooling Rate

Technique and Method

The MultiScan MS20 (Fig. 2) from DataPhysics Instruments is the measuring device for automatic optical stability and aging analysis of liquid dispersions and the comprehensive characterisation of time- and temperature-dependent destabilisation mechanisms. It consists of a base unit, to which up to six ScanTowers with temperature-controlled sample chambers can be connected.

The ScanTowers of the MS20 can be individually controlled and operated at different temperatures between 4 °C and 80 °C. With its matching software MSC, the MS20 is an ideal partner for the stability analysis since even the slightest changes within dispersions can be detected and evaluated. Thus, the MS20 enables a fast and objective analysis of the tempering process of chocolate.

Fig. 2: Stability analysis system MultiScan MS20 with six independent ScanTowers

Experiment

A commercial milk chocolate, which can be treated as well-mixed chocolate, was used as an example in this study. The entire tempering process was studied with an MS20. An exemplary tempering process[1] involves four steps (compare Fig. 7 green temperature curve): (I) melting chocolate completely to remove most of the crystals; (II) cooling to the crystallisation point; (III) keeping the temperature at this point for several minutes; (IV) reheating for melting unstable crystals. Varying kinds of chocolate have a different melting temperature and temper time. In this note, the melting temperature, crystallisation point and reheat temperature are 50 °C, 22 °C and 32 °C, respectively.

The chocolate samples were cut as fine as possible and filled into transparent glass vials (Fig. 3 left). The melting process was measured every 13 s for 19 min. The measurement started at a temperature of T = 50 °C. After the chocolate was completely melted (Fig. 3 middle), the samples were cooled to 22 °C at different rates of 0.1 °C/min, 0.2 °C/min, 1 °C/min, 2 °C/min, 4 °C/min and 6 °C/min, respectively.

All samples were kept at 22 °C for 10 min, then reheated to 32 °C at a rate of 4 °C/min and kept at 32 °C for 5 min. The sample vials were then cooled at room temperature for solidification, rather than being poured into a cool mould, to simplify the process. The measured zone was between 0 mm (bottom of the vial) and 57 mm (top of the vial).

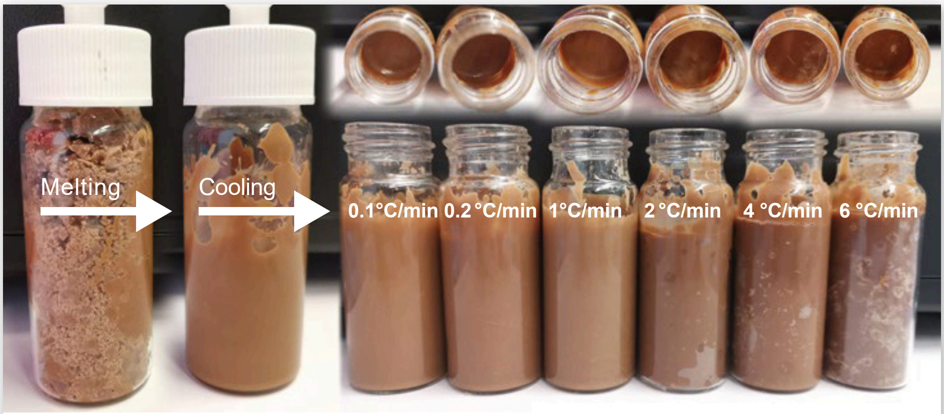

Fig. 3: The chocolate sample before (left) and after (middle) melting at 50 °C;
The sample vials (right) after solidification at room temperature

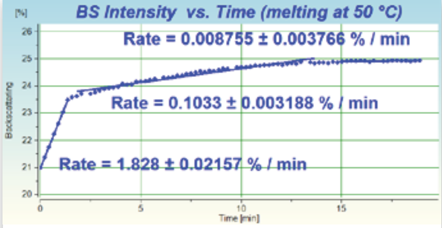

Fig. 5: Kinetics in chocolate melting process at 50 °C

Notably, the six measurements were carried out simultaneously, thanks to the possibility to measure up to six samples with individual settings using just one MS20. Fig. 3 right shows the sample vials cooled at different rates at the end of the experiment after solidification.

Results

Fig. 4 plots the backscattering (BS) intensities against the position for the melting process at 50 °C. The colour-coding of the curves indicates the time at which they were recorded, from red (start of the measurements, t = 0 s) to purple (end of the measurements). The backscattering diagram in Fig. 4 shows that the backscattering intensity increases first and then stays constant.

The kinetic analysis of the melting process (Fig. 5) reveals that the changes in backscattering intensities are more pronounced in the first two minutes after the start of the measurements. In the first two minutes, big pieces of chocolate with wider interspaces lead to a lower backscattering intensity, which raises unevenly as the chocolate starts to melt. The change rate in those first 2 min is 1.83% per min. After 15 mins, the backscattering intensity stays constant with a change rate of 0.009 % per min, indicating that the melting process is complete and most of the crystals are melted out. This is confirmed by checking the chocolate in the sample vials visually.

To have an insight into the effect the cooling rate has on the tempering process and therefore chocolate quality, the process was measured at different cooling rates. The samples showed similar change of backscattering intensities over time. As displayed in Fig. 6 left, the backscattering intensities decrease globally, suggesting that the particles are growing as they cool down and start initiating the nucleation of seed crystals.

The data in Fig. 6 right shows that the particles grow faster at a more rapid cooling rate. However, a too rapid cooling rate leads to the wrong crystal form and fat blooming (Fig. 3 right). This is consistent with previous studies[1], which conclude that rapid cooling rates cause a lower degree of crystallisation than slower cooling rates. Additionally, it can be observed that the cooling rate of 1 °C/min is the optimal rate to produce high quality chocolate effectively.

To get an entire picture of the tempering process, the measurements and the temperature profile can be displayed in one graph (Fig. 7). The changes in backscattering intensities over time/temperature are consistent with the model tempering process[1]. Most notably, even very slight changes in the rapid shifts can be detected with a small error margin underlining the very high precision of the MS20.

Summary

The MS20 stability analysis system and its MSC software provide a fast and simple way to study the tempering process of chocolate. Changes can be detected sensitively and objectively. This enables food designers to anticipate and quantify stability Issues time and cost effectively.

References

[1] Fryer, P., Pinschower, K. The Materials Science of Chocolate. *MRS Bulletin* 25, 25–29 (2000). https://doi.org/10.1557/mrs2000.250

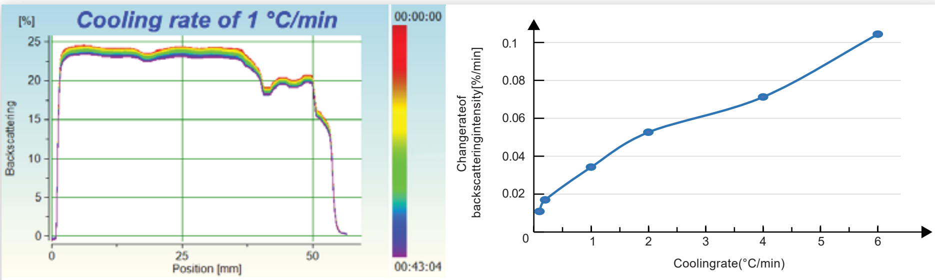

Fig. 6: Backscattering diagram of tempering process at a cooling rate of 1 °C/min (left) and the change rates of BS intensity vs. cooling rate (right)

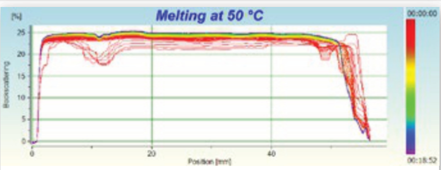

Fig. 4: Backscattering diagram of melting process at 50 °C

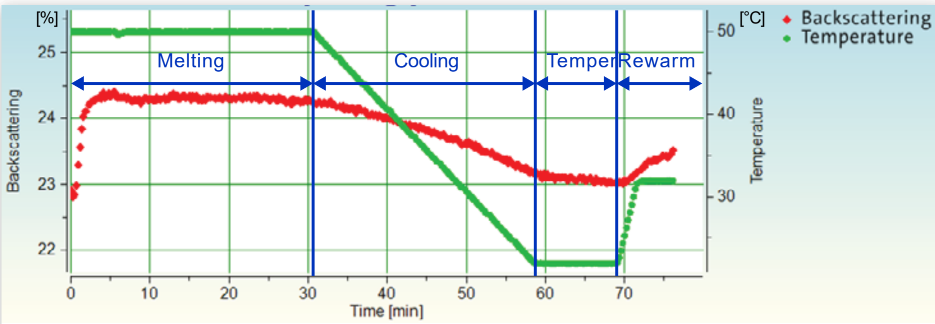

Fig. 7: Kinetics in tempering process at the cooling rate of 1 °C/min

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