Changes in Viscosity during Tempering of Milk Chocolate and Supercoatings

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Introduction

The flow characteristics of chocolate are critical to many aspects of its performance, particularly during production. They determine the pick-up weights on enrobed products; they determine how easy (or difficult) it is for chocolate to drain during the production of chocolate shells; they are especially important in controlling the ratio of coating to filling in one-shot depositing processes. Chocolate manufacturers make every effort to ensure good batch-to-batch reproducibility in terms of the viscosity of the chocolate they produce yet they don’t always give enough thought to the changes in viscosity that can occur as a result of tempering.

Viscosity, and flow properties in general, of chocolate are dependent upon a number of factors:

- Fat content
- Emulsifier type and level
- Moisture content
- Particle size distribution
- Temperature
- State of temper

Whilst the first four of these are ‘quality controlled’ by the normal monitoring of the flow properties of chocolate, the last two are not. It is these two parameters that I propose to look at in more detail.

The chocolate industry normally uses the viscosity of chocolate measured at 40°C as a means of quality control. Whilst such measurements do ensure batch-to-batch consistency they bear no real relationship to the viscosity of the chocolate once it is tempered. There are two main reasons for this. Firstly, the temperature of the tempered chocolate will be some 10°C or so lower and this alone will contribute to a higher viscosity. Secondly, a proportion of the fat phase will have crystallised at temper leaving less of the fat in the liquid phase. This also will contribute to a higher viscosity. So tempering chocolate will increase its viscosity. The questions which then arise from this are (a) by how much, and (b) is the viscosity increase dependent on the way in which the chocolate is tempered?
To look at the effects of both of these parameters in more detail we chose to study a simple milk chocolate with a fat phase consisting of 80% cocoa butter and 20% milk fat. The actual recipe is shown in Table 1. In a second phase of this work we also studied a supercoating recipe - this is one in which the added cocoa butter is replaced by a compatible vegetable fat

Table 1  Milk chocolate recipe

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa powder (10/12)</td>
<td>6.0%</td>
</tr>
<tr>
<td>Skimmed milk powder</td>
<td>24.0%</td>
</tr>
<tr>
<td>Sugar</td>
<td>37.1%</td>
</tr>
<tr>
<td>Cocoa butter</td>
<td>26.0%</td>
</tr>
<tr>
<td>Butterfat</td>
<td>6.5%</td>
</tr>
<tr>
<td>Lecithin</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

Tempering Methods

Two methods of tempering the milk chocolate and supercoating were evaluated:

- Batch seeding in a small tempering kettle
- Continuous tempering in a three-stage tempering unit

In the batch seeding method, milk chocolate was stirred in a tempering kettle at 28°C (after cooling from 50°C). Powdered chocolate in which the cocoa butter was in a stable crystal form was added at a level of 0.1% of the total chocolate. The chocolate was stirred until it was tempered.

In the continuous tempering method, milk chocolate was passed through a three-stage tempering unit in which the temperature of the three stages was controlled. The third (exit) stage was set to 28°C. The second stage temperature was 1.5°C below that of the first stage; the first and second stage temperatures were varied until temper was achieved in the chocolate exiting the unit.

The state of temper of all the chocolates was measured using a normal tempermeter - not just at the end of the tempering period but also prior to making all the viscosity measurements. Unless otherwise noted all the chocolates gave a flat plateau on the tempermeter graph, indicating a state of temper that was neither under- nor over-tempered.

Viscosity Measurements

Viscosity was measured using a Haake Rotovisco viscometer at various shear rates. Viscosity measurements were made on all the tempered chocolates at 28°C and at 31.5°C. All the chocolates had retained their state of temper at this temperature. We also measured the viscosity of the untempered chocolate at 31.5°C after first ensuring that all crystals had melted by holding at 50°C.

Kettle Tempering
The viscosities of the untempered chocolate at 31.5°C and of the tempered chocolates at 28°C and at 31.5°C are shown in Figure 1. At 28°C the chocolate was neither over- nor under-tempered; at 31.5°C there was evidence of slight under-temper on the temprometer curve.

Figure 1

Kettle Tempering

Depending on the shear rate there is about 7-13 poise difference between the viscosities of the tempered chocolate at 28°C and at 31.5°C. Some of this difference may be accounted for by the temperature increase itself causing a reduction in the viscosity. It is theoretically possible that some of the difference could also be as a result of the chocolate becoming over-tempered during measurement of the viscosity. Whilst this could be a contributing factor at 28°C it is unlikely to be so at 31.5°C where the chocolate was slightly under-tempered to begin with. The difference in viscosity between tempered and untempered chocolate at 31.5°C is about 5-7 poise. This is a result of the reduction in fat in the liquid phase at temper (because some of the fat is, by then, in a crystallised form).

Three-stage continuous tempering

The viscosities of the untempered chocolate at 31.5°C and of the tempered chocolates at 28°C and at 31.5°C are shown in Figure 2. At 28°C the chocolate was marginally under-tempered; at 31.5°C it was tempered and showing a plateau on the tempermeter graph.

In the case of continuous three-stage tempering the reduction in viscosity by warming the chocolate from 28°C to 31.5°C is of the order of 7-11 poise. The difference between tempered and untempered chocolate at 31.5°C is about 5-7 poise.
Both the differences in viscosity between the various temperatures and states of temper and the absolute levels of the viscosities themselves are very similar in both kettle tempering and continuous three-stage tempering.

Controlling viscosity is important to chocolate manufacturers because it can determine such critical parameters as pick-up weight on enrobed products, drainage from shell-moulding, elimination of air bubbles etc.

Nelson and Beckett advise the use of a low-viscosity coating (15-20 poise) for enrobing but a higher viscosity coating (30-120 poise) for moulding. Whilst the variations which we saw in these trials were well within the range suggested by Nelson and Beckett for moulding chocolates they were much larger than the range suggested for enrobing.

However, this is not the whole story because in looking at the supercoating recipe we found some quite surprising results after tempering using the continuous three-stage tempering equipment.

The supercoating was studied in much the same way. We call this a supercoating rather than chocolate because, although, its fat phase is polymorphic and hence needed to be tempered it was composed of a mix of cocoa butter, milk fat and vegetable fat in which the vegetable fat portion was well above the 5% permitted by EU legislation.

This coating was tempered in a tempering kettle at 28°C and in the continuous three-stage tempering unit with an exit temperature (third stage temperature) of 28°C. In both cases the coating showed an ‘in-temper’ curve as denoted by a plateau on a tempermeter. The apparent viscosity of the continuously tempered coating was, however, significantly lower than that of the kettle tempered coating (Figure 3).
Both coatings were then held in the viscometer at 28°C and at a shear rate of 5.44 sec⁻¹ (Figure 4).

The viscosity of both coatings increased with time. Not surprisingly, perhaps! However, when we then measured the state of temper of the two coatings after about 13 minutes in the viscometer, the kettle tempered coating had become overtempered whereas the continuously tempered coating had completely lost all temper.

The results on the kettle tempered coating were as one might expect - holding the tempered coating at that temperature would cause it to crystallise further giving both over-temper and an increase in viscosity.
But why did the continuously tempered coating behave in such an unusual way and also in a way that was not encountered with our standard milk chocolate? Our theory is that the tempering conditions we were using were such that both $\beta$ and $\beta'$ crystals were being formed (see Figure 5). The presence of the $\beta$ crystals would account for the ‘in temper’ curve measured after the coating exited the tempering unit.

**Figure 5**

Why?

However, if the two types of crystal had relative rates of crystallisation such that $\beta'$ crystallisation proceeded faster than $\beta$ crystallisation when the coating was then held in the viscometer at 28°C this would account for both the viscosity increasing with time and also the temper being ‘lost’.

So, in conclusion, both temperature and state of temper have a large role to play in the flow characteristics of a tempered chocolate. Their effects are not predicted by the more normal means of controlling the flow characteristics of chocolate by measuring untempered at 40°C as is common in the industry. Nor does having a good state of temper and good flow characteristics immediately after tempering necessarily guarantee that these states will continue during subsequent use of the chocolate - it is always necessary to exercise vigilance and continue to take representative samples after the tempering stage.