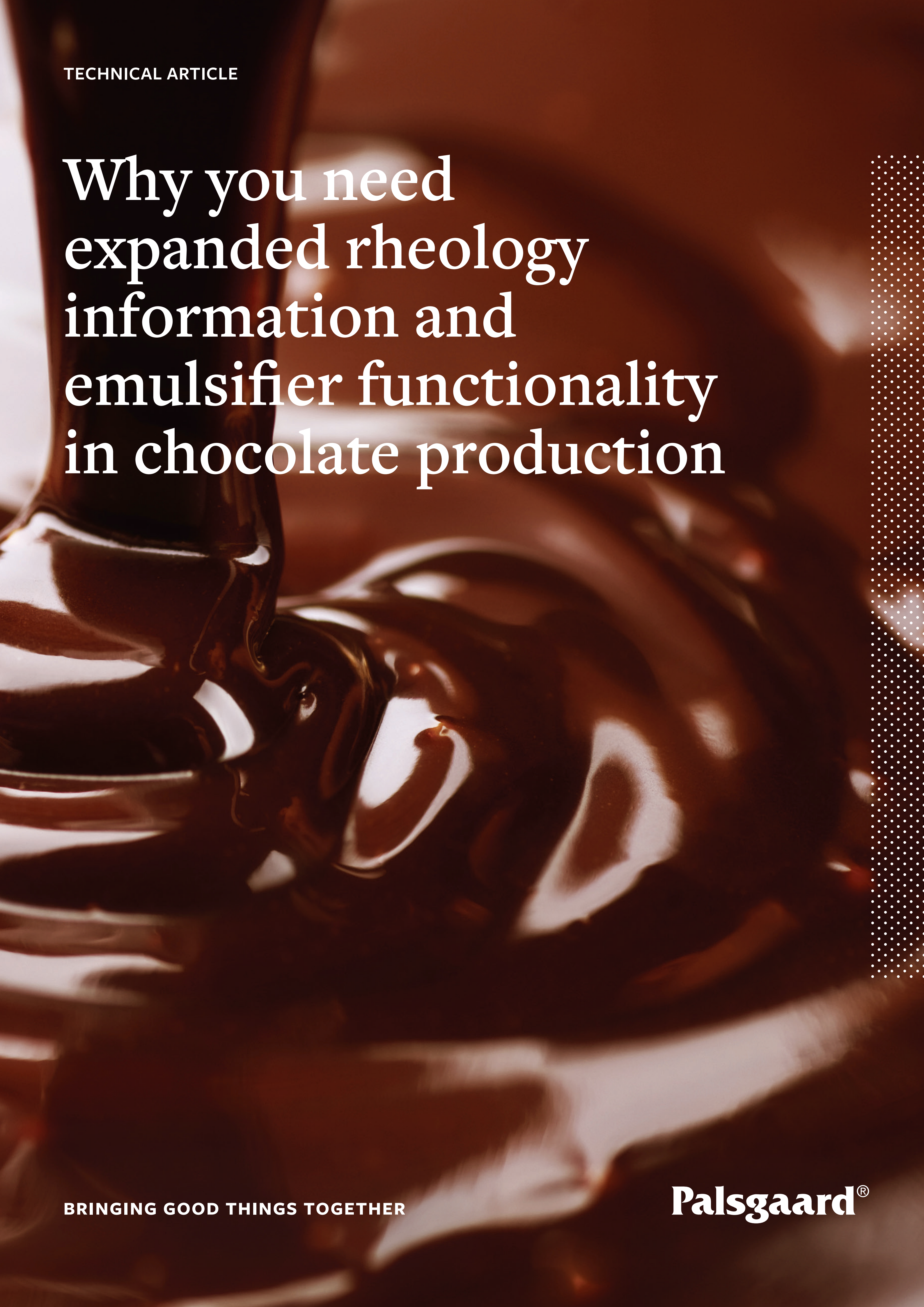

TECHNICAL ARTICLE

Why you need expanded rheology information and emulsifier functionality in chocolate production

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Keeping rheology simple and accessible can cause problems in the daily production of chocolate due to a lack of information. Moving beyond single-speed chocolate viscosity measuring to flow-curve or three-step viscosity measuring, allows for a better understanding of practical production situations such as moulding and enrobing as well as the true savings of optimal emulsifier usage, exemplified by **Palsgaard® AMP 4455** and **Palsgaard® PGPR 4190**.

Enhancing chocolate rheology measurements for optimal processing

The overall idea of rheological chocolate measurements is to give information of any chocolate or compound's workability in moulding, enrobing, panning, spinning, shell moulding etc. In order to obtain this, a more informative way of measuring rheology is needed.

Historically, the confectionery industry has been working with relatively simple instruments to obtain information of chocolate and compound textures. The Ford-cup beaker, the Mac Michael viscometer and single-speed viscosity measurements are still being used to measure the flow properties of chocolate and compounds. However, the art of measuring chocolate flow properties can and should be evaluated, as the results obtained is only indicative and does not include vital information.

In the factory, semi liquid chocolate is a mixture of solid particles - sugar, cocoa and milk - floating in a surrounding continuous liquid fat phase. Because of this, chocolate (and similar confectionery systems) is a non Newtonian substance, see Table 1. Newtonian substances, such as liquids, see Table 2, have constant viscosity (texture); independent of shear rates (speeds), while non Newtonian substances have different viscosities at different shear rates..

Single-speed measurements

Many producers have used an elderly method when evaluating chocolate flow properties for a long time. This single-speed evaluation method was originally created so that everyone with even a simple viscometer could use it. However, there is a relation between production type and chocolate flow, hence more shear rates are needed to describe the link between chocolate shear rate and the measured viscosity. During chocolate moulding, the chocolate speed is low (0.1-5 [1/S]) while the chocolate moves relative fast at the blowing stage of enrobing (>25 -30[1/S]).

Simple instruments and measuring methods all look at limited numbers of shear rates, often only one. Using the single-speed method, it is possible to obtain good pumping information of the chocolate but it doesn't give any indication of moulding performance, enrobing layer thickness or feet forming. There is no proper viscosity overview when relating measurements to practical production situations such as moulding, shell moulding and enrobing.

Table 1: *Viscosities of a 30% TF milk chocolate at 40ºC (104ºF) (Non-Newtonian substance).*

Shear rate	100 rpm	50 rpm	25 rpm	10 rpm	5 rpm	2 rpm
Viscosity	6000 Cp	6400 Cp	7000 Cp	8000 CP	12000 Cp	40000 Cp

Internationally it has been defined to measure chocolate rheology slightly above the cocoa butter melting point, at 40ºC (104ºF).

Table 2: *Viscosity of milk at 25ºC (77ºF) (Newtonian substance).*

Shear rate	100 rpm	50 rpm	25 rpm	10 rpm	5 rpm	2 rpm
Viscosity	120 Cp	120 Cp	120 Cp	120 Cp	120 Cp	120 Cp

Moulding evaluation

Out of the depositing and vibration aspects of chocolate moulding, vibration has the most crucial impact on the final product. During depositing, the chocolate moves relatively fast, while vibration makes the chocolate move quite slowly and spread out into all impressions of the mould. To properly evaluate a moulding chocolate you need to imitate this slow movement by selecting a fairly low shear rate. This low shear rate viscosity is very important and a vital point during tablet production - the lower viscosity, the better flow.

You require a rheological method that, by making one set of measurements, is going to provide sufficient information to define the type of critical chocolate speed that is needed to link to shell thickness formation during shell moulding. It also needs to imply feet forming properties, chocolate ability to flow into a specific mould design, chocolate depositing and chip forming as well as air release.

As an example, it is possible to demonstrate how two milk chocolates containing 29.8% and 34.8% total fat can still work in very different ways during moulding and enrobing production, despite having an identical single-speed viscosity at shear rate 7.0 [1/S]. In Figure 1, across, the low fat 29.8% milk chocolates seem to distribute itself better into the various moulds compared to the 34.8% milk chocolate, even though they both have same single-speed viscosity. Hence, these viscosity results do not show the actual difference in moulding performance.

Enrobing behaviours

Other forming processes such as enrobing consist of more critical chocolate speeds and is therefore a combination of different sets of flow behaviours that must be observed. In one example (Figure 2), using the same 34.8 and 29.8% milk chocolates as the moulding example above, Granola bars are enrobed under exactly the same enrobing conditions - same belt speed, curtain and blowing conditions and similar cooling. However, the low fat, 29.8% milk chocolate coats the bars with 15.6g chocolate while the 34.8% milk chocolate coats the bars with 11.9g chocolate even though both milk chocolates have same single-speed viscosity.

Figure 1: *Differences in moulding performance using 29.8% vs. 34.8% chocolate despite similar single-speed viscosity at shear rate 7.0 [1/S]*

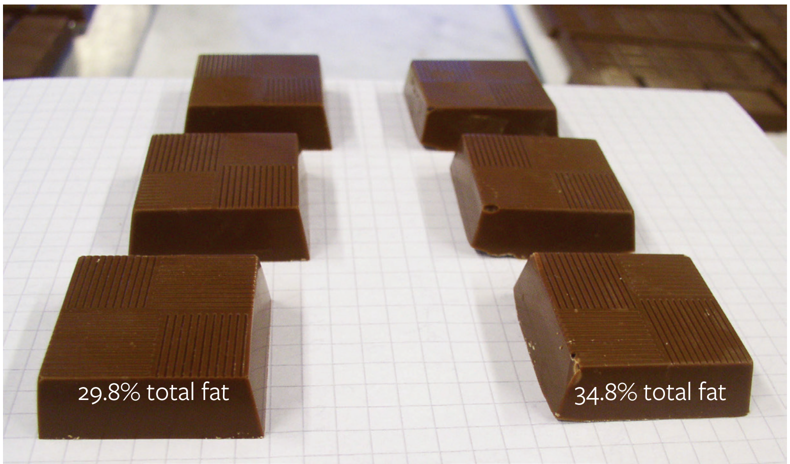


Table 3: *Viscosity data of the 29.8% and 34.8% total fat chocolates.*

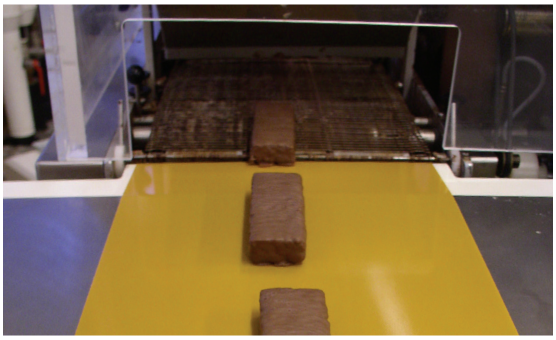
MILK CHOCOLATE	MOULDING VISCOSITY SHEAR RATE 0.54[1/S]	SPIN/PUMP VISCOSITY SHEAR RATE 7.0[1/S]	Enrobing viscosity shear rate 25.0[1/S]
29.8% total fat	64000 mPas	9800 mPas	10200 mPas
34.8% total fat	132000 mPas	10000 mPas	5500 mPas

This shows that the single-speed viscosity information does not conform to the enrobing production results. If they did the chocolate pick up should have been the same.

The enrobing viscosity (high shear viscosity) is relevant to know when layer thickness is formed by blowing excess chocolate away. After enrobing, it is possible to evaluate if the proper and expected chocolate layer is obtained as calculated and designed (weight control).

During passages of the enrobing curtain, the chocolate shear rate is medium and covers Swiss rolls in a relative thick layer of chocolate. After the

Figure 2: *Variations in coating of Granola bars using 29.8% and 34.8% fat milk chocolates despite both chocolates having same single-speed viscosity.*



enrobing curtain, the chocolate layer thickness is formed by the relative high shear rate created by the air velocity from the blower. A lower enrobing viscosity, (at high shear viscosity) ensures a thinner chocolate enrobing layer while a higher enrobing viscosity achieves a thicker chocolate enrobing layer.

The low shear viscosity is going to inform if the enrobing chocolate is going to develop feet, when travelling down the cooling tunnel. It can predict if a rippled chocolate decoration formed during blowing will stay put. If the low shear viscosity is above a certain critical minimum level, the top layer chocolate will stand up keeping it's original rippled "blowing" shape.

Flow curve measurements

Two evaluation methods provide this additional information and allow for a better understanding of practical production situations – flow curve and three-step shear rate measurements.

Flow curve measurements are a form of viscometer programming done using a viscometer with a rotational spindle and stationary cup to create a well defined chocolate shear rate. When rotating the spindle, hereby making the chocolate flow, the viscometer can detect the force required to create the flow. By selecting a series of different shear rates, the flow curve covers different production related chocolate speeds – slow, medium and fast. Different instruments have different detailed ways of doing this but all imitate a number of different critical chocolate production steps.

The force (in Pa or dyn/cm2) required to create the chocolate flow is displayed against the shear rate (speed of the chocolate [1/s] or the spindle speed: rpm). The Casson yield value is the force required to start flow of chocolate and the Casson plastic viscosity is the force required to maintain a constant flow in chocolate, also referred to as "shear thickening factor".

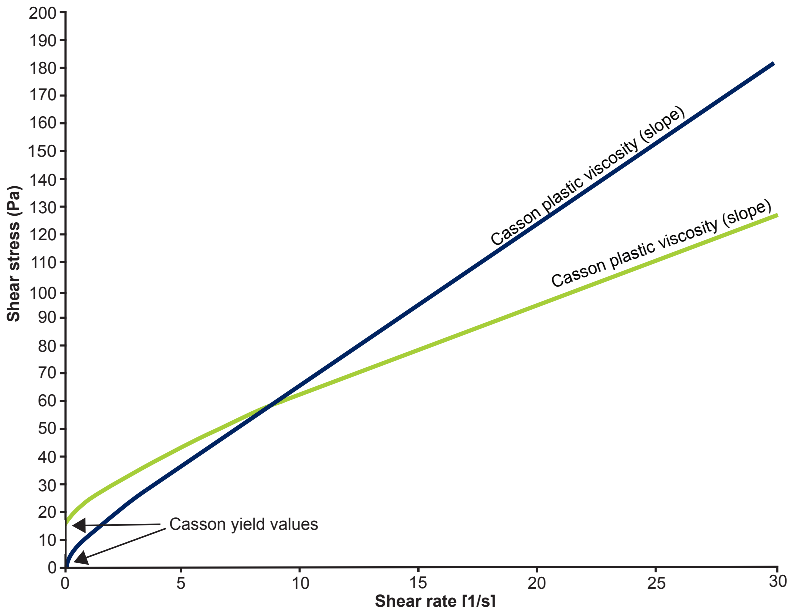


Figure 3: *2 flow curves with the same "flow" at shear rate 11.5, but very different yield values and plastic viscosity.*

The two flow curves shown in Figure 3 (above) determine differences between the chocolates: The green curve chocolate has a higher Casson "yield value" than the blue (force required to start flow). The blue curve chocolate has a higher Casson "plastic viscosity" (curve steepness), than the green curve chocolate.

The green curve chocolate is going to coat with the thinnest layer of chocolate, due to the lowest enrobing viscosity/plastic viscosity. The blue curve chocolate is going to be the most liquid chocolate in difficult tablet moulding, due to its very low yield value. It is capable to fill a very small and difficult mould at normal vibration because of its low Casson yield value. The single-speed viscosity measurement would not indicate this type of production relevant information.

The advantages of using the flow curve model is that by simply looking and comparing the graphics makes it very easy to see and understand the differences between various chocolates.

Three-step viscosity measurements

The second way of making rheological measurements is to look at apparent viscosities, at selected speeds. These shear rates imitate slow moving chocolate moves similar to chocolate during vibration (moulding viscosity at shear rate 0.54), medium moving chocolate simulates tempering, pumping or spinning chocolate speed at shear rate 7.0. Finally, a faster moving chocolate imitates blowing movement during enrobing (enrobing viscosity at shear rate 25.0). (Figure 4).

The benefit of this viscosity measurement at three shear rates is, that it often seems to be easier to explain that a moulding chocolate needs a certain minimum moulding viscosity to fill the moulds nicely without holes and defects. It is equally logical to instruct a production team that the enrobing chocolate needs an appropriate low enrobing viscosity of e.g. 8200 to 8700 Cp (mPas), in order to coat a cake with appropriate layer thickness suitable for the final product.

The impact of emulsifiers

Advanced evaluation methods also reveal more information about the true savings created by the optimal emulsifier inclusion. Emulsifiers have a strong effect on the flow behaviour of chocolate and confectionery products.

Three types are primarily used: Soy lecithin is the oldest and most well known emulsifier used in the confectionery industry while ammonium phosphatide (AMP) has powerful surface active properties. AMP often replaces soya lecithin for various reasons, such as cost in use effectiveness, cocoa butter saving, food safety and GMO status. PGPR (Polyglycerol Polyricinoleate) is used in various confectionery products as well as margarines, food emulsions, bakery release agents and in cosmetics.

Emulsifiers can be divided into two categories. Basic emulsifiers, such as lecithin and sunflower-based **Palsgaard® AMP 4455** and it's rapeseed-based twin **Palsgaard® AMP 4458**, can be included on their own as well as work in combination with other emulsifiers. Co emulsifiers, such as PGPR, don't work well when added alone to a chocolate mass and need to be used in combination with basic emulsifiers to show a positive optimal impact to the chocolate rheology.

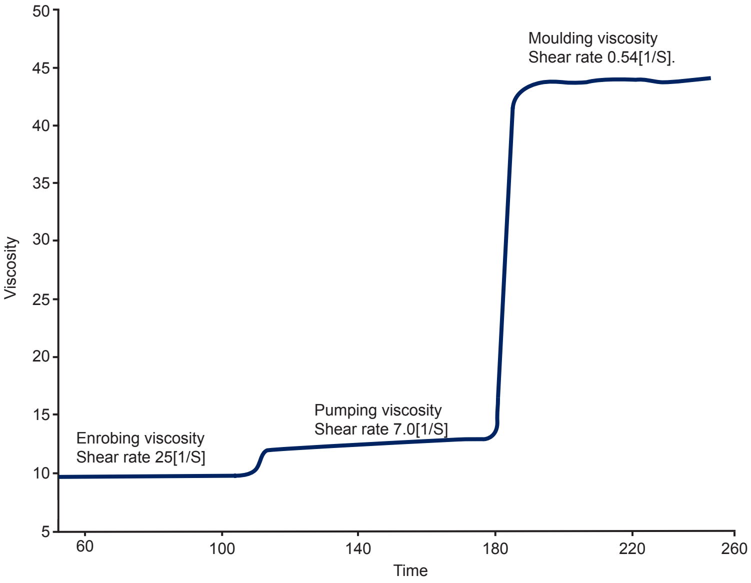


Figure 4: *The curves show: viscosity against time (at 3 different shear rates 25.0, 7.0 and 0.54 [1/s].*

Rheological effects

The effect of adding lecithin to an emulsifier free chocolate is that both the force required to start flow, the Casson yield value, and the force required to maintain that flow, the Casson plastic viscosity, is reduced. Lecithin has an optimum chocolate dosage around 0.35-0.40% and higher lecithin additions make the yield value increase.

Adding AMP to emulsifier free chocolate will reduce both the Casson yield value and the Casson plastic viscosity. Higher dosages levels of AMP will not have the undesired effect of increasing the yield value compared to lecithin. This means that a stronger effect can be achieved by using AMP and the optimal dosages is 0.60-1.0%.

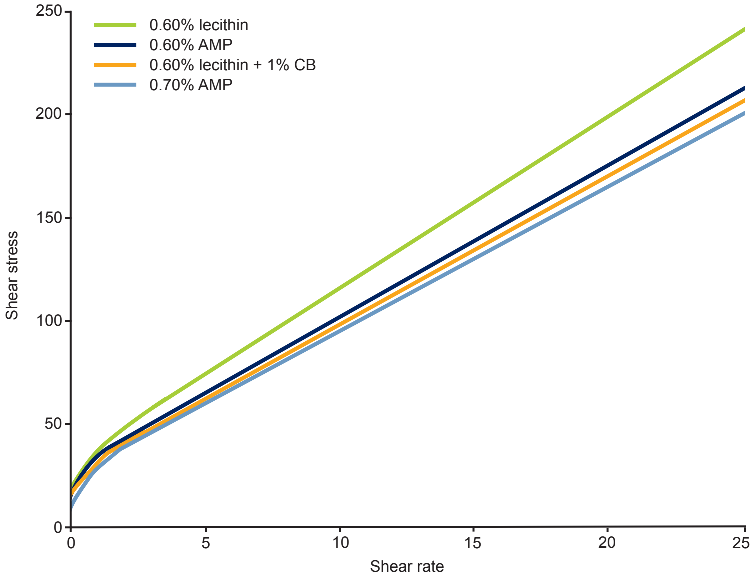
The two products do not have the same impact on the very same chocolate. The AMP reduces the

Casson plastic viscosities (the enrobing viscosity) to the lowest possible level.

The difference in Casson yield value and Casson plastic viscosity comparing addition of lecithin and AMP to milk chocolates can be expressed in yield value and plastic viscosity variations.

The contrast can also be quantified by the difference in total fat level, required to create the same rheology in the same starting chocolate. If a chocolate manufacturer producing a 29.5% enrobing milk chocolate using 0.40% lecithin wanted to reduce his chocolate layer thickness during enrobing, he could change emulsifier. A primary change from 0.40% lecithin to 0.60% AMP can reduce the enrobing layer thickness of the chocolate. AMP generally needs 2-4% less cocoa butter to create a "normal" rheology in chocolates (Figure 5).

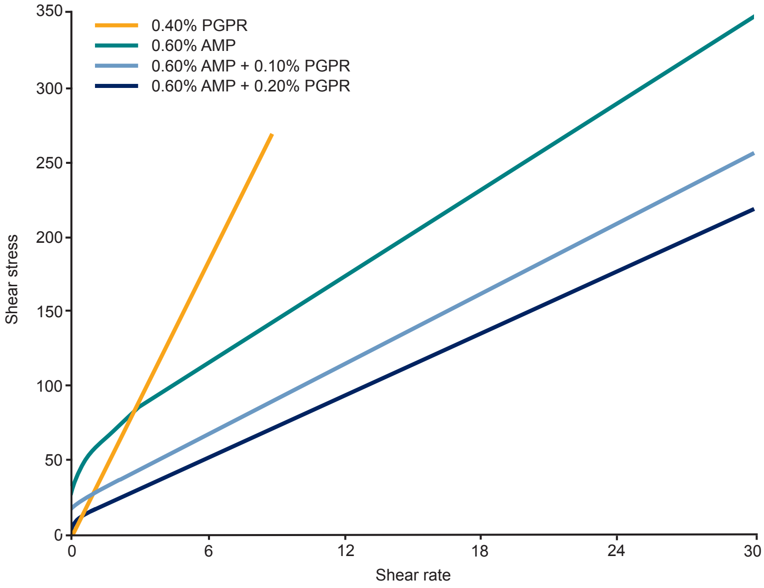
Figure 5: *The curves show the difference in emulsifier effect between chocolates based on lecithin versus AMP. The milk chocolate based on AMP requires 1.0% less cocoa butter compared to the lecithin chocolate.*



PGPR

PGPR added without lecithin or AMP is not suitable for "normal" chocolate applications (the very steep yellow flow curve in Figure 6wwww) but the graph shows that the combination AMP/PGPR creates the most effective blend, making space for significant cocoa butter reduction and that PGPR lowers the Casson yield value in an extremely effective way. By choosing the proper PGPR dosages, it is possible to achieve virtually any low yield value required. PGPR has only little effect on the Casson plastic viscosity.

Figure 6: *Addition of 0.40% PGPR to a milk chocolate clearly shows that yield value is "removed" whereas plastic viscosity is extremely high. PGPR on top of basic emulsifiers works quite well lowering the yield value whereas the effect to plastic viscosity is limited.*



Conclusion

Flow curve and three-step shear rate measuring allow for more informative chocolate measurements with a clear link from viscometer information to chocolate production. The examples shown have given clear indications as to the benefits that can be obtained, especially in moulding and enrobing.

The expanded understanding of viscosity also allows for an increased use of emulsifiers to enhance the properties of the chocolate. Lecithin, as a basic emulsifier, works well at 0.35-0.40% while AMP, such as **Palsgaard® AMP 4455** and **Palsgaard® AMP 4458**, has improved functionality at optimal dosages level of 0.60-1.0%. PGPR, such as **Palsgaard® PGPR 4190**, is a strong yield value reducing agent and has a very strong effect on low shear viscosity. The typical level of PGPR addition to chocolate is 0.10-0.30%. This ensures that many companies can make interesting economical savings working with Palsgaard emulsifiers.

Using these methods, there is a direct link from viscometer information to chocolate production and laboratory observation relates to direct production in a logical way.

Contact us to order samples of **Palsgaard® AMP 4455** and **Palsgaard® PGPR 4190** to try out in our vast library of recipes, or visit **www.palsgaard.com** for more information.

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