The Nature of Fat Bloom on Lauric Compound Coatings

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Introduction

The pressure on confectionery manufacturers to move away from high trans-containing compound coatings to either lower trans or completely non-hydrogenated fat bases is increasing as more becomes known about the effects of trans fatty acids on health. But what are the alternatives? Essentially there are four alternatives:

- Move to 'real' chocolate – but this is more expensive and also requires sophisticated tempering and processing equipment
- Move to a 'supercoating' – a coating whose fat base is essentially a cocoa butter equivalent – less expensive than real chocolate but sophisticated tempering and processing equipment is still needed
- Move to one of the new low-trans or no-trans compound coatings – the low-trans compound coatings still have an hydrogenated fat base and still contain some trans; the no-trans compound coatings overcome this issue but are still in the stage of being evaluated by the industry.
- Move to a lauric compound coating – this is the subject of this paper and one which we will therefore explore in more detail.

Lauric compound coatings

Lauric compound coatings are generally based on palm kernel oil, usually in the form of either a palm kernel stearine (PKS) or a fully hydrogenated palm kernel stearine (HPKS). Although the latter would need to be declared as hydrogenated, the fact that it is fully hydrogenated makes it effectively 'trans-free'. The advantages of lauric compounds over the other options available are (a) their price and (b) their ease of use. The disadvantage, however, is their lack of tolerance to cocoa butter. This means that formulations should have cocoa butter levels of less than 5% of the total fat phase. This in turn means that any cocoa element in the recipe must be a low-fat cocoa powder, not a higher-fat cocoa mass. If the cocoa butter level is higher than 5% there is an increasing risk of bloom forming on storage. It is the composition and nature of this bloom that can form on storage that we have been studying.

A quick re-cap

In a previous paper (1) we reported on what was the composition of the bloom on lauric compounds. In this paper we go a stage further and look in more detail at the nature of the bloom, in particular, its thermal properties and crystal structure. But, it's useful to first summarise the results we found on the composition of the bloom.

Two compound coatings were used, both of which had the same basic recipe (Table 1)

Table 1 Coating recipes

Lauric fat (PKS or HPKS)	31.2%
Cocoa powder (containing 22-24% CB)	15.1%
Icing sugar	45.3%
Skimmed milk powder	8.0%
Lecithin	0.4%

These deliberately had a higher level of cocoa butter (CB) than would be recommended in order to promote bloom formation. Bars were moulded and stored at 15°C, 20°C or 25°C for 12 months before evaluation. After this storage time the bloom was carefully removed at 20°C and analysed.

The results showed that:

- At 15°C the bloom in both the PKS and HPKS systems is considerably enriched in cocoa butter compared with the bulk composition.
- At 25°C the bloom is almost completely composed of lauric fat.
- At 20°C the bloom is cocoa butter rich but this is more predominant in the PKS coating than in the HPKS coating.
- There is a general trend of the bloom being more enriched in cocoa butter the lower the storage temperature.

Knowing what the bloom was in chemical compositional terms we turned our attention to the nature of the bloom in physical and structural terms. This is the subject of the rest of this paper.

Rate of bloom formation

Perhaps the first question to answer is – how fast does this bloom develop? This is very much temperature dependent. Chocolate manufacturers are used to the fact that chocolate itself blooms more rapidly the higher the storage temperature. In lauric compound coatings, however, the exact opposite is true. The PKS coatings bloomed after 4 weeks at 15°C but after 23 weeks at 20°C and 25°C. The HPKS coatings showed bloom after 10 weeks at 15°C and, again, after 23 weeks at 20°C and 25°C.

Physical characteristics of bloom

The physical characteristics were measured using a Perkin Elmer DSC-2 differential scanning calorimeter. Not only were the bloom samples themselves evaluated but we also looked at the underlying compound by sampling from the centre of the bars. Samples were first cooled in aluminium DSC sample pans to -20°C so that each had a specific and constant starting temperature. The melting curves were measured during heating from -20°C to 60°C at a heating rate of 5°C/minute. The melting curves are shown in Figures 1a-1d. Figures 1a and 1b relate to the samples of the compounds themselves, whereas Figures 1c and 1d relate to the corresponding bloom samples. The

first thing that is immediately obvious, simply from the shapes of the curves, is how much sharper are the melting peaks for the bloom compared to those for the compound. Looking firstly at the samples stored at 20°C and 25°C, the melting points of the bloom samples (as defined by the DSC peak onset temperature) are 2-3°C higher than the melting points of the underlying compound. Coupling this with the much sharper peaks found with the bloom samples means that the temperatures at which the DSC peak maxima occur are much the same in bloom and compound. At 15°C, however, the whole thing turns round in that the melting points of the bloom and the compound are much closer together but, again because of the sharpness of the bloom peak, the peak maximum of the bloom sample is lower than that of the corresponding compound.

A further observation that we can make relates to peaks at temperatures below those of the main peak. In the bloom samples there really are no such peaks, whereas they are quite apparent in the compound samples. This shows that the amount of liquid oil in the bloom is almost zero.

So, we can draw two fundamental conclusions from this:

- The bloom is very sharp-melting and much sharper-melting than the underlying compound
- The bloom is almost completely solid.

Structural characteristics of the bloom

The structure of the bloom was studied by means of X-ray diffraction (XRD). We expected to find some complexities in this because of the large differences in the stable crystal forms of palm kernel stearines and of cocoa butter. As is well known in the industry, cocoa butter can crystallise in a number of polymorphic forms, the most stable of which are the two β-forms, Form V and Form VI. Each of these crystal forms pack in a triple-chain configuration, that is to say the crystal 'layers' are three fatty acid chain lengths long. Palm kernel stearines, on the other hand, crystallise in a β'-form with a double-chain configuration, i.e. the crystal 'layers' are two fatty acid chain lengths long. Clearly with both fats present there is scope for considerable interaction and the formation of mixtures of polymorphs, especially in the bloom.

One of the problems with performing XRD on compounds, chocolates and even, to some extent, on bloom is the contamination of the fat with sugar. Sugar also shows XRD peaks in the same region as fat. Indeed there was some evidence of sugar being present in the bloom samples taken from storage of PKS compound at 15°C and 20°C, but not in the other bloom samples. To overcome this problem and to look at the basic fat phase we moulded bars containing only the lipid components of the formulations (i.e. PKS or HPKS plus CB and lecithin) and measured X-ray diffractograms after 24 hours at 20°C. Both were in a β'-2 configuration (i.e. β' polymorphic form with a double-chain configuration). Assuming the same thing happened in the compounds themselves then this is our start point.

As already indicated, the bloom samples themselves showed a much more complex crystal structure (Table 2).

Table 2 Polymorphic Structure of Bloom After Storage

	Bloom at 15°C	Bloom at 20°C	Bloom at 25°C
PKS/CB compound	β′ + β double and triple	β′ + β double and triple	β′ + β double
HPKS/CB compound	β′ + β double and triple	β′ + β double and triple	β′ + β double

During storage, therefore, there has been a polymorphic transition from β′-2 to a mixed β′ + β configuration. This is consistent with observations made by Noorden (2), Rossell (3) and Timms (4). Whilst we may be able to relate this transition to the mechanism of bloom formation, we are unable to say whether it occurred before, during or after the formation of the bloom.

In our earlier paper relating to this subject (1) we defined in detail the concentrations of specific triglycerides in the bloom as have been summarised above. The major triglycerides in the compositions are LLL (trilaurin from PKS and HPKS) as well as POP, POSt and StOSt (from cocoa butter). Interestingly, although we found that the fat phases of these compounds crystallised in the β′-2 form, each of these triglycerides individually are β-stable. This, then, could be the key to presence of β crystals along with β′ crystals in the bloom samples. Whilst we cannot assume that polymorphic changes always result in bloom formation, nor can we assume that they are even necessary for bloom to occur, it does appear from this work, that the formation of bloom is linked to a polymorphic change from β′ to β of triglycerides that themselves are β stable.

Control of bloom

So now we know both what the bloom is composed of in triglyceride terms and we can define a mechanism by which it is being produced. But how does this help us in terms of being able to slow down or prevent altogether the formation of bloom in lauric compounds?

Because the main triglycerides in the system are all β stable the compounds themselves which crystallise in a β′-2 form are effectively metastable. Two routes therefore suggest themselves for minimising bloom formation:

- Preserve the crystal structure in the metastable form throughout storage
- Promote crystallisation in the stable form before storage.

The latter is, with our present technology at least, unlikely to be successful. Various attempts have been made, mainly by additions of specific triglycerides, to retard the onset of bloom (5, 6). In these the addition of LLL (trilaurin) accelerated bloom formation whereas others (LML – lauric-myristic-lauric; LPL – lauric-palmitic-lauric; SSS – tristearin) did retard the formation of bloom.

Perhaps a more successful route would be to try to preserve the metastable structure throughout storage. Here, both temperature and composition can play a role. From a temperature point of view bloom occurred much more quickly when the bars were stored at 15°C than when stored at 20°C or 25°C. Ensuring that the storage temperature is not too low is therefore of importance. There is, of course, a balance to be made here between not having the temperature so low that bloom will occur within a short time and not having the temperature so high that the compound will start to soften. This is where the aspect of composition comes in.

Using the higher melting HPKS as a basis for the compound rather than PKS has two effects. Firstly it increases the temperature at which the coating will begin to soften and so allows a higher storage temperature to be used. Secondly, we saw that bloom formation, certainly at lower temperatures, was slower with HPKS than with PKS. A second, and perhaps even more important, aspect of composition is that of the level of cocoa butter used in the formulation. In the compounds studied in this work we deliberately used a much higher level of cocoa butter in the compound formulation in order to accelerate and exaggerate the effects. There was about 10% cocoa butter in the fat phases of the compounds we studied compared with a recommended maximum of 5%. Despite using this high level we saw differences and effects that can be important in defining the optimum composition and storage for an enhanced bloom-free shelf life.

Summary

From the studies reported both here and in our previous paper (1) we can make the following recommendations to maximise the bloom-free shelf life of lauric compounds:

- Ensure that the level of cocoa butter used in the compound is no more than 5% of the total fat phase – and, ideally lower consistent with any cocoa solids materials used in the formulation
- Where possible, use HPKS in preference to PKS. This may not always be possible because, whilst HPKS is effectively free of trans fatty acids, consumers may make a mental link between 'hydrogenated vegetable oil' on labels and the presence of trans.
- Use as high a storage temperature as possible within the limitation, of course, of not unduly softening the coating on storage. Ideally sub-20°C storage temperatures should be avoided.

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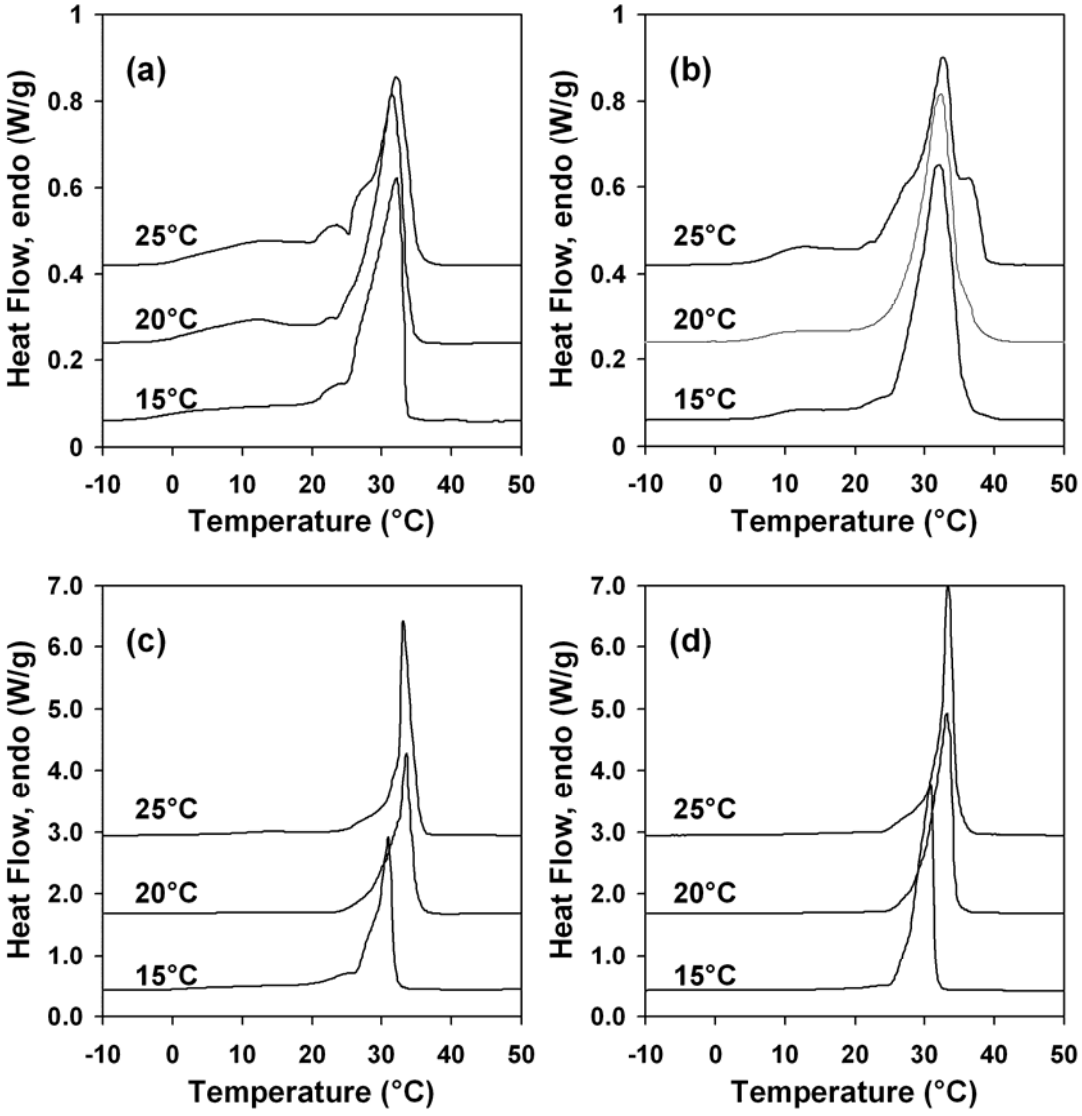

Figure 1

DSC melting thermograms of compound chocolates prepared from (a) PKS or (b) HPKS and the associated bloom, (c) PKS, or (d) HPKS after storage at 15°C, 20°C or 25°C for 12 months