Introduction

The Olmec civilization (1500 BC) was the first to transform the cacao bean into a form of chocolate. For a long time the cacao bean has been used as a foodstuff as well as currency. It also has had both religious and divine aspects. In the eighteenth century, the Europeans found it had some aphrodisiac properties (Coe & Coe, 1996). Although chocolate is no longer reserved for the elite, from a scientific point of view, chocolate still retains some mysteries. For example, bloom in chocolate, perhaps a less poetic notion but just as much exciting, is still somewhat of a mystery.

Fat bloom is directly related to the fat in chocolate products, either cocoa butter (CB) or vegetable oils. Its commercial impact is significant. Although records of its economic impact due to lost sales and rework are not revealed, most confectioner manufacturers and food manufacturers consider it an important quality defect with a significant impact on profits. There is definitely a commercial incentive to better control, minimize, or eliminate fat bloom in confections.

In this chapter, we intend to review the current knowledge of fat bloom, what it is, what causes it, and what manufacturers can do to avoid it. It is our intention to apply our current understanding of the chemical and physical properties of cocoa butter and confectionery fats, as presented in previous chapters, to understanding the possible mechanisms that may provide an actionable explanation of fat bloom formation.

More specifically, this chapter will attempt to identify causes and/or contributing factors for bloom from formulation/composition (interaction between different sources of fats, minor lipids, and interactions with non-lipid ingredients), processing (blending, tempering, depositing, cooling, packaging), and storage/distribution, and it will attempt to provide a bridge between research and commercial perspectives to gain an improvement in manufacturing practices and identify technical gaps that require additional research.
Definition and Characterization

A glossy to matte surface is universally accepted as an important attribute associated with quality chocolate and confectionery coatings, “glossy” most likely having a greater acceptance by consumers than matte, but matte being within consumers’ range of acceptability. The crystalline properties of the fat system directly impact structural properties that impact surface appearance. Generally, small crystals that provide a homogeneous crystalline network, or structure, impart a reflective surface to confections. A change in structure which imparts a visual change in appearance from glossy/matte to dull and rough is what is known as bloom. A change in sugar structure can also impart a bloomed appearance in confections, however this chapter will cover only bloom related to changes in structure related to fat.

Bloom can vary in appearance from dull to gray to white. Bloom may appear as spots, streaks, irregular shapes, or marbled. The bloom areas may be dark brown or light brown in addition to white. Kinta’s chapter on The Morphology of Chocolate Fat Bloom provides an excellent overview on characterizing and classifying different types of bloom as well as identifying their underlying causes.

In addition, Fig. 7.1 provides examples of Type 1, and Fig. 7.2 examples of Type 2 Bloom.

The products with Type 1 are compound coatings. Sample A bloom development after 1 year storage, Sample B is bloom development from scuffing. Fig. 7.2 shows a sample of cocoa liquor, or mass, cooled slowly after 1 year storage at room temperature.

While there is no data to support which bloom has the greatest commercial impact, an informal survey of industrial and retail confectioners encounter Type 1 more frequently. Type 1 bloom is generally associated with incompatible fats (either from the product formula or inadvertent comingling of fats or products during processing), oil migration, mild temperature abuse during distribution, and oil migration. These factors will be discussed more thoroughly in the chapter.

Fig. 7.1. Confectionery wafers with bloom.
Generally any change in surface appearance, any change consumers believe to be unacceptable, which is due to a change in fat structure, is considered bloom.

Our analysis indicates less than 1.5% of the formula fat is in the bloomed fraction in heavily bloomed confections and chocolates, in which the confection surface is 90% covered in a Type 1 bloom (Sample A in Fig. 7.1). Very little of fat needs to be altered or participate to have a significant impact on structure and product appearance.

Type 1 bloom observed by the naked eye appears to a variation of intensity of the same event—dull surface to definite white crystalline material. However, scanning electron microscopy (SEM) reveals bloom to have many forms, generally related to the mechanism that formed the bloom conditions which is influenced by composition of the confection, processing, and/or storage conditions.

Fig. 7.3 (Lechter, 2010) is an SEM of compound coating at 300× with no apparent bloom to the naked eye.

Fig. 7.4 (Lechter, 2010) is an SEM of a compound coating stored over a long period of time under undocumented conditions which developed a heavy bloom surface. The difference between surface structure in Figs. 7.3 and 7.4 is obvious. At higher magnification [Fig. 7.5 (Lechter, 2010)] some of the structures, observed in Fig. 7.4, resemble volcano tubes. This observation supports Kleinert’s description of bloom in 1962 as a migration of liquid fat to the surface by capillary action and recrystallization.

Similar observations of this type of bloom mechanism were observed by Rousseau & Smith (2008) and Wang et al. (2010), contributing both diffusion and nan-pores, inherent to the confections microstructure, as mechanisms for transferring liquid fats to the surface.
Fig 7.3. Confectionary fat with no visible bloom (Lechter, 2010).

Fig. 7.4. Compound bloom (with cocoa butter present). Long storage time uncontrolled conditions. Heavy bloom on surface 300×.

Fig. 7.5. Compound coating (with <4% cocoa butter present). Long storage time uncontrolled conditions. Heavy bloom on surface 1200×.
How and why liquid fat migrated to the surface can be explained by many factors which will be discussed later in this chapter.

The SEM of bloom on fully hydrogenated palm kernel (FHPK) is shown in Fig. 7.6 (Lechter, 2010), and bloom on fractionated palm kernel oil (FPK) is shown in Fig. 7.7 and Fig. 7.8 (Lechter, 2010).

Both products were cycled under controlled conditions between 65°F and 80°F for 1.5 months (six days at 65 and one day at 80°F). To the naked eye the bloom in all three samples, compound with cocoa, FHPK, and FPK appear the same. Under SEM magnification, the morphologies are significantly different. Since both fats were chilled and cycled under identical conditions, it may be safe to infer the surface

**Fig. 7.6** Fully hydrogenated palm kernel oil following 2 months cycling. Visible bloom, smooth to dull surface 600x.

**Fig. 7.7.** Fractionated palm kernel oil following 2 months cycling. Visible bloom, heavy haze on surface 600x.
structures developed are characteristic of these fats. In Fig. 7.9 (Lechter, 2010) the temperature cycle is boxed over the SFC of each fat.

While neither fat completely melted during temperature cycling, a significant level of partial melt most likely occurred, allowing sufficient liquid to accumulate at the surface and recrystallize upon re-cooling. Through each cycle the TAG population of

![Fractionated palm kernel oil following 2 month cycling conditions. Visible bloom heavy haze on surface 1200×.](image)

**Fig. 7.8.** Fractionated palm kernel oil following 2 month cycling conditions. Visible bloom heavy haze on surface 1200×.

- Isothermal conditions at 65°F
- Cycling conditions between 65°F and 80°F for 1.5 months. (6 days at 65°F, one day at 80°F)

![Storage conditions and cycling conditions.](image)

**Fig. 7.9.** Storage conditions and cycling conditions.
the melted phase changes based on the TAG population available to participate in the partial melt. Likewise, the TAG population that is recrystallized on the surface also based on the pool of TAG in the liquid phase available to recrystallize on the surface. It appears that crystallization occurring after each cycle builds onto the crystals developed after the first cycle, versus developing new groups of crystals.

**Compositional Analysis of Bloom**

Comparison between the fatty acid composition analysis of the base fats and bloom of FHPK (Fig. 7.6) and FPK (Fig. 7.7) indicate a modest increase in shorter chain fatty acids in the bloom fat versus base fats and slight decrease in longer chain fatty acids (Table 7-A).

Results suggest the bloom is the result of the melting and recrystallizing of lower melt TAG generated by the recycling storage temperatures. Although the change in fatty acid composition was modest, the impact on microstructure and bloom was significant. This example is to reinforce that only minor changes can have a dramatic impact on microstructure and visual appearance.

It should be emphasized that most commercial bloom is not the result of a polymorphic transition. Specifically, chocolate bloom is not the result of the transformation from Form V to Form VI. Rather, polymorphic change is the consequence of a physical change in the microstructure that preceded the polymorphic transition. Bricknell & Hartel (1998), Wang et al. (2010), and others have demonstrated that while bloom crystals may be in a more thermodynamically stable state, it is the result and not the cause for the change in the physical structure. Form VI polymorph can exist in chocolate without bloom.

**Table 7-A. Comparison between Fatty Acid Composition Analysis of the Base Fats and Bloom of FHPK and FPK.**

<table>
<thead>
<tr>
<th>% FAC:</th>
<th>FHPK</th>
<th>FPK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base</td>
<td>Bloom</td>
</tr>
<tr>
<td>C8:0</td>
<td>3.5</td>
<td>4.7</td>
</tr>
<tr>
<td>C10:0</td>
<td>3.3</td>
<td>3.8</td>
</tr>
<tr>
<td>C12:0</td>
<td>46.3</td>
<td>46.1</td>
</tr>
<tr>
<td>C14:0</td>
<td>15.6</td>
<td>15.3</td>
</tr>
<tr>
<td>C16:0</td>
<td>8.6</td>
<td>8.3</td>
</tr>
<tr>
<td>C18:0</td>
<td>21.4</td>
<td>19.8</td>
</tr>
<tr>
<td>C18:1</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>C18:2</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Total</td>
<td>99.0</td>
<td>98.4</td>
</tr>
</tbody>
</table>

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Overview of Key Attributes in Confectionery Fats

Before discussing the causative factors for bloom, it may be important to review why confectioners use the fats they do use in chocolates and compound coatings. Why use fats that have a potential to bloom?

What does fat provide in confections (chocolate and compound coatings)? What are the important attributes/properties of a fat or fat system in confections? Not necessarily in the order of importance they include the following:

1. Melting properties—the ability for a fat to go from a solid to liquid quickly at body temperature is a key attribute. This imparts desirable sensory sensations of an audible snap, mouthfeel, and quick flavor release. Only a few fats deliver this unique property, cocoa butter recognized as having ideal melting profile for confections and setting the traditional standard for confectionery fats. Like butter set the standard for table spreads, cocoa butter established the melting standards most people associate with fine confections.

2. Solidification properties—as important as melting is to the consumer of chocolates, solidification properties are as equally important to the confectioner. Instant solidification is not necessarily a desired attribute. Especially if the confection is to be formed in mold or enrobed onto another material. There is a need for confections to solidify within an optimum time, that time being dependent on the application. The rate of solidification is key to delivering confections in a preferred form (bars, truffles, bunnies, enrobed snack cakes) is extremely important. Confections that solidify too quickly may not provide an even coating over a truffle, or may not completely fill all the crevices in a novelty mold to capture the detail of the novelty item. Confections that solidify too slow may flow off a truffle and not provide an even coating or take too long to solidify in a mold increasing production costs by slowing down production rates.

3. Crystal size/shape—crystal size is important from a sensory requirement to impart a smooth mouthfeel. Small fat crystals develop a microstructure that imparts a glossy and smooth surface appearance, also a critical attribute for meeting consumer acceptance and expectations. Small crystals and resulting microstructure are important for capturing and stabilizing small amounts of liquid fat and other solid particles dispersed in the confection matrix (sugar, cocoa, and dairy solids).

4. Level of solids—minimum level of solids, in addition to optimum size and shape, are required to provide sufficient structure to capture and hold the dispersed solids, provide sufficient rigidity to maintain structural integrity through distribution, deliver a “snappy” texture, and provide a pleasant mouthfeel.
5. Stability—ability to not change over time, or minimize changes that effect microstructure is critical and highly desirable. Most bloom is a result of two stability issues. One, not achieving an optimum or critical level of stable crystals during manufacturing. Two, intolerant to fluctuations in temperatures during storage and distribution (melting and recrystallizing into an undesirable crystal form within a narrower range than the range of temperatures encountered during distribution).

6. Marketing/Economics—the fats must be within defined or implied standards of identity for a confection, must have sufficient supply to be sustainable and economical, and must meet consumer’s perceived requirements and government’s regulatory requirements for health, nutrition and safety.

Meeting all these attributes at some minimum level is required for a fat to be used in confections. All of the attributes are interrelated. Changing one most likely impacts another. From a commercial perspective it would be difficult to assign priorities.

No fat in their natural form excels in all the attributes. While cocoa butter sets standard for melting and textural attributes, it is not tolerant to temperature change during distribution and has this polymorphic property that makes maintaining structural integrity over time a challenge.

Causes

Fat bloom is a broad term to cover a multitude of changes in appearance in confections related to structural changes in the fat system. Fat bloom is not always the consequence of a single factor or single mechanism. It can be due to a specific factor and it can be due to multiple factors and interactions of multiple factors. This is why identifying a definitive mechanism for bloom and controlling bloom has been a mystery for as long as we have had chocolate confections.

Very broadly and in very general terms, bloom development is related to several internal and external factors.

The internal factors may include the following:

1. Interaction and incompatibility between fats or major TAG populations within the confectionery fat composition. Negative interactions from using/ blending fats not completely compatible with each other, that is, fats that disrupt each other’s crystallization/solid behavior (from super saturation, nucleation, growth, networking, and development of microstructures) may be considered incompatible fats. In reality, all fats and major TAGs within a fat influence behavior or other fats, it is a matter of degree which separate compatible and incompatible fats. Also an area which requires further clarification and more exact science based definitions.
2. A fat system's inherent sensitivity to changes in temperature and fluctuations in temperatures, resulting in melting and recrystallization or changes in polymorphic form. Both resulting in a change in the overall crystal structure and microstructure and development of bloom on the product surface.

3. Ineffective or excessive levels of minor lipids, emulsifier, or crystal modifiers and/or ineffective methods for incorporating minor lipids into the product during blending and melting.

4. Improper or sub-optimal heating and cooling during blending, tempering, depositing, or final cooling that produces a sub-optimal crystal network/structure which reorganizes itself over shelf life, alter the microstructure or surface structure of the confection which develops into bloom.

5. Scuffing, physical damage, to the cooled confection or product application. A disruption to the confectionary surface stimulating changes in crystal growth behavior leading to changes in microstructure and surface structure which develops into bloom with time.

The external factors may include

1. Physical properties of the non-lipid ingredients; size, shape, and surface chemistry of sugar, dairy solids, cocoa solids.

2. Oil from fats or oils within other components of the confection (fillings) or other fats or oils from other components in a food made with the confection (enrobed snack cake) that migrate and recrystallize on the surface as bloom, or co-mingle with confectionery fats and recrystallize on the surface as bloom.

3. Storage temperatures and fluctuating temperatures.

Any factor, chemical, physical, or environmental, that disrupts the structural integrity of the chocolate/confection lipid microstructure over time has the potential to create a bloom condition.

Because more than one factor can be responsible for a bloom situation, discussions of each session will require some overlap. It is nearly impossible to discuss factors independently and without being redundant.

**Key Factors Contributing to Bloom from Composition to Oil Migration**

**Composition**

Composition will include the ingredients commonly used in confections: cocoa butter (CB), cocoa butter substitutes (CBS), minor lipids (milk fats), non-lipid particles (sugar, cocoa powder, dairy ingredients).
Two main composition problems tend to induce bloom. The first is when two “incompatible” fats are used in a chocolate or coating. The second composition problem occurs when the coating comes in contact with a filling, inclusion or nut having a lower solid composition allowing for fat migration.

**Use of “Incompatible” Fats**

It is important to differentiate incompatibility of fats due to dilution effects from problems due to eutectic mixing behavior (Bigalli, 1988). When two fats are compatible but have different melting points, a dilution effect is observed where the decrease in solid fat content is proportional to the amount of low-melting component added. An example of two compatible fats used in chocolate are a Malaysian cocoa butter with a “high” disaturated TAG content and solid fat content (SFC) and a Bahian cocoa butter with a “low” disaturated TAG and SFC content (for cocoa butters). When blended together the SFC of the blend is very close to the values contributed in proportion to the parent butters (Fig. 7.10).

In this example rate of solidification (ROS) was used to measure crystal behavior and monitor compatibility or incompatibility between fats. More commonly melt points, solid fat content or DSC melt curves are used to monitor compatibility. The DSC being the preferred method, and best method of the three to determine a true eutectic condition.

**Fig. 7.10.** Rate of solidification curves of cocoa butter from Malaysia, Bahia and a 50/50 blend.
However, from a commercial perspective, monitoring crystal behavior by ROS provides the confectionery manufacturer valuable information on rate of solidification development in addition to melt and total solids at a given temperature. From a commercial perspective ROS can be as important as SFC and melt point because solidification rate impacts processing time and capabilities. A fat with a slow ROS may require reduce production rates to ensure crystallization is complete through processing, even though the fat after complete crystallization will contain a minimum level of solids deliver sufficient structure to the finished product.

In contrast to the compatible fats, when truly incompatible fats are mixed together, they tend to separate from each other and the solid fat content decreases below that of either individual fat. The concentration at which the two fats separate determines the limits of solubility. Below this concentration, the fats are compatible, but above this concentration, the fats are incompatible and tend to separate. To observe a true incompatibility, both fats must have a certain SFC (at the studied temperature). Two such blends can contribute to bloom formation in chocolates and coatings. Fig. 7.11 is an ROS of blend of fats that incompatible and the theoretical ROS based on the solids

**Fig. 7.11.** Rate of solidification curves.
from each component fat in proportion to their percentage in the blend. In this example the sample is a blend of 70% fractionated palm kernel oil with palm mid fraction and 30% pressed cocoa butter from Ghana (FFA under 1.5%, and DAG under 2.0%).

The data shows the ROS of the actual blend is significantly lower than the calculated contribution from each component, but also lower than the solids from the contribution of the PKS/PMF component. Most likely these fats are forming a eutectic and meet the commercial criteria for being incompatible.

**Cocoa Butter (CB) with Cocoa Butter Substitutes (CBS).**

Coatings made with hard lauric butter, or combination of hard lauric butter and palm oil fractions (may include palm stearines and or palm mid fractions), are very sensitive to the presence of cocoa butter (Hogenbirk, 1988; Noorden, 1982). A eutectic is formed at very low addition levels of CB to CBS. In addition to softening of the mixture, the blend of these two fats promote bloom formation. A cocoa butter concentration above 4% can result in a bloomed product in a few months and that time drops to less than a week when the concentration is around 10% (Hogenbirk, 1988). If the proportion of C in CBS is very high, bloom could appear in less than two days (Sequine, 2001). Moreover, in a study comparing fully hydrogenated palm kernel oil/cocoa butter, FHPKO/CB and fractionated palm kernel oil/cocoa butter, FPKO/CB blends, Williams et al. (1997) showed that blends with higher SFC had faster bloom formation. The softest compound coatings, so the most affected by the fat incompatibility, were not the most affected by bloom. This effect remains to be explained.

**Key Factors from Other Components/Ingredients**

I highly recommend reviewing each of the following chapters in this book for greater detail on other components in confections and their potential impact on bloom:

- Talbot – *Chocolate and Cocoa Butter—Structure and Composition*
- Smith – *Confectionery Fats*
- Garti, Asein – *Effect of Emulsifiers on Cocoa Butter and Chocolate Rheology, Polymorphism and Bloom*
- Metin, Hartel – *Milk Fat and Cocoa Butter*
- Lechter – *Effects of Minor Components on Cocoa Butter Polymorphism and Kinetics of Crystallization*
- Svanberg – *Non-Cocoa Ingredients in Cocoa Butter Crystallization*

In addition to the components discussed in other chapters, Nakae (2000) demonstrated glycolipid fractions (mono-, di-, and tri-galactosyldiacylglycerols) added at 2% in place of lecithin could inhibit bloom in dark and milk chocolates in accelerated
tests (25 cycles, 12 hours at 32 and 20°C, per cycle). While the inclusion of these materials are not compliant with standards of identity of chocolate in many countries, and may not provide a commercial solution for bloom within chocolate standards, the impact of glycol lipids on bloom of non-standard products and compounds may provide an economic advantage and should be studied further.

Summary Compositional Factors that Impact Bloom

The goal in making a traditional chocolate-like confection is to entrap in a fat crystal matrix, sugar, cocoa powder, dairy solids (optional), and a little vanilla or other flavoring, with emulsifiers added to improve the rheological properties and/or reduce fat. The physical, structural, melting properties of the final product are a result of the interactions of all the ingredients and how they impact the crystal/solidification behavior of the primary TAGs.

Not only do minor changes in TAG profiles impact crystal behavior, by blending fats together, the minor ingredients inherent in these fats (the phospholipids, diacylglycerols, fatty acids), the emulsifiers, and solids (amount, particle size, distribution and surface chemistry) found in the composition of the confection influence and impact crystal behavior. And their influence/impact may take place at different points along the sequence of crystallization/solidification—supersaturation, nucleation, growth and microstructure. And any change to a fat’s supersaturation, nucleation, growth, and microstructure can impact its response to tempering, cooling, and storage conditions, resulting in a change in structure and potential bloom development.

Advice to the confectioner: proceed with caution when making changes in composition based upon conclusions from research that examines single ingredients or variables.

Processing

In this section we shall review processing steps after the confectionery ingredients are refined and conched or liquefied, and ready to convert from a liquid state to a solid state. The process I will review can be followed in Fig. 7.12, beginning with blend tank, supply tank, tempering and/or dynamic cooling, depositing, final static cooling/solidification and packaging.

Blending and Supply Tanks

Maintaining minimum temperatures to avoid pre-crystallization is critical. Generally, maintaining confection slurries above 50°C for compounds and above 43°C provides sufficient temperature to inhibit crystallization of the base fats and minor lipids (crystal modifiers, stearines) over 24 hours, provided the minor lipids were fully melted prior to incorporation into confectionary fat or confectionery slurry. Best manufac-
Minimizing Bloom in Confections

Manufacturing practices generally require blending higher melting lipids together with a portion of the confectionery fat (no less than 50/50) prior to incorporating the minor lipid into the remaining confectionery fats or confectionery slurry. Crystal modifiers and stearines are most effective if they are completely melted and incorporated into the fat phase prior to blending with other confectionery ingredients. Failure to completely melt the crystal modifiers and/or stearines can influence development of sub-optimal crystallization during cooling and solidification, which may lead to early blooming.

Some manufacturers add rework to the supply tank, which is generally an acceptable practice providing sufficient time and temperature are applied to thoroughly melt, erase the crystal memory or any of the lipid components. The minimal time temperatures must be determined by the manufacturer based on the product components and heat transfer efficiencies of their equipment. It will vary from formula to formula and from process to process.

Tempering/Dynamic Cooling

Tempering chocolate. Chocolate must be tempered to control the polymorphism of cocoa butter (Dimick, 1991; Gerhard, 1979; Jocanovic et al., 1995; Kempf, 1949).
The melted chocolate undergoes a temperature cycle to induce the formation of nuclei in Form V (and also to destroy the other unstable forms). The addition of seed is also used to induce the crystallization step. New tempering methods used Form VI cocoa butter seed. It facilitated greatly this step that is less sensitive to temperature fluctuation, quicker and gives even better final quality (Zeng et al., 2002). The seed crystals formed during tempering permit the surrounding liquid TAG to crystallize quickly in the right polymorphic form (Kleinert, 1965, 1970). Effectively, it is more favorable for TAG to attach to a growing crystal face than to find sufficient energy to create new nuclei (Seguine, 1991). When the seed crystal concentration is sufficiently high (0.5 to 2% total mass), the chocolate can be used for the production of deposited free-form, molded, coated, or enrobed products.

**Under-tempering chocolate.** Chocolate is considered to be under-tempered when the concentration of nuclei is not large enough to ensure a good crystallization of chocolate mass upon cooling. In this case, the crystallization time increases drastically since nucleation must occur rather than crystal growth. Furthermore, if new seeds are spontaneously generated during cooling, they form in an unstable polymorph, and re-crystallization problems can occur. In such cases, bloom occurs relatively quickly, often in less than two days, and causes a drastic modification of the surface, which appears as large white spots and/or white rings surrounding a black and glossy center.

**Over-tempering chocolate.** The term over-tempered is used when the seed concentration in the melted chocolate mass is too high. The seed concentration may increase due to excessive tempering time. In this case, the extent of crystallization in the mold is not sufficient to produce the desired mass contraction. The molded surface is not bright and the unmolded surface turns a gray dull very quickly (Hettich, 1966).

**Cooling compounds.** Since compound coatings made with CBS crystallize directly in the most stable form, beta prime, they do not need to be tempered prior to cooling. However, some companies choose either to add a nucleating agent (like fully hydrogenated oils) or temper to ensure complete and proper crystallization of lauric-based coatings.

Because it is becoming popular to make compound fats from combinations of lauric fats and palm mid fractions, tempering to optimize crystal stability maybe required. This is dependent on the ratio of the component fats and compatibility of the resulting TAG population.

**Depositing**

Impact on bloom during depositing is generally a result of inadequate melting of recirculated product back to the supply tank, or developing a build-up of solids on the depositing equipment which comes in contact with fresh product.
Generally, chocolate and compounds are deposited slightly above their crystallizing temperature to ensure that crystallization occurs immediately upon static cooling. As a result, some material that is either not deposited, or during enrobing or bottoming, is the excess material required for adequate coverage but does not remain on the product being covered. It is the overrun material which is recirculated back to the supply tank. The crystals formed in the recirculated product and residual “build-up” is not likely to be in a stable crystalline form and may influence undesirable, sub-optimal crystal behavior, eventually resulting in bloom after packaging and well into distribution. Recirculated product must be thoroughly melted upon return to the supply tank, and residual build up on equipment must be monitored and controlled.

**Static Cooling/Solidification**

The product is cooled statically through a cooling tunnel before storage to ensure complete solidification of the confectionery fat. Proper temperature control during cooling is critical to growth of seed crystals in tempered chocolate.

For chocolate, the cooling rate is also an important issue in preventing bloom formation. Cooling too fast may induce crystallization of unstable crystal polymorphs as well as formation of hair cracks and pores on the surface. Both effects could promote further bloom. Homogeneous heat release, which occurs through the inside, as well as from the outer layer, is the best way to avoid any tension on the chocolate surface and consequently, reduce subsequent bloom [79].

Additionally, if the cooling tunnel temperature is too low it may shift the crystallization to favor nucleation of undesirable, unstable polymorphs, versus crystallization and growth influenced by the desirable polymorphic crystals developed during tempering.

In general, trying to increase production by decreasing the tunnel temperature is not a good idea. It will promote unstable crystals that are more likely to bloom.

Common practice is to begin cooling under moderate cooling (60–65°F) during the first stage of the cooling tunnel (generally the first third), followed by lower temperatures (45–50°F) during the second stage, and slightly warmer cooling temperature (55–60°F) during the third stage to avoid condensation upon exiting the tunnel. Generally 12 to 15 minutes is adequate for cooling.

However, optimum cooling conditions is really product and equipment-design dependent, and a best operating conditions and procedure must be developed for each product with the equipment manufacturers.

Changes in formulation/composition that change supersaturation, nucleation, growth, or microstructure (crystallization behavior) will change tempering and cooling parameters and conditions.

For coatings, the cooling rate must be sufficient to insure complete crystallization (Hogenbirk, 1988; Sequine, 2001). Generally the lower the tunnel temperature and the shorter the cooling time, the better the bloom resistance (Wennermark & Carlsson, 1994).
Packaging

Although most of the heat of crystallization is removed during the static cooling, the product surface is very vulnerable to scuffing or smearing. This is especially a concern when demolding bars or novelty figurines, and conveying wafers, drops, chips, and chunks.

Scuffed product will bloom and must be avoided or minimized during the packaging process. Even product to product contact is sufficient to scuff the outer layer and initiate bloom. The wafer B in Fig. 7.1 is an example of bloom that can occur from scuffing. Some manufacturers will apply a mild heat treatment to the cooled product prior to packaging to increase bloom resistance. The heat treatment will be dependent on the melting characteristics of the confectionery fat, but generally sufficient heat is applied for a minimal time to eliminate the cracks and crevices generated from scuffing. A more detailed explanation to the mechanics is provided in the next section.

Distribution and Storage

Keeping storage temperatures below the melting point of the confectionery fat is not sufficient to prohibit bloom. Because of the narrow melt range of confectionery fats and the significant impact of slight changes in temperature on solid content it is difficult to make recommendations of maximum temperatures for confections.

Generally colder is better; keeping chocolates and compounds under 65°F is recommended to minimize bloom.

Chocolate Storage

For chocolate, three ranges of storage temperature can be distinguished, each with different bloom propensity. The same temperature ranges were also applicable for filled chocolates (Adenier et al., 1975; Ali et al., 2001; Wooton et al., 1970).

Low Temperature Chocolate Storage (<18°C)

Cebula and Ziegleder [88] reported that storage below 18°C inhibited storage bloom in chocolate over 1 year. The storage of chocolate at low temperature generally minimizes bloom formation; however, even if the storage temperature is low, bloom can occur after more than one year.

Medium Temperature (18 < T < 30°C)

In this range of temperature, which is below the melting point of Beta V crystals, bloom occurs more quickly with an increase in temperature.
High Temperature (32–34 °C)

When temperature goes sufficiently high, the cocoa butter is partially melted. Upon subsequent cooling, the cocoa butter crystallizes uncontrolled, in unstable polymorphic forms. This is a similar cause for bloom as in under and untempered chocolate: low seed concentration and unstable polymorph. Thus bloom will occur very quickly after crystallization and the chocolate will exhibit large white spots.

Compound Coatings

For compound coatings, the effects of temperature storage is more confusing. It has been suggested that storage temperatures slightly lower than room temperature, about 18°C, promotes the most rapid bloom formation in compound coatings. Storage temperatures either higher or lower give better bloom stability.

A study by Smith (Smith et al., 2004) indicates compound coatings made with fractionated palm kernel (FPK) and fractionated and hydrogenated palm kernel (FHPK), both containing 10% cocoa butter in the fat phase, developed bloom significantly faster when stored at 15°C versus 20 and 25°C. The FPK developed bloom within 4 weeks at 15°C, compared to 23 weeks at 20 and 25°C. And FHPK developed bloom in 10 weeks at 15°C compared to 23 weeks at 20 and 25°C. They demonstrated that bloom is not due simply to separation of the PK and CB components and is temperature dependent. The bloom developed at 15 and 20°C, contained more CB TAG, whereas the bloom developed at 25°C was predominantly from lauric fat.

Fluctuating Storage Temperatures

Fluctuating temperatures, even if the range of temperatures is within a “high” solid content of a confectionery fat, can change the microstructure sufficiently over repeated cycles to induce bloom. Temperature gradients within the confection (the surface see higher temperature fluctuations, which are dampened in the interior) lead to a driving force for liquid TAG to move to the surface. As temperature increases, the amount of liquid TAG increases as does the volume of the system (in reverse, there is a contraction as more fat crystallizes upon cooling). The liquid TAG are pushed (or pumped) through the confection to the surface due to this dilation effect. When the temperature decreases again, not all of the liquid fat is reabsorbed back into the chocolate matrix, leaving a “pool” of liquid fat near the surface. One of the key points in bloom formation is the surface state and whether the liquid fat actually crosses to the surface. As long as the surface of the confection remains smooth, compact and free of defects like scratches or crevices (scuffing), the liquid fat does not cross the surface, as seen in the NMR results of Guiheneuf et al. (1997), and bloom may be delayed. Once the surface loses its impermeability, liquid fat easily crosses to the exterior of the piece and re-crystallizes.
Oil Migration

Migration of liquid fat from a center into a chocolate or coating occurs due to the concentration difference in specific TAG between the coating and center (the same driving force as for any mass transfer situation). Diffusion of TAG, from center to coating and from coating to center, occurs due to this concentration driving force. However, capillary forces may also draw liquid TAG from center to coating. Once the liquid TAG from the center are absorbed into the coating, the two fats mix according to their phase behavior. Whether due to dilutional softening or a eutectic formation, the solid fat content within the coating occurs as some of the fat crystals in the coating dissolve in the liquid TAG. The dilution of CB crystals leads to a softer coating with more liquid TAG with greater mobility that are more likely to re-crystallize into a more stable polymorph, initially at the surface, and appear as visible bloom. Once fat migration and softening occur, the bloom mechanism is similar to that which occurs in storage bloom.

The rate of migration of liquid TAG may be influenced by numerous factors, including the hardness of the fat (change in liquid fat with temperature), the particulate structure (sugar, cocoa solids, milk solids, etc.), emulsifier interactions and the porosity of the confection (cracks, crevices providing access to the surface and capillary forces) (Ziegleder, 1997). Thus, increased porosity of the chocolate due, for example, to crack and crevice formation from cooling too quickly, results in immediate migration of liquid fat to the surface and rapid onset of bloom.

Conclusions

There are many internal and external factors that contribute to bloom in confections. Generally not a single factor is responsible but generally a combination of factors in commercial processes that influence a sufficient change in microstructure to develop a bloom condition.

Based upon the multiple possible factors for bloom, when trying to identify a cause, it is important to review the entire process, from formulation through distribution to identify the causes and take appropriate corrective action.

From a commercial perspective, we tend to view fat bloom as a product defect, although it is not a defect of the fat, it is simply the fat reacting to its environment to reach a preferred state of equilibrium.

My greatest learning from writing this chapter is fat bloom cannot be studied as an independent event that occurs in confections. Each ingredient and process step influences crystal behavior (supersaturation to nucleation to growth and microstructure). While we understand the influence of many individual components, there is still more to learn about the interactions between components and their interaction and influence on the confectionery fat.

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References


Lechter, A. Fat bloom in palm kernel oil based confectionery coatings. Paper presentation at AOCS annual meeting, May 19, 2010.

