The materials science of pleasure

Understanding the behavior of chocolate is a materials science problem and, as usual, the key is the structure-property relationship.

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In the 1980s there was a TV advert in the UK featuring a woman having a terrific time in a bath. I was young at the time, and baths did not fill me with the kind of delight that this woman was experiencing. For me, baths were functional, usually slightly cold, and only occasionally jolly when I was allowed to bring along my toy submarine. The woman on the TV didn't have toys of any kind but instead was equipped with some confectionary. Nevertheless, every time she put some of it into her mouth, waves of contentment seemed to flow over her that would then overflow into the purest pleasure. I realized that I had never experienced this kind of emotion, let alone in a bath. So began my fascination with chocolate.

> **Chocolate is no less remarkable and technically sophisticated than semiconductors or steels**

My experiments to reproduce such pleasure were dealt early blows, first by the severe rationing of chocolate in my life, and then by the moratorium that my mother placed on the eating of my meager rations in the bath. It was not until I was much older that I was free to try to recreate the phenomenon of the Lady of the Flake†.

The first thing I discovered was that chocolate was addictive, in or out of the bath. This might be because of a number of psychoactive ingredients, the most prominent of which is theobromine, a powerful mood-altering alkaloid that behaves as a mild stimulant. The presence of this stimulant is one of the reasons why chocolate is often included in soldiers rations', the use of which goes back more than 200 years. Chocolate also causes the production of serotonin and dopamine in the brain, which are associated with pleasure sensations in the brain. However, the doses are small and are certainly not enough to cause the kinds of ecstasy experienced by the Lady of the Flake.

There is more to chocolate than its stimulating chemicals, just as there is more to wine than alcohol. At its heart is the cocoa bean, harvested in the tropics, pulped, fermented, dried, roasted, and transformed into cocoa solids and cocoa butter (the fat). When blended together, these ingredients create a brown solid with a complex, smooth but slightly bitter taste. Chocolate differs uniquely from other confections because it is not designed to be chewed at all but rather to melt in the mouth. A brittle solid at room temperature, it transforms in the mouth into a warm, succulent sweet mass that finally collapses in a melt, releasing a cocktail of nutty aromas, and creating a unique sensation of warm burnt cream at the back of the throat.

There are six types of cocoa butter crystal structures. Since each one has a different melting temperature, the exact mix creates very different textures in the chocolate and so a different experience in the mouth. These structures are highly sensitive to changes in temperature and humidity. A shelf life of a few weeks is typical for a chocolate bar unless the material can be stabilized or protected from the environment. The white discoloration of chocolate is often evidence of a failure to do this. The discoloration comes in two forms: a fat-bloom, where temperature fluctuations cause phase separation of the constituent fats and subsequently their recrystallization, or a sugar-bloom, where humidity causes sugars to crystallize on the surface.

Thus, as in other areas of materials science, the structure-property relationship is the key to understanding chocolate. Tempering, composition control, and even the seeding of the chocolate with different chocolate crystals all play an important role in chocolate making. The complication from a materials science point of view is that the final desired property is ultimately senso-aesthetic: a combination of taste, smell, texture, color, and form.

A recent poll of the community by The Minerals, Metals, and Materials Society (TMS) has identified the top 100 materials science moments. Sadly, chocolate was nowhere to be found on the list. This is shame, because chocolate is no less remarkable and technically sophisticated a material than semiconductors or steels. Through our ingenuity, we have found a way to create a cold, dark, brittle piece of refined tropical rain forest nut designed for one purpose only – to put it in your mouth and wait while it melts and floods your senses with warm fragrant bitter sweet flavors and simultaneously ignites the pleasure centers of the brain. Despite our scientific understanding, words or formulas are not enough to describe this sensual material. It is a material poem, as complex and beautiful as a Shakespearian sonnet. If materials science has no place for materials poetry such as this, then it is pity indeed. We are poorer as a community without the Lady of the Flake.

†*The Lady of the Flake is a Cadbury's TV advert. It can still be viewed on www.youtube.com.*