Chocolate characterisation using the Mastersizer 2000

Introduction

Chocolate is without doubt one of the world's best-loved foodstuffs. Fry and Sons produced the first plain chocolate bar in 1847, with the first milk chocolate product being launched by Nestle in 1870's [1]. Initially product consistency was poor. However, the introduction of the chocolate kneading process, referred to as conching, by Lindt in 1879 yielded improved flavour and texture [1]. Since then the world's desire for chocolate products has expanded rapidly such that in 2001 chocolate consumption in the US reached over 1.75 million metric tons, with worldwide sales values of over $13 billion [2].

For the consumer, taste is the overriding factor in selecting a chocolate product; for the producer, consistent high quality using optimised, economical and efficient production systems is vital. While there are many parameters to be considered in the production of chocolate, a major factor at all stages is the solid ingredient particle size distribution as this has a significant effect both on the final product and on the cost and efficiency of the production process itself.

This application note examines why particle size analysis is so important in the manufacture of chocolate. Examples of the characterization of different chocolate products using laser diffraction are also described.

Achieving Efficient Production

For many years, chocolate manufacture was regarded as a highly skilled process, heavily dependent on the expertise and experience of those involved at each stage of production. However, given the expanding and competitive market for chocolate, there have been moves towards increased mechanization and automation of the production processes to achieve higher output. This change has required a greater analysis and knowledge of the underlying processes involved in chocolate production. Understanding, monitoring and controlling particle size has therefore become an important factor in ensuring consistent, high quality product the world over.

The manufacturing process

To understand the significance of particle size and particle size analysis it is necessary to take a brief look at the various stages between cocoa bean and final product.

Chocolate is basically a suspension of sugar, cocoa and milk particles in a continuous fat phase, and the aim of chocolate production is to give the product the optimum flow properties for further processing.

Through the processes of fermentation, drying and roasting, the cocoa bean remains reasonably intact with a particle size of several millimetres. While subsequent processing may take many different forms, there is a common requirement for cocoa particles, sugar and any milk solids to be too small for detection on the tongue (typically less than 30 microns in size). This demands particle size reduction, or grinding, for which a number of processes are used depending on the final quality required and the raw materials used. Control of particle size is important for a number of reasons, not least the final taste. For example, if cocoa and sugar particles within the product are too coarse consumers will describe the mouthfeel as "gritty" and flavour release will be poor. Conversely, if the particle size is too fine the product require higher amounts of cocoa butter to achieve the correct flow properties, resulting in a mouthfeel that is "sticky" or "sickly".

Cocoa mass, cocoa powder and cocoa butter

Cocoa bead pods are the fruit of the Theobroma Cacao tree. Each tree produces around 20-30 pods a year, yielding around 2 ounces of cocoa beans. Once harvested, the beans are fermented and dried prior to being shipped to the chocolate producers for processing.

During processing only the nib, the crushed and skinned bean, is ground. Shell removal breaks the nib into coarse pieces and a relatively small proportion of fine material. Whether the final product is to be cocoa powder, cocoa butter or chocolate, the nib must be further ground to a fine homogeneous mass. Pre-grinding of the nib results in an increase in temperature and produces cocoa butter as a liquid mass, producing a liquid called “chocolate liquor”. During this initial grinding state it important that the cocoa butter is completely released from the cocoa cells. It is also vital that the proportion of very fine cocoa solid particles is kept low because finer particles bind fat and lead to a cocoa mass with poor flow properties. At the end of this process the cocoa butter and cocoa solids are separated, ready for further processing.

Sugar

In chocolate production there is a trend towards grinding sugar in a two-step process, when mixed with cocoa mass, milk powder and other ingredients. A major objective in grinding the sugar is to produce a closely defined particle size distribution, as this leads to well defined physical properties within the chocolate masse. For sensory reasons the particle size in the chocolate should not exceed 30 µm whereas for optimum rheology it should not fall below 7µm.

Milk

A number of factors are important when considering milk products for chocolate production. Milk proteins, some components of the milk fat and the milk fat triglyceride structure have an influence on the physical and processing properties of milk. When bespoke milk-based ingredients are produced, the crystalline structure of the lactose is of tremendous importance as it influences the particle size distribution in the final chocolate product.

Milk and chocolate crumb

Milk and chocolate crumb are used specifically in the manufacture of milk chocolate. Crumb is produced by blending the cocoa mass with milk and sugar. Originally, this crumb was developed as a means of storing fresh milk during the peak milk production times of spring and summer, which are low seasons for chocolate. Here the Cocoa mass stabilizes the crumb to prevent it from become rancid when exposed to air

Conching

Conching is a final mixing stage prior to the formation of the final chocolate product. The chocolate crumb is slowly mixed with cocoa butter, emulsifiers and flavoring. It is then subjected to shear at relatively high temperatures for long period of time (sometimes up to 72 hours). The nature of the changes which occur within the product during this processing stage are poorly understood. However, it is believed to eliminate unwanted aromas and flavours associated with volatile organic compounds whilst the required flavours are developed in the chocolate paste. Cocoa butter is also added to increase fluidity.

The conching process results in a smooth glossy product with has a relatively fine particle size. This is then tempered and molded to produce the final chocolate product.

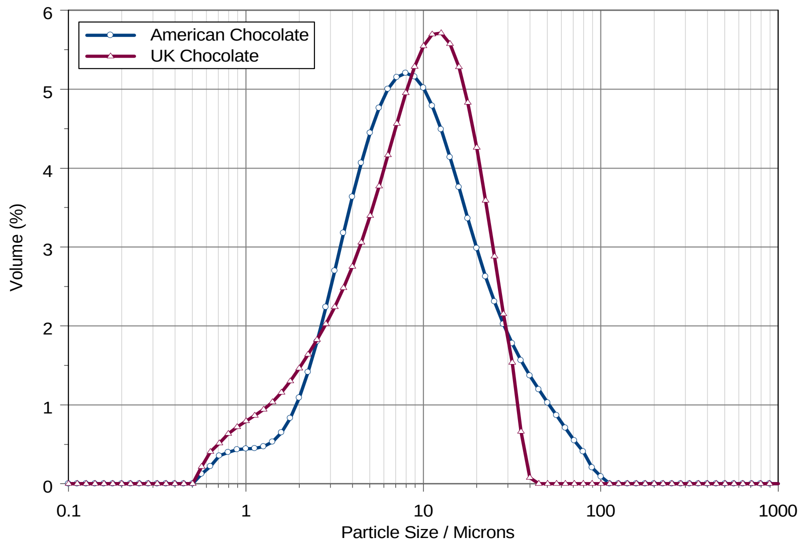

Figure 1: Particle size distributions recorded for UK and American chocolate bars.

Optimizing Chocolate Production

When conching is complete every particle should be coated with fat to ensure good lubrication. The most expensive constituent is the cocoa butter. As its price has increased it has become important to achieve the same product properties whilst minimizing its use. Manipulation and control of the particle size distributions of the solid materials is crucial role in achieving this. Small particles have a large specific surface and therefore a high fat requirement, whereas large particles have a small specific surface and need less fat. However, because a chocolate is perceived to be gritty when particles greater than 30 microns in size exist, strictly defined size distributions must be maintained.

Challenges of particle size measurement

It is clear that particle size at many different stages of chocolate production will have a significant impact either on downstream processing or on the final product. Particle size measurement is therefore critical. Laser diffraction is the most effective measurement method for this type of system. It requires that a sample of the product with its agglomerates is dissolved in an appropriate solvent to suspend particles and at the same time dissolve fats and other intermediates.

Originally chocolate was dispersed in trichloroethane during laser diffraction measurements. However, this solvent can no longer be used in analysis laboratories. Instead, Volasil 344 can be used as, due to its polarity, it has similar solvent properties to trichloroethane and therefore yields equivalent results. IsoPropyl Alcohol (IPA) or sunflower oil can also be used, although these yield slightly different results to Volasil as they dissolve out some of the non-volatile organic material.

Characterizing Different Chocolates

The chocolate products available for resale have different properties dependant upon the country of origin and the target market within each country. As such, there is no standard chocolate recipe and significant differences both in raw ingredients and the particle size distribution can be observed.

Here, the Mastersizer 2000 has been used to characterize different chocolate products. Each measurement was carried out in IPA, with 3 minutes low-power sonication being used to melt and disperse the chocolate prior to measurement.

American and UK Chololate Products

Figure 1 shows a comparison of the particle size of two leading brands, one sold in America and the other in the UK. The requirements for mouthfeel and flavour differ between these two countries, with the UK consumer being used to a smoother mouthfeel. This not only affects the composition of the chocolate but also defines the end particle size. As can be seen in figure 1, the size distribution for the American chocolate extends to much larger particle sizes compared to the UK product. This yields a grittier product with different melting and taste release characteristics compared to the UK product.

Luxury Brands

Some brands of chocolate market themselves as providing a luxurious, smooth feel. Again, the required melting characteristics and lack of grittiness are achieved both through the choice of ingredients and through

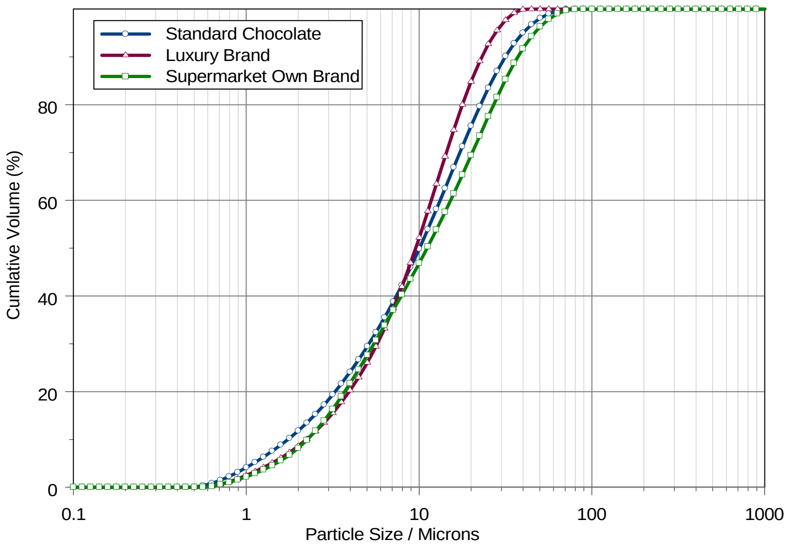

Figure 2: Particle size distributions recorded for Standard, Luxury and economy (Supermarket own) brands.

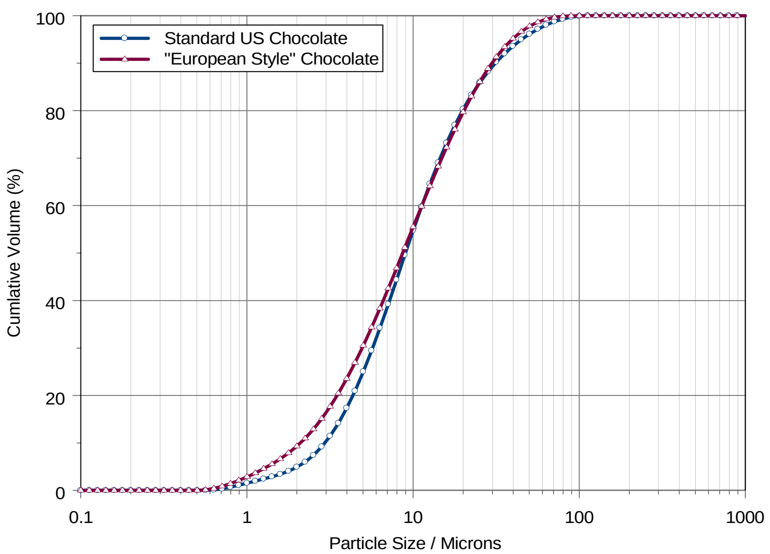

Figure 3: Comparison of a standard US brand against a chocolate product designed to be “more European” in taste.

controlling the particle size. This is shown in figure 2 where a so-called luxury brand is compared against a standard brand and a economy brand. As can be seen, the particle size distribution moves to larger particle sizes in moving from the luxury product to the economy product. Obviously the milling and conching duration used for the economy brand will be much shorter. In addition, the amount of expensive cocoa butter required during processing will also be less.

The above example related to the UK market. A similar trend is also observed for the US market. In figure 3 the US brand shown in figure 1 is compared against another product designed to yield a smoother, more-European mouthfeel. Again, in order to achieve this, the ingredients are ground to a finer particle size, although the difference observed is less pronounced than would be expected considering the properties of most UK brands. More noticeable, perhaps, is the change at the fine end of the distribution. This relates to the change in the cocoa and milk solids content required to mimic a European brand.

Comparing Dark and Milk Chocolate

The difference between dark and milk chocolate is shown in figure 4.Here, the differences observed relate to the ingredients used. Dark chocolate generally contains a large amount of sugar in order to produce a palatable product. This yields a coarser particle size and a grittier mouthfeel. Differences are also observed at the fine end of the distribution – these relate to the presence of milk solids within the milk chocolate.

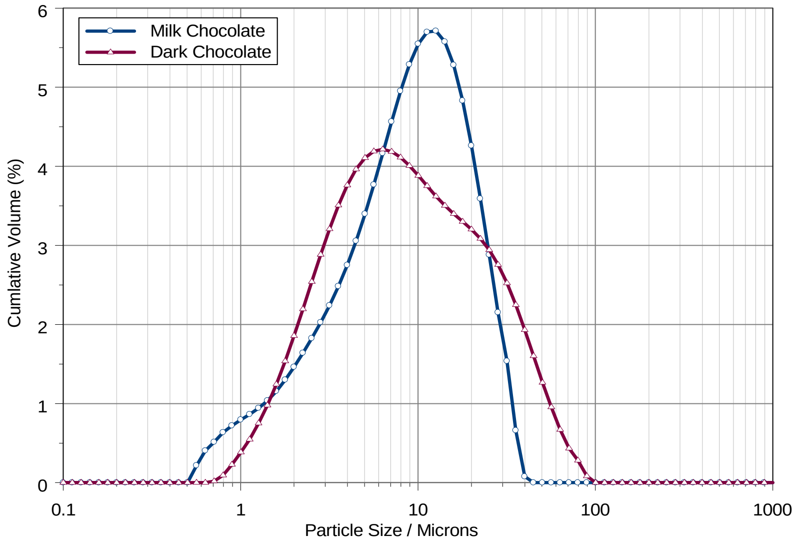

Figure 4: Particle size distributions recorded for milk chocolate and dark chocolate (UK market).

Conclusion

Most people would say they like chocolate, but what they're enjoying could be vastly different in terms of flavour release and mouthfeel. Particle size is an important parameter in defining the properties of the final chocolate product. Its measurement is therefore vital in allowing the desired product properties to be developed in an economic way.

References

[1] Tannebaum, G., "Chocolate: A Marvelous Natural Product of Chemistry", Journal of Chemical Education, vol 81, no 8 (August 2004), p 1131- 1135

[2] Deis, R.C., "Chocolate and Compound Coatings", Food Product Design, March 2003