Ball mills and refiner-conches are both good mixers relative to roll refiners and, since both employ wet grinding, agglomeration may be lower, leading to potentially shorter conching times. Small-scale processors who wish to manufacturer their own chocolate or producers of high fat, chocolate-flavoured coatings may find so-called "universal" systems an acceptable alternative.

9.5.5 Refining in the presence of water

In their United States patents, Martin and Stumpf (1992) and St. John *et al.* (1995) describe a process for producing chocolate containing 20.0–24.5% fat, comprising the steps of mixing a small amount of water (1–3%) into a sugar–fat mixture, refining the mixture and then evaporating the moisture using heat and agitation. This sugar–fat mixture is then combined with cocoa mass, milk solids and additional fat and lecithin to produce the finished product. It is claimed that the moisture added is sufficient to dissolve the very fine sugar crystals (<5 μm). Upon evaporation this dissolved sugar recrystallises onto larger crystals, resulting in a chocolate or chocolate-like material with improved rheology, that is lower viscosity, and in particular a much lower yield value. It is further claimed that a chocolate of less than 25% fat with flow properties suitable for moulding, extruding or enrobing can be produced.

9.5.6 Milling cocoa powder

Cocoa press cake is first of all coarsely milled, generally in some sort of crusher, to cocoa kibble. These kibble particles are ductile and have the added problem of containing fat that can melt when heated. Furthermore, they are aggregates of smaller particles; cake pulverisers do not further reduce primary particle size, but break up particle agglomerates. Impact milling at low temperatures (5–10 °C; 42–50 °F) is appropriate for cocoa powder production. For grinding 10–12% fat cocoa powder, the air flowing through the mill is usually sufficient to cool it, whereas cryogenic grinding has been used for high fat content cocoa powders.

9.6 Particle size reduction and chocolate flow properties

As stated in the introduction, while the outcome of a grinding process is a particle size distribution, it is important to know the relationship between this distribution and finished product quality. For chocolate products, particle size distribution affects flow properties and sensory perception. The flow behaviour of molten chocolate is important in moulding and enrobing, for proper cookie drop formation and in the design of bulk handling systems. Size reduction operations influence product quality and cost through their impact on chocolate flow properties. It is often desirable for chocolate to have as low a viscosity as possible with a minimum addition of its most expensive ingredient – cocoa butter. Chocolate flow properties are discussed in detail in Chapter 11; and Bouzas and Brown (1995) have published an excellent review of the literature on the effect of structure, including particle size, on chocolate rheology. In order to avoid duplication this chapter will focus on the influence of particle size distribution on flow properties of chocolate as described by the Casson parameters. As the preceding section has shown, there has been considerable attention given to reducing the proportion of fine particles in an effort to control chocolate rheology.

Conventional wisdom assumes that the presence of small particles is detrimental to "flow properties", since smaller particles have a greater surface area that must be coated by fat. However, this is somewhat oversimplified. Typical flow curves for chocolate can be divided into three or four shear rate or, better, shear stress regimes (Windhab, 1995, 1997). At shear stresses near the yield value, particle–particle interactions – friction and adhesion – or "network" effects dominate. The close-packed particles behave like a pile of powder, and particle surface area and surface properties (e.g. roughness) become extremely important. Particle shape is also important in this low stress regime, and rounding of particles due to selective dissolution of protrusions and jagged edges may be as important as reduction of fine particles in the aforementioned patents (see Section 9.5.5). Once flow has been initiated, above shear rates of about 1 s^{-1}, hydrodynamic effects become significant and particle packed volume relevant. Although the Casson model has its limitations, it none the less gives a useful insight into the behaviour of chocolate in the first two stress regimes.

Several studies have been conducted at the Pennsylvania State University to understand the relative influence of particle surface area and packing ability (as affected by particle size distribution) on the Casson parameters for molten chocolate. In general, it is known that the viscosity of a particulate suspension like chocolate decreases as particle size increases, particles become more spherical, the particle size distribution broadens and the solids loading is reduced (fat content increased). The competing effects of particle surface area and packing density on the Casson yield value and plastic viscosity were therefore evaluated for four sweet dark chocolates with distinct particle size distributions, but the same mean diameter (with respect to their volume distribution; mean diameter = 20.1 ± 0.5 μm; Fischer, 1994). The volume histograms for these distributions are presented in Figure 9.10. A bimodal distribution resulted in a much lower Casson plastic viscosity (Figure 9.11a) but higher yield value (Figure 9.11b) when compared with unimodal distributions at the same volume mean diameter. The effect was greater at lower fat contents; little difference in plastic viscosity was observed above 34% fat, while differences in yield value persisted to 45% fat. Figure 9.12 shows the influence particle size distribution had on the apparent viscosity as a function of shear rate. One consequence is that, where polyglycerol polyricinoleate (PGPR) is permitted, it can be used to reduce the yield value and particle size distribution can be manipulated to improve flow at higher shear rates.