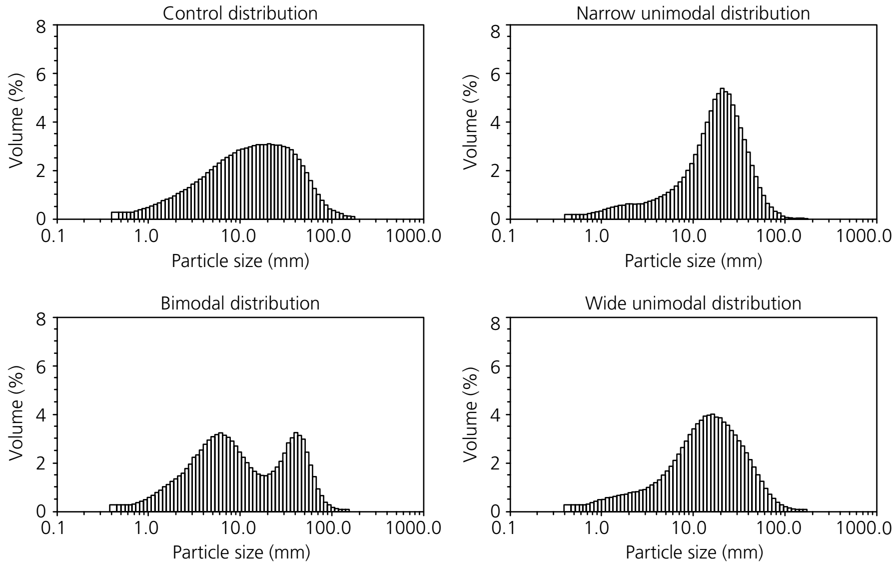

Figure 9.10 Volume histograms of four different dark chocolate samples. The specific surface areas as recorded by the Malvern Instrument were: "Control" = 1.1696 $m^2\ g^{-1}$, "Bimodal" = 1.2676 $m^2\ g^{-1}$, "Narrow" = 0.9342 $m^2\ g^{-1}$ and "Wide" = 1.0512 $m^2\ g^{-1}$.

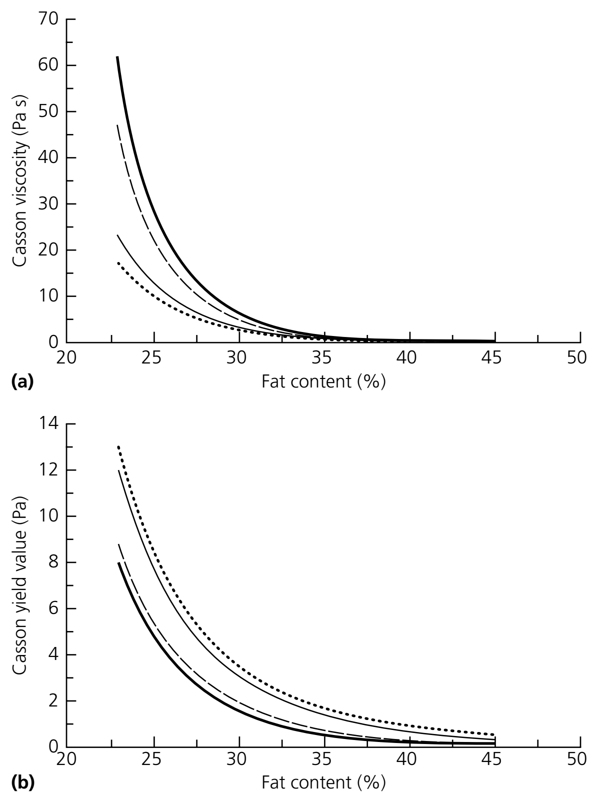

Figure 9.11 (a) The effect of the particle size distribution and the fat content of dark chocolates upon the Casson plastic viscosity. (b) The effect of the particle size distribution (psd) and the fat content of dark chocolates upon the Casson yield value. (——) Narrow psd, (---) wide psd,; (▬▬) control psd, (···) bimodal psd.

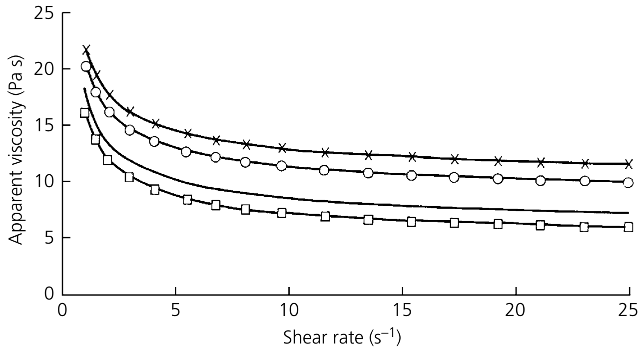

Figure 9.12 The effect of particle size distribution upon the apparent viscosity of a 28% fat dark chocolate. (×) Narrow psd, (○) wide psd, (——) control psd, (□) bimodal psd.

Fat fills the spaces or voids between the solid particles in molten chocolate and reduces the resistance to flow. The void volume in a packed bed of solids depends on the particle shape, size distribution (especially number of distinct sizes) and packing arrangement of the particles. The packing efficiency is defined as the ratio of the actual volume of solids to the volume occupied by the bed of solids (which includes the interparticle spaces). For a given distribution of particles, the packing efficiency can be improved by adding solid particles of sizes corresponding to the size of the voids in a packed bed. Filling these voids with smaller solid particles allows for a higher amount of solids to be present per unit volume and reduces the amount of space to be filled by the fat. The extent of reduction in the void volume depends on the ratio of the sizes, number of distinct sizes and the volume fractions of small and large components (McGeary, 1961; Sudduth, 1993a–c). However, the addition of smaller particles increases surface–surface contacts.

Figure 9.13 illustrates the relationship between particle packing (bulk density) and the apparent viscosity for milk chocolates of equivalent composition, but different particle size distribution. As anticipated from theoretical treatments, apparent viscosity decreases exponentially with increasing solids bed density. Again, this effect would be exaggerated at lower fat content. Particle packing becomes important once flow has been initiated and therefore affects the plastic viscosity component of the flow behaviour. Yield value is affected largely by interparticle contacts and consequently shows a linear dependence on the mean particle size, or more accurately, on the specific surface area (Mongia, 1997; Mongia and Ziegler, 2000).

Although we obtained these distributions through a combination of separate grinding and classification, they may be easily manufactured using conventional equipment like roll refiners. For example, a bimodal distribution containing a ratio of coarse fraction to fine fraction of 2:1 can be obtained by feeding a single conche from three refiners, two set coarse and one fine. The overall throughput of the system is not much different than if all were set to an intermediate size.