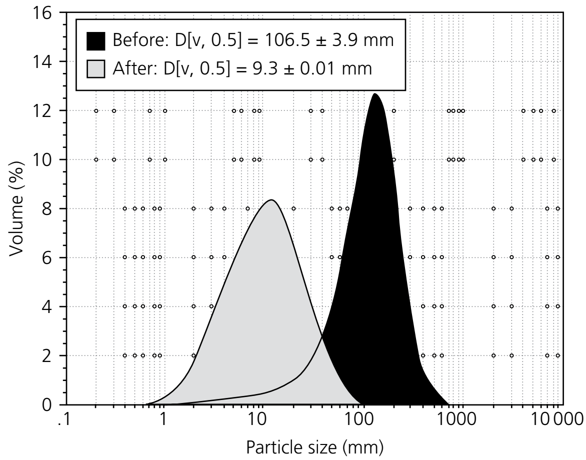

Figure 9.5 Particle size distribution before and after roll refining of spray-dried whole milk powder with an equal amount of cocoa butter.

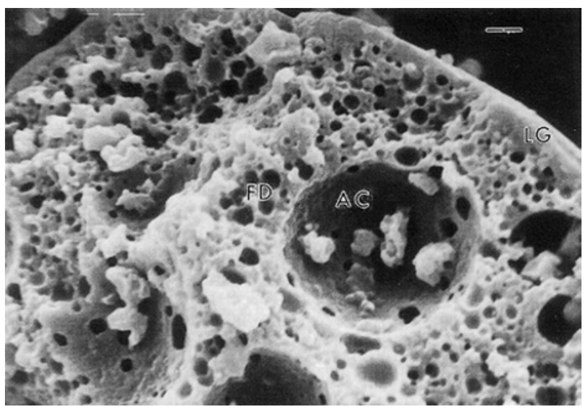

Figure 9.6 Interior surface of a milk powder particle fractured during roll refining. Bar equals 1 μm. AC = Air cell, FD = fat droplet, LG = lactose glass.

As the grinding temperature exceeds the glass transition temperature, either because the roll temperature increases or the glass transition temperature decreases, say because of an increase in moisture content, spray-dried milk particles deform plastically (Figure 9.7a). These highly asymmetric particles (Figure 9.7b) have a deleterious effect on product viscosity and sensory properties.

Spray-dried skim milk powder, or non-fat dry milk (NFDM), behaves somewhat differently. As with whole milk powder, NFDM exhibits brittle fracture below the glass transition temperature, but requires greater force (more energy) to grind since it does not contain the defects introduced by the milk fat droplets. Air vacuoles (Figure 9.8) serve as defects and their volume and distribution will dramatically influence the energy required to grind them. Above T_g, NFDM particles only slightly larger than the gap are distorted as they pass through the roll gap. However, they appear to recover their original shape to a greater extent

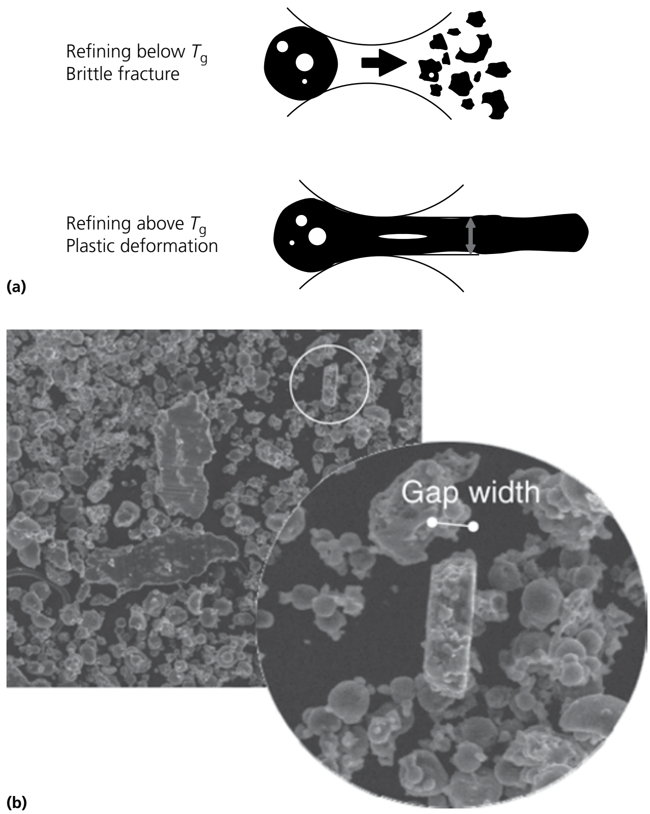

Figure 9.7 (a) Illustration of the effect of the glass transition temperature (T_g) upon the refining process. (b) Electron microscope picture showing asymmetric particles after refining at a temperature above the T_g.

than do particles of whole milk powder, that is they do not show the same degree of permanent plastic deformation that whole milk particles do. However, above T_g, the surface of NFDM becomes sticky and particles agglomerate. The end result is a particle size distribution that may contain agglomerates that are larger than the roll gap.

9.5.1 The five-roll refiner

The fine grinding of chocolate mass is most often carried out using a five-roll refiner. Four grinding rolls, up to 2.5 m (8 ft) in length and 400 mm (16 in) in diameter, aligned vertically form a stack (Figure 9.9). The "feed" roll (R1) is placed at an angle to the lowest stack roll (R2). The feed rate determines the throughput and end fineness of the chocolate, and is adjusted by changing the feed roll gap at a constant roll speed or by changing the roll speed at a constant gap. At a constant gap, faster roll speeds mean greater product throughput and coarser chocolate. At 100–150 μm (0.004–0.006 in), the feed gap does little