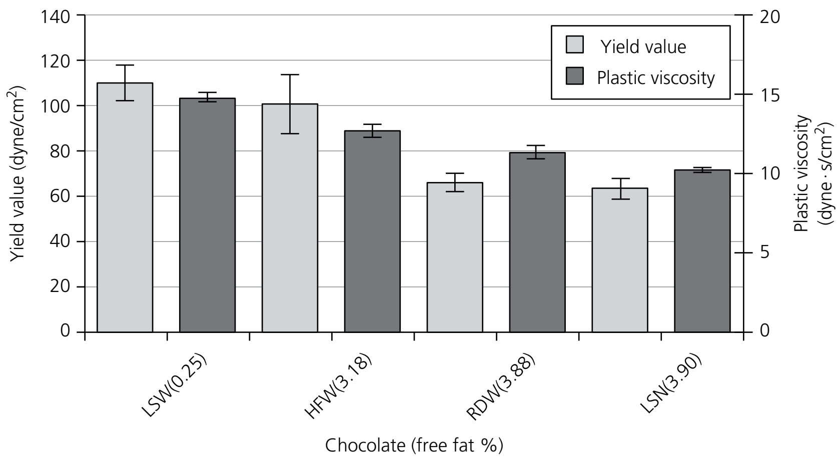

Figure 5.7 Effect of free fat level in milk powder on rheological properties of melted chocolate.LSN: Spray-dried skim milk powder; LSW: spray-dried whole milk powder; RDW: roller-dried whole milk powder; HFW: High free fat whole milk powder. Source: Liang and Hartel (2004). Reproduced with permission of Elsevier.

The chocolates with the lowest yield value and plastic viscosity were those that had the highest free fat level. In the latter with AMF the free fat was 100%, the chocolate made with the roller powder had almost the same yield stress and plastic viscosity. The chocolate made with standard sprayed whole milk powder with low free milk fat had the highest yield value and plastic viscosity (Liang and Hartel, 2004).

Milk powders with different structures and free fat content will lead to differences in tempering requirements, consistency and melt down properties of the finished chocolate. In Figure 5.8 the hardness profile was measured, using a Texture Analyser (model TA-XT2, Haslemere, England) at 20 °C. The chocolate samples were penetrated by a 2-mm stainless steel cylindrical probe at 0.2 mm/s to a depth of 5 mm. Maximum force for penetration was determined as well as the work required for penetration (area under the force curve; Attaie *et al.*, 2003). An increase in free milk fat content led to a decrease in hardness. However the chocolate made with the spray-dried skim milk powder and AMF had higher hardness than expected based on free milk fat content. So the nature of the milk powder particles also has an influence on the hardness of the chocolate (Liang and Hartel, 2004).

Liang and Hartel (2004) reported that the degree of lactose crystallisation increased the degree of free fat (Aguilar and Ziegler, 1994), which effected chocolate particle size formation during refining and bloom formation in the final chocolate. The impact from amorphous or crystalline lactose on the hardness and sensory perception of milk chocolate was described by Bolenz *et al.* (2003), who found that it took longer to melt chocolate and the hardness increased with degree of crystalline lactose content. The rapid drying process used to produce

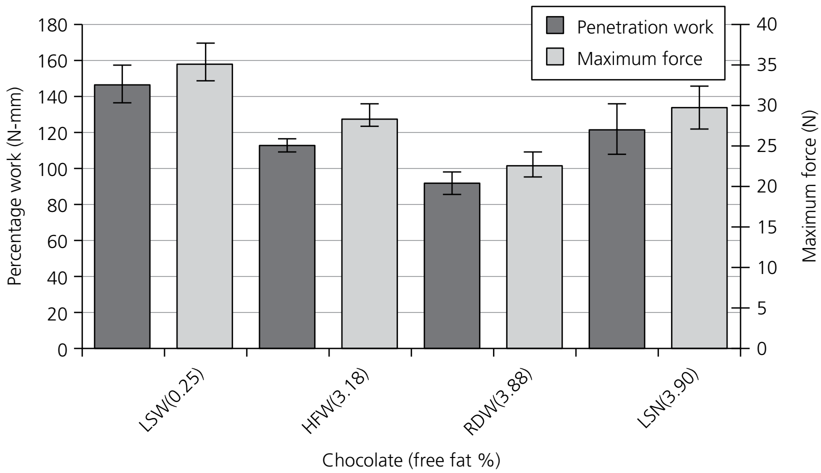

Figure 5.8 Hardness of chocolates made with different milk powders. LSN: Spray-dried skim milk powder; LSW: spray-dried whole milk powder; RDW: roller-dried whole milk powder; HFW: high free fat whole milk powder. Source: Liang and Hartel (2004). Reproduced with permission of Elsevier.

whole milk powder results in amorphous lactose, which forms a continuous matrix in which protein, fat globules and air are dispersed (Siebenga and Timmermans, 1995). The amorphous lactose is unstable and crystallisation will take place if the powder is kept at a higher temperature than the glass transition temperature (T_g). The glass transition temperature is normally above the storage temperature, but amorphous lactose is very hygroscopic and will absorb water if stored under humid conditions and the increased moisture reduces the T_g, allowing crystallisation to take place (Fitzpatrick *et al.* 2005).

Saito (1985) reported that in fresh whole milk powder (WMP) only a few crystalline lactose crystals were found and that crystallisation during storage facilitated movement of free fat to the surface of the particles. Crystalline lactose in milk powder increases the bulk density, but the chocolate viscosity decreases with the degree of amorphous lactose content. Aguilar and Ziegler (1993) stated that the chocolate viscosity increase with degree of crystalline lactose is due to the release of bound water to the chocolate during transformation.

Roller dried WMP contains more crystalline lactose than spray-dried due to the longer holding time on the rollers. Crystalline lactose will not impact the properties the same as spray-dried powders, since crystallisation takes place during production of the powder. Roller dried WMP has a lower bulk density and a higher occluded air content, which does not correlate with its lowering impact on chocolate flow properties in chocolate (Hansen and Hansen, 1990).

A powder with a larger particle size and high occluded air content will break up more easily into smaller particles. A high content of fines, particles less than 10 μm, contributes to an overall larger surface area that needs to be covered by