fat during the chocolate processing, thereby contributing to a higher chocolate viscosity and a dryer mouthfeel in the final chocolate (Liang and Hartel, 2004).

A high powder bulk density, expressed as g/ml, reduces the volume and facilitates incorporation during blending, refining and conching (Liang and Hartel, 2004). Low occluded air leads to higher bulk densities, which are influenced by the viscosity in the feed, the atomiser and fluid bed settings during drying (Hansen and Hansen, 1990). High dry matters gives higher bulk densities and so does the use of pressure nozzle atomisers, since the air incorporation is less (Liang and Hartel, 2004), but lower feed concentration is required compared to centrifugal atomisers (Aguilar and Ziegler, 1993).

Keogh *et al.* (2002) investigated the seasonal influence on milk powder properties and reported increased protein content resulted in higher free fat content and a reduced final viscosity in the milk chocolate.

5.3.2.2 The spray drying process

The drying process is a multiple-step process:

1 Concentration of fluid milk through evaporation.
2 Atomisation of the concentrate into very fine droplets in a hot air stream.
3 Water evaporation.
4 Separation of the powder from the drying air.

The first step in the dehydration process always involves an evaporation step, which is necessary to produce high-quality powder. Without prior concentration, the powder particles will be very small with high occluded air content, have a poor blending ability and short shelf life and the process would not be economical (Caric, 1994). Falling film tubular evaporators are generally used for concentration because the vacuum process decreases the boiling point and allows for the use of low temperatures for the process. Falling film evaporators enable highly efficient heat transfer and short residence time.

5.3.2.2.1 Single-stage drying

The simplest installation is the single-stage dryer. The entire drying process takes place in a single unit, encompassing the drying chamber with an atomisation system. The atomiser disperses the milk into the hot air and can be of centrifugal or nozzle type. The centrifugal atomiser system accelerates and atomises the milk using centrifugal forces in a rotating disk. The nozzle atomiser system forces the milk through the nozzle under high pressure. In the bottom of the chamber is a system for collecting the powder from the dry air. A powder with small particle size and high fines content is produced (Anhydro, 2012).

5.3.2.2.2 Two-stage drying

The two-stage system builds on the single-stage system and is extended by means of an external fluid bed dryer and/or a cooler. The powder leaves the drying chamber with higher residual moisture and moves into the fluid bed, where drying happens at relatively low temperatures. In two-stage drying, the fluid bed dryer ensures that the desired residual moisture is achieved and that the powder is cooled. In terms of energy, the two-stage dryer is superior to the single stage dryer because it is possible to work with considerably lower air exit temperatures, increasing the temperature difference between inlet and outlet, thus reducing energy required for drying by 10–15% compared with the single-stage process. The finished products consist mainly of individual particles and the fines separated in the fluid bed. The bulk density is higher and occluded air content is lower in powders produced using a two-stage process compared with those from a single-stage process.

5.3.2.2.3 Multi-stage drying

Multi-stage dryers are a further extension of the two-stage process by adding an integrated fluid bed before the external fluid bed dryer and/or cooler. This method was developed to achieve savings in process costs and to meet various product quality demands more effectively. Fines are led back from cyclones and/or bag filters to the integrated fluid bed. An example of a multi-stage dryer is shown in Figure 5.9 (Anhydro, 2012).

To obtain the correct porosity, the particles must first be dried so most of the water in the capillaries and pores is replaced by air. The particles are humidified so the surfaces of the particles swell quickly, closing the capillaries. The surfaces of the particles will become sticky and the particles will adhere to form agglomerates of free-flowing dustless powder.

5.3.2.2.4 Atomisation

Correct atomisation and air distribution are key the spray drying process – they influence the final powder quality and can be adjusted according to desired performance. In spray-dried whole milk, the milk fat is largely encapsulated inside the lactose–protein structure of the dried milk particles (Aguilar and Ziegler, 1993). Generally, the finer the droplet atomisation, the larger the specific area and the more effective the drying process. The small droplets turn into milk powder particles with spherical form.

There are important functional differences between pressure and centrifugal nozzle atomisation and the principles in the two systems are shown in Figures 5.10 and 5.11 (Anhydro, 2012).

In pressure atomisation, the pressure at the nozzle determines the particle size. The pressure is built up by a high-pressure pump, which is often the homogeniser. At high pressures the powder particles is small with a narrow size distribution and a high bulk density and at low pressure large particles will be formed. In the centrifugal atomiser, the product is fed into the middle of a rotating disc and forced through a number of horizontal passages by centrifugal forces. The disc rotates at speeds of 10 000–20 000 rpm, depending on the diameter of the disc. Increasing the speed results in finer particle sizes, more efficient drying, a decrease in the content of free fat and an increase in bulk density (Sharma *et al.*, 2012).