the fat as it is being cooled. Initially, as the speed is increased, more seed nuclei are able to spread throughout the sample. This eventually tempers it, enabling it to set quickly. The actual crystal content required to temper chocolate varies considerably from author to author but is probably in the range of 1–3%. Eventually the speed becomes so high that the energy generated by the crystalliser melts some of the crystals. Subsequent increases in speed further decrease the temper.

Windhab (1994) overcame the melting problem by maintaining the walls of his crystalliser (Figure 15.3) at a very low temperature [4 °C (35 °F)] and keeping the outlet temperature between 28 and 30 °C (82–86 °F) to prevent the machine from blocking. This was possible because the cocoa butter or chocolate was being pumped through the concentric cylinder shear gap in a way in which there was no possibility that there were any "dead spots" and because some heating was being provided due to the shearing. The actual shear energy was controlled by varying the speed of the inner cylinder within the range 600–1200 rpm. It was possible to obtain a stable temper by using in line temper/viscosity readings on the outlet from the crystalliser to control its speed of rotation. It would have been expected that, because of the low temperatures, unstable crystalline forms of cocoa butter would be produced. Windhab showed, however, that in his crystalliser the crystal type was related to the power input per unit volume of material. He was also able to show that the crystals produced contained a higher proportion of Form V crystals than a conventional temperer. He was therefore able to produce a very good temper with a residence time of about 10–15 s. This principle has been incorporated into a new tempering machine that is sold by the Bühler Company of Switzerland and is described in Chapter 13.

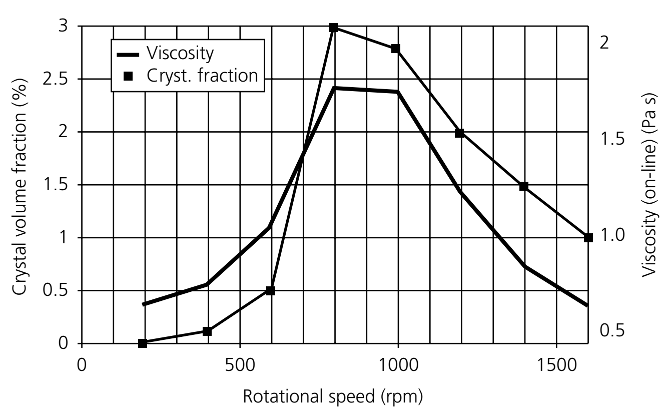

Figure 15.2 Pre-crystallisation of dark chocolate in a pilot plant crystalliser under constant cooling conditions (15 °C, 59 °F).

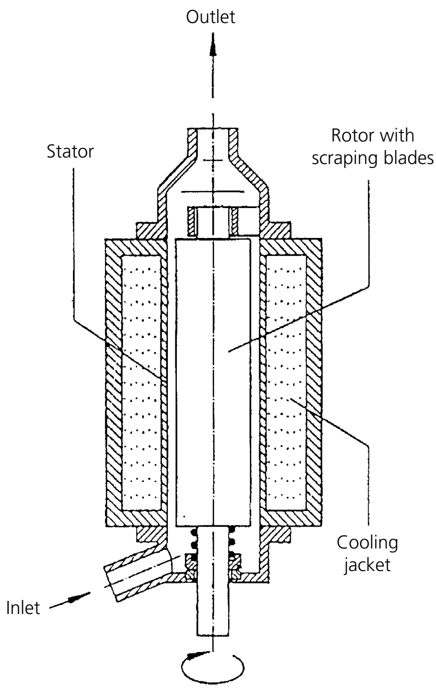

Figure 15.3 Principle of the continuous shear crystalliser. Source: Windhab (1994). Reproduced with permission of Springer.

15.4 High pressure temperer

A Bauermeister pressure tempering system has existed for many years operating at pressures of between 175 and 1000 kPa (25–150 psi) in combination with shearing and cooling. Trials in Japan, however, have shown that it is possible to temper pre-cooled chocolate by pressure alone (Yasuda *et al.*, 1992), but at much higher levels (about 150 MPa; 20 000 psi).

Very high pressure systems have been developed for the food industry in order to kill vegetative bacteria without the need for heat. Fruit colour and flavours are therefore better preserved and commercial machines are used to manufacture jams and preserves. This type of machine has been shown to be also able to act as a temperer.

The principle behind this process lies in the fact that the melting point of cocoa butter rises linearly with pressure (Figure 15.4; Yasuda *et al.*, 1992) according to the equation:

$$T = 0.14P + 26.6 \quad (15.1)$$

where T is the solidifying temperature (°C) and P the pressure (MPa). From this it can be calculated that applying a pressure of 150 MPa has an equivalent effect to lowering the temperature of the cocoa butter by 20 °C (36 °F). This means that, if this pressure is applied to liquid cocoa butter at 30 °C (86 °F), all the main different crystal types are formed. When the pressure is released