as described above. The cocoa mass was then produced by grinding followed by thin-layer roasting. The second extruder was then used to mix in the other ingredients, apart from the emulsifier and some of the cocoa butter. It also completed the flavour development by heating and venting. A roll refiner then reduced the solid particles to the required size, before the chocolate was fed into the third extruder for the final additions and liquefying. The total process was reported to take 30 min and to be able to operate at between 300 and 3000 kg/h (660–6600 lb/h) and to produce a wide range of flavours.

Although described as a twin-screw, co-rotating, high-shear continuous mixer, the Readco Kurimoto continuous processor has many of the features of an extruder. The close clearances between the paddles and between the paddles and barrel walls provide the high shear for all the material present and thus very efficient liquefying. The movement of the shafts is essentially self-wiping so very little cleaning time is required. Units have been designed with hollow paddles and/or jacketed barrels to give a precise temperature control.

This type of machine has been used as an alternative to the conche in order to produce a relatively thin chocolate with a very short processing time. Ziegler and Aguilar (1995) and Aguilar *et al.* (1995) describe experiments in which two 5 cm (2 in) shaft processors were used in series to conche a milk powder-based milk chocolate. The first processor acted as a flavour developer, with the second being used as a liquefier, the final lecithin/cocoa butter additions being metered at half-way along the barrel (see Figure 15.9). In some experiments, an additional roll refiner was used between the two processors, or following conching. The latter was said by Niediek (1991) to be a method of producing some of the best quality chocolate.

The residence time in a Readco Kurimoto continuous processor was determined by the screw configuration, mass feed rate, discharge opening size and screw speed. Using the high shear system, only the feed rate was found to have a significant effect. For rates between 30–10 lbs/h (14–4.5 kg/h) the mean residence times were between 2 and 8 mins. Even with these short times the chocolate appeared to be fully liquefied. The temperature of the first processor

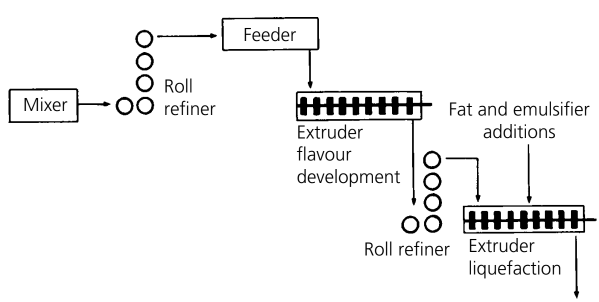

Figure 15.9 Continuous conching system using Readco Kurimoto Processor (Aguilar *et al.*, 1995).

was critical both for the flavour of the chocolate and its viscosity. The Casson yield value and the plastic viscosity (see Chapter 11) were much lower for a temperature of 70 °C (158 °F) than for 40 °C (104 °F). When an even higher temperature was used, however, the chocolate became gritty and post-processor refining was required.

The flavour of the chocolates produced was compared with that produced from the same roll refiner material, but which had been processed in a traditional batch conche for 24 hours at 60 °C (140 °F). The samples were found to be significantly different, but there was no significant preference for either. The chocolates were evaluated in terms of sweetness, caramel, milk and chocolate flavour. Of these, only caramel was found to be affected by the processing time and temperature. The chocolate processed at 90 °C (194 °F) was found to be most like the batch conched control chocolate. This chocolate was however gritty. This may have been due to the crystallisation of amorphous lactose as many milk powders contain a high proportion of lactose in the amorphous state. Crystallisation is both time- and temperature-related and Arvanitoyannis and Blanshard (1994) demonstrated that, in anhydrous mixtures with sucrose (i.e. as in chocolate), this transition would take place within minutes at temperatures of 90 °C (194 °F). This crystallisation, which would be expected to change the flavour and improve the flow properties, would also take place in a batch conche, but over a much longer period of time.

The Readco Kurimtoto continuous processor was therefore able to match many of the properties of a traditional conche. Its advantages were said to be:

1 Reduced conching time;
2 Faster product changeover and greater flexibility;
3 Increased production rates;
4 Reduced energy requirements;
5 Smaller floor space needed;
6 Less material in process;
7 Enclosed operation and improved cleanliness.

15.5.4 The extrusion of tubular shapes, ropes and nets

When chocolate is tempered part of the liquid fat solidifies, thus increasing the viscosity. The viscosity is, however, still low enough for the chocolate to be used for enrobing or moulding. As the chocolate is further cooled, more of the fat solidifies and it becomes paste-like. In other words it will deform under pressure, but will retain that shape once any force is removed. In this state it is possible to extrude the chocolate onto a mould or belt, where it is subsequently cooled in the traditional manner. The extrusion must of be done quickly whilst there is sufficient liquid fat present to enable it to deform in the extruder nozzle but before it has become solid.

Cadbury Schweppes (1981) applied this principle to produce net shaped or tubular products. The tempered chocolate is rapidly cooled, whilst continuously