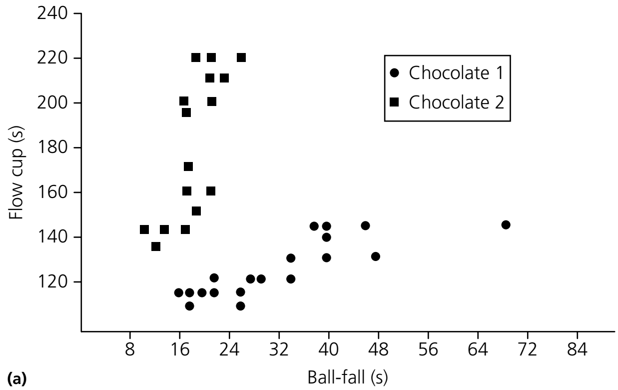
The Casson equation therefore provides two figures that can be used in production to describe a chocolate and it does indeed provide useful information when the measurements are made on a single viscometer. Where several laboratories are involved in measuring the same chocolate, for example when it is transported between two factories, then the apparent viscosity should be used, as measured at agreed shear rates (Beckett, 2001). The reasons why the Casson model is unreliable for this purpose was illustrated when the same chocolates were measured in 32 laboratories in eight countries (Aeschlimann and Beckett, 2000). These showed that, for shear rates greater than 5 s^{-1}, the apparent viscosity could be measured between laboratories with a reproducibility with a coefficient of variation of less than 8%. (The repeatability within a single laboratory was better than 2%.) Using the same data in the Casson equation, the Casson yield value was found to vary between 3 and 23 Pa and the Casson plastic viscosity from 2 to 4 Pa.s. This covers the range for most useable chocolates, whereas measurements to be of use to the manufacturer need to be accurate to better than 20%. There were several reasons for this. One related to the fact that there are several different Casson models being used in the industry. It also makes a difference whether the data is fitted to the model in the linear or square root form. Many viscometers automatically calculate the Casson parameters without saying how this is done.

Another challenge is that very few chocolates have a flow curve that fits the square root (power 0.5) relationship of the Casson model, indeed many flow according to a 0.6 power (Chevalley, 1991). The Casson yield value is obtained by predicting outside the range of measurement and so very large errors may arise often rendering the values unusable.

11.4 Single point flow measurement

A single point measurement can provide information about part of the flow curve and, if this is the critical one for the process, this may be all that is needed. If the measurement is outside of specification then corrective action is necessary. Even if the corrected value appears what it should be, this does not mean to say that the chocolate will process correctly. Figure 11.8a shows the measurements obtained for two chocolates by a higher shear rate measuring instrument (flow cup, Figure 11.8b) plotted against a low shear rate measuring one (ball fall) over a period of several days. As can be seen for chocolate 1, the ball fall had a big range indicating large fluctuation in yield value, whereas the flow cup was relatively stable. If only the ball fall had been used the chocolate would probably have been modified, but this would not have been the case for the flow cup. The reverse situation occurred for chocolate 2.

The instruments used are relatively inexpensive and are still occasionally used in the industry, for example the flow cup and falling-ball viscometer



(a)

(b)

Figure 11.8 (a) Flow-cup and ball-fall measurements for two chocolates. (b) Flow cup.

(Figure 11.9a), the Gardner mobilometer as well as rotational devices. The reader is referred to earlier editions of this book (Beckett, 2009) or other text-books (Mezger, 2006) for details of the former, whereas single point rotational devices have been included in this edition. The reason is that these rotational devices are often the standard instrument in many factories, in particular for measuring the viscosity of chocolate compounds. Their main disadvantage compared to multi-speed rotational viscometers or rheometers is that their data tends not to be comparable between laboratories and the results depend very much on how the device was used and the sample handled.

11.4.1 Gallenkamp torsion viscometer

Figure 11.9b shows the Gallenkamp torsion viscometer. It consists of a torsion wire, suspended at the top and with a bob at the bottom. Approximately half-way up the wire is a pointer set at right angles to the wire. The bob is placed in the chocolate and the pointer turned so as to twist the wire through 360°. Upon