7 Extrusion of brewers’ hops
K.T. WESTWOOD

7.1 Introduction

The art of brewing has been practised for many centuries. It is only relatively recently, however, that the science involved has been understood to any great extent. An outline of the traditional process is given below (see Figure 7.1).

The first part of the process involves the mashing of a malted cereal, usually barley, with water at a temperature of 60–65°C. Under these conditions, starch is gelatinised and degraded into a spectrum of fermentable sugars by the action of various amylotic enzymes. The solution of sugars resulting from the mashing process is referred to as sweet wort. After removal of solid material, the sweet wort is then boiled with hops. In this part of the process bittering precursors, which are present in hops, are extracted into the boiling wort. At this temperature, the precursors are then transformed into components which are responsible for the char-

![Diagram of brewing process]

Figure 7.1 An outline of the brewing process.
acteristic bitterness that is associated with beer. When boiling is completed, after 1–2 hours, the bitter wort is cooled prior to fermentation by brewers' yeast. Fermentation is complete within 3–7 days and after removal of the yeast, conditioning and final clarification, the beer is ready for consumption.

Malted cereals are relatively expensive raw materials and it is therefore common practice to replace some of the malted grist with cheaper sources of extract. These supplements are referred to as adjuncts and include raw cereals such as barley, wheat, maize and rice. Cereals with high gelatinisation temperatures, such as rice, may be cooked separately by the brewer before addition to the mash. It is in the area of adjuncts where there is obvious potential for the application of extrusion technology. Review of work in this area is beyond the scope of this chapter. Suffice to say, however, that in spite of extensive efforts, technical difficulties arising from the use of extruded cereals in brewing (high and unacceptable wort viscosities) have not been overcome to date. As a consequence, as far as the author is aware, extruded cereal adjuncts are not being used in the brewing industry.

A less obvious, but more successful, application of extrusion technology to brewing concerns the other major raw material – hops. In this case, the extruder is not being used as a cooker but as a reactor, facilitating the transformation of bittering precursor to bittering component. This application will now be discussed in detail.

7.2 Application of extrusion technology to the production of bitterness in beer

7.2.1 Background

As stated above, hops are introduced into the wort boiling stage of the brewing process in order to impart bitterness to beer. The bittering precursors present in the hop are a group of three compounds referred to as alpha acids [1] and their molecular structures are illustrated below (Figure 7.2).

The total alpha acid content of the hop is usually in the range of 2–12% by weight, depending on the variety and the conditions experienced during the growing season. Another varietal characteristic is the ratio of the individual homologues to each other. Humulone is usually the major constituent at 30–60% of the total alpha acid content. In some older varieties cohumulone is the major constituent but is more usually in the range of 20–40%, with adhumulone being the minor constituent at 5–15%.

These alpha acids are not particularly bitter in their own right, or readily soluble in beer (5 mg l^{-1} maximum). During the boiling process,