fermentation, acetic acid affects the nib pH value and consequently enzymatic reactions and flavour precursor formation. This means that the optimum condition for the enzymatic hydrolysis of sucrose and proteins in the beans is in the acid range (Biehl and Passern, 1982; Biehl *et al.*, 1985). According to Jinap and Dimick (1990) cocoa beans from Malaysia or Brazil (Bahia) have low pH (4.7–5.2), those from West Africa or Indonesia medium pH (5.2–5.5) and those from Ecuador, Venezuela or Guatemala high pH (5.5–5.8). The higher pH correlates to a lower fermentation degree. The concentrations of acetic acid and of lactic acid in Malaysian or Brazilian cocoas are 5.2–8.2 g/kg and 2.7–5.0 g/kg, respectively, and in the other cocoas 4.2–5.6 g/kg and 2.1–3.0 g/kg, respectively (Jinap and Dimick, 1990). In heap fermented and dried Ghana cocoas 3.3–7.9 g/kg of acetic acid and 1.9–3.9 g/kg of lactic acid were found, with large differences between one and the next fermentation heap (Camu *et al.*, 2008). Pulp preconditioning by post-harvest storage of cocoa pods for about 10 days leads to the reduction of nib acidification during subsequent fermentation and a reduction of the acid note (Biehl *et al.*, 1989; Jinap *et al.*, 1994a; Ofosu-Ansah *et al.*, 2013).

8.2.2.5 Alkaloids

Cocoa beans contain about 1–3% of theobromine, 0.1–0.2% of caffeine and traces of theophylline, with no quantitative change of the concentration being reported during fermentation and roasting. Owing to its low taste detection threshold of 10 mg/l, theobromine is believed to contribute to the bitter taste. After roasting, theobromine may form chemical adducts with diketopiperazines (see also Figure 8.11 in Section 8.4.3), which seem to have some connection with the characteristic bitter notes of roasted cocoa (Pickenhagen *et al.*, 1975).

8.2.3 Over-fermentation

A detrimental hammy off-flavour defect can arise due to a prolonged treatment following the optimum fermentation time. Over-fermentation is caused by a direct aerophilic microbial attack on the beans, destroying the cocoa flavour potential, increasing the pH value and blackening the beans. This process may arise especially in the wet, well-aerated mass. Aerophilic bacteria metabolise amino acids and peptides. The hammy off-flavour can be explained by the formation of a surplus of propionic acid, 2-methylpropanoic acid and 2/3-methylbutanoic acid (Lopez and Quesnel, 1973). However, some of these acids, in usual concentration levels, were postulated as important in cocoa flavour (Schnermann and Schieberle, 1997; Frauendorfer and Schieberle, 2006). In practice, it is often difficult to distinguish the “hammy taste” and “smokiness flavour” caused by incorrect drying techniques.

8.3 Drying

8.3.1 Influence of drying on flavour and flavour precursors

After fermentation, the beans are dried and this process is also instrumental in flavour precursor development. Indicators of good drying practices, which also relate to the flavour quality of the beans, are a good brown colour and a low astringency and bitterness. For sun-drying, the beans are spread on the ground, on mats or on wooden floors raised from the ground and protected against rain. Five to seven days are usually necessary to reduce the water content to about 7%. In artificial drying, wood fires or oil burners are connected to a flue under a floor of closely spaced slats. Hot air is passed through a layer of cocoa beans.

Flavour assessment of cocoa beans dried using different methods, that is sun drying, air-blowing, shade drying and oven drying, demonstrated that the sun-dried samples rated higher in cocoa flavour development and had fewer off-notes (Jinap *et al.*, 1994b). Excessive heat and rapid drying may not allow for adequate loss of volatile fatty acids (C_2–C_5) and therefore have a detrimental effect on quality. If smoke, during oven-drying, comes in contact with the beans, an off-flavour known as smoky or hammy flavour can result, as cocoa easily absorbs volatile phenols from smoke. Figure 8.3 shows the total amount of volatile phenols in correlation with the sensorial intensity of smokiness (Lehrian *et al.*, 1978). In smoky cocoa beans phenol, methyl-phenols, dimethyl-phenols, 1,2-dihydroxy-benzene, dimethoxy-phenols and 3-methyl-guaiacol have been identified via HPLC in combination with an electrochemical detection, whereas cocoas of good quality are mostly free of them (Sandmeier, 1987). Incomplete drying or rain soaking may result in mould contamination. Heavy mould growth yields high concentrations of methyl-ketones and volatile aldehydes, causing harsh and unpleasant flavours (Hansen and Keeney, 1970; Afoakwa, 2010).

During drying the Maillard reaction takes place and Amadori compounds, the first intermediates of Maillard reaction, have been identified in dried, unroasted

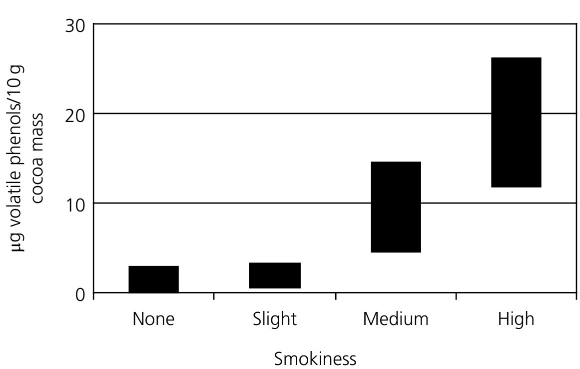

Figure 8.3 Correlation of the total amount of volatile phenols (µg/10g cocoa) and sensorial smokiness of cocoa. *Source* Lehrian *et al.* (1978). Reproduced with permission of John Wiley & Sons.