in preventing bloom than intact milk fat (Bricknell and Hartel, 1998). Lohman and Hartel (1994) reported that high-melting fractions (HMF) inhibit bloom in chocolate containing 30% of the fat as milk fat. Low-melting fractions (LMF) have been shown either to have no effect on bloom inhibition or to actually induce bloom. Lohman and Hartel (1994) have suggested that the reason why lower melting milk fat fractions induce bloom is because the addition of more liquid fat increases the mobility of the unstable triglycerides. Although it appears that it is a high-melting component of milk fat that prevents bloom, the exact components responsible and their mechanism are unknown.

There are various theories on how milk fat prevents bloom. Milk fat crystallises in a solid formation with cocoa butter and the triglycerides that are unique to milk fat prevent or slow down the transformation of the form β(V) crystal structure of cocoa butter to form β(VI) (Timms, 2003). When chocolate crystallises more slowly, as happens when milk fat is present, microscopic cracks are less likely to occur within it (Kleinert, 1961). A further theory claims that milk fat inhibits bloom by maintaining a solution in which the unstable forms of cocoa butter are held (Cook, 1984). Tietz and Hartel (2000) and Wright *et al.* (2000) have shown that the minor lipids of milk fat affect the crystallisation of cocoa butter and milk fat in chocolate and have suggested that the minor components inhibit bloom formation through their influence on the crystal structure of cocoa butter.

Hartel (1999) and Liang and Hartel (2004) suggested that the structure of the non-fat or dispersed phase of chocolate (sugar, milk powders and non-fat cocoa particles) has an influence on bloom formation. The way milk fat interacts with this solid phase may affect the rate of bloom inhibition. The dairy ingredient used, whether it is free milk fat added directly to chocolate or through the use of fat-containing dairy powders, may also have different effects on the bloom stability of chocolate. Further work is still required to fully understand the mechanism of bloom development and the mechanism of bloom resistance by milk fat.

Use of milk fat through a high free-fat system (SMP and AMF) is thought to be more effective than the use of WMP in preventing bloom in products in which oil migration is a likely cause, for example, in chocolates containing nuts (Urbanski, 2000). Liang and Hartel (2004) showed that HFF WMP and SMP and AMF gave a much higher bloom retarding effect than roller and traditional dried whole milk powder.

Other modified fats or compounds are available as bloom inhibitors (Timms, 2003), but many of these do not have regulatory approval in many countries. Milk fat as a bloom inhibitor has the advantage of being able to be legally added to chocolate in most countries of the world.

Lactose crystallisation also seems to influence bloom formation, since milk powders with the same degree of free fat but different degrees of lactose crystallisation influence the bloom development differently.

5.2.3 Lactose

Lactose contributes to flavour, can be used to modify the sweetness of chocolate and contributes to the total milk solids content legally required in chocolate. Lactose, or milk sugar, is a disaccharide synthesised from the monosaccharides, glucose and galactose. The process is unique to the mammary glands and produced under hormonal control (Dijksterhuits, 1990). Lactose can be hydrolysed back into these constituent sugars by the enzyme β-galactosidase, also called lactase.

Lactose and its constituents, galactose and glucose, are reducing sugars that play active roles, along with milk proteins, in the Maillard reaction. Lactose also can undergo caramelisation. Both of these reaction types are essential in achieving the rich, caramelised, cooked dairy flavour typical of milk chocolate.

As lactose is a disaccharide, it responds in a similar way to sucrose when processed in milk chocolate. Lactose is less sweet than sugar, the relative sweetness is about 0.3 compared to 1.0 for sucrose (Timmermans, 1990), and lactose can be used to reduce the sweetness in chocolate. Lactose is a far less water soluble than sucrose (17 g in 100 ml water, compared with sucrose at 67 g in 100 ml water at 20 °C; 68 °F).

The use of lactose in place of milk powder offers chocolate manufacturers a further means of reducing costs, while still achieving levels of milk solids specified in regulations. Replacement of high levels of standard milk powders with lactose does cause detectable changes in the sensory properties of the milk chocolate.

5.2.4 Vitamins and minerals

The vitamins and minerals in milk contribute nutritional benefits to chocolate consumers. Milk is a good source of the water soluble vitamins thiamin, riboflavin and vitamin B12. Milk is an important source of the fat soluble vitamins, such as vitamin A (retinol), vitamin E (α-tocopherol) and D (calciferol). β-Carotene, the precursor to vitamin A, provides the distinctive yellow colour of milk fat.

Milk is an excellent source of important nutritional minerals such as calcium and potassium. Other minerals found in milk in significant quantities are sodium, phosphorus and magnesium.

5.3 Milk-based ingredients for chocolate

Dairy ingredients used for chocolate must first be concentrated to remove water in order to allow for proper crystallisation of the cocoa butter matrix. The composition of typical dairy ingredients used in chocolate is shown in Table 5.3. Note that the maximum moisture of these ingredients in 4.5%. Higher moisture ingredients like cream may be used in truffle fillings, caramels and other confectionery products but these are not covered in this chapter, which is focused on solid chocolate products with a continuous fat phase.