factors (see also Section 4.9). The sweetening character of the monosaccharide fructose is somewhat different from that of the disaccharide sucrose (see also Section 4.10). Fructose is of importance for the manufacture of chocolates with low or reduced glycaemic response and suitable for diabetics. This is because there is only a low blood sugar increase in the body after eating fructose, unlike sucrose or glucose. Fructose is absorbed more slowly than glucose and only a small proportion is converted into glucose during absorption. This slow absorption, as well as the speedy metabolism, of the fructose reduces any rapid peaks in blood glucose concentration. Furthermore, fructose is mainly metabolised in the liver, that is without insulin involvement, whereas the corresponding glucose metabolism reaction depends on insulin. This makes fructose a valuable sugar substitute in low glycaemic diets. It should, however, be used only in moderate quantities in order to avoid overstressing the fructose metabolism.

Certain factors need to be taken into account when fructose is used in the manufacture of chocolate. For instance, the water content of the other ingredients, such as milk powder, should be kept as low as possible and the temperature during the conching processes should not exceed 40 °C (104 °F). Failure to do so may result in a gritty mouthfeel and/or the formation of degradation or reaction products that give off-flavours. This risk is very high since fructose caramelises and takes part in Maillard reactions fairly easily.

4.7.4 Tagatose

Tagatose is a monosaccharide, which has a similar structure to fructose. Traces of tagatose can be found in heat-treated dairy products, for exampe sterilized cow milk and milk powder (Levin *et al.*, 1995). It is produced from lactose, by enzymatic hydrolization to glucose and galactose, which are separated by a chromatographic fractionation. Then galactose is isomerized to tagatose under alkaline conditions, using calcium hydroxide. By treatment with carbon dioxide the suspension is neutralized and the calcium carbonate that is formed is then removed by filtration. Tagatose is a reducing sugar with a sweetening power of 92% compared to that of sucrose (Arla, 2004). However, as a monosaccharide it has a somewhat different sweetening character than sucrose (see Section 4.10).

Tagatose is metabolized like fructose, but only 15–20% of the tagatose are absorbed in the small intestine. The major part of ingested tagatose is fermented in the colon by the indigenous microflora (Calorie Control Council, 2004). Therefore tagatose has a low calorific value, prebiotic effects and a low glycaemic response (Arla, 2004). However, it has a similar laxative potential to the sugar alcohols (Levine *et al.*, 1995).

Tagatose can be used for tooth-friendly confectionery products (Nordzucker InnoCenter, 2005). Like fructose and other monosaccharides, it has a sweetness character with some scratchy and burning aftertaste, particularly when used to make chocolate. However, the sweetness profile of chocolates made with disaccharide alcohols or combinations of these sweeteners with polydextrose and

sweetened up with intense sweeteners can be further improved by adding a small percentage of a monosaccharide, for example about 6% tagatose (see Section 4.10). Here tagatose has the advantage of being tooth-friendly and, because it is a reducing sugar, it also possesses flavour-enhancing properties.

4.7.5 Lactose

Lactose, also called milk sugar, is a disaccharide consisting of the monosaccharides glucose and galactose and is an integral part of all types of milk. In cow's milk it amounts to about 4.5%. The present-day large-scale production of lactose is based on whey, from which it is isolated to a very high degree of purity following several purification steps (see Chapter 5). Lactose crystallises with one molecule of water as a monohydrate. It does not expel this water, even when heated to 100 °C (212 °F). Lactose has been used traditionally in the production of milk chocolate as a constituent of full cream milk powder, skimmed milk powder or chocolate crumb. However, pure lactose has more and more frequently been added in small quantities to sucrose in the manufacture of chocolate (Hogenbirk, 1985).

Lactose monohydrate is non-hygroscopic and forms crystals harder than those of sucrose. Compared with sucrose, its sweetening power is very low.

4.7.6 Isomaltulose

Isomaltulose, which is also known by the trade name "Palatinose", has been detected in very small quantities in honey and cane sugar extract. It is produced by enzymatic conversion from sucrose (Weidenhagen and Lorenz, 1957). Isomatulose is a disaccharide made up of the monosaccharides glucose and fructose that crystallises with one molecule of constituent water. It has less sweetening power than sucrose. Like sucrose, isomaltulose has a calorific value of 4 kcal/g but it has a lower glycaemic response than sucrose, is tooth-friendly and well tolerated. It has been recommended as a sugar substitute for confectionery and chocolate items (Kaga and Minzutani, 1985; Beneo-Group, 2010).

4.7.7 Trehalose

Trehalose is a naturally occurring disaccharide consisting of two glucose molecules, which recrystallises as a dihydrate. It is found in small quantities in mushrooms, honey and shrimps and is produced enzymatically from starch. It has less sweetening power than sucrose. Trehalose, like sucrose, has a calorific value of 4 kcal/g. However, it has a lower glycaemic response than sucrose and is described as having "less cariogenicity" (Figura and Michaelis, 2003).

4.7.8 Polydextrose

Polydextrose is made up of glucose and small amounts of sorbitol which, because of its manufacturing process, also contains minor residues of citric acid. It is sold as an amorphous powder in several different quality standards. The original