grades were not only hygroscopic, but also contained relatively large amounts of citric acid and had a tart and slightly bitter aftertaste. Newer grades, for example Litesse®II and Litesse®Ultra™, are much improved. They have a clean, mildly sweet flavour and can be used satisfactorily in chocolate when combined with other bulk sweeteners (e.g. lactitol) and further sweetened with an intense sweetener (Krüger *et al.*, 1996, Krüger and Fairs, 2000). Because polydextrose types such as Litesse®II, can caramelise, the flavour of chocolates made with polyols is enriched when these sweeteners are used together with a suitable polydextrose grade. The further developed Litesse®Ultra™ does not caramelise and therefore cannot participate in this Maillard reaction. It is, however, used in combination with sugar alcohols for the manufacture of sugarless and non-cariogenic chocolates (sometimes for flavour reasons blended with one of the caramelising polydextrose grades). Because polydextrose is an amorphous powder, an exothermic reaction takes place when it dissolves in water. This means that there is a "warming sensation" when it is dissolved in the saliva in the mouth. This can be used to offset the heat of solution of sugar alcohols when they are used together with polydextrose in chocolate. This means that sometimes undesirable "cooling effects" of sugar alcohol-sweetened chocolates can be overcome (see Section 4.10).

Since polydextrose is only partly metabolised in the human body, it is also used as a bulking agent for low calorie food. The FDA has recognised it as containing not more than 4 kJ/g, whereas sucrose and other carbohydrates contain about 17 kJ/g (Liebrand and Smiles, 1981). Polydextrose is also regarded as either a resistant polysaccharide (RP) or resistant oligosaccharide (RO), providing those physiological benefits associated with fibre (Craig *et al.*, 1996) and prebiotic effects (Probert *et al.*, 2004; Stowell and Krüger, 2006; Lahtinen *et al.*, 2010). It is in fact classified as a fibre and prebiotic ingredient in a number of countries.

Generally polydextrose can be eaten in larger quantities than sugar alcohols. In the EU and other European countries no laxative warning label is necessary for products containing even more than 10% polydextrose. During the last few years polydextrose has been particularly used for calorie reduced, "low carb", as well as low and reduced glycaemic products. It is also a suitable ingredient for tooth-friendly chocolates (Roulet *et al.*, 2001).

4.7.9 Inulin

Inulin is a naturally occurring carbohydrate mixture of oligo- and polysaccharides. These are composed of fructose units, mainly with an end standing glucose unit. Its degree of polymerisation ranges between 3 and 60 (Beneo-Group, 2012). Inulin functions as a carbohydrate reserve in thousands of plants and is produced commercially from chicory roots, which contain about 17% inulin. Nutritionally it is classified as dietary fibre and a prebiotic and low calorie ingredient (De Soete, 1996; Franck, 2002). It cannot be used to make tooth-friendly

chocolates (Krüger, 1997), however, because it can be fermented by oral microorganisms. A lower percentage of inulin can be used in combination with sugar alcohols in "no added sugar" chocolates or with fructose or sugar alcohols in low glycaemic chocolates.

4.7.10 Sorbitol

Sorbitol is a monosaccharide alcohol that is present in small quantities in numerous fruits. The commercial production process is based on the catalytic hydrogenation of glucose. Sorbitol is hygroscopic and its sweetening power is about half that of sucrose. The heat of solution of sorbitol is such that it generates a slight cooling effect when it dissolves in the mouth. In the past sorbitol was one of the sweeteners used in the production of "no sugar added" chocolates (Caliari, 1983). Nowadays, "no sugar added" chocolates are more often produced with disaccharide alcohols, for example isomalt, maltitol or lactitol, often in combination with polydextrose.

4.7.11 Mannitol

Mannitol is a monosaccharide alcohol present in manna, the dried juice of the flower or manna ash. Its large-scale industrial production is a catalytic hydrogenation process based on pure invert sugar, which results in a mixture of sorbitol and mannitol, from which mannitol is separated in a multistep process. Mannitol has a low solubility and its sweetening power is comparable or slightly less than that of sorbitol. In combination with sorbitol and enhanced in its sweetening power by intense sweeteners, it was occasionally used for the production of "no sugar added" chocolates. However, of all the sugar alcohols, mannitol manifests the greatest laxative effect; the safe daily intake for adults is only about 10 g (0.35 oz; Kammerer, 1972).

4.7.12 Xylitol

Xylitol is a monosaccharide alcohol, which has only five carbon atoms unlike sorbitol and mannitol, which have six carbon atoms each. Xylitol is a naturally occurring sweetener and is present in numerous mushrooms, vegetables and fruits. Furthermore, xylitol is an inherent part of the normal human metabolism. Every human generates between 5 and 15 g (0.2 and 0.5 oz) of xylitol every day as part of the normal carbohydrate metabolism. The large-scale production of xylitol is based on birch wood, corncobs, straw and other plant material containing a high amount of xylan. Xylan, a polymer of xylose, is hydrolysed to xylose by means of acids once it has been isolated from the raw material. Following further isolation and purification of the xylose, it is hydrogenated into xylitol. Now xylitol is also produced by enzymatic conversion of glucose.

Xylitol is non-hygroscopic and has a very high heat of solution (153.1 J/g), which results in a remarkable cooling effect when melted in the mouth. The sweetening power of xylitol is the highest of all sugar alcohols and comparable to