40% of that of sucrose. Lactitol monohydrate and anhydrous lactitol are suitable for the production of no sugar added chocolates and tooth-friendly confectionery when combined with intense sweeteners. Lactitol has prebiotic properties (Probert *et al.*, 2004) and can be used to produce low or reduced glycaemic index products. Lactitol monohydrate does not lose its water of crystallisation very easily, which means that conching temperatures up to about 60 °C (140 °F) can be used without any adverse effect on the flow properties of the chocolate. Chocolates made with anhydrous lactitol can be conched at temperatures as high as 80 °C (176 °F). Lactitol chocolates have viscosities comparable to those of sugar chocolates (Arntzen, 1992). Chocolates produced using lactitol, polydextrose type Litesse®II and the intense sweetener aspartame were found to be not significantly different from sucrose-sweetened chocolate when evaluated by a trained sensory panel (Krüger *et al.*, 1996).

4.8 Physiological characteristics of sugars, bulk sweeteners and special polysaccharides

Bulk sweeteners are sugar alcohols, also known as polyalcohols or polyols. Polydextrose and inulin are special polysaccharides. Because of their sweetening power and/or their lower calorific value, they are used as sugar substitutes. Sugar alcohols and polydextrose are applied in "no added sugar", sugarless, "low carb", low or reduced glycaemic index and calorie reduced confectionery and chocolate products. Fructose, isomaltulose and tagatose can be used for low or reduced glycaemic index products. In addition, sugar alcohols, polydextrose, isomaltulose and tagatose are tooth-friendly sugar substitutes as they are scarcely, if at all, converted into acids by oral micro-organisms, unlike sucrose, fructose and other saccharides.

Conventional milk powder cannot be used for tooth-friendly milk chocolates because the lactose in the milk powder is cariogenic. Therefore a lactose free skimmed milk powder substitute must be used. This is available by spray drying a solution of non-cariogenic sweeteners, for example lactitol, milk proteins and milk minerals, which are necessary for a good milk flavour. Milk fat can be added to the conched masse (Roulet *et al.*, 2001).

It is important to take into account the laxative effects of the sugar alcohols and tagatose. The EU Scientific Committee on Foods has emphasised that the laxative effect of sugar alcohols should not be neglected and stated that "consumption of the order of 20 g (0.7 oz) per person per day of polyols is unlikely to cause undesirable laxative symptoms. The safe level for individual polyols ingested singly is higher in many cases". The Committee was fully aware that most people will tolerate sugar alcohols even at levels of 30–50 g (1.1–1.8 oz) per day without any laxative effect (van Esch, 1987). The sugar alcohol erythritol, has an even higher digestive tolerance (Cerestar, 2004).

Table 4.4 Amounts of sugars, sugar alcohols (Kammerer, 1972) and polydextrose (adapted from Craig *et al.*, 1998) that can be tolerated in the diet. Reproduced with permission of Food and Agiculture Organization of the United Nations.

	Average daily intake in g/day (oz/day)		
	1 kg (2.2 lb)	**70 kg (154 lb)**	**20 kg (44 lb)**
	Body weight	**Body weight (adult)**	**Body weight (child)**
Mannitol	0.14	10	2.8
	(0.005)	(0.35)	(0.1)
Sorbitol	0.43	30	8.6
	(0.02)	(1.1)	(0.3)
Xylitol	0.43–0.71	30–50	8.6–14.3
	(0.02–0.025)	(1.1–1.8)	(0.3–0.5)
Fructose	0.71	50	14.3
	(0.025)	(1.8)	(0.5)
Sucrose	1.00–1.28	70–90	20–25
	(0.035–0.045)	(2.5–3.2)	(0.7–0.9)
Polydextrose	1.28	90	—
	(0.045)	—	—

A daily consumption of about 50 g (1.8 oz) of polydextrose, even consumed as single dose, is unlikely to cause gastrointestinal effects. The mean laxative dose of polydextrose is 90 g (3.2 oz) per day (Pfizer, 1978).

Table 4.4 summarises daily intake values as a function of body weight to illustrate the levels at which some of the sugar alcohols and polydextrose can be eaten without any undesirable side effects (Kammerer, 1972; Craig *et al.*, 1998).

All sugar alcohols have less metabolizable energy than sugar. This fact has been taken into account by legislative bodies. The current EU Nutritive Labelling Directive designates an energy value of 2.4 kcal/g (10 kJ/g) for all sugar alcohols, which is 40% less than the value for sugar, which is 4 kcal/g (17 kJ/g). A summary of European and USA legislative calorific values for sugar substitutes is given in Table 4.5. The glycaemic response and the suitability of these ingredients for tooth-friendly products is presented in Table 4.6.

Foods with low glycaemic effects (blood glucose raising ability) have been scientifically validated as having an important role in the dietary management of weight reduction, diabetes and reducing the risk of heart disease (Leeds *et al.*, 1996). Sugar alcohols, polydextrose, inulin, as well as fructose, tagatose and isomaltulose provide a means to producing low or reduced glycaemic index confectionery products because they have low glycaemic responses, as can be seen on Table 4.6.

It should be noted that there is no correlation between the glycaemic response of polyols or speciality carbohydrates and their molecular weight or number of