Health effects of erythritol
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Abstract
Erythritol (1,2,3,4-butanetetrol) is a non-caloric C4 polyol made by fermentation that has a sweetness 60–70% that of sucrose. The safety of erythritol has been consistently demonstrated in animal and human studies. Erythritol has a higher digestive tolerance compared to all other polyols because about 90% of the ingested erythritol is readily absorbed and excreted unchanged in urine. Erythritol is used in a wide range of applications for sweetening and other functionalities, e.g., in beverages, chewing gum and candies. In this review, we summarise the health effects of erythritol described in the literature. We focus on studies involving the anti-cariogenic and endothelial protective effects of erythritol. We conclude that erythritol could be of great importance and could be considered to be the preferred sugar substitute for a rapidly growing population of people with diabetes or pre-diabetes to reduce their risk of developing diabetic complications.

General characteristics
Erythritol (1,2,3,4-butanetetrol) is a four-carbon sugar alcohol, or polyol, and a meso-butanetetrol (Fig. 1). It occurs naturally in some mushrooms, some fruits (e.g., watermelon, grapes and pears) and in fermented foods including wine, cheese, sake and soy sauce [1, 2]. Consumption of erythritol natu-
Erythritol does not affect reproductive performance or fertility of parental rats. In addition, no adverse effects on the developing foetus were observed [2, 5–7]. Erythritol does not have mutagenic potential, as observed in the Ames test and chromosomal aberration test [2, 5, 8, 9].

In summary, animal toxicological studies and clinical studies have consistently demonstrated the safety of erythritol. Therefore, it is not expected that erythritol will cause adverse effects under the conditions of its intended use in food.

**Metabolic fate**

The metabolic profile of erythritol is not like that of any other polyol, which gives rise to some of erythritol’s unique properties. Erythritol is readily and virtually completely absorbed from the small intestine via passive diffusion similar to fructose. Fructose transport can also occur via GLUT2 transport with absorption enhanced in the presence of glucose due to greater GLUT2 insertion in the apical membrane as SGLT1 transports glucose. This explains the enhanced absorption of fructose in the presence of glucose. In addition, the presence of glucose has been shown to enhance paracellular flow due to the opening of tight junctions resulting in increased absorption of small solutes [10]. Enhanced GLUT2 insertion and enhanced paracellular flow in the presence of glucose has been hypothesised to be the same pathway with altered functions in the absence/presence of glucose. However, this hypothesis does not support the differences noted for minor increases in small solute transport compared to the greatly enhanced transport of fructose when glucose is present [11, 12]. As erythritol is readily absorbed on its own, the impact of the presence of glucose on erythritol absorption would be minimal and has not been investigated to date. After absorption, erythritol is distributed throughout the body, with maximum plasma concentrations occurring within the first 2 h of digestion. Up to 90% is excreted unchanged in the urine [5, 13, 14]. Unabsorbed erythritol may be subjected to microbial

**Manufacturing process**

Large-scale production of erythritol uses fermentation. Pure glucose, sucrose or glucose from maize (as a source of starch) is used as a starting material. Starch is extracted from the maize, and through hydrolysis the starch chains are broken down into glucose molecules, which are fermented into erythritol using an osmophilic yeast, like Moniliella pollinis. After fermentation, yeast cells and other impurities are removed by filtering. Once the fermentation broth is filtered, erythritol is purified by ion exchange resin, activated charcoal and ultrafiltration. In the last step, crystallisation, the broth is cooled down and erythritol precipitates from the solution yielding crystals with over 99% purity [3, 4].

**Safety**

A number of toxicological studies have been performed to evaluate the safety of erythritol. These have been extensively discussed in reviews by Bernt et al. and Munro et al. [2, 5].

In summary, based on acute toxicity studies, erythritol is classified as essentially non-toxic after oral administration. Subchronic studies further support the safety of erythritol. Chronic studies (up to 2 years) revealed that erythritol has no effect on survival or carcinogenicity [2, 5].

Even at high doses (up to 16 g/kg body weight), erythritol does not affect reproductive performance or fertility of parental rats. In addition, no adverse effects on the developing foetus were observed [2, 5–7]. Erythritol does not have mutagenic potential, as observed in the Ames test and chromosomal aberration test [2, 5, 8, 9].

In summary, animal toxicological studies and clinical studies have consistently demonstrated the safety of erythritol. Therefore, it is not expected that erythritol will cause adverse effects under the conditions of its intended use in food.