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Fig. 1: Erythritol

ERYTHRITOL

A Sugar Substitute Makes a Career for Itself in Dentistry

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The sugar substitute erythritol is known as an agent for sweetening calorie-reduced food, baked products and candy. Up to now, less attention has been paid to the positive effects of erythritol on the composition of the oral biofilm, which make the substance increasingly interesting for caries and periodontitis prevention at home. What's more, the sweet white crystals also play an important role in the air-polishing technique as a low abrasive powder.

Institutions like the German Society for Nutrition (DGE) and the World Health Organization (WHO) have for a long time warned about the health risks associated with high sugar consumption. The WHO recommends consuming no more than 25 grams of free sugar per day. Sugar contributes to obesity, which can cause further diseases. In addition to influencing systemic diseases, sugar consumption also plays a very important role in dentistry: The significance of sugar in the development of caries has long been known [Gustafsson et al., 1954]. There are also links between sugar consumption and gingivitis or periodontitis [Janus et al., 2017; Hashino et al., 2013]. So it is understandable that medical and dental research is looking for ways of replacing sugar.

In general terms, sweeteners and sugar substitutes can be used as sugar substitutes. Sweeteners are distinguished depending on whether they are produced synthetically or occur naturally.The best-known synthetic sweeteners are cyclamate, aspartame and saccharin. Stevia on the other hand occurs in nature. These sweeteners are not carbohydrates, have no calories or hardly any, and do not raise blood sugar levels. They are frequently used in low-carb formulas or „light" products. High-dose sweeteners are criticized because they have been found to cause complaints in animal experiments (from allergies to cancer). However, there is no evidence that these risks also exist in humans.

Sugar substitutes are sweet-tasting compounds, mostly polyols (so-called sugar alcohols), which have less in-

fluence on blood sugar levels. The main representatives of this group are sorbitol, mannitol, lactitol, isomalt, xylitol and erythritol.

According to the German Federal Institute for Risk Assessment (BfR), sugar substitutes may be used in foodstuffs without limitation. According to the EU, there is therefore no limit value for an acceptable daily intake. It is noteworthy that sugar substitutes can cause flatulence, diarrhea and stomach pains. Of the sugar alcohols, erythritol is considered the most tolerable.

ERYTHRITOL

Erythritol (Chemical Abstracts Service (CAS) No.: 149–32–6) is a white crystalline powder with the chemical formula C4H10O4. It occurs in small quantities in nature in honey, grapes, melons and mushrooms, for instance. Today erythritol is produced by microbiologically transforming (fermenting) natural sugars. It is more difficult to produce industrially than other sugar substitutes – so production costs are much higher.

The most important properties of Erythritol:

- Density: 1.45 g/ml
- Solubility: 100 g/l
- pH value: neutral
- 60 to 70 percent of the sweetening power of sugar
- Stable in acidic and alkaline environments
- Heat-stable
- Contains next to no calories (only about 0.2 kcal/g), which corresponds to 5 percent of the caloric value of sugar

Oral bacteria cannot metabolize erythritol, which means that it is not cariogenic, but rather tooth-friendly [De Cock et al., 2016]. The glycemic factor is 0, so erythritol is suitable for diabetics as it does not increase glucose levels in blood plasma or insulin levels. In contrast to other polyols, erythritol is almost completely (> 90 percent) absorbed in the small intestine, not metabolized and excreted unchanged in urine. Small amounts are also to be found in the stool.

This is why side effects such as flatulence and diarrhea occur less frequently and with less intensity with erythritol than with the other sugar alcohols.

Erythritol is an antioxidant and acts as a radical scavenger. Erythritol is safe. It is approved without restriction in over 60 countries (Europe, USA, Japan, Canada, Australia, New Zealand, Russia and many Asian countries).

ERYTHRITOL IN PREVENTIVE DENTISTRY

For many years, sorbitol and above all xylitol were considered the gold standard of sugar alcohols in preventive dentistry [Mäkinen, 1972; Mäkinen et al., 2008; Mäkinen et al., 1995 a; Mäkinen et al., 1995 b; Mäkinen et al., 1996 a; Mäkinen et al., 1996 b]. The advantages of erythritol over other sugar alcohols as described were the spur for many scientific studies on the use of erythritol in preventive dentistry. The latest literature shows erythritol's great potential [Regnat et al., 2018; Falony et al., 2016; Janus et al., 2017; Hashino et al., 2013; Hägi et al.,2013; De Cock et al., 2016].

Erythritol and biofilm

The influence of erythritol on the growth of biofilm and individual bacteria, particularly of Streptococcus mutans in saliva and biofilm, is well known and has been described multiple times in the literature [Regnat et al, 2018; Falony et al, 2016; Janus et al, 2017; Hashino et al, 2013; De Cock et al, 2016; Mäkinen et al, 2001; Mäkinen et al, 2005; Söderling et al, 2010; Park et al, 2014; Honkala et al, 2014]. The evaluation of the literature in comparing xylitol, erythritol and sorbitol on biofilm growth, bacterial levels in saliva and biofilm can be summarized as follows:

- All three polyols show a significant reduction of biofilm weight (biofilm thickness) as well as a reduction of S. mutans in plaque and saliva.
- The best results were obtained in the erythritol group.
- These results are attributed to the lowest solubility (longer retention) and the lowest molecular weight of erythritol in the group of polyols and the related ease of penetrating the cell membrane [Munro et al., 1998]. In addition, xylitol tends to inhibit biofilm growth non-specifically, whereas the growth of S. mutans is specifically inhibited by erythritol.
- Erythritol also reduces plaque adhesion for some polysaccharide-forming streptococci (S. mutans, S. sanguinis, S. salivarius, S. sobrinus) [Regnat et al., 2018; Falony et al., 2016; Hashino et al., 2013; Mäkinen et al., 2002].

With their work in 2013 [Hashino et al., 2013], Hashino et al. attempted to close a large gap in the knowledge of sugar alcohols and their influence on oral biofilms. Assuming that Streptococcus gordonii is an important early colonizer of biofilms (responsible for the adhesion of biofilms) and that Porphyromonas gingivalis as a late colonizer is the main bacterium responsible for the development and maintenance of periodontitis, Hashino et al. investigated the influence of sugar alcohols on the microstructure and metabolism of a biofilm composed of S. gordonii and P. gingalis. The results of this work:

- The greatest inhibition of growth of S. gordonii and P. gingivalis was obtained with erythritol, followed by xylitol and sorbitol.

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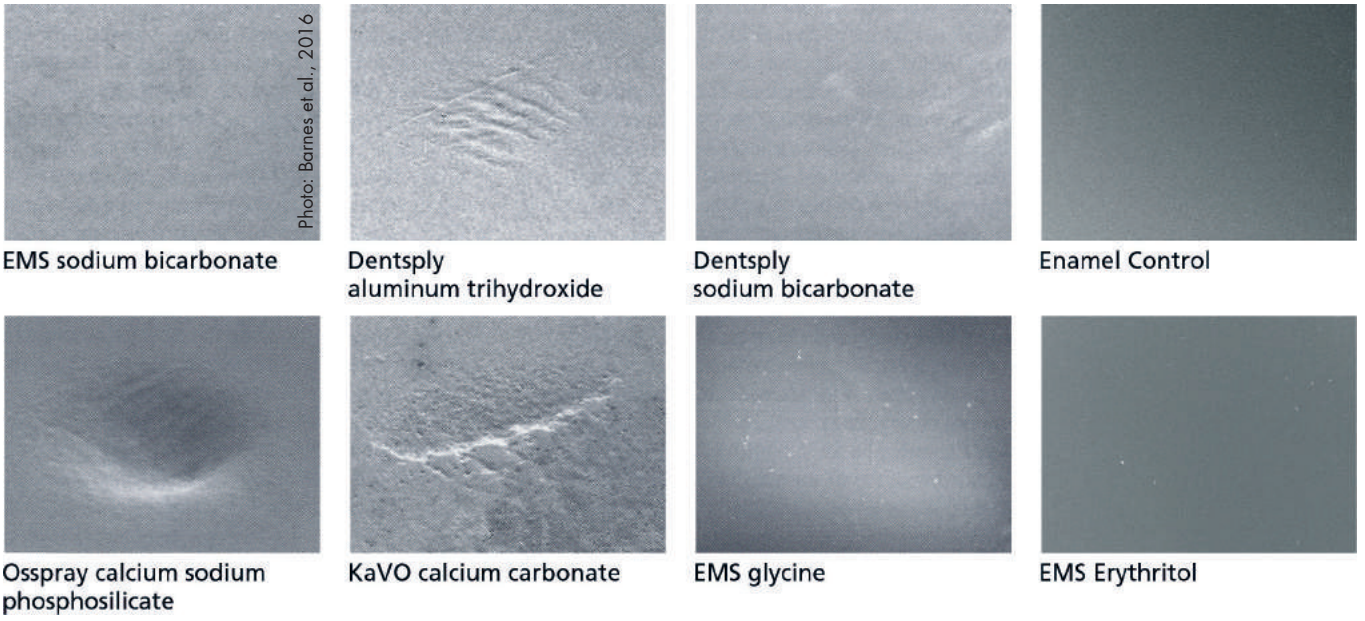

Fig. 2: Enamel surfaces after treatment with various air-polishing powders

- The metabolic profiles of erythritol related to S. gordonii and P. gingivalis show a dose-dependent reduction of bacteria and the extracellular matrix.
- The direct cellular influence of erythritol and sorbitol on P. gingivalis shows that erythritol inhibits the growth of P. gingivalis and sorbitol promotes it.

In summary, the work shows that erythritol has an inhibitory effect on both S. gordonii and P. gingivalis in biofilm growth via various biological pathways (suppression of growth due to DNA and RNA depletion, attenuated extracellular matrix production and changes in dipeptide procurement and amino acid metabolism).

Erythritol and caries

Xylitol has long been shown to prevent caries and its advantages are especially apparent in chewing xylitol gum [Mäkinen et al., 2008; Mäkinen et al., 1995a; Mäkinen et al., 1995b; Mäkinen et al., 1996a; Mäkinen et al., 1996b]. Although the non-cariogenic effect of erythritol had been known since 1992 [Kawanabe et al., 1992], it took 13 years for the first paper on erythritol and caries to be published [Mäkinen et al., 2005]. Adolescents, 17-years-old on average, used candy drops and toothpaste containing xylitol, erythritol or sorbitol for six months (daily dose 7 g, including 0.5 g from the toothpaste).

Results: Both the plaque weight and the S. mutans count in plaque and saliva were significantly reduced in the xylitol and erythritol groups.

The values for the plaque weights were significantly lower in the erythritol group than in the sorbitol and xylitol groups.

In 2014, another study was published on the effect of erythritol compared to xylitol and sorbitol [Honkala et al., 2014]. This double-blind, randomized, controlled, prospective clinical trial was conducted over three years in children from an elementary school (mixed dentition). The daily dose of sugar alcohols was 7.5 g per day. Result:

- The number of dentin and enamel caries was significantly lower in the erythritol group.
- The period of time before dentin or enamel caries developed was significantly longer in the erythritol group.
- The caries score (age-modified DMF-T, dmf-t, DMF-S, dmf-s value) was lowest in the erythritol group.

Falony et al. published a follow-up study to Honkala et al. in 2016 [2014]. This study confirmed the results in all aspects [Falony et al., 2016].

Further studies, such as those from Runnel [Runnel et al., 2013], Mäkinen [Mäkinen, 2010], Söderling [Söderling et al., 2010], Ghezelbash [Ghezelbash, 2012], White [White et al., 2015], Saran [Saran et al., 2015] and Park [Park et al., 2014], showed similar results. It can be seen that erythritol has currently superceded xylitol as the gold standard in caries prevention.

Erythritol und gingivitis and periodontitis

Sugar alcohols have direct effects on caries prevention and impede oral biofilms. It is evident that they also have effects on the development of gingivitis and periodontitis. The research group Janus et al. investigated the influence of erythritol on the microbiology of the biofilm in gingivitis [Janus et al., 2017]. The aim of the study was to determine the effect of erythritol on the development and progression of gingivitis. The results show that biofilms mature in the presence of erythritol towards a less pathogenic composition and overall biofilm growth is reduced. As a consequence the paper concludes that erythritol can contribute to a healthy oral ecosystem. This is important because gingivitis, when untreated, can lead to period-

ontitis. As shown above, erythritol can inhibit the development of P. gingivalis, one of the most important bacteria in the development and progression of periodontitis, through various biochemical pathways [Hashino et al., 2013].

Erythritol in professional prophylaxis

Besides its use as a sugar substitute in food and for home caries prevention, erythritol is also used in professional prophylaxis. EMS introduced an air-polishing powder based on erythritol in 2011. Alongside powders based on glycine and trehalose, erythritol is a low-abrasive air-polishing powder that can be used for both supragingival and subgingival applications. The literature on air-polishing technology with low-abrasive powders for biofilm management in comparison with hand and ultrasonic instruments impressively demonstrates the advantages of this new technology [Hägi et al., 2013; Steinmann et al., 2003; Tunkel et al., 2003; Hetzel et al., 2007; Arushanov et al., 2012; Décaillet et al., 2010; Hofmänner et al., 2015].

It was demonstrated that air-polishing with low-abrasive powders reduces bacteria more than is possible with hand and ultrasonic instruments [Steinmann et al., 2003; Tunkel et al., 2003; Hetzel et al., 2007; Arushanov et al., 2012; Décaillet et al., 2010; Hofmänner et al., 2015; Wennström et al., 2011; Trtic et al., 2016; Hägi et al., 2015; Bühler et al., 2015]. Supragingival plaque and discoloration can also be removed more effectively and faster than by classical polishing with rotating instruments, polishing brushes, rubber cups and polishing pastes [Büh ler et al., 2015; Camboni et al., 2016; Haas et al., 2019; Strafela-Bastendorf et al., 2016].

In addition to cleaning performance (effectiveness), today the focus is also on protecting substance. Air-polishing with erythritol does not cause irritation of the gingiva [Petersilka et al., 2018]. The work of Barnes and the photos she has presented at international lectures [Barnes et al., 2014; Barnes, 2016] clearly show that only low-abrasive powders can be applied to enamel surfaces and composite fillings without causing changes to the surface structure (Figure 2). On glass-ionomer surfaces, only the application of erythritol powder did not cause any surface changes. The use of erythritol-based powder also resulted in almost no changes in the surface of milk tooth enamel [Reimann et al, 2015]. Subgingival and supragingival biofilm management show the lowest loss of substance with the lowest surface roughness, not only on enamel and dentin, but also on root cement and implants [Hofmänner et al., 2015; Hägi et al., 2015; Bühler et al., 2015; Camboni et al., 2016; Haas et al., 2019; Bozbay et al., 2016; Hägi et al., 2015]. The work of Petersilka et al. showed the smallest changes in the gingiva compared to hand instruments and ultrasonic scalers [Petersilka et al., 2018].

Comparing glycine powder with erythritol powder, the advantages lie with erythritol. It is a light powder (grain size approx. 14 µm, low abrasiveness), with sufficient hardness for good supra- and subgingival cleaning performance. It is safe to use on hard tooth substance and mucous membranes and besides the mechanical effects, it inhibits biofilm as well as individual bacteria (S. mutans, S. gordonii) through a biochemical pathway. [Janus et al., 2017; Drago et al., 2014].

CONCLUSION

Erythritol—the sugar substitute—offers numerous advantages in general and oral health. As an alternative to sugar, erythritol enables a reduction in calorie intake, which is important for controlling obesity and its associated diseases. Erythritol is used for home caries prophylaxis in lozenges, chewing gum, toothpaste, mouth rinse, etc. – whereby the sweet powder offers two advantages: It is non-cariogenic and also inhibits the development of cariogenic and periodontal bacteria in oral biofilms. Routine preventive use of erythritol at home can reduce caries load and hence the corresponding need for dental treatment. The literature shows that erythritol is superior to other sugar alcohols.

Erythritol also shows better results than other sugar alcohols as a supportive measure in curbing disease progression in both gingivitis and periodontitis. The potential of erythritol in home prophylaxis—for example in toothpaste, chewing gum, chocolate or candy—is probably far from being exhausted.

Ultimately, when used in air-polishing technology, erythritol enables a wide range of clinical applications and offers advantages over all other powders – there are good reasons to consider it today's gold standard. ■

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