Jungbunzlauer

From nature to ingredients®

facts

ERYLITE® Erythritol in oral care

Introduction

Even 2000 years ago the Romans understood the need to clean their teeth and used crushed ashes, soda and myrrh as their *dentifricium*. In the 19th century the addition of flavourings and abrasives such as marble powder and soap powder led to a more sophisticated formulation. The most simple polyol, glycerine, was added as a humectant and sweetener at the end of the century and the “toothpaste” went into industrial production. At the same time the cariogenic nature of oral bacteria was discovered, along with a scientific understanding of the damaging effect of the metabolism of sucrose and organic acids on the enamel.

Polyols are applied as a bulk sweetener in a large number of oral care products globally. Polyols cannot be metabolised by oral bacteria and the findings of some new studies suggest that erythritol in particular displays better functionalities than other polyols. The efficiency and properties of sugar alcohols are dictated by their chemical structure. They have some functions in common but their chemical profile determines the efficiency of specific anti-caries properties. Sorbitol and xylitol are the main polyols used in toothpaste, mouthwash and dental chewing gums. In recent years, oral care products containing xylitol – and latterly erythritol – have increasingly been available on the global market. Even the EFSA (European Food Safety Authority) recognises that the use of polyols as a sugar replacement in food items contributes to the maintenance of tooth mineralisation (EU Commission Regulation 432/2012).

Typical functional ingredients in toothpaste

Fluoride
The American Dental Association (ADA) states on its Mouth Healthy website that this common ingredient is “nature's cavity fighter”. Fluoride makes the enamel of the teeth harder and more resistant to acid damage. The forms most often used are sodium fluoride, sodium monofluorophosphate or stannous fluoride.

Abrasives
The most common abrasives remove plaque, debris and stains. Used in combination with the toothbrush, they help to polish teeth to a shine. Today's abrasives typically include calcium carbonate, hydrated silica gels and hydrated aluminium oxides. The purpose of the abrasive ingredients is to scrub the surface of the teeth without scratching or damaging the tooth enamel.

Detergents
Sodium lauryl sulfate (SLS) is the most common detergent used in toothpastes. SLS creates a bubbly foam like that produced by soap and shampoo.

Polyols as humectants and sweeteners
Glycerol keeps the toothpaste from drying out, gives it a consistent texture and helps produce a nice smooth paste when squeezing the tube. Sorbitol, used with glycerol, has a dual role: it holds the toothpaste together and it is a sweetening agent. Erythritol and xylitol also offer excellent properties for toothpaste application in a unique way described below.

ERYLITE® Erythritol – made naturally by biofermentation

Erythritol is a naturally-occurring sugar alcohol (polyol) that is manufactured from glucose using a natural fermentation process. It is a great alternative to other polyols and bulk sweeteners due to its unique attributes: it is calorie-free, it has a high digestive tolerance of around 0.8 g/kg bodyweight. Systemic effect studies demonstrate that erythritol is readily absorbed, not metabolised, and excreted in urine. Thanks to this metabolic profile, it is noncaloric, non-glycaemic, non-insulinemic, and more easily tolerated without gastrointestinal side effects (den Hartog et al., 2010).
Unlike other polyols, erythritol is naturally present in many foods such as wine, soy sauce and a variety of fruits. Erythritol is approximately 60% as sweet as sugar although this varies by application. It is therefore recommended that erythritol be blended with high-intensity sweeteners in order to increase the sweetness in oral care products and to mask off-tastes from other ingredients. This kind of blend usually yields a higher perceived sweetness than theoretically calculated and the synergy allows a reduction in high-intensity sweeteners and, consequently, in actual costs.

ERYLITE® Erythritol for oral health

Background

Although tooth enamel is the hardest substance in the human body, it is susceptible to erosive processes provoked by the interplay of a diet high in fermentable sugars and an unfavourable microbial composition in the oral cavity. To counteract the development of caries lesions, the recommendation is to reduce consumption of fermentable sugars and to perform regular oral hygiene measures. A wide range of oral care products is available, targeting the issue of caries development on multiple levels. These include delivering remineralisation agents such as fluoride to be incorporated into the enamel, stimulation of the flow of saliva as a buffer against low pH, the suppression of bacterial growth using antimicrobial agents, and the mechanical removal of plaque by abrasive agents. Furthermore, novel therapeutic approaches such as modulation of the oral microbiome to favour the growth of beneficial bacteria and disrupt biofilm formation are receiving increasing attention (Featherstone et al., 2018).

Polyols can support these efforts in various ways. The beneficial effect of these non-acidogenic sweeteners in the context of oral health was first observed in xylitol in the 1970s (Scheinin et al., 1975). The mechanism of action of xylitol can generally be ascribed to the stimulation of salivary flow and interference with the energy production cycle of acidogenic bacteria such as *Streptococcus mutans* (Nayak et al., 2014). To exploit these benefits, polyols can be delivered in different ways, for example in chewing gum, suckable tablets, toothpaste or mouthwash. According to Innova Market Insights, about 180 oral care products containing xylitol were launched globally in 2018.

While xylitol is a long-established ingredient in the formulation of dental hygiene products, the benefits of erythritol have been gaining attention over the last two decades. Erythritol is derived from fermentation and thus provides a natural alternative to xylitol. Furthermore, erythritol as a non-cariogenic sweetener is highly tolerable when ingested. Its role in oral health has been demonstrated in both *in vitro* and *in vivo* studies.

Effect of erythritol observed in *in vitro* and *in vivo* studies

Several *in vitro* studies on erythritol have investigated its effect on the bacteria frequently associated with caries development. It has been shown that erythritol can suppress the growth of streptococcus strains and reduce their surface adherence (Ghezelbash et al., 2012). Erythritol has also been shown to modulate gene expression in *Streptococcus mutans*, thus interfering with its energy production cycle (Park et al., 2014). In addition to the isolated view on streptococci, the effect of erythritol on the ecology of microorganisms residing in the oral cavity has been studied (Janus et al., 2017). The oral microbiome plays a major role in the development of oral diseases such as gingivitis. The authors observed that the presence of erythritol changed the microbial ecology of the biofilm, preventing maturation to an unhealthy composition dominated by the bacteria associated with gingivitis.

A long-term *in vivo* study investigating the effect of daily intake of polyols was conducted in Finland between 2008 and 2011. Schoolchildren were given erythritol, xylitol or sorbitol candies (total polyol intake per day approx. 7.5 g) and oral health indices, including caries lesions and the composition and build-up of plaque, were documented periodically. After three years, the amount of dental plaque and the levels of different organic acids were lowest in the group consuming erythritol candies (Runnel et al., 2013). Furthermore, the consumption of erythritol candies delayed the development of caries and reduced their overall occurrence (Honkala et al., 2014). This beneficial effect of erythritol persisted beyond the intervention period. A follow-up check three years after the end point of the study showed a delayed development of caries and dentist interventions in the group of children, who had consumed erythritol (Falony et al., 2016). This observation underlines the long-term positive influence of erythritol on oral health, possibly through the promotion of a healthy oral microbiome.

Additional benefits

In addition to influencing the oral microbiome, erythritol can support remineralisation by forming complexes with calcium ions. While the affinity of erythritol to calcium ions is not strong enough to pose a risk to enamel integrity, erythritol does stabilise calcium ions in saliva, thus enhancing their bioavailability and promoting remineralisation of caries lesions (Mäkinen, 2017). Furthermore, erythritol can boost the efficacy of antimicrobial agents as was demonstrated regarding the fungicidal effect of benzethonium chloride (BTC) on *Candida albicans* when combined with 5–20% erythritol (Ichikawa et al., 2008). Erythritol and chlorhexidine is another combination with strong antimicrobial and anti-biofilm properties (Mensi et al., 2018). The small molecular size of erythritol may allow for easier diffusion into the biofilm, making it more permeable for antimicrobial compounds.

Formulating oral care products with ERYLITE® Erythritol

Erythritol's distinct physicochemical properties render it a highly interesting ingredient in the formulation of oral care products (table 1).

Table 1: Physicochemical properties of erythritol compared to standard polyols for oral care (xylitol, sorbitol)

	ERYLITE®	Xylitol	Sorbitol
Solubility at 25°C [g/100g]	36	66	230
Heat of solution (= cooling effect [kcal/kg]	-43	-36.5	-26
Sweetness (vs. Sucrose)	0.6 - 0.7	1	0.6
Origin	yeast fermentation	catalytic hydrogenation	catalytic hydrogenation

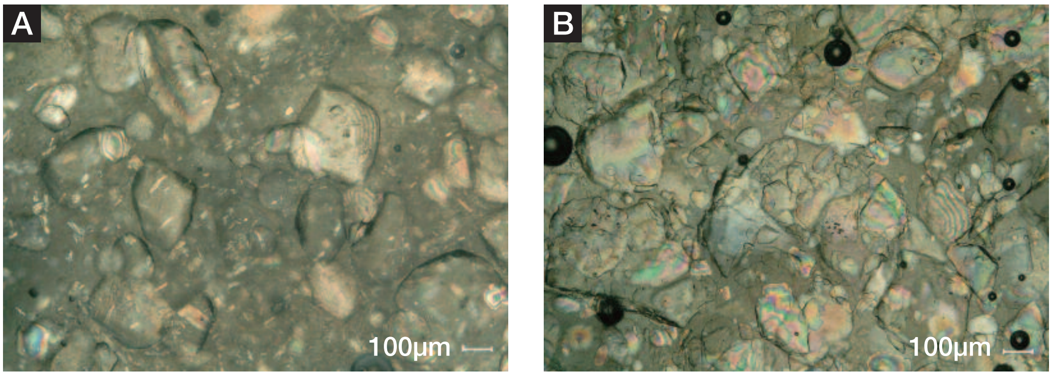
In products with a high water content such as mouthwashes, erythritol can replace xylitol both fully and partially as a natural sweetener and non-cariogenic agent. Internal tests showed no difference in taste and sweetness when formulating a mouthwash with a blend of 70% xylitol and 30% erythritol compared with 100% xylitol. While the sweetness of pure erythritol is less intense than that of xylitol, the formulator can boost sweetness as required by using Jungbunzlauer's blends of erythritol with stevia (ERYLITE® Stevia 100, 200 or 400), thus achieving a fully natural sweetening solution. Similarly, erythritol or erythritol-stevia blends can be incorporated in dissolved form in the aqueous phase of a toothpaste. At a 15–30% water content, the application of 5–10% is straightforward.

Cooling crystals of ERYLITE® in toothpaste formulation

As an innovative alternative, erythritol may be incorporated in toothpaste in crystallised form by increasing its ratio to water significantly above solubility. This results in a toothpaste with visible, transparent crystals which quickly dissolve in the saliva upon brushing. The heat consumed upon dissolution results in a cooling effect which is directly perceptible by the consumer. This offers unique formulation possibilities which cannot be obtained with xylitol due to the higher solubility and lower cooling effect of this polyol.

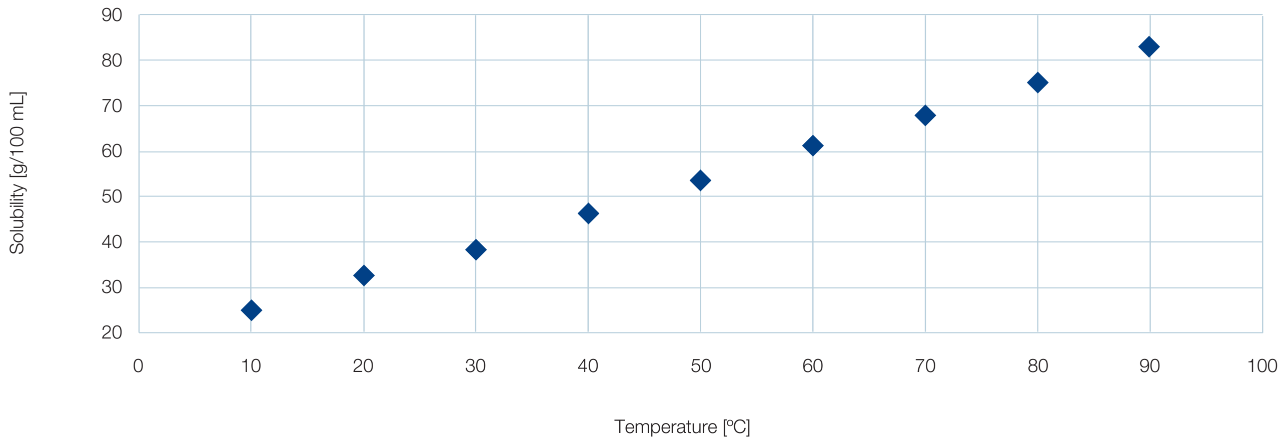
One important consideration when formulating a high erythritol content toothpaste concerns crystal size. Crystals exceeding a diameter of approximately 500 μm are perceived as sandy by the consumer. In contrast, small crystals give a pleasant mouth feel and dissolve quickly, immediately provoking the cooling effect. An examination of the crystal size in a benchmark toothpaste containing 40% erythritol identified a particle size of approximately 350 μm as an upper limit (figure 1A). Furthermore, the presence of a significant proportion of particles below 50 μm was detected. These values served as a guide for the micronisation of ERYLITE® to be incorporated into a toothpaste prototype developed by Jungbunzlauer (figure 1B).

Figure 1: Microscopic image showing the crystal size distribution in a benchmark toothpaste (A) and Jungbunzlauer's prototype (B). Scale bar denotes 100 μm in both images. Black, circular spots in image B are air bubbles.



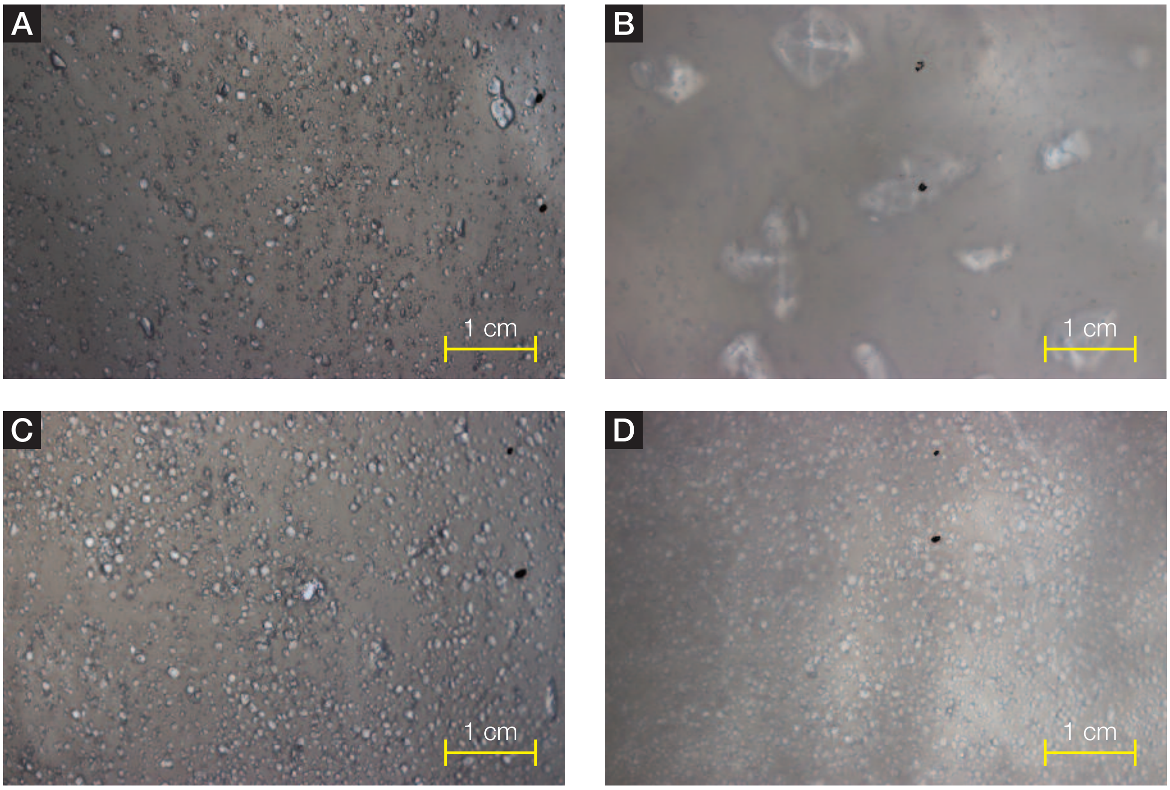
Another relevant aspect concerns the stability of erythritol crystals over time and at varying temperatures, which is closely connected to the solubility curve of erythritol (figure 2).

Figure 2: Solubility of erythritol in water depending on temperature



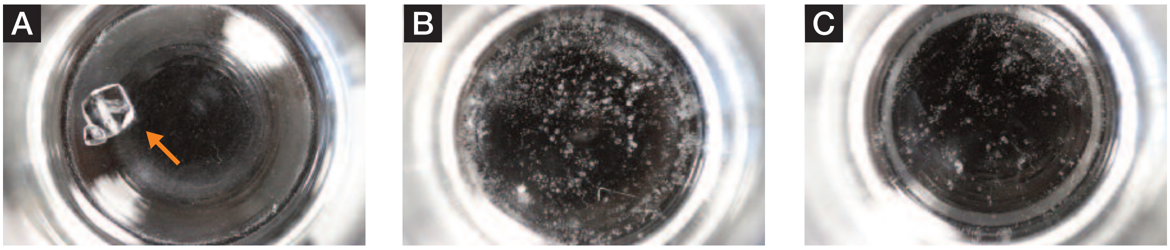
In a preliminary screening trial, basic formulations with an erythritol-water ratio of 0.8:1, 0.9:1 and 1:1 were compared, keeping the water content constant at 34% while increasing erythritol content at the expense of glycerol. To check crystal stability, the formulations were exposed to temperature cycles between 40°C and 1°C. As shown in figure 3A, a low erythritol to water ratio resulted in dissolution at high temperatures and uncontrolled re-crystallisation at lower temperatures, leading to the formation of large crystals of up to 1 cm in diameter (figure 3B). In contrast, a higher erythritol to water ratio prevented the formation of large crystals (figure 3C and D).

Figure 3: Crystal stability in toothpaste formulation with a low and high erythritol to water ratio after exposure to temperature cycles. Images show toothpaste with erythritol to water ratio of 0.8:1 immediately after production (A) and temperature cycles (B) compared to an erythritol to water ratio of 1:1 immediately after production (C) and temperature cycles (D).



In addition, saturation with sorbitol is another approach to prevent uncontrolled re-crystallisation of the dissolved proportion of erythritol. This was demonstrated by comparing a 30% erythritol solution in distilled water at 1°C when adding up to 225% sorbitol. While one large crystal formed when no sorbitol was added, only fine crystals appeared in the sorbitol-saturated solution (figure 4).

Figure 4: Re-crystallisation of a 30% erythritol solution in distilled water at 1°C (A) compared to the same solution with the addition of 175% sorbitol (B) and 225% sorbitol (C)



As a result of these observations, Jungbunzlauer's prototype toothpaste was formulated with 38% (w/w) ERYLITE®, keeping the water content in the formulation as low as possible (13.3% w/w) and saturating it with sorbitol (21% w/w) (table 2). This toothpaste features a refreshing mouth feel, pleasant texture and stable erythritol crystals.

Furthermore, the low water activity of $a_w = 0.605$ resulting from the low overall water content and saturation with polyols helps prevent microbial spoilage of the product. Indeed, the toothpaste formulation passed the microbial spoilage test in accordance with DIN EN ISO 11903 both with and without 0.1% sodium benzoate as an additional preservative agent. This observation raises the possibility of formulating a toothpaste based on natural ingredients using erythritol.

Table 2: Formulation of Jungbunzlauer toothpaste prototype with cooling crystals of ERYLITE®

Ingredients	INCI	Quantity
Water demin.	Aqua	13.30%
Phoskadent® SF	Sodium Fluoride	0.30%
Zinc Lactate	Zinc Lactate	0.80%
Potassium Citrate	Potassium Citrate	2.00%
Sodium Benzoate	Sodium Benzoate	0.10%
Beauté by Roquette® PO160	Sorbitol	21.00%
Glycerine	Glycerine	11.00%
Xanthan Gum FN Oral Care Grade	Xanthan Gum	0.30%
Zeodent® 103	Silica	8.00%
Zeodent® 167	Silica	3.00%
ERYLITE® Stevia 200	Erythritol, Stevia Rebaudiana Extract	4.00%
ERYLITE®	Erythritol	34.00%
Unipure® Green LC 721	CI 19140, CI 42090	q.s.
Stepanol® WA-100 NF	Sodium Lauryl Sulfate	1.50%
Aroma	Mentha Spicata Herb Oil	0.70%

Conclusion

Erythritol has excellent nutritional properties and advantages over other polyols, having zero calorific value and glycaemic index and much greater digestive tolerance, and being produced by natural fermentation.

Erythritol can be used effectively in dental health products as a xylitol replacement, functioning as a sweetening ingredient which provides excellent non-cariogenic properties. In addition to positively influencing the oral microbiome, erythritol can support remineralisation by forming complexes with calcium ions.

Longer-term caries studies comparing the cariogenic effect of erythritol, xylitol and sorbitol demonstrate a slower rate of caries development and lower incidence of caries in the erythritol group compared with the sorbitol and xylitol group.

The formulation of a toothpaste with a high concentration of crystalline erythritol and menthol yielded an incomparably pleasing product with a great synergistic cooling effect upon application without a preservative agent.

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About Jungbunzlauer

Jungbunzlauer is one of the world's leading producers of biodegradable ingredients of natural origin. We enable our customers to manufacture healthier, safer, tastier and more sustainable products. Due to continuous investments, state-of-the-art manufacturing processes and comprehensive quality management, we are able to assure outstanding product quality.

Our mission "From nature to ingredients®" commits us to the protection of people and their environment.

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