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ZEROSE® ERYTHRITOL

The natural* zero calorie sweetener
from a trusted supplier.



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*FDA has not defined natural. Contact Cargill for source and processing information.

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Cargill Advantage

Why Cargill?

- **Trusted ingredient expert with a broad portfolio of products and services**
- **Deep R&D resources with expertise in regulatory, applications and product development**
- **Proprietary marketing data and unique insights to help create innovative product solutions**
- **Reliable and sustainable US supply chain**

As a customer-focused supplier of ingredients for the food, beverage, dietary supplement and pharma/personal care industries, Cargill is uniquely positioned to help customers develop exciting new solutions for their customers and consumers.



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Overview

What is Zeros® Erythritol?

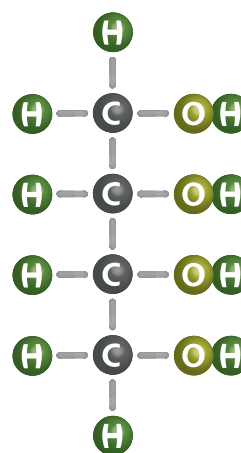
Zeros® erythritol is a natural*, zero calorie bulk sweetener, with a taste and functionality similar to sucrose. With zero calorie content, Zeros® erythritol offers a solution for both health and indulgence. In addition, erythritol has the highest digestive tolerance compared to other polyol sweeteners. It excels in food and beverage applications promoting reduced sugar and weight management. It is also non-cariogenic, and does not promote tooth decay, making it an excellent ingredient for products positioned to promote oral health. Zeros® erythritol will appeal to product formulators looking to create excellent taste, satisfying mouthfeel and an appeal to the healthy lifestyle market.

How is it made?

Zeros® erythritol is a low molecular weight polyol, comprised of four carbon atoms. It appears as a white crystalline, odorless product which rapidly dissolves in water (up to 60 g/100 ml at 30°C) to give a brilliantly clear, low viscosity, colorless solution.

Zeros® erythritol is the first polyol to be industrially manufactured by a fermentation process. The starting material is a simple sugar-rich substrate which is fermented using a yeast to yield erythritol. The product is then crystalized to 99.5% purity from the filtered and concentrated fermentation broth.

* FDA has not defined natural. Contact Cargill for source & processing information.



Regulatory Status

Erythritol received a “No objection letter” from the FDA on September 11, 2001 as an ingredient in food and beverages; additional uses are self-determined as GRAS. In Canada, it was approved for use as a food additive in November 2004. In Mexico, it is authorized for use at GMP levels. Brazil received approval effective March, 2008; it is included in the ANVISA Sweeteners list.



Zeros® erythritol is now Non-GMO Project Verified

Zeros® erythritol has always been, and will continue to be an ingredient produced by fermentation. In order to enable Non-GMO Project Verification, carbohydrate feedstocks from conventionally-bred non-GMO crops were selected. Both Non-GMO Project Verified and Standard erythritol are still available to customers.



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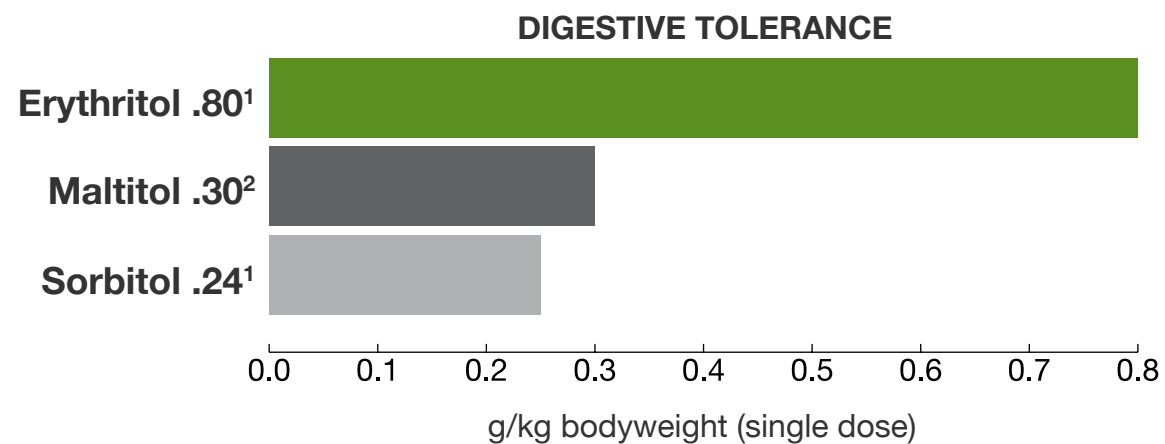
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Nutritional Benefits

- **Zero calorie**
- **High digestive tolerance**
 - Clinical studies show that erythritol has better digestive tolerance when compared to other polyols
- **Suitable for people with diabetes**
 - Does not raise blood glucose or insulin levels
- **Non-cariogenic**

With the growing demands to reduce overall sugar consumption, the food industry is seeking ways to respond to consumer demand for foods that help meet their dietary and weight loss goals. This means developing foods that are sugar-free, lower calorie and low in glycemic carbohydrates while also trying to achieve the desired texture, flavor and stability of traditional products.



Sources: 1 Oku et al (1996)
2 Koizumi et al (1983)



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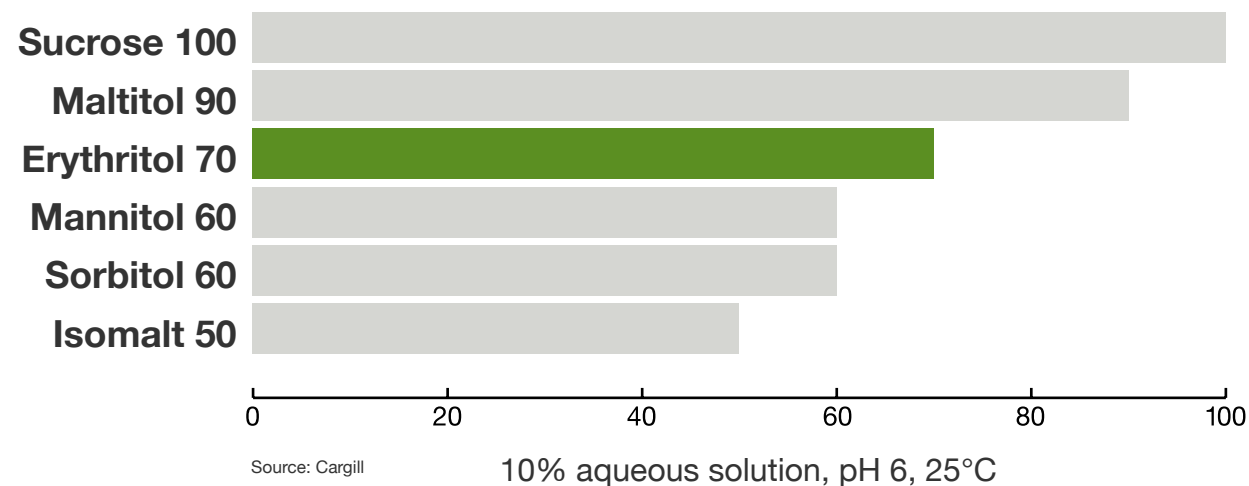
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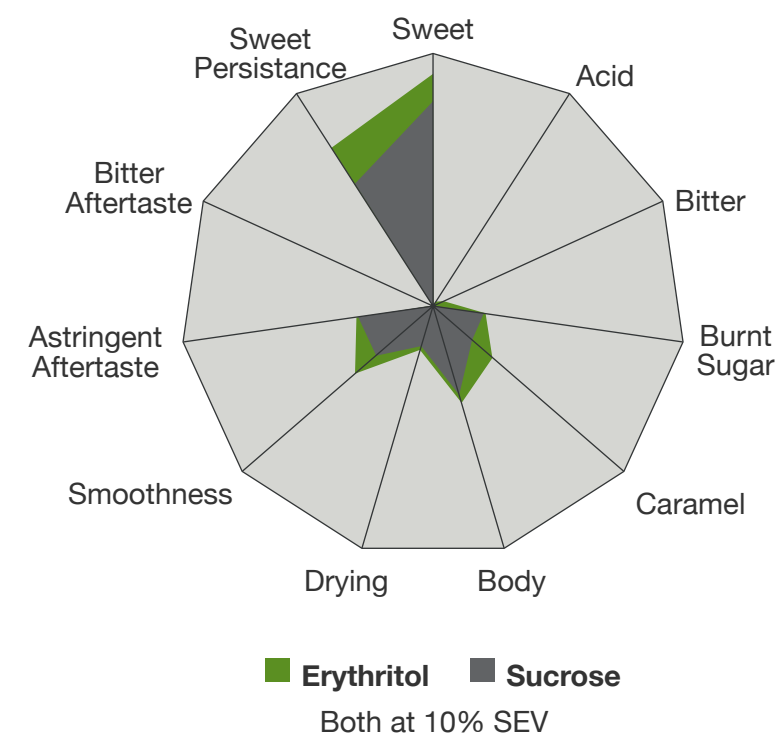
Functional Benefits

- Clean, sweet taste similar to sucrose
- Natural
- Adds smoothness and body
- Masks off-flavors
- Cool mouthfeel (high negative heat of solution)
- Synergy with intense sweeteners
- Extends storage stability
- High processing (acid and heat) stability
- Low hygroscopicity
- High speed of crystallization

RELATIVE SWEETNESS



TASTE COMPARISON OF ERYTHRITOL TO SUGAR



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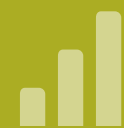
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Confectionery

- **Clean sweet taste**
- **Fine crystal structure**
- **Non-hygroscopic**
- **Attractive cooling effect**

In gum: Zeroses® erythritol can improve the flavor profile, and its cooling effect gives a unique and enjoyable chewing experience.

In sugar-free chocolate: Sweetener blends with Zeroses® erythritol, as a bulk sweetener, yield calorie reduction with excellent gloss, texture, snap and melting characteristics. It masks aftertastes of intense sweeteners and is useful in sugar-restricted diet.



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Food

- **Great sugar-like taste in combination with intense sweeteners**
- **Excellent heat and acid stability**
- **Improved shelf life**
- **Excellent water activity management**
- **Enhanced bulk and body**
- **Optimal freezing point depression**

When compared to sucrose in baking, Zerose® erythritol exhibits different melting behavior, a more compact dough, less color formations, better moisture control and softer baked products.

The use of Zerose® erythritol as a bulking agent can support sugar replacement strategies and allow for lower calorie profiles in many dairy products and frozen desserts such as pudding, yogurt, smoothies, ice cream or sorbet.



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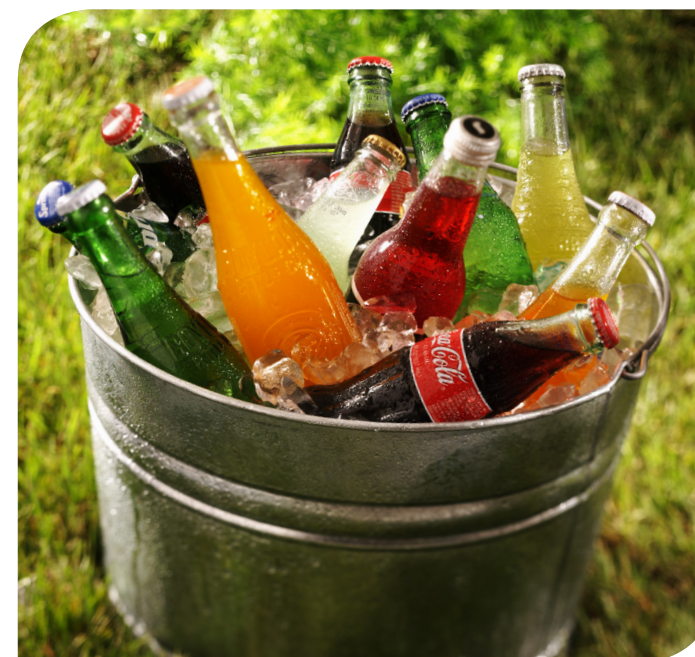
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Beverage

- **Sugar-like taste**
- **Works well with high intensity sweeteners**
- **Enhanced body and mouthfeel**
- **Optimal freezing point depression**
- **Excellent heat and acidity characteristics**

Zerose® erythritol is ideal for diet soft drinks, flavored waters and milks, sports drinks, smoothies, iced teas, frozen beverages and soy-based beverages.



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Tabletop Sweeteners

- **Sugar-like taste when used in combination with intense sweeteners**
- **Non-hygroscopicity**

Make spoonable sweeteners or cubes with taste and texture very similar to sucrose by combining Zeros® erythritol and intense sweeteners for enhanced taste profile and reduced calories.



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Oral Care

- **Not fermented by oral bacteria**
- **Clinically shown to reduce plaque and the risk of dental caries better than other polyols**
- **Well tolerated (highest digestive tolerance of all polyols)**
- **Certified “toothfriendly”**
- **Attractive cooling effect**
- **Works well with other polyols and high intensity sweeteners**

Dental caries is a disease caused by oral bacteria that convert carbohydrates into organic acids and dental plaque, resulting in damage to the teeth. Unlike sugar, erythritol is not fermented by oral bacteria, and therefore does not promote dental caries.

In oral care applications, Zeros® erythritol acts as a salivary stimulant and provides masking properties for astringent and bitter tastes. It also has demonstrated non-cariogenic properties. Its sugar-like taste and cooling effect makes it a great option for oral care products like toothpastes and rinses.

Zeros® erythritol is certified as “toothfriendly” by Toothfriendly International.



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Pharmaceutical

- **Inert excipient; excellent carrier in capsules**
- **Excellent flowability and stability in powders**
- **Attractive cooling effect**

As a non-caloric excipient, Zeroses® erythritol can be used in a wide range of solid and liquid dosage formulations including granulated powders, lozenges and syrups. Sugar-free lozenges crystallize easily, producing a hard, crunchy texture and refreshing, cooling effect.



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Regulatory Status

Zerose® DC is a compound composed of erythritol and 10% maltodextrin as binder using a patent-pending process. It can be used for the convenient production of tablets by direct compression.

Erythritol and maltodextrin are fully compliant with the current specifications of the European Pharmacopoeia (Ph. Eur) and the US Pharmacopoeia (USP).

Erythritol and maltodextrin have been widely authorized globally for use in foods including the EU, USA and Japan. For queries regarding a specific country or application, please reach out to your local Cargill contact.

Zerose® DC has an energy value of 0.4 kcal/g.

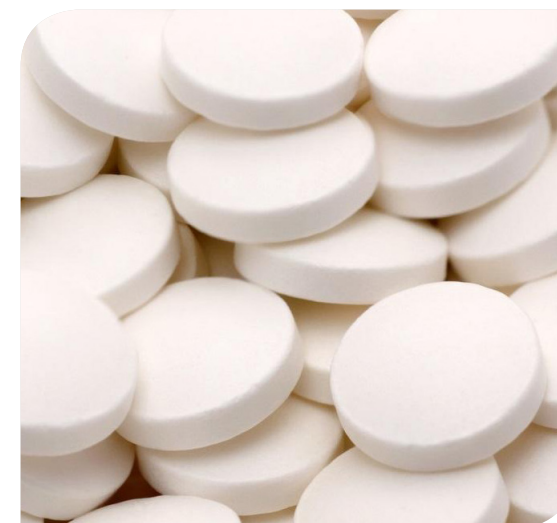
Applications

- **Nutraceutical and medicinal candies, lozenges and other confectionery items.**
- **Tablets like suckable, chewable, swallowable, dispersible and effervescent tablets.**
- **Compressed gums.**

Powder Properties (showing typical values)

Powder Property	Value
Particle size (Volume mean diameter)	400 um
Bulk density	610 g/l
Hausner Ratio	1.13
Compressibility Index	12%
Flow character*	Good

* According to Ph. Eur 8.0 - Method 2.9.34 "Bulk density and tapped density of powders"



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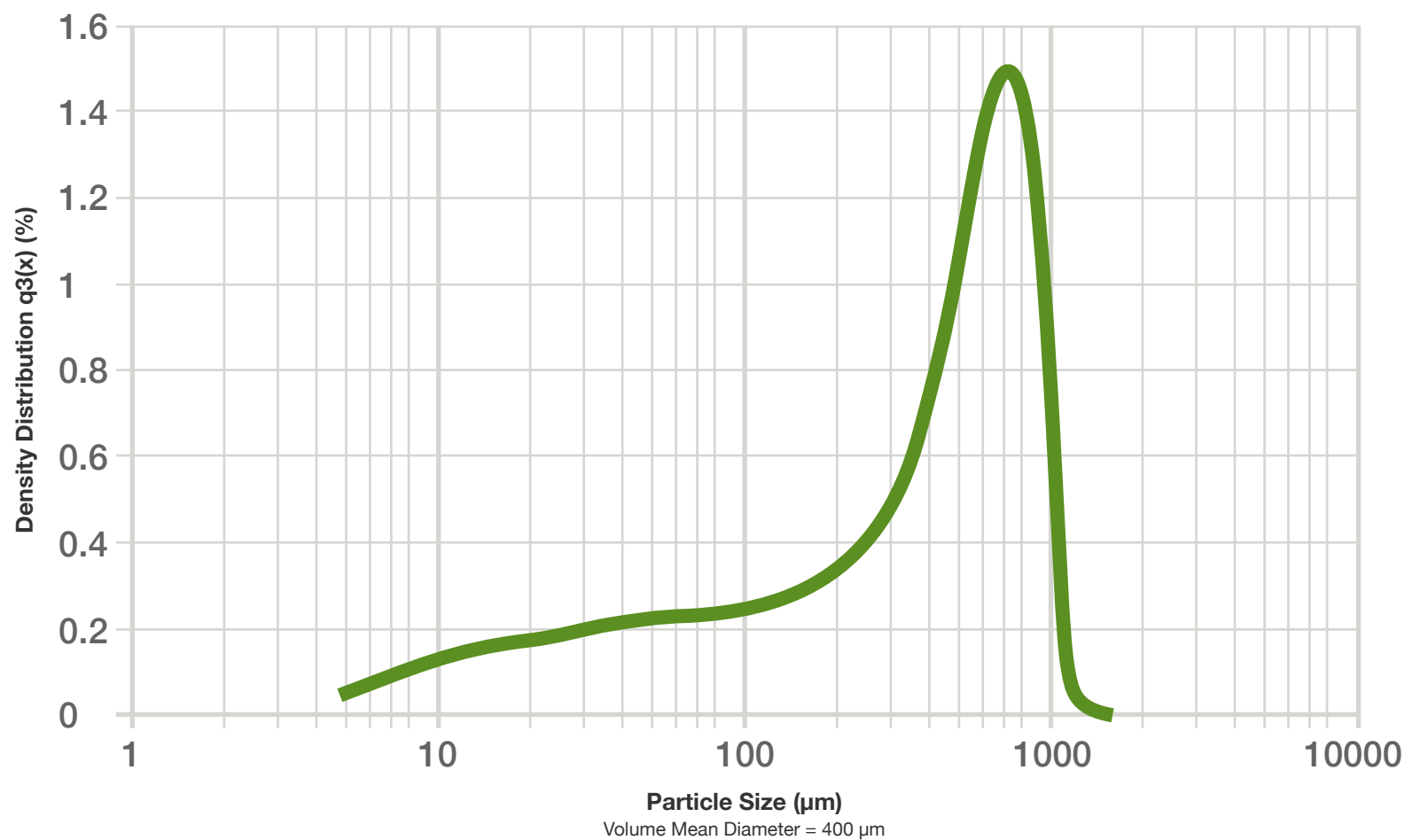
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Particle Size



Flowability

	Hausner Ratio	Compressibility index (%)	Flow character
Zerose® DC Erythritol	1.13	12	Good

Density

A loose or bulk density of about 550 g/l to 650 g/l, with a typical value around 610 g/l.



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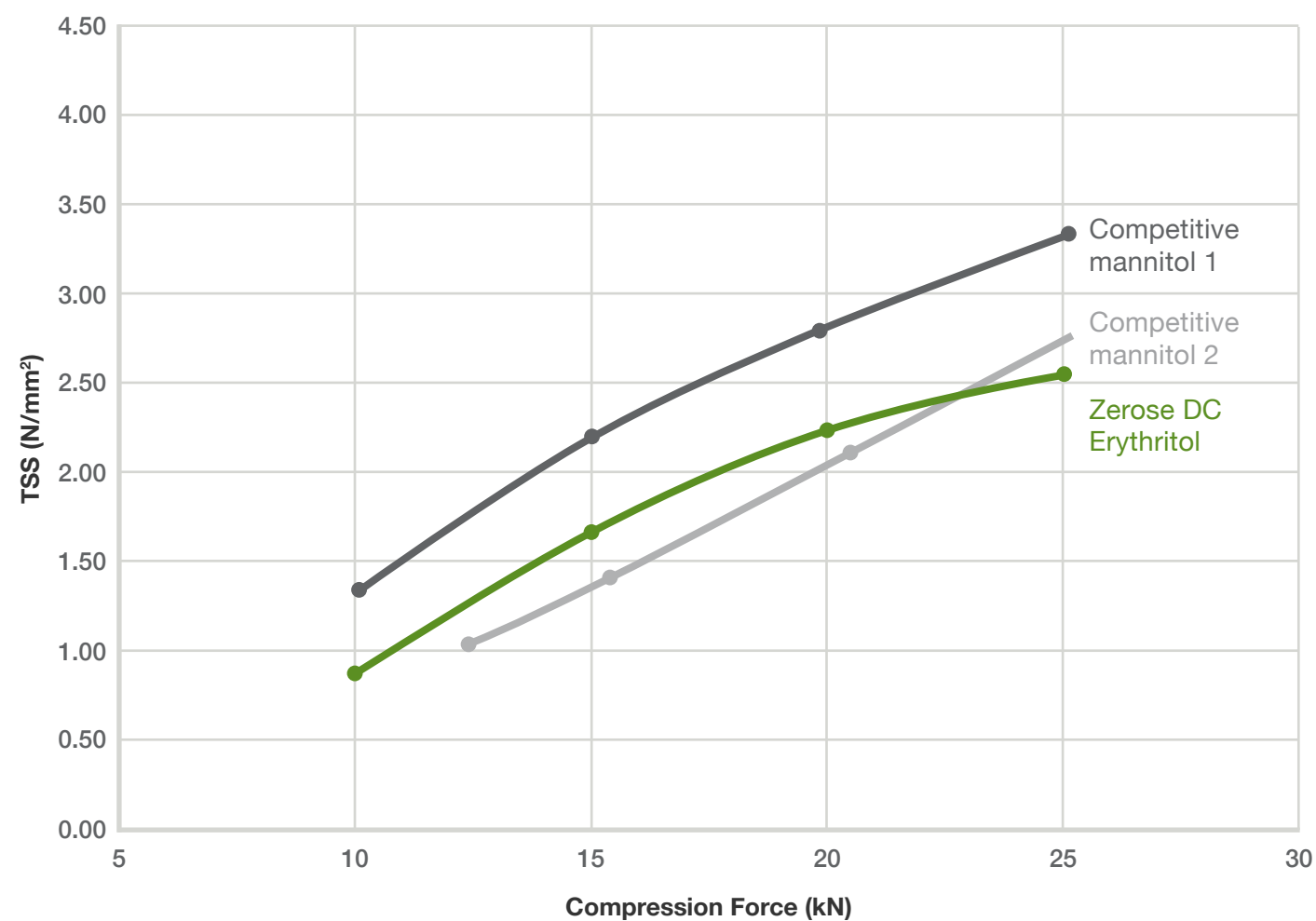
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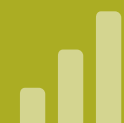
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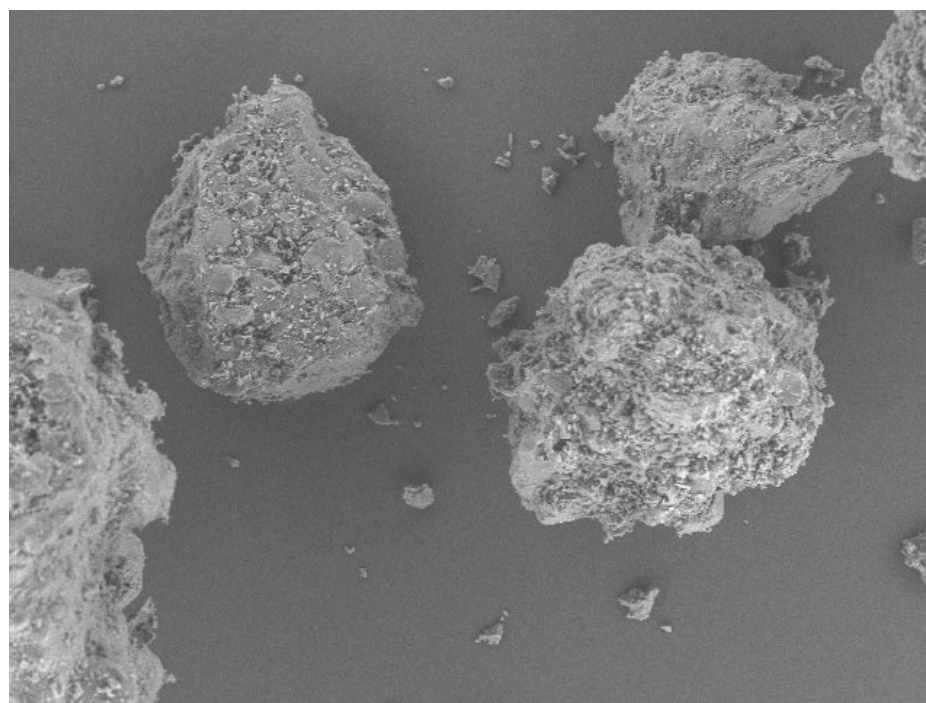
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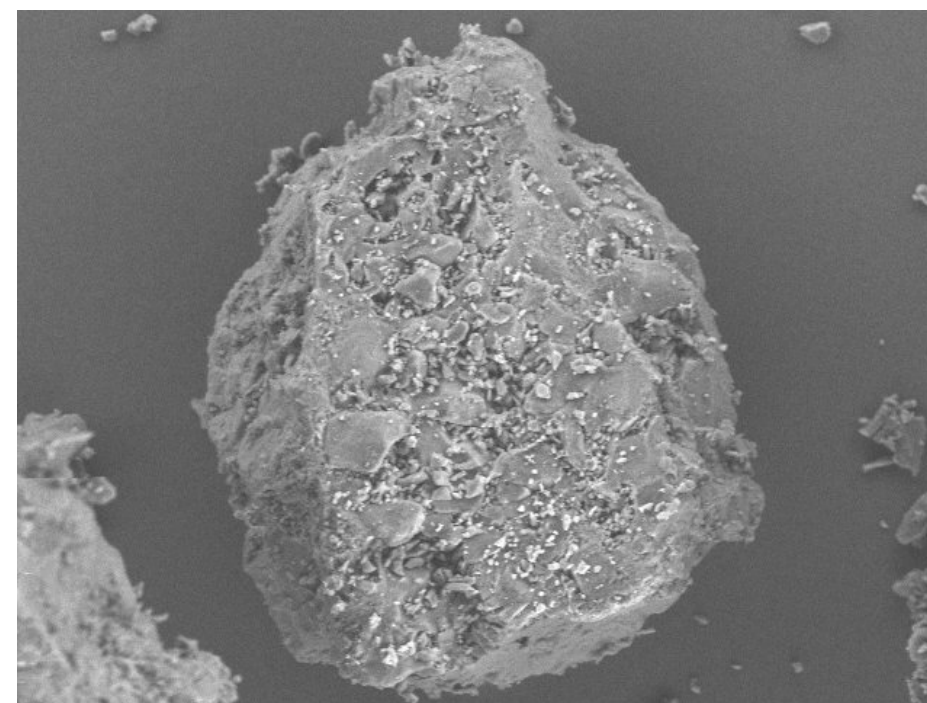
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Scanning Electron Microscope (SEM) pictures



TM-1000_0006 2015/01/26 11:31 300 um

Magnification of 250x



TM-1000_0007 2015/01/26 11:32 200 um

Magnification of 500x



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Regulatory Status

Zerose® erythritol for Pharma applications is produced in compliance with the IPEC Good Manufacturing Practices guideline for pharmaceutical excipients. It complies with the current specifications of the European Pharmacopoeia (Ph. Eur), the US Pharmacopoeia (USP), and the Japanese Pharmacopoeia (JPE).

Applications

- **Nutraceutical and medicinal candies, lozenges, coatings and other confectionery items.**
- **Medicinal capsules, powders, liquids, toothpaste.**
- **Topical applications, ointments**
- **After milling, combined with a binder, this product can also be used in suckable, chewable, swallowable, dispersible and effervescent tablets.**



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PHARMA COMPLIANT

Polyol Comparison (Erythritol vs mannitol)

Similarities

- Toothfriendly
- Very low hygroscopicity
- Low glycemic and insulinemic index
- Kosher
- A relative sweetness of 70 for erythritol and 60 for mannitol
- A white crystalline powder
- Chemical stability

Major benefits (Erythritol vs mannitol)

- Zero calorie value (0 vs 1.6 calories/gram)
- Lower molecular weight for (122 vs 182)
- Higher negative heat of solution (-43 vs -28.5)
- Higher solubility (36 vs 18 @ 25°C)
- Higher rate of small intestinal absorption (90% vs 15%), and therefore well-tolerated
- Erythritol has the ability to mask off-flavors
- Erythritol provides a notable cooling effect
- Erythritol is more effective than mannitol in reducing plaque and caries risk

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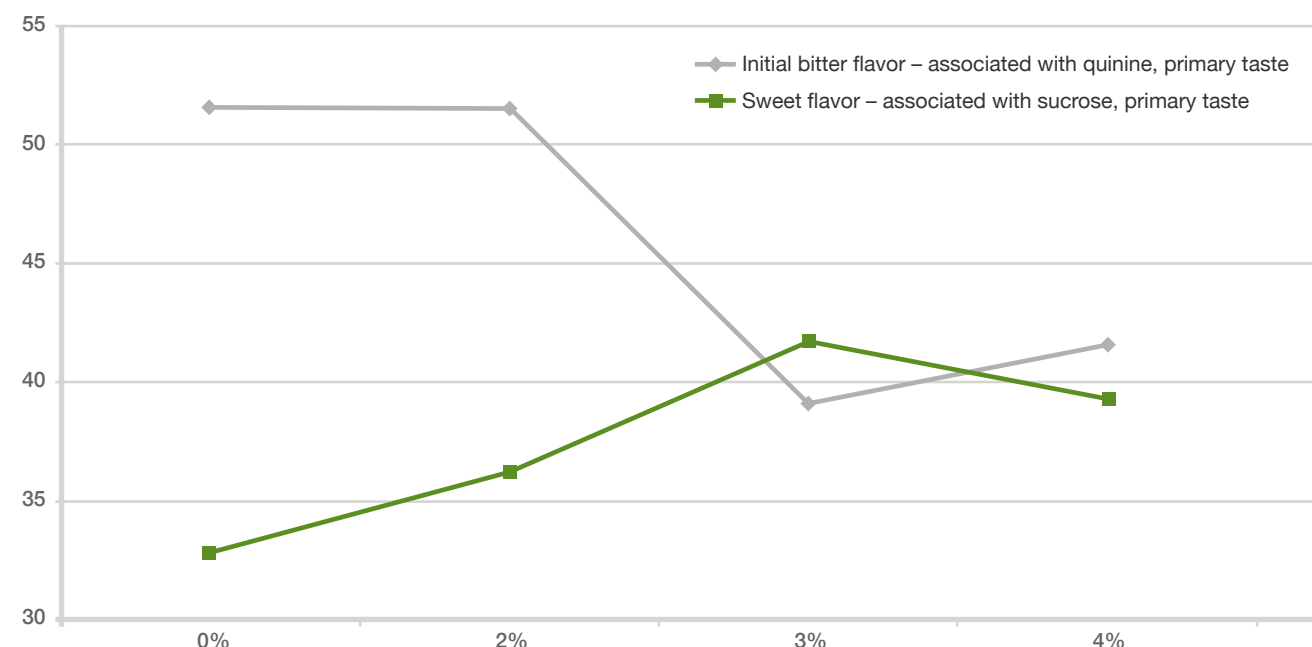
PHARMA COMPLIANT

Organoleptic Benefits

Erythritol has a similar sweetness compared to mannitol, but unlike mannitol it has significant off-taste masking properties. Tablets made with mannitol and an ingredient with an acidic taste were compared to tablets made with the same use levels of erythritol and acidic ingredient. An internal sensory evaluation showed a clear preference for the tablets made with erythritol over those made with mannitol. The main reason was the better taste and mouthfeel. Due to the cooling effect of erythritol a refreshing sensation is

perceived in the mouth and this, in combination with a soothing moisturizing effect, resulted in a clear preference for erythritol.

Another study investigating the off-taste masking properties of Erythritol in mouthwash showed positive effects by reducing the initial bitter flavor caused by chlorhexidine.



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Metabolism

The metabolic profile of erythritol is unique because it is mostly inert to the human body. Unlike mannitol, erythritol is readily and essentially completely absorbed from the small intestine via passive diffusion. It is not systemically metabolized and therefore is excreted unchanged with the urine. Because of this metabolic profile, erythritol does not provide any energy to the body and has a caloric value of zero. Clinical studies have demonstrated that erythritol is well-tolerated at intakes up to 1 g/kg bw per day. As it is so well-absorbed, erythritol does not impact the gastrointestinal transit time at these levels. In addition, erythritol does not notably increase plasma glucose or insulin levels and therefore can be regarded as suitable for people with diabetes.



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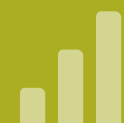
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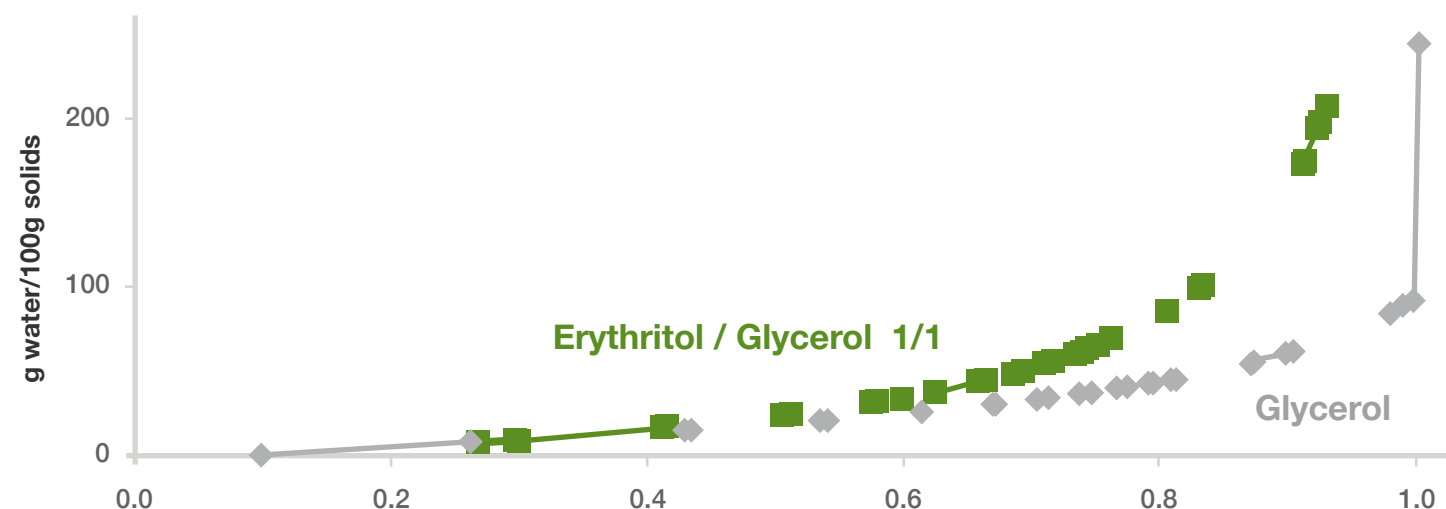


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Moisturizing Effect

Glycerol has high humectancy (hydration) properties and for that reason is often used in topical applications as a moisturizer. As shown in the figure below, use of erythritol with glycerol in a 1:1 ratio results in significant humectancy synergy and consequently higher moisturizing capacity.

WO 01/60167 – Low calorie humectant



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DENTAL STUDY

Dental Study Overview

A newly published clinical study shows evidence that erythritol demonstrated significant caries, dental plaque and *Streptococcus mutans* reduction versus sorbitol and xylitol.

In a three-year clinical study,* the dental effects of erythritol, xylitol and sorbitol were compared among elementary school-age children. The results showed that while each polyol sweetener had dental benefits, erythritol outperformed xylitol and sorbitol in the following ways:

- The amount of dental plaque was lower in the erythritol group.
- The number of dentine caries on teeth were lower in the erythritol group.
- Counts of *Streptococcus mutans* in saliva and upper dental plaque were lower in the erythritol group.

Methodology

In a double-blind, parallel, randomized, controlled three-year study, 485 primary school children in Tartu, Estonia, were given 2.5g polyol tablets three times per day during school days (200 days per year). The study tested the efficacy of long-term daily intake of erythritol and xylitol candies as compared to sorbitol (control) candies. The subjects were examined annually to collect the following data:

- Dentin caries development
- Plaque weight
- Oral counts of *Streptococcus mutans* and *Lactobacilli*

Enamel and dentine caries lesions were determined with ICDAS (International Caries Detection and Assessment System) criteria by four calibrated dentists.



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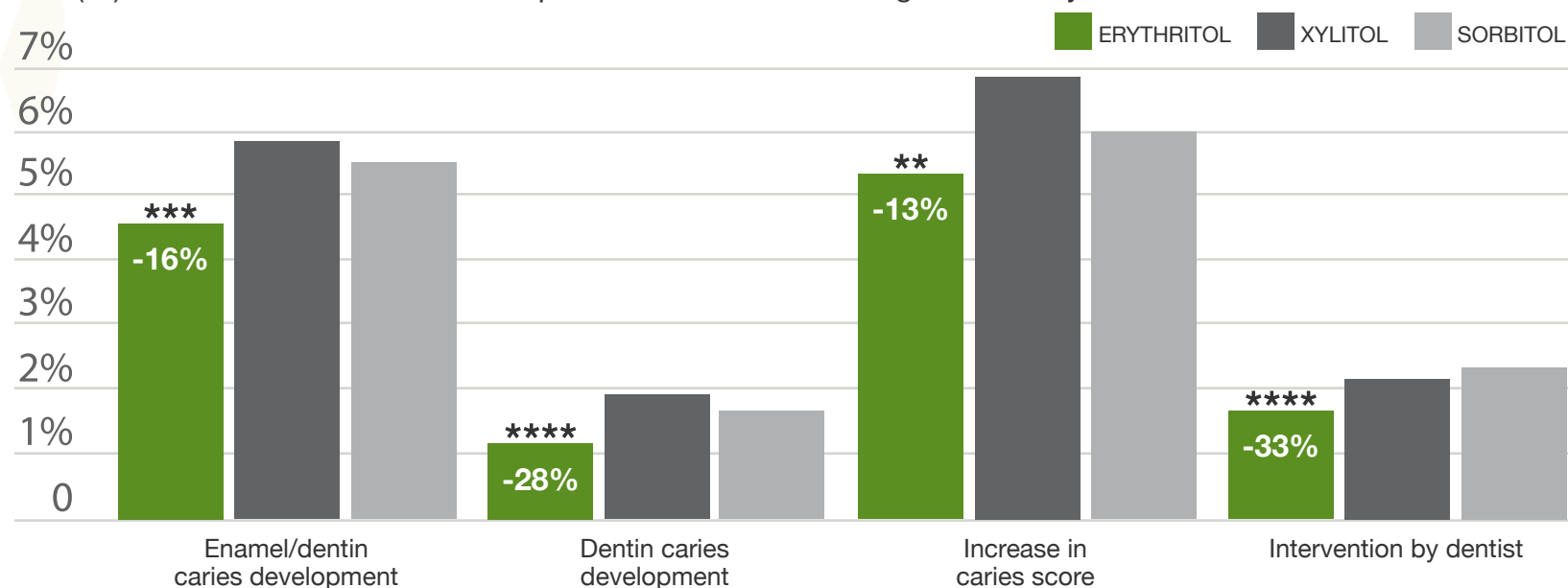
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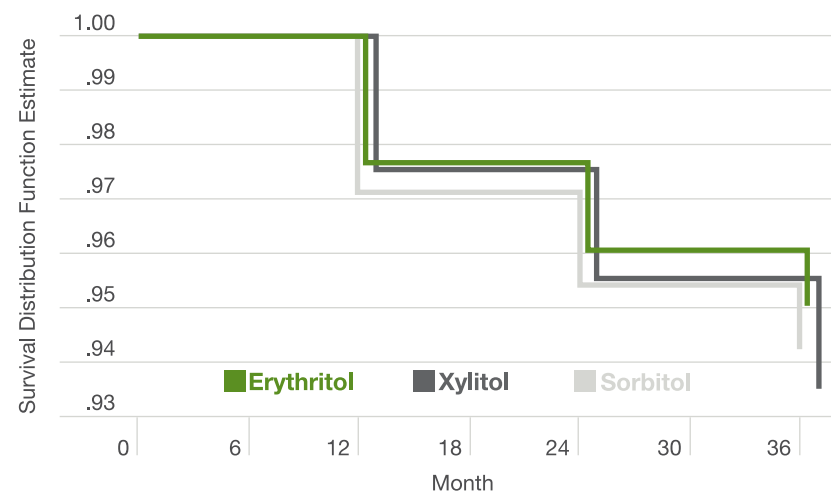
Dental Study Results

Dentin Caries Development:

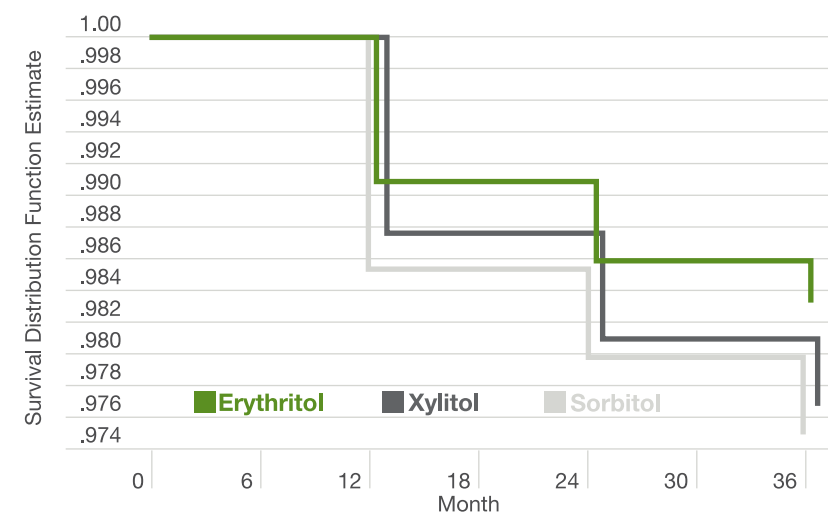
Number (%) of surfaces with caries development or restoration during entire study.



*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001, all vs. sorbitol



Time to develop enamel/dentin carries
(carries score 0-3 to 4-6)



Time to dentist intervention
(restoration score 0 to 3-8)

[more results](#) ►



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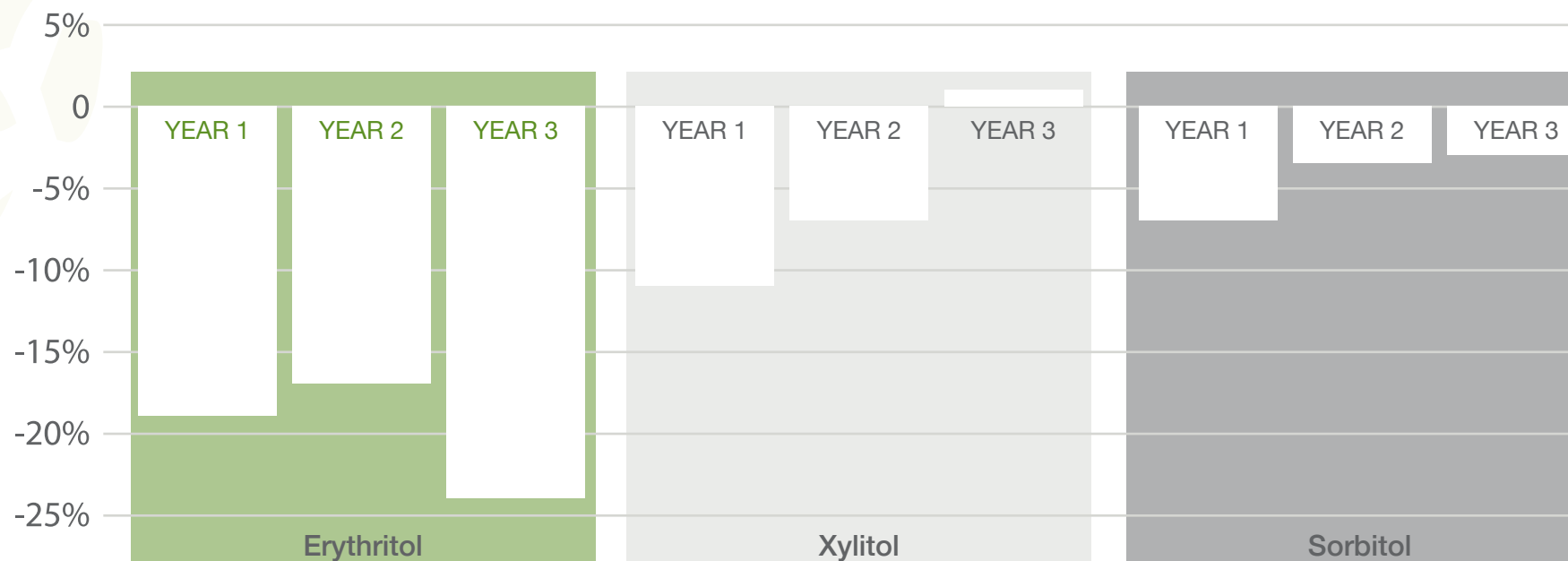
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Dental Study Results

Dental Plaque Weight

Change against baseline over 3 years



Oral Counts

Saliva *Streptococcus mutans* (SM) count and plaque SM counts in quadrants 1 and 2 were significantly lower in erythritol group than in the sorbitol (control) group.

	Erythritol				Xylitol				Sorbitol			
	2008 n=165	2009 n=141	2010 n=138	2011 n=128	2008 n=156	2009 n=145	2010 n=137	2011 n=131	2008 n=164	2009 n=149	2010 n=142	2011 n=130
Saliva SM*	1.76 (0.08)	1.56 (0.08)	1.58 (0.08)	1.21 (0.09)	1.85 (0.08)	1.61 (0.08)	1.68 (0.08)	1.47 (0.09)	1.74 (0.08)	1.44 (0.08)	1.62 (0.09)	1.65 (0.08)
Plaque SM1	1.55 (0.08)	1.34 (0.08)	1.38 (0.08)	1.11 (0.09)	1.68 (0.08)	1.41 (0.08)	1.41 (0.08)	1.24 (0.09)	1.48 (0.08)	1.44 (0.08)	1.35 (0.08)	1.45 (0.09)
Plaque SM2	1.52 (0.08)	1.41 (0.08)	1.29 (0.08)	1.10 (0.08)	1.77 (0.08)	1.50 (0.08)	1.45 (0.08)	1.37 (0.08)	1.60 (0.08)	1.45 (0.08)	1.44 (0.08)	1.40 (0.08)
Plaque SM3	1.66 (0.08)	1.57 (0.08)	1.43 (0.08)	1.23 (0.08)	1.80 (0.08)	1.48 (0.08)	1.47 (0.08)	1.41 (0.08)	1.67 (0.08)	1.54 (0.08)	1.42 (0.08)	1.33 (0.08)
Plaque SM4	1.69 (0.08)	1.36 (0.08)	1.49 (0.08)	1.13 (0.08)	1.78 (0.08)	1.34 (0.08)	1.39 (0.08)	1.23 (0.08)	1.60 (0.08)	1.36 (0.08)	1.48 (0.08)	1.31 (0.08)
	2008 n=161	2009 n=137	2010 n=137	2011 n=125	2008 n=149	2009 n=138	2010 n=129	2011 n=125	2008 n=161	2009 n=148	2010 n=141	2011 n=128
Saliva LB	4.36 (0.13)	3.94 (0.16)	3.37 (0.17)	3.46 (0.18)	4.36 (0.13)	4.28 (0.14)	3.82 (0.17)	3.93 (0.17)	4.47 (0.13)	4.11 (0.15)	3.81 (0.16)	3.52 (0.18)

Significant p-values: 2011 Saliva SM p=0.0019. Plaque SM1 p=0.0256. Plaque SM2 p=0.0280

* "The Caries Preventative Effect of Erythritol, Xylitol and Sorbitol," conducted by Prof. Mare Saag, Prof. Eino Honkala, and Prof. Kauko Mäkinen, the Department of Stomatology, Faculty of Medicine, University of Tartu, Estonia. This study was funded by Cargill.



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The program reaches dental professionals through public relations initiatives, professional conferences/exhibits, sponsorships, speaking engagements, webinars and direct marketing efforts. Zeros[®] erythritol customers can participate in Cargill's Dental Professional Outreach program to promote their products in many ways. For example, customers can display and sample products at professional conferences as well as tap into Cargill's proprietary opt-in dental professional database to directly reach the audience with product information.

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