Erythritol

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Modern life has transformed our eating habits and medical science has extended life expectancy. These two major changes have exposed the fact that we are increasingly vulnerable to the so-called "civilized world" diseases such as caries, diabetes, cancer and rheumatoid diseases. It was recognized only recently that changes in diet may have played a part. However, it has been known for a long time that our caloric intake is excessive. The fact that these calories are often being delivered by fatty substances rather than carbohydrates only makes things worse.

Healthy eating is a priority for many consumers. Of all new food products launched in a year, almost 20 percent incorporate some kind of health benefit — ranging from simple calorie reduction to foods enriched with ingredients that claim to prevent disease. So far, probably the most successful new market has been the sugarfree product sector.

Replacing sugar results in a product that is both reduced in calories and toothfriendly. Although a wide range of sugar replacers is now available, many have shortcomings. These include the following:

- limited calorie reduction
- side effects, such as digestive intolerance, which limit the level of use
- low solubility
- unsatisfactory taste profile
- lack of storage stability
- insufficient texture and bulking properties

ERYTHRITOL

Erythritol occurs naturally in a wide variety of fruits and vegetables. Its taste and functional properties are similar to sucrose, though its calorie content is close to zero, and when used in combination with intense sweeteners it can enhance the sweetness of both ingredients. Unlike many other polyol sweeteners, erythritol does not cause digestive intolerance, even when consumed in large quantities.

It can be used in a wide variety of processed food, baked products, confectionery and beverages. In Japan it has been widely adopted by the soft drinks industry.

Chemical and Physical Properties

Erythritol is a linear carbohydrate molecule of four carbon atoms, each carrying one hydroxyl group.

Chemically, erythritol therefore belongs to the class of monosaccharide polyols, which also includes sorbitol, mannitol, xylitol and glycerol. Erythritol is a symmetrical molecule and therefore it exists only in one form, the mesoform. It forms anhydrous crystals with a moderately sweet taste without off-taste or odors. The powder has a transparent white brilliant appearance and dissolves in water to give a colorless nonviscous solution. Crystals melt at 122°C to form a colorless and brilliant nonviscous melt.

Erythritol's chemical properties are similar to those of other polyols in that it has no reducing end-groups and thus has excellent heat and acid stability. It differs in having a low solubility, and its heat of solution is very low. However, compared to the group of polyols presently used as sugar replacers, erythritol has the lowest molecular weight — which of course gives it different properties, such as higher osmotic pressure and lower water activity in solution (Figure 1).

The most important and special nutritional properties that differentiate erythritol from other polyols are due to its small molecular size.

Although chemically a polyol, erythritol is such a small molecule that it behaves very differently from all other polyols.

Chemical and Physical Properties of Erythritol
(In comparison to other low calorie bulk sweeteners)

	Erythritol	Xylitol	Mannitol	Sorbitol	Maltitol	Isomalt	Lactitol
Carbon n°	4	5	6	6	12	12	12
Molecular weight	122	152	182	182	344	344	344
Melting point °C	121	94	165	97	150	145 150	122
Heat of solution kJ/mol	-23.3	-36.5	-28.5	-26	-18.9	-9.4	-13.9
Heat stability °C	>160	>160	>160	>160	>160	>160	>160
Acid/alkaline stability pH	2-12	2-10	2-10	2-10	2-10	2-10	>3
Solubility %ww (25°)	37	64	20	70	60	25	57

Figure 1

A Naturally Occurring Substance

Erythritol is present in a wide range of micro-organisms, plants and animals, as well as being found in many foods as a naturally occurring substance. Figure 2 lists the concentrations detected in various common foods, giving an indication of our present erythritol intake.

Erythritol is the first polyol to be manufactured by an entirely biotechnological process, based on the ability of some yeasts or fungi, especially osmophilic species, to produce it in large amounts. The starting material is a glucose-rich substrate obtained by enzymatic hydrolysis from natural raw materials such as starch or sugar. Glucose is then fermented by an osmophilic yeast (*Moniliella* sp., *Trichosporonoides* sp.) or fungus (*Aureobasidium* sp.) to yield a mixture of polyols containing mainly erythritol, glycerol and ribitol, with other polyols in trace amounts. Erythritol is crystallized at over 99 percent purity from the filtered and concentrated fermentation broth.

Natural Occurrence of Polyols in Various Foods

Foods	Erythritol Content
Wine	130-300 mg/l
Sherry Wine	70 mg/l
Sake	1,550 mg/l
Soy Sauce	910 mg/l
Miso Bean Paste	1,310 mg/kg
Melons	22-47 mg/kg
Pears	0-40 mg/kg
Grapes	0-42 mg/kg

Figure 2

Nutritional Properties

Although chemically a polyol, erythritol is such a small molecule that it behaves very differently from all other polyols in the way it passes through the animal and human digestive systems. The resulting nutritional properties of erythritol are therefore unique and offer new opportunities for designing and formulating healthy foods.

Following are four key nutritional properties of erythritol:

- very low calorific value of less than 0.4 Kcal/g—only 10 percent of the calorific value of sugar
- high digestive tolerance
- suitability for diabetics
- noncariogenicity

Each of these properties is related to aspects of carbohydrate utilization, absorption, fermentation, metabolism and excretion by the human digestive system, in which erythritol behaves differently from all other bulk sweeteners. Since it is a very small molecule, it is rapidly and easily absorbed by the small intestine—80 percent is excreted immediately in the urine, and there are few breakdown products remaining to cause the digestive problems characteristic of other bulk sweeteners. For the same reason, erythritol does not affect blood glucose levels and so can safely be consumed by people with diabetes. Finally, mouth bacteria cannot feed on erythritol, so its use does not promote dental caries.

Functional Properties

As a four-carbon polyol, erythritol has many

Typical Reduction in Calories	
Table top sweeteners	90%
Chocolate	34%
Chewing gum	85%
Lozenges	90%
Comprimates	85%
Fondant	65%
Fat cream	36%
Instant bakery cream	31%
Sponge cake	25%

Figure 3

properties similar to other polyols currently used as food ingredients, such as xylitol, sorbitol and mannitol or the disaccharide polyols maltitol, lactitol and isomalt.

It is a moderately sweet bulking agent with 60 to 70 percent of the sweetness of sucrose in a 10 percent solution. As it has a taste profile which is very close to sucrose and no bitter aftertaste, it is ideal for improving the taste of a combination of intense sweeteners like aspartame or acesulfame-K.

Like other polyols, erythritol has excellent heat and acid stability, but differs in having low solubility and a very low heat of solution. When erythritol is dissolved in water the crystals need energy to dissolve. This high negative heat of solution provides the crystalline material with a strong endothermic cooling effect. This property is particularly relevant in applications such as chewing gum, fondant or fat cream.

The excellent heat stability of erythritol ensures no product decomposition and/or discoloration at temperatures up to 170°C (Figure 13). Erythritol resists decomposition both in acidic or alkaline media and remains stable under prolonged exposure to products with a pH in the range of 2–12.

The low solubility of erythritol, only 37 percent at 25°C, provides it with excellent crystalline and powder properties, making it an ideal replacer when the crystalline structure of sucrose is essential. High viscosity syrups, such as maltitol syrup, can be used to prevent unwanted crystallization if necessary, similar to the use of glucose syrup in traditional confectionery.

Confectionery Applications

The combined nutritional and functional properties of erythritol make it unique among low calorie bulk sweeteners, and open up new possibilities for formulating functional and health foods (Figure 3).

There are three main advantages of erythritol:

- It can significantly reduce the calorific value of products based mainly on carbohydrates, which can be substituted with erythritol.
- It improves the digestive tolerance of reduced-calorie foods.
- It offers new ways to improve taste and texture quality and the storage stability of reduced calorie foods.

Intense sweeteners such as aspartame, cyclamate, saccharin and acesulfame-K have such high sweetening properties that they are used in food at extremely low doses, but have no bulking properties of their own. Erythritol can be combined with these intense sweeteners to provide the desired texture and to achieve a taste very similar to sugar.

- **Chocolate.** *Calorie reduction: 30 percent.* Erythritol can be used to replace sugar in chocolate with only minor adjustments to the traditional manufacturing process. Its high heat stability and low moisture pick-up makes it possible to work at temperatures of up to 80°C during the conching stage, reducing processing time and enhancing flavor development.
- **Fondant.** *Calorie reduction: 65 percent.* In combination with Maltidex 100 syrups, erythritol can be used to produce sugar-free fondant with a brilliant appearance, a pleasant, cool taste and excellent consistency. A range of different textures can be achieved by varying the beating time and temperature. Erythritol-based fondant also has very good shelf stability due to its low residual moisture content and water activity.

Erythritol has many properties similar to other polyols currently used as food ingredients.

Confections

Fondant

Formulation	%
Erythritol	50
Maltitol syrup (75% maltitol content)	50

Manufacturing Process

- Dissolve erythritol in maltitol syrup.
- Cook the mix to ± 140°C.
- After cooling to 40–45°C, the mass is beaten for 5–10 minutes to obtain the required consistency and crystal size.
- The fondant is placed in containers and matured for 1 day.

Lozenges

Formulation	
Erythritol	1.5 kg
Gelatine solution (10% ds)	230 ml

Manufacturing Process

- Prepare 10 percent gelatine (170 Bloom) solution by slowly adding the gelatine to warm water (±50°C).
- Put erythritol into the Z-blade mixer preheated to 40–45°C.
- Slowly add the warm gelatine solution while continuing to mix.
- Mix for ±10 min. to obtain a smooth, homogeneous paste.
- Remove the paste from the kneader, roll out and cut in shape.
- Store at 45°C for 8 hours.

Fudge

Formulation	%
Erythritol	22.5
Maltitol syrup (75% maltitol content)	45.5
Water	5.5
Unsweetened whole concentrated milk	18.7
Hydrogenated cocoa fat GMS	7.5
Sodium bicarbonate	0.2
Seeding Blend	
Erythritol 81%	5–10
Water	19

Manufacturing Process

- Mix erythritol, maltitol syrup and water and heat to ±70°C.
- Add the milk, melted fat and GMS and homogenize during ±2 min.
- The mix is further cooked to ±140°C.
- Cool the mass to ±100°C and seed with 5–10% of seeding blend.
- Cool and cut.

Chewing Gum

Ingredients	%
Gum base	30
Erythritol	55
Maltitol syrup	13
Glycerine	2

In order to achieve a chewing gum with excellent appearance, chewability, texture and stability, the following method is recommended. The temperature of operation is a critical factor.

Manufacturing Process

- Heat the gum base to 60°C and knead.
- While still kneading add the hydrogenated starch hydrolysate: maltitol syrup.
- Add one-third of the erythritol and knead for 6 minutes.
- Add one-half of the glycerine and knead for 1 minute.
- Add the second third of erythritol and knead for 6 minutes.
- Add the second half of the glycerine and knead for 1 minute.
- Add the remaining third of erythritol and knead for 6 minutes.
- Discharge the chewing gum and cool.

A chewing gum with a harder texture can be produced using the following formulation:

Ingredients	%	Ingredients	%
Gum base	38.0	Mannitol	10.0
Erythritol	45.5	Glycerol	3.0
Maltitol (75%)	2.0	Mint flavor	1.5

In both formulations, erythritol particle sizes up to 300 microns may be used, although it is generally preferred that the particle size be less than 300 µm to avoid a grainy texture.

Chocolate

Formulation		EROH Chocolate		Sucrose Chocolate	
Ingredients	Kcal/g	%	Kcal/100g	%	Kcal/100g
Cocoa mass	6.1	39	237.9	42	256.2
Cocoa butter	9.3	13	120.9	13.5	125.5
Erythritol	0.4	47.7	19	—	—
Sucrose	4.0	—	—	44	176
Lecithin	9.3	0.48	4.5	0.48	4.5
Vanillin	—	0.02	—	0.02	—
Aspartame	—	0.03	—	—	—
Caloric Value in Kcal			382.3		562.2
Reduction %			68		100

Manufacturing Process

Kneading

- Insert erythritol, cocoa mass (liquid) and 5–10 percent cocoa butter into the mixer.
- Kneading time: 10–15 minutes
- Kneading temperature: 30–40°C

Refining

- The mass is milled on a cooled 5-roll refiner.

Conching

- Temperature: up to 80°C
- Total conching time: 16–22 hours
- Conching conditions: according to equipment

Near the end of the conching period the remaining cocoa butter and the lecithin are added. E.g., for a 16-hour conching time: addition of the remaining cocoa butter after 14-hours, addition of lecithin after 15 hours.

Tempering

- Tempering temperature: 28–31°C

Should the sweetness level be unsatisfactory this can be adjusted; for example, by the addition of 0.03 percent aspartame.

Bakery

Fat Cream

A typical erythritol-based fat cream formulation in bakery.

Formulation	%
Erythritol <300 micron	60
Shortening	40

Manufacturing Process

- Gently mix all the ingredients for 5 minutes at full speed in a Hobart mixer using the harp beater configuration.

Instant Pie Filling

A typical erythritol-based instant pie filling formulation.

Formulation	%
Sorbitol powder	10.3
Erythritol	6.2
Fructose	1.4
Spray dried glucose syrup 21 DE	2.7
Cold soluble modified waxy maize starch	10.3
Citric acid	0.7
Water	68.4

Manufacturing Process

- Dissolve the citric acid in the water.
- Add the mixture of the other ingredients to the solution and mix for 30 seconds at low speed and 30 seconds at higher speed in the Hobart mixer.

Instant Bakery Cream

Formulation	%
Sorbitol powder	8
Erythritol <300 microns	4.65
Fructose	1.1
Spray-dried glucose syrup 21 DE	1.4
Cold soluble modified potato starch	7.1
Whole milk solids	5.7
Lactitol D336	0.5
Color/flavor	0.05
Water	71.5

Manufacturing Process

- Blend the dry ingredients.
- Add the mix to the water and blend in a Hobart mixer for 30 seconds at low speed and for 3 minutes at a higher speed (whisk).
- Deposit the cream.

Used in combination with sorbitol, erythritol improves flexibility and shelf life in sugarfree gum.

- **Lozenges.** *Calorie reduction: 90 percent.* Erythritol solutions crystallize easily, producing sugarfree lozenges with a hard, crunchy texture. Sugarfree lozenges can be prepared using conventional manufacturing processes and have a pleasant, cool taste and excellent storage stability.
- **Chewing gum.** *Calorie reduction: 85 percent.* Erythritol's high negative heat of solution gives chewing gum a pleasant cooling effect in the mouth. Used in combination with sorbitol, erythritol improves flexibility and shelf life in sugarfree gum.
- **Tabletop sweeteners.** *Calorie reduction: 90 percent.* Spoonable sweeteners or sugar cubes with a taste and texture very similar to sucrose can be made with a combination of erythritol and intense sweeteners.
- **Bakery.** *Calorie reduction: instant bakery cream, 31 percent; sponge cake, 25 percent.* Erythritol can be used successfully in cookies, biscuits and cakes, where it improves baking stability and shelf life. Compared to sucrose, erythritol gives a different melting behavior, a more compact dough, softer end products, less color formation and better water-binding capacity in bakery products.

CONCLUSION

With its unique nutritional and metabolic characteristics, erythritol combines more interesting properties than any other sugar replacer on the market today.

The fact that it is an entirely natural product, already present in many foods, has made it very popular in Japan as a health food ingredient. The FDA has awarded erythritol GRAS (generally recognized as safe) status after extensive safety studies, and it is now being launched on the U.S. market as the sweetener for an age of increased public interest in healthy, natural foods. ❑