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Polyol Usage in Confectionery Applications

By Peter Jamieson.

As Americans try to get a handle on their growing waistlines, they are looking for ways to make weight loss and living healthy easier. Traditional candies – often considered comfort foods/snacks – re-formulated as sugar free can be useful tools to help consumers reach their goals while limiting sacrifices of dieting. The success of sugar free confectioneries is apparent in current IRI data, indicating that, in a time when interest in “low carb” has seemed to level off, they are more popular than ever. Sales of sugar free confections from May 2003 to October 2004 have increased by 48%, and 453 new products have been introduced in 2004 (Jan.-Nov. 2004), according to data obtained by Mintel International Group Limited. Most people don’t need that information to confirm the popularity of “sugar free” – just walk into any grocery or drug store chain and look around. You’ll find sugar-free products not just in those special dietetic aisles anymore, but all over the store in their own little point of purchase displays near candy aisles and/or check out counters.

Although sugar-free confections have been more visible recently, they are not new to the industry. In fact, diabetics have been using them for decades to help manage their blood glucose levels. One of the major ingredients used for sugar replacement in these products is a group of carbohydrates known as “polyols” or “sugar alcohols.” These unique carbohydrates are metabolized more slowly by the body, reducing blood glucose response levels and caloric density (Figure 1), while still providing the same bulk as traditional sugars (glucose, maltose, sucrose etc.) and carbohydrates (corn syrups, maltodextrin, and starches).

Figure 1. Calories

	U.S.	E.U.
Erythritol	0.2	N/A
Mannitol	1.6	2.4
Isomalt	2.0	2.4
Lactitol	2.0	2.4
Maltitol	2.1	2.4
Xylitol	2.4	2.4
Sorbitol	2.6	2.4
Maltitol syrup	3.0	2.4
Polyglycitol syrup	3.0	N/A
Sucrose	4.0	4.0

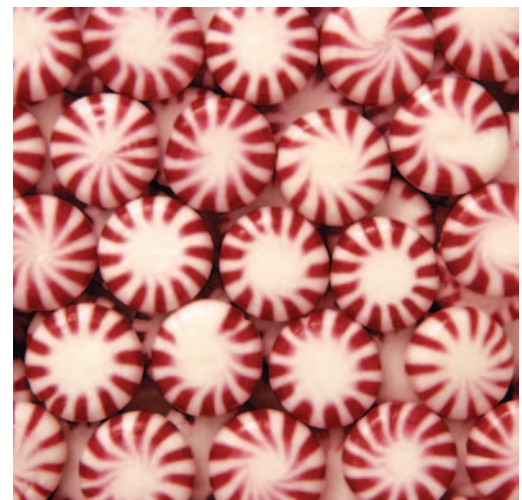
All of the polyols are considered either a “Food Additive” or “Generally Recognized As Safe” (GRAS) by the Food and Drug Administration (FDA) as noted in Figure 2. Furthermore, since they are not fermented by oral bacteria in the mouth, they are non-cariogenic (do not contribute to dental caries or cavities). The FDA allows a “dietary sugar alcohol and dental caries” health claim

(21 CFR 101.80) for sugar-free foods containing polyols. The full claim would read “frequent between-meal consumption of foods high in sugars and starches promotes tooth decay. The sugar alcohols in [name of food] do not promote tooth decay”.

Figure 2. Regulatory Status

	U.S. Status	E.U. Approval
Sorbitol	GRAS (21 CFR184.1835)	Yes
Mannitol	Food Additive (21 CFR180.25)	Yes
Xylitol	Food Additive (21 CFR172.395)	Yes
Erythritol	GRAS1	Pending
Isomalt	GRAS1	Yes
Lactitol	GRAS1	Yes
Maltitol	GRAS1	Yes
Maltitol syrup	GRAS1	Yes
Polyglycitol syrup	GRAS1	Pending
1Self-Affirmed	GRAS	

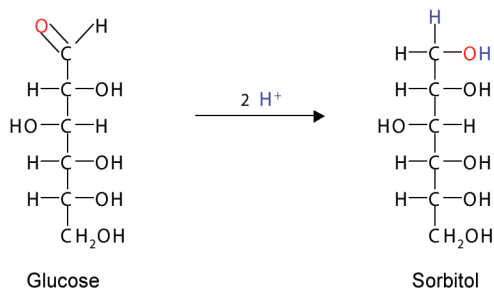
In the past, only about two or three polyols were either cost effective or available for use but, with advances in biotechnology and manufacturing, others have found their way into the market. These newer polyols, if used correctly, can allow a formulator to create high-quality confections that were not possible just a few years ago.



Polyols: Carbohydrate Derivatives

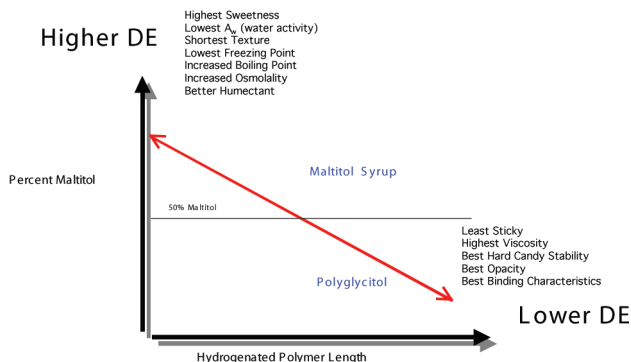
Why are polyols such great bulk replacers for “sugar free” confections? The answer to this question becomes more apparent when you examine their origin. Focusing on the United States, polyols start out as traditional corn syrups which are then modified by reducing reactive sites (aldehyde or ketone) through either one or a combination of the following production methods: catalytic hydrogenation, enzymatic conversion, or fermentation (Figure 3). Because only the reactive groups are changed, polyols retain much of the sugar’s structure, bulk, and function, which is what makes them the perfect 1:1 bulk replacement.

Figure 3 – Glucose to Sorbitol



Polyols can be divided in three groups: monosaccharides, disaccharides, and polymeric mixtures. The monosaccharides consist of erythritol, mannitol, sorbitol, and xylitol. The disaccharides, consisting of two glucose units, are isomalt, lactitol, and maltitol. Finally, the polymeric mixtures are mixtures of polyols that are identified as “polyglycitol syrups”, also known as “hydrogenated starch hydrolysates” (HSH), and “maltitol syrups” - these are the most similar to corn syrups. Nomenclature is determined by the amount of maltitol (dry basis) present - a syrup that contains greater than 50% maltitol is considered a “maltitol syrup” and anything less is a “polyglycitol syrup” (Figure 4).

Figure 4 – Maltitol/Polyglycitol Syrups



Physical Characteristics

A common misconception is that all polyols are the same. This is far from the truth. Functional and physical properties (which will be talked about later) such as sweetness, solubility, cooling effect, molecular weight, laxation and osmotic effects, can differ greatly between them. Therefore it is important that the formulator understand these differences to choose the correct polyol for a successful product. Remember - no matter what nutritional benefit you provide the consumer, if the finished product doesn’t taste good or causes them to experience discomfort, it will fail.

Sweetness

When talking about sugar based confections, the first thing that pops into everyone’s mind is sweetness. This is no big surprise since this is why we love them so much. But when formulating sugar-free confections, one must realize that polyols have a varying range of sweetness from 0.3 – 1.0 times that of sucrose (Figure 5). Interestingly enough, this is the easiest attribute to get around when formulating because there are many effective high potency sweeteners (HPS), such as aspartame, acesulfame-K, and sucralose available to pick up the sweetening slack. There are some formulators out there, however, who are not interested in using these HPS. In this case they obviously need to consider a polyol that can deliver the most sweetness similar to that of sucrose and there are a few that come close. But formulators beware - just because a polyol might deliver the same sweetness as sucrose doesn’t mean it will function well in the application. It turns out that there are many other important physical characteristics that need to be addressed to determine the right polyols for the application.

Figure 5. Sweetness

	Relative Sweetness to Sucrose (%)
Sucrose	100
Xylitol	100
Maltitol	90
Erythritol	60
Sorbitol	60
Mannitol	50
Isomalt	40
Lactitol	30-40
Maltitol Syrup	70-80
Polyglycitol	30-50

Note: Since sweetness is determined through subjective methods, these values are meant to be approximate values and may vary among individuals.

Cooling Effects

Individuals biting into a sugar -based chocolate mint patty might notice a cooling sensation as they chew. Many think this sensation is caused solely from the flavors – like peppermint and spearmint – added to the crème center, but it is not. Surprisingly enough, sucrose provides a cooling effect as it dissolves into water, or saliva in this case. This effect, known as the “heat of solution”, is an actual exchange in energy that can either lower (in this example) or raise the temperature of a solution when a substance (sugar) is added to water (saliva). The heat of solution is measured in either joules or calories per gram and can occur if the substance interacting with water is in liquid or, in most cases, solid form. As the heat of solution decreases into negative values the cooling effect becomes greater, and the opposite holds true for the warming effect.

Most polyols in crystalline form tend to have a cooling effect, with some being very significant at -42.0 cal/g when compared to -4.0 cal/g of sucrose (Figure 6). High cooling polyols such as erythritol, xylitol, and sorbitol are perfect for formulators that want to deliver a strong cooling sensation for a specialty or mint based application. There are also times when a formulator might require a minimal cooling effect for an application, such as in a traditional dark chocolate or crème center. In this case, he or she can choose polyols lower in cooling effect, such as isomalt, lactitol, and maltitol. If the formulator feels that the high cooling polyol provides a certain functional advantage – such as cost, crystallization, solubility, reduced calories, or higher laxation threshold – to maintain product goals and quality, they can combine them with the lower cooling polyols to reduce overall cooling effect. In addition, these high cooling polyols can be combined very well with other low digestible carbohydrates like fructo-oligosaccharides, inulin, and polydextrose to create the same effect and reduce overall cooling effects greatly. These options allow for great flexibility in sugar-free confectionery applications but only if all aspects are understood well by the formulator.

Figure 6. Cooling Effects

	Heat of Solution cal/g)
Glycerin	+9.0
Sucrose	-4.0
Maltitol	-5.5
Isomalt	-9.4
Lactitol	-13.9
Sorbitol	-26.5
Mannitol	-28.9
Xylitol	-36.6
Erythritol	-42.9
Maltitol Syrup	N/A
Polyglycitol	N/A

Solubility

Solubility is generally defined as the amount of a solute (sugar or bulking agent) that can be dissolved into a solvent (water) at a given temperature before becoming saturated. As the temperature of the solution increases, it can hold more of the solute. Therefore, if a saturated solution at a higher temperature is cooled to a lower temperature, eventually the solute will begin to fall out, typically in crystal form. Interestingly enough, this is the basic idea behind almost all confections and is the most important. All traditional confections – such as caramels, crème’s, marshmallows, and hard candies – in their most basic form are supersaturated sugar/corn syrup solutions that are either meant to be crystallized (grained) to some degree or not (ungrained). Through years of trial and error, confectioners have used sucrose’s solubility to create the standards of appearance, taste, texture, shelf life, sweetness and manufacture that we now expect from these types of products.

To recreate these products for sugar-free, the formulator must first understand the functional requirements of the application. Is the product going to be grained? Is it going to be a low moisture system? Are there any handling, storage, or processing concerns? What is the expected shelf life of the product? Once the formulator knows the answer to these types of questions, he or she can have a better idea of where to start.

Polyols such as erythritol, isomalt, and mannitol provide the lowest solubility and crystallize most readily (Figure 7). These work well for applications that require low moisture, low hygroscopicity or rapid crystallization such as compound coatings, crème centers, and grained marshmallows. One must be careful though, for in the case of mannitol it’s solubility is so low, it doesn’t dissolve as quickly in the mouth. The result is a chalky mouth feel or texture for products such as a compound coating.

Figure 7. Solubility

	Solubility at 25°C (g/100g H2O)
Sorbitol	235.0
Xylitol	200.0
Sucrose	185.0
Maltitol	175.0
Lactitol	140.0
Erythritol	61.0
Isomalt	29.0
Mannitol	22.0

Lactitol, maltitol, and xylitol on the other hand are more moderate in solubility and are most similar to that of sucrose. This means that their texture and flavor release will be most similar as well. This allows them the potential to be used in more traditional applications like sucrose. Although all crystallize relatively close to sucrose, lactitol seems to do so the closest, followed by maltitol, then xylitol.

In crystalline form, lactitol and maltitol are non-hygroscopic while xylitol tends to be hygroscopic. Xylitol's tendency to pick up moisture can cause some handling issues, in the form of clumping, if not properly stored. Also, unlike the other two, its hygroscopicity limits its use in applications that are lower in moisture like a compound coating.

One of the most soluble polyols next to glycerin is sorbitol, a monosaccharide. Unlike sucrose its crystals are polymorphic, meaning it can have different structures. Today the most common and stable crystalline form manufactured is called gamma sorbitol. Although the most stable, it is still hygroscopic and like xylitol can clump during storage if conditions are not properly controlled.

It is commonly used as a humectant and plasticizer in various applications ranging from chewing gum to gummy candies. A lesser-known attribute is sorbitol's ability to control crystallization in, sugar or sugar free, fondants or crèmes extending their shelf life. This hygroscopicity can also limit its use in other applications such as compound coatings where moisture pick up during manufacture can be detrimental to the finished product.

Maltitol and polyglycitol syrups are more like the corn syrups and for the most part are very soluble. They come in a range of percent solids levels from 70 – 85. These are either used alone or in combination with other polyols – like erythritol, isomalt, maltitol, and lactitol – to control crystallization. Therefore these find a wide range of use in many sugar-free applications that would traditionally use corn syrups.

Molecular Weight

Traditional sugars/carbohydrates like glucose, maltose, sucrose and corn syrups all have weight. The smaller molecules like the mono- and disaccharides mentioned can actually be measured and the weights are given in units of “grams per mole.” The larger molecules of corn syrup, consisting of many glucose units connected together, are not so easily measured. Therefore, there is a term that is commonly used to give an approximate idea of how large these can be - “Dextrose Equivalence” (DE). During processing, corn syrups are created through hydrolyzing (breaking down) starch with acid, enzymes, heat and time creating various polymer distributions. Basically, the longer the time starch is exposed to these elements the more those longer chains are reduced to mono- and disaccharides. Something like this would be considered a higher DE corn syrup, with a value greater than say 43DE. This would have less viscosity, more sweetness, higher boiling points and a lower water activity. Conversely, a DE below 43 would indicate that there was a greater presence of longer chains and less of the mono- and disaccharides. This syrup would have greater viscosity, less sweetness, more binding capability and lower water activity. Polyols – like these traditional carbohydrates mentioned – have weight (molecular weight) too and follow similar trends. So in turn, they can potentially offer the same colligative properties and viscosity as their sugar counterparts (Figure 8).

The molecular weight can play a significant role in influencing the overall texture and functionality of the finished product. More importantly to the plant operator it will determine how these products will flow when in liquid or molten form during processing. When formulating sugar-free products, it is best to examine the sugars and

corn syrups that are being replaced and match them with the polyols accordingly. For instance, if an application were to use a 43DE corn syrup, it would be best to consider using a polyol such as a polyglycitol or maltitol syrup of similar molecular weight instead of either a mono- or disaccharide polyol. For most applications, this works well or is at least a good starting point. Today there are many different types of polyols available that mimic traditional sugars and corn syrups so, if one does their homework, they can find the best fit.

Figure 8. Molecular Weight

	Molecular Weight (g/mol)
Polyglycitol Syrup	Variable
Maltitol Syrup	Variable
Corn Syrups	Variable
Lactitol	362.3
Isomalt	344.2
Maltitol	344.2
Sucrose	342.0
Mannitol	182.0
Sorbitol	182.0
Xylitol	152.2
Erythritol	122.0

Polyols and Laxation

Polyols have been an important part of sugar-free confections for several decades. They have proven to be great formulation tools for reducing calories, lowering blood glucose responses, and formulating tooth-friendly confections. These same advantages also carry with them a caution – like fiber, polyols are low digestible carbohydrates (LDCs). What is not absorbed in the upper gastrointestinal tract can, at certain levels, lead to osmotic imbalances and/or fermentation by bacteria – causing loose stools and gas.

It is important to understand that all polyols are not the same in terms of laxation. Table 7 shows the laxation thresholds for various polyols and some LDC's. These values represent the total amount of polyol or LDC that can be typically consumed daily before a laxation effect is observed. Understandably, these will vary for each individual due to factors such as - individual response, age, makeup of individual colonic microflora, gender, psyche, health, diet, any drugs or antibiotics, and other foods consumed. Laxation is also dictated by chemical factors such as molecular weight (larger molecules will cause less osmotic imbalance), solubility, and whether or not the substance is absorbed in the small intestines. Some of this is also reflected in the grams/day number of Figure 9.

Considering all these factors, at what point are you, as a manufacturer, required to put an “excessive consumption may cause laxation” claim on a product's label? Currently in the U.S., only sorbitol, mannitol, and polydextrose are required to do so.

- In the USA these are 20g/d for mannitol (21 CFR 180.25), 50g/d for sorbitol (21 CFR 184.1835) and 15 g polydextrose per serving (21 CFR 172.841).
- In the EU a trigger amount is expressed differently. Mandatory labeling is triggered when polyol comprises 10% of the food product .
- Codex Alimentarius: Standard 181 (1991) If the food provides a daily intake of sugar alcohols in excess of 20g per day, there shall be a statement on the label to the effect that the food may have a laxative effect. This is not mandatory – it is a guideline.

Although no other polyols are specified for a mandatory warning in the U.S., it is important to realize that these threshold values in table 7 are meant to give a general idea for the level of tolerance for a specific polyol per day. Consumption of any LDC's at levels more than 30 - 50 grams per serving is not recommended. Considering the fact that most individuals will consume more than one serving size per meal, it might be wise to choose a safety zone of the following:

- Less than 15 g/serving for disaccharides.
- Less than 20 g/serving for polysaccharides.

The key point here - if used within sensible guidelines, polyols can improve a formulation without causing problems.

Figure 9. Laxation

	Laxation (g/day)
Erythritol	125
Sucrose	>100
Polyglycitol Syrup	>100
Maltitol Syrup	>100
Maltitol	90
Fructose	70
Isomalt	50
orbitol	50
Lactitol	20-50
Mannitol	20

Examples in Confectionery

Now that a general understanding of polyols has hopefully been established, let's look at a confectionery application to help tie everything together. For this example I have chosen to examine caramels. The reason is that this application often involves many of the aspects or potential issues often encountered when formulating a reduced-sugar, no-sugar-added, and sugar-free product.

Before we get started, it is important to note that many articles have been published by the PMCA extensively covering sugar-based confections. The following discussions will provide some background but assumes the reader has a basic understanding of the topic.

For more on the subsequent topic, I recommend reviewing PMCA articles "Caramel – Raw Materials and Formulations" by Mark Heim and "Caramel – The Essential Elements" by Mel Warnecke as they are excellent primers.

Caramels

Caramels are very versatile and often used in combination with many other confections – such as chocolate, crèmes, nougats, and hard candy – to create some of our most favorite candy products. Interestingly enough, unlike most other candies, they are not limited to the candy shelves or aisles and find their way into other areas like baked goods and frozen desserts.

In a general sense caramels consist of fat, milk solids, sugar, and/or corn syrup. It is the reaction between the reducing sugars (sugar and corn syrup) and milk proteins while being heated – known as the Maillard reaction – that gives caramels their unique brown color and flavor. Furthermore, caramels can vary greatly in texture, being either chewy/stringy or short, and structure ranging from a hard candy glass to a free flowing liquid. All of these use variations in the finished water content, amount of protein, ratios of sucrose to corn syrup, and melt point of fat to achieve each specific product. This is no different when considering "reduced sugar", "no sugar added" or "sugar free" caramels. Since the polyols will be acting as the sucrose and corn syrup, we will focus our attention on how these two act in controlling the various finished properties. When beginning to look at formulating reduced-sugar, no-sugar-added or sugar-free confections – in this case caramel – it is important to realize that since polyols do not have any reducing groups, they will not participate in the Maillard reaction. What this means to the formulator is that he or she will need to use a caramel color and flavor to achieve the desired product. As one would imagine this will need to be considered for any application where a similar reaction is expected. Next, the formulator must establish if the product is going to be reduced-sugar, no-sugar-added, or sugar-free. These choices will dictate what type of ingredients, besides the polyol, one will be able to use in the formula. This is more of an issue when considering sugar-free because to make such a claim according to CFR 21 101.60(c)(1)(i), the finished product must have less than 0.5 grams of sugars per serving as defined in CFR 21 101.9(c)(6)(ii). In the case of caramel, the many dairy ingredients often used – such as sweetened condensed milk, condensed whole milk, dried whole milk powder, and non-fat dry milk – will often contain either sucrose or lactose. These amounts are often large enough to make it almost impossible to keep the sugars in the finished product below 0.5 grams per serving. In turn, the formulator now needs to determine other sources of proteins such as sodium caseinates, which have very little or no sugars at all. As one would imagine it is this reason that makes the formulation of sugar-free, in this application, the most challenging.

No-sugar-added caramels are more flexible and easier to formulate because they can use more traditional dairy ingredients, for example condensed whole milk, dried whole milk powder, and whey concentrates. These ingredients have no additional sugars added during manufacture or packaging allowing caramels made from them, using polyols of course, to be considered no-sugar-added according to the CFR 21 101.60(c)(2)(i). Furthermore, these sugar levels are often

very low, and when combined with other sugar-free candies, like chocolate and/or nougat to create a finished product, can have total sugars low enough to be labeled sugar-free.

Recently, there has been a lot of interest in reducing the sugars of traditional confections instead of removing them altogether. Reduced-sugar products, and caramel in this example, are typically the easiest to formulate. According to the CFR 21 101.60(c)(5)(i), there needs to be a reduction of only 25% in sugars per reference serving size when compared to that of the full sugar equivalent when utilizing this claim. In confectionery products, this reduction can easily be met since the majority is usually made up of sugars. If thoughtfully chosen, polyols can partially replace the sugar exceptionally well in these applications with little or no change to the overall processing, sweetness, or functionality of the product. As in the case of a “reduced sugar” caramel, there would be no need for any color or flavor to be added since there would be more than enough reducing sugars available for the Maillard reaction occur.

Once the formulator has decided on which type of caramel to consider they need to focus on how to identify which polyol would be appropriate for their application. The best way to do this is first establish what type of texture and structure is desired from the application. In the case of the caramel what’s the texture going to be like? Is it going to be soft, stringy, chewy, flowable, grained, or firm? How does varying the different ratios of sucrose and corn syrup affect these attributes in a caramel applying them to the polyols? For instance, as the ratio of sugar increases over the corn syrup the more crystallization or graining of the caramel will be apparent. This will yield a softer shorter texture but limits shelf life, (due to crystallization) depending on how much is used and final moisture content. On the other hand, if the ratio of corn syrup increases over the sugar the caramel will become more sticky, chewy, firm and stringy while limiting crystallization further, extending shelf life.

Now consider the polyols: mono- and disaccharides – such as erythritol, isomalt, lactitol, maltitol, sorbitol and xylitol – will crystallize to varying degrees, while the mixtures (maltitol and polyglycitol syrups) act like the corn syrups and control crystallization as well as other textural properties. Utilizing the same ideas discussed previously when using sugar and corn syrup, but applying it to polyols, a formulator wanting to make a grained caramel could possibly combine erythritol and maltitol syrup at specific ratios to give a short soft texture with a moderate shelf life. Conversely, they could use solely polyglycitol syrup in a formulation and yield a firm chewy caramel that is stringy. Although these statements are true, it is not always that simple to obtain a finished product. Other aspects such as cooling effects, costs, laxation, regulations, and solubility of the polyols must be considered as well. Therefore it is up to the formulators to do their homework and understand fully what roles each ingredient plays in order to formulate these products appropriately.

Conclusion

There are many more polyols for a formulator to choose from today than there were 10 years ago. Remember that much of the understanding of polyols can be related to that of sugars and corn syrups. By understanding the many physical properties of each, the formulator can make an informed decision on which polyols will provide the functional aspects needed for their reduced-sugar, no-sugar-added, or sugar-free confection.

Reference:

Livesey, Geoffrey. (2001). Tolerance of low-digestible carbohydrates: a general view. *British Journal of Nutrition*, 85 (Suppl.1), S7-S16.