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CHAPTER 10

Polyhydric Alcohols

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Introduction

Polyhydric alcohols, or polyols, are valuable aids in formulating a wide range of food products. When present naturally, or when added during processing, they can impart one or more of several beneficial characteristics. These effects include crystallization retardation, improvement of stability on aging, control of viscosity or bodying, preservation, solvency, moisture retention, and others.^{39, 99 - 102, 120, 170}

Natural Occurrence

Many of the commonly used polyhydric alcohols occur in nature. The frequency of occurrence appears to be directly related to the carbon-chain length of the polyol. Two- and three-carbon polyols rarely, if ever, occur in

nature; four- and five-carbon polyols occur occasionally; six-carbon polyols have been found in many instances; and seven-carbon polyols have been observed in only a few cases. This frequency distribution is probably related to the corresponding sugars and their presence in nature, with some specific exceptions. Only one of the tetrityls and two of the pentityls have not been observed in natural foods.¹⁰⁶

Butylene glycol and glycerine are both reported as occurring in fermented products. The presence of 2,3-butylene glycol in tomato conserves has been reported.³⁸ Glycerine has been reported to occur in fermented products such as wines and beers.¹¹⁶ The isomer erythritol occurs in algae,^{12,152} grasses,⁸¹ and lichens.^{62,79} In the group of polyols known as pentityls, *d*-arabitol and ribitol are found in nature. Arabitol is reported in lichens¹⁰⁴ and in a species of mushroom,⁵⁸ and ribitol is reported in plants.^{124,165} Xylose (wood sugar) is one of the most abundant natural sugars in the plant world. However, xylitol, its corresponding polyhydric alcohol, has not been found.¹⁰⁷

The hexityls, or six-carbon polyols, are the most widespread.¹⁰⁸ Sorbitol was reported in 1877, when it was isolated from the juice of the berries of the mountain ash tree.^{27,123} It has since been reported in other fruit berries⁸⁰ and in many fruits, including pears, apples, cherries, prunes, peaches, and apricots,¹⁵⁶ in red seaweed,⁷⁵ and in *Sorbus commixta*.⁸ Strain has presented a listing of a large number of plants in which the sorbitol content was determined.¹⁴⁶ Mannitol was the first crystalline polyol discovered;¹²⁶ and, since it is crystalline, it frequently occurs in plant exudates.^{83,109} The sap exudate from a tree was the Italian commercial source of mannitol for many years.^{21,150,151} Mannitol is also present in seaweed²¹ and grasses.⁷⁴

The seven-carbon heptityls are considerably less prevalent in nature. Volemitol is found in algae,¹⁰⁵ lichen,¹⁰⁴ mushrooms,²⁵ and plants of the primrose family.²⁴ Perseitol is found in avocados.^{112,113}

Definition

The term *polyols* in this discussion will be restricted to those molecules that have two or more hydroxyl groups and have only hydroxyl groups. This will exclude sugars, although they have many hydroxyl groups and, in some instances, exhibit similar properties.¹⁷ The chief difference noted between polyols and sugars is related to the aldehyde linkage present in the sugars.

As a class polyols are more stable chemically and thermally than sugars. They are usually more expensive than sugars; hence, the food industry demands that a polyol contribute a notable desired property to the final product. For these reasons we shall not treat sugars as polyhydric alcohols.

Polyhydric alcohols for our use then are defined as derivatives of aliphatic hydrocarbons formed by the replacement of two or more hydrogen atoms with two or more monovalent hydroxyl groups, each being attached to a different carbon atom.

Both glycols that we shall consider—propylene glycol and butylene glycol—have a longer carbon-chain length than the number of hydroxyl groups. The balance of the polyhydric alcohols to be discussed—triols to heptityls—have an equal number of hydroxyl groups and carbon atoms.

While the polyhydric alcohol family continues to challenge the curiosity of the scientist, only a few polyols are of actual commercial importance in the food industry—propylene glycol, glycerol, sorbitol, and mannitol.

Properties of Polyhydric Alcohols

The properties of polyhydric alcohols may be summed up quite briefly by stating that they are generally water-soluble, hygroscopic materials that exhibit a moderate viscosity at high concentrations in water. For the most part polyols exhibit a sweet taste ranging in sweetness from less than half that of sugar to slightly higher. These properties are shown schematically in Figure 1.

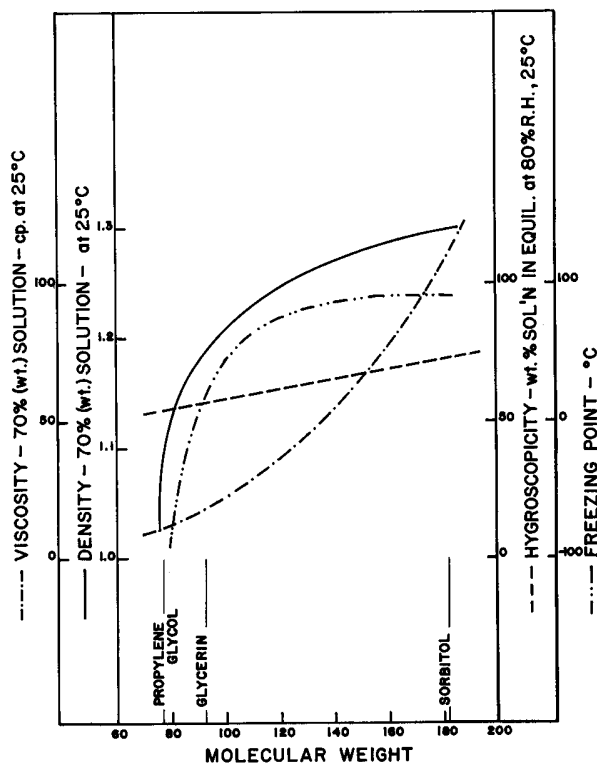


Fig. 1. Polyhydric alcohol behavior vs. molecular weight.

Table 1 shows a comparison of the properties of the four commercial polyhydric alcohols approved for use in foods.* They are all permitted in unstandardized foods, provided the amount used does not exceed that reasonably required to accomplish the intended physical or technical effect. Of course, they are not permitted in standardized foods, unless the standard of identity permits their use. Each case for a standardized food must be investigated separately.

Data in Table 1 show that as the molecular weight increases, the melting points, boiling points and viscosities generally increase. It has also been observed that with increasing molecular weight solvent properties for non-polar

* In addition (A) §121.1057: Polyethylene glycol 6000 is permitted (1) as a binder in plasticizing agents, (2) as an adjuvant in tablet coatings, and (3) as an adjuvant to improve flavor and body work with non-nutritive sweeteners; (B) §121.1114: Xylitol is permitted in some special dietary uses.

TABLE I
Properties of Polyhydric Alcohols and Sugars

	<i>Propylene Glycol</i>	<i>Glycerine</i>	<i>Sorbitol</i>	<i>Mannitol</i>
Molecular Weight	76	92	182	182
Melting Point °C	Supercools	18.6	Metastable 93	166
Boiling Point °C 760 mm	187	290°C Decomposes	Decomposes	Decomposes
Density—25°C	1.036	1.2613	1.49	1.49
Viscosity cp. 25°C	44.0	954	Solid	Solid
Viscosity 70% solution 25°C	10	17	110	Insoluble (Crystallizes)
Hygroscopicity	High	Med-High	Med-Low	Low
Solvency (for oils)	Good	Fair	Poor	Poor
Solubility* in water @25°C	Infinite	Infinite	71%	22%
High Temperature Resistance	Stable, Volatile	Stable, Sl. Volatile	Stable	Stable
Taste	Bitter	Sl. Sweet	Cool, Sweet	Sweet

*grams/100 g. water.

materials decrease. While generalizations of this type are useful, detailed comparative studies have been made and it is now possible to recommend, with some assurance, a specific polyol to contribute a certain function or property to a food. These studies have revealed that polyhydric alcohols act in a special way, each having its own functionality profile.

Most sugars have properties quite similar to that of high molecular weight polyols. However, though they are polyhydroxy compounds they also contain aldehyde linkages that adversely affect their high temperature stability.

Of the various properties of polyols described in Table 1, those most important in food processing are water solubility, hygroscopicity, viscosity, and taste.

Water Solubility Water solubility of the typical polyhydric alcohols appears to be correlated with molecular weight, as well as with crystalline structure and melting point. For example, the lower-molecular-weight polyols, glycerine and, although it is not generally considered in this discussion because of toxicity, ethylene glycol, are infinitely water soluble. As the molecular weight increases, the tendency toward crystallization increases and inherent solubility decreases; common hexitols, for example, range in water solubility from sorbitol at a maximum of 70–75% weight at room temperature to dulcitol at less than 10% at room temperature. The known solubilities of polyols in water are presented in Table 2. The chance to combine polyols of different water solubilities and different viscosities, as well as those with different crystallization characteristics, is a prime tool in modifying crystallization in foods.

Hygroscopicity The hygroscopicity, or the ability to absorb and retain water under conditions of medium and high relative humidity, also varies partially according to molecular weight. Generally, the higher the molecular weight, the less hygroscopic the polyol, although xylitol appears to be an

TABLE 2
Solubility of Polyols in Water

<i>Polyol</i>	<i>Water Solubility, g/100 ml water, 25°C</i>
Propylene Glycol	∞
Glycerol	∞
Erythritol	75
Sorbitol	251
Mannitol	22

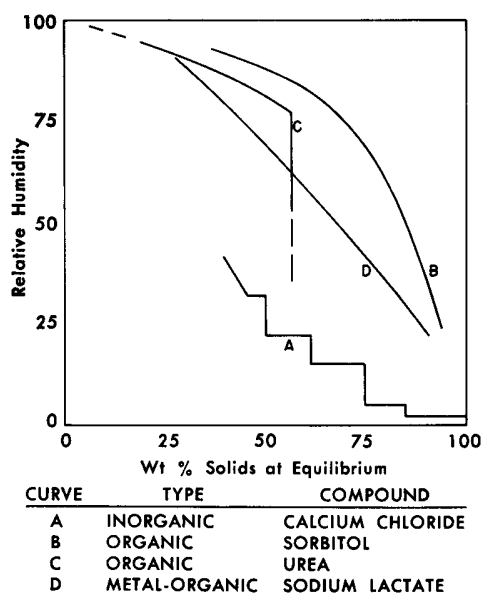


Fig. 2. Comparative hygroscopicities.

Source: W. C. Griffin, R. W. Behrens, and S. T. Cross, 1952, *J. Soc. Cosmet. Chem.*, 3:5.

exception. A non-hygroscopic material does not imbibe water even at high humidities. Many inorganic substances exhibit a "stepwise" humectant action, depending on water of crystallization (Figure 2). Hygroscopic materials such as polyols show a smooth transition curve holding more and more water as the humidity increases.^{64, 66, 171, 176} Many organic materials, such as flour, cellulose, and protein, show a modified stepwise curve, holding about 13% ($\pm 5\%$) moisture over a large range of humidity.⁶⁴

Figure 3 shows the hygroscopicity for the polyols listed in Table 1. The dotted line, in both instances, is invert sugar, which is only slightly hygroscopic. Cane sugar (sucrose) is even less hygroscopic, because it is relatively more crystalline. The effect of crystallization is shown in Figure 3, in the comparison of sorbitol and mannitol. Mannitol, when crystallized (which applies to most of the humidity range), exhibits a very low hygroscopicity, making it useful as a nutritive powder that is stable at high humidity.¹⁷¹

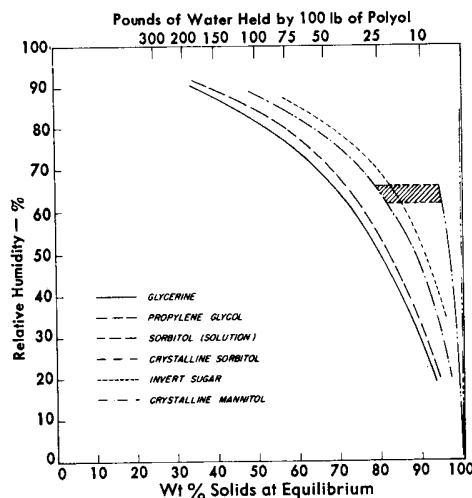


Fig. 3. Comparative equilibrium hygroscopicities of polyols.

For comparison, consider the usual polyols versus a similar food raw material, sugar. Equilibrium data for glycerine, invert sugar, and sorbitol are presented in Figure 3.

Proteins, cellulose, and similar products that exhibit a "shelf" in their hygroscopicity at about 13% water actually show a diminution in moisture-holding capacity when small amounts of polyol are added; this is recovered only when the amount of polyol becomes appreciable with relation to the other ingredients.⁶⁶

A further consideration with respect to hygroscopicity is whether static (equilibrium) or dynamic moisture control is the point at issue. Most reported data, as in Figures 2 and 3, are equilibrium values. Seldom is it practical to add sufficient polyol to achieve adequate moisture levels or protection from evaporation at low humidities, or even moderate humidities. This is true primarily because foods inherently have high moisture levels to provide the desired texture, taste, and mouthfeel.

On the other hand, polyols in many instances can help control the rate of moisture gain and loss.^{66, 171} Generally, the higher the molecular weight, the lower the rate of change (Figure 5). Note, though, that these rate change times are short term hours, not days or weeks; and moisture levels over longer periods of time are not controlled under these circumstances.

Dynamic hygroscopicity, the rate with which moisture is gained or lost, is far more difficult to measure accurately. Hygroscopicity is often studied by placing a small amount of liquid, unstirred, in a crystallizing dish or beaker and exposing it to a higher or lower humidity (Figure 4A). If the sample is carefully examined after this exposure, striation lines will be observed showing that the surface concentration has changed because of either gain or loss (Figure 4B). At this point change in weight of the sample is related not only to the rate of gain or loss of moisture at the surface of the sample but also to the rate of moisture transfer within the bulk of the sample, which is, in many instances, the controlling function. The ideal situation would be to present

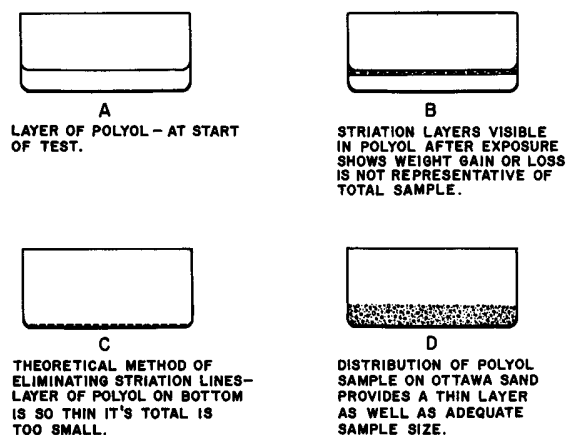


Fig. 4. Hygroscopicity determinations.

essentially a layer of polyol only a few molecules thick, as in Figure 4C. Since the sample would be too small to note meaningful weight changes, it appears most expedient to disperse a small sample on Ottawa sand and observe the rate of moisture change (Figure 4D).¹⁷³ Even with this method, it is necessary to take precautions that the samples are exposed to a uniform draft, maintained, of course, at a constant temperature and constant relative humidity. Following these techniques, valid dynamic hygroscopicity information can be obtained. Figure 5 shows data obtained on sorbitol and glycerine by this technique.

Viscosity The viscosity of polyhydric alcohols in aqueous solution is of importance in food applications because of the bodying effect that is conveyed. Viscosity generally increases with increasing molecular weight. Viscosity is, of course, a function of concentration and temperature. Room-temperature viscosity data for a number of the major polyols are presented in Figure 6.

Taste Although the polyhydric alcohols are a relatively homogeneous family of compounds, their taste characteristics can vary from the decided bitterness of propylene glycol to the sweetness of sugar. Isomers in any one of the higher classifications can show tremendous differences in sweetness, although their overall molecular weight and many other characteristics are similar. However, none of these polyhydric alcohols should be classed as synthetic sweeteners. They range in sweetness from half as sweet to essentially three-quarters as sweet as sugars. The results of a recent study of relative sweetness of polyols and sugars are presented in Table 3¹⁶¹ with a comparison of some earlier published data. This comparative property has been the subject of many studies.^{32, 35, 52, 57, 69, 135, 153, 160}

Reasons for Using Polyhydric Alcohols in Food

Polyhydric alcohols are added to manufactured foods either to promote the retention of the original quality of the food on aging and shipment to

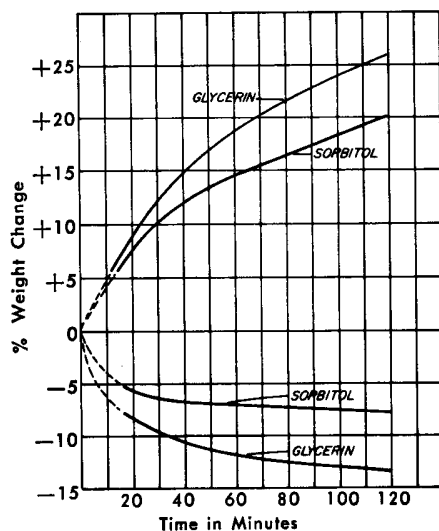


Fig. 5. Comparative dynamic hygroscopicities of polyols.*

*Source: *Atlas Sorbitol and Related Polyols*, CD-60. Copyright 1951, Atlas Chemical Industries, Inc.—now ICI America, Inc. Revised June 1953.

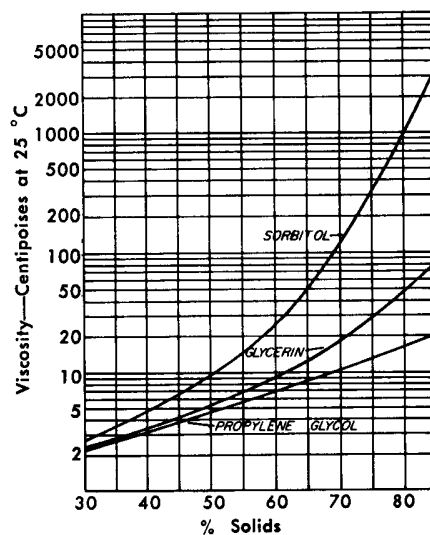


Fig. 6. Comparative viscosities of polyol solutions.*

TABLE 3
Relative Sweetness of Polyols and Sugars (Sucrose = 1)

<i>Polyol or Sugar</i>	<i>Relative Sweetness</i>
Fructose or Levulose	1.4-1.7
Invert Sugar	1.0-1.3
Sucrose	1
Dextrose, anhydrous	0.7-0.8
Xylitol	} 0.7
Iditol	
Maltitol	
Dextrose, monohydrate	0.6-0.7
Galactose	} 0.6
Corn Syrup—enzyme converted	
Glucose Hydrate	} 0.5-0.6
Sorbitol	
Mannitol	
Dulcitol	} 0.5
Inositol	
Erythritol	} 0.4-0.5
Lactitol	
Xylose	0.4
Corn Syrup, unmixed	} 0.3
Maltose	
Raffinose	0.2
Lactose	0.1-0.2
Erythritan	0

the consumer, or to gain a texture or product quality that was not present in the original formula. These qualities are achieved through physical or chemical effects in which the polyols function variously, as follows:

1. Viscosity or Bodying Agents
2. Crystallization Modification
3. Taste or Sweetness
4. Hygroscopicity or Humectancy
5. Solvency
6. Rehydration Aids
7. Sequestering
8. Antioxidant
9. Microbiological Preservation
10. Softening
11. Bulking Agents
12. Dietary Foods

Viscosity or Bodying Agents While the viscosity effect of a dilute polyol is minimal when compared with viscous liquids, it is apparently an effect that the tongue and other sensory receptors of the mouth are able to discern. Relatively small proportions of polyols added to beverages convey an improvement in mouthfeel that is described as bodying action. Similar effects are obtained with thickening agents, although frequently their overall flavor characteristics are not as desirable as those of polyols.

Polyols may be employed in some foods to increase their viscosity and in others to effect a reduction. Sorbitol is effective in increasing viscosity because of the inherent high viscosity of its aqueous solution. Propylene glycol represents the other end of the viscosity scale. Often the best control of viscosity can be achieved by a blend of glycerine, sorbitol, and sugars.¹⁶²

Crystallization Modification (related to water solubility) Many foodstuffs are dependent on a semi-equilibrium mixture of sugar crystals and sugar syrup for their texture characteristics, especially in the field of confectionery. These products include the typical creams, fondants, and fudge. Because the crystallization continues in storage, this type of product exhibits a limited shelf-life with reference to texture. It has long been standard practice to add invert sugar as a "doctor" to maintain the desired consistency. It has been found that the addition of glycerine^{67,132} and sorbitol,^{3,5,13,14,37,47-49,70,88,140} when properly employed, can increase the shelf-life by further complexing the crystalline nature of the confection, thus reducing its tendency to harden. DuRoss has studied the development of sugar crystals with and without the addition of sorbitol and has shown a beneficial difference.⁴⁷⁻⁴⁹ This reduction in crystallizing tendencies is also of value in the production of marshmallow and nougat where the crystallization inhibitory action provides advantages in processing.^{46,47,61,167} Polyhydric alcohols are included in military specifications for shelf-life improvement.¹⁷⁴

Taste or Sweetness Taste is an unusually complex property, comprising flavor, texture, temperature, mouthfeel, and many other factors. The actual taste of polyols is generally of little consequence when they constitute a minor additive. When a polyol is a major component, such as in "sugar-free" candies

(see p. 448, Special Dietary Foods), it usually is the major source of sweetness. Sorbitol and mannitol are especially good in this application.

On the other hand, even in minor amounts polyols may exert a decided effect on taste. Polyols have also been used to modify the sweetness of a product rather than to create sweetness. Sorbitol has been reported to cause a taste improvement when used with saccharin^{157,159} by inhibiting the strong bitter characteristic that is correlated with saccharin.^{76,157} In wine a small amount of sorbitol exhibits a distinct smoothing and bodying action, probably due to a combination of viscosity and sequestrant (or complexing) action.¹⁸

Hygroscopicity or Humectancy Humectancy, hygroscopicity, or moisture-holding power of a polyol added to a confection has been reported to be of importance in maintaining freshness.⁶⁷ It is believed that the effect of crystal modification discussed in the previous section is of far greater importance. This belief is based on the premise that the polyols that are employed cannot sufficiently influence the moisture-holding power of the confection to create the indicated effect. The loss of moisture has been shown not to be a primary factor in bread or cake staling.⁷⁸ Usually, polyols are added at considerably less than 10% of the weight of the confection; if they were twice as effective at holding moisture, they would tend to raise the moisture-holding power by less than 5%. Humectancy is important in the processing of marshmallows,^{46,61,167} where the rate of moisture loss to the casting starch over a specific time interval is reduced.

In a few instances the reverse of hygroscopicity is desired, as in the dusting of chewing gum. In this instance the low hygroscopicity of crystalline mannitol is a distinct advantage and is extensively used, blended with starch. A further advantage is the cool, sweet taste also exhibited by mannitol.¹⁷¹

Solvency Solvent action of polyols increases rapidly with decreasing molecular weight; thus, propylene glycol is the most potent solvent of the food-grade polyols. Glycerine is the next best solvent, but it is already high enough in molecular weight to be used only rarely as a solvent.^{55,82,97,99-102,143} Sorbitol and mannitol have been used in various ways: (1) as flavor carriers or flavor-encapsulating agents,^{42,65,133,147} (2) as flavor enhancers in a wide variety of products, such as coffee concentrates,^{53,114} meat-curing compositions,^{72,73,86} flavor additives for nuts,⁹⁻¹¹ and pure juice concentrates;^{45,149} and (3) in a number of flavor-enhancing compositions.^{42,141,166,169}

Rehydration Aids The dehydration of foods is of value in preservation and reduction in weight for shipping. Unfortunately, in many instances food dehydration causes difficulty in rehydration, and the reconstituted food is significantly different from the original foodstuff. Many years ago the use of a hexitol to improve the rehydration and terminal characteristics of vegetables was described.²⁸ More recently the armed-services laboratories have determined that the inclusion of a small amount of a polyol blend during dehydration will allow a marked improvement in quality of rehydration characteristics.²⁹ It is probable that the polyol avoids the total collapse of the cellular structure during dehydration and keeps it in a better form for acceptance of water at the time of rehydration.

Sequestering The hexitols have been shown to have a mild sequestering action, although it is not comparable to EDTA.* This sequestering behavior shows up as a reduction in wine precipitate.¹⁸ Sorbitol has also been used to advantage in fruit beverages.⁵¹

* EDTA—Ethylene diaminetetraacetic acid.

Antioxidant The objectionable taste called rancidity may occur as a result of one or both of two chemical reactions. The first is oxidation of double bonds, catalyzed by heavy metals; the second is hydrolytic rancidity.

Hexitols exert a mild sequestering action, as noted in the previous discussion of sequestering; in a few instances, particularly with natural oils present such as butter, a mild resistance to rancidity may be observed.

Polyols may also aid in hydrolytic rancidity, glycerine having been reported to retard free fatty-acid formation and thus reduce the rancidity tendency.¹³⁰

Microbiological Preservation Polyols as well as sugars act as preservatives at high concentrations based generally on osmotic-pressure effects. These concentration levels are usually at greater than 75 weight per cent to be effective. An exception to this is the effectiveness of propylene glycol as a preservative. Often propylene glycol is effective at a level as low as 10 per cent. In many instances combinations of propylene glycol and higher molecular weight polyols are employed.¹⁵

Softening The softening effect of polyols, also referred to as plasticizing, is primarily related to their moisture-holding power, or humectancy. True softening, or plasticizing, is required to a lesser extent in foods than in other products. Softening is closely allied with hygroscopicity and the ability of the polyol to hold moisture. However, at low concentrations of polyols in aqueous systems, the moisture-holding power of the combination is usually less than the calculated combined holding power of the polyols and the substrate. This is probably best explained by the hypothesis that polyols satisfy some of the hydrogen-bonding capacity of the vehicle, just as water does at higher moisture levels. At low moisture content a good softener or plasticizer will still exhibit a softening effect. In considering a polyol for this use, a general rule to follow is that the lower the molecular weight, the better the polyol will plasticize or soften.

Bulking Agents If artificial sweeteners are used instead of sugar, one of the immediate problems that is encountered is the reduction in solids content, or the change in ratio of solids of sweetener to other ingredients. For example, only a few milligrams of artificial sweetener are equivalent to one ounce of sugar. It is frequently possible to formulate powdered beverage concentrates without a bulking agent, because the beverage concentrates contain acidulants that can act as carriers for the flavor and artificial sweetener. In foods such as ice cream, cakes, cookies, and confections, the problem is pronounced. Elimination of the sugar gives a totally unbalanced formula that does not behave properly and results in an unpalatable end product. Polyols such as sorbitol and mannitol are the most commonly used bulking agents.

Dietary Foods Polyols are used in dietary foods as replacements for sugars. The metabolism of hexitols in comparison with sugars has been studied, although not extensively.^{54,122,145} Studies have shown that sorbitol is less readily attacked by *Lactobacillus* than sucrose—thus, possibly reducing potential tooth decay.^{33,59,60} At times processors have labeled their products “sugar-free” when using the hexitols in place of sugar. This may have some valid basis on the above, but often the inference leads the consumer to believe the product contains fewer or no calories. This is not true, since basically the hexitols have the same caloric value as sugar—and this is true of the polyols in general. Certain polyols (mannitol and dulcitol) actually afford fewer

absorbed calories because of the lack of solubility. The major uses in dietetic foods have been in confectionery products.^{4,93,96,98,115,125}

Selection Methods

There is no easily followed set of instructions or method in the selection of polyols for food applications. Property improvements that are desired should be considered and compared with the reasons for use presented above. Based on the desired functionality indicated, polyols should be evaluated at probably what initially would appear to be higher than desirable levels. This type of evaluation will give an indication as to whether or not the inclusion of a polyol will have any effect on the formula. Should a desired effect be observed, retrial at lower levels will allow a choice of concentration that should be suitable.

A brief summarization of behavior characteristics and application data has been assembled in Table 4 for use as a starting reference to simplify the selection of a polyol to perform a specific task. The formulas presented on pages 443-451 will serve as examples to illustrate these points.

TABLE 4
Guide for Choosing Polyhydric Alcohols

	<i>Propylene Glycol</i>	<i>Glycerine</i>	<i>Sorbitol</i>	<i>Mannitol</i>
Crystallization Modifier		x	x	
Humectant	x	x	x	
(Moisture Resistant Dust)				x
Plasticizer		x		
Bodying Agent			x	
Solvent	x			
Bulking Agent			x	x
Rehydration		x	x	

Equipment

Most of the polyols above the three carbon-chain length are available in either crystalline form or a solution or syrup. The choice of liquid or solid will depend on the economics of handling and the desired moisture content of the final products. Where a low final moisture content is desired, for example, as in some forms of tableted mints, it may be desirable or even necessary to maintain a relatively uniform low humidity in the manufacturing area throughout the year. Seldom is it necessary to go below approximately 40 per cent relative humidity to gain excellent processing characteristics.

Food Uses of Polyhydric Alcohols

Polyols are used in conventional foods for varied reasons, based on the many functionally different effects they exhibit. Applications in conventional foods will be presented according to the type of food or food ingredient in which they are used. Polyols employed in dietary foods are sufficiently different to warrant separate discussion.

Flavor Concentrate

Propylene glycol is the edible polyol of choice to use as a solvent for flavor compounds.^{82,97,102,143} A typical formula follows:

SINGLE FOLD VANILLA FLAVOR CONCENTRATE

Ingredients:		
Vanillin		13.5 mg
Propylene Glycol		q.s. to one gallon

Glycerine is employed to some extent as a flavor vehicle, although it exhibits less solvency than propylene glycol. The polyols replace the formerly used alcohol and provide a more uniform flavor level because of lack of volatility of the carrier. Propylene glycol is also used as a carrier for emulsifiers.⁹⁴

Confections

As mentioned previously, polyols contribute significantly to improving both "as made" quality and shelf life of confections based on sugar.^{47,85,92} When properly blended with sugar, polyols act as "doctors," or crystallization modifiers, and exert beneficial texturizing and stabilizing influence on the mass. Example formulas follow:

FONDANT

Ingredients:		
Sucrose		75%
Corn Syrup (80 % solids) 43 D.E.		15
Sorbitol Syrup (70% Sorbitol)		10

Preparation:

1. Mix all ingredients.
2. Boil to 244°F.
3. Pour onto a water-jacketed fondant mill.
4. Allow to cool quiescently to 100°F, then agitate.
5. Homogenous nucleation begins approximately six to nine minutes after agitation is started.
6. Agitate until a proper fondant consistency is obtained (15-18 minutes).

BAR FUDGE

Ingredients:		
Corn Syrup (42 D.E.)		23.42%
Sweetened Whole Milk		16.60
Sucrose		23.60
Hard Fat (92°F)		3.57
H ₂ O	approx.	3.00
Salt		1.00
Fondant (80-20)		23.50
Flavor		q.s.
Sorbitol Syrup (70% Sorbitol)		5.00

Preparation:

1. Cook corn syrup, water, sweetened condensed milk and sorbitol syrup in a steam jacketed kettle to 244°F.
2. Cool to 201°F. Add fondant, fat, and flavor; mix well.
3. Cast into foil pans.

HIGH COOK CARAMEL

Ingredients:		Ingredients:	
A)	Caramel	B)	Caramel Paste
	Sucrose		Corn Syrup 63 D.E.
	Corn Syrup		Sucrose
	Condensed Milk (Eagle)		Condensed Milk (Eagle)
	Butter		Starch, 60 Gluidity
	Salt		Vegetable Oil (70° MP)
	Caramel Paste		Butter
	Lecithin		Vanilla
	Invert Sugar		Water
	Sorbitol Syrup (70% Sorbitol)		

Preparation:

A) Caramel

Ingredients are weighed into a Groen kettle and heat is gradually applied to slowly warm the batch to 150°F. Care is exercised to prevent any sticking or scorching of ingredients. When the batch is homogeneous and at a temperature of 150°F, heat is applied and the batch cooked to a temperature of 255°F. The batch is cooled to 245°F and maintained at this temperature while being cast into starch (90°F). After 24 hours the caramels are removed from starch, dusted and enrobed with a dark sweet chocolate. The samples are then boxed.

In a high cook caramel, the primary function of sorbitol is to improve the tenderness of the caramel without reducing its machinability, i.e., flattening out when removed from starch, and to increase the shelf life.

B) Caramel Paste

Weigh up all ingredients in stainless bowl. Warm, using steam, to 150°F (with steam), using agitation to keep starch and condensed milk from sticking and burning.

When paste has been warmed to 150°F and checked to insure it is completely homogeneous, heat is again applied and the paste cooked to 220°F, cooled and held for caramel.

PEPPERMINT PATTIES (Creams)

Ingredients:

1. Bob Syrup	
Sucrose	19.94%
Corn Syrup (65 D.E.)	10.97
Sorbitol (70% sorbitol)	1.00
Water	3.96
Cook to 246°F (Keep container covered to wash sides down)	
Remelt	
Fondant	
(80/20), 242°F cook)	47.86
Add fondant at 175°F	
Mazetta	15.96
Invertase	0.10
Flavor	0.21
2. Mazetta	
Corn Syrup	58.19
Sucrose	29.09
Water	7.27
Egg Albumin	1.82
Water	3.63

Cook to 238°F, whip to a density of 4 lb/gal.

Preparation:

Boil bob syrup to required temperature and cool with agitation to 150°F. Add fondant and disperse well. Re-adjust temperature to 150°F. Add egg cream and disperse well. Cast cream in starch mold at 153°F. Let stand in starch trays for 3 hours. Enrobe with chocolate; package and store. MAKE SURE REMELT IS AT PROPER TEMPERATURE (153°F).

CAST MARSHMALLOWS

Ingredients:	%
Sucrose	42.47
Corn Syrup	25.49
Gelatin	0.89/4.30
Fondant	10.93
Sorbitol Syrup (70% sorbitol)	2.97
H ₂ O	12.94
Color	q.s.
Flavor	q.s.

Preparation:

Heat sucrose, corn syrup, sorbitol syrup, and water to 180°F (just enough heat to dissolve ingredients). Agitate the solution on a Hobart mixer on low speed. Cool the batch to 155°F, so that the fondant is thoroughly incorporated. Agitate the solution again at high speed; slowly add the gelatin-water mixture during agitation. Whip the total batch to a density of 4 lb/gal. Add flavoring and color. Cast the marshmallow into starch at a temperature of 115–120°F.

Chewing Gum

Glycerine has been reported as a lubricant additive to chewing gum as an aid in processing.^{87,111,134} Sorbitol and mannitol are used in the preparation of noncariogenic chewing gums^{20,30} (discussed in greater detail under Dietary Foods, p. 448).

Dried Roasted Nuts

A process has been developed for the production of a low fat-containing dry-roasted nutmeat confection. The nuts are roasted in a molten mixture of sorbitol and mannitol.^{9,10}

Meat Products

Sorbitol has been described as an additive to meat emulsions (sausages) and bacon to improve color and flavor retention.⁸⁶ Sorbitol has also been described as an additive for meat-curing compounds^{72,86} and as an additive to meat casings.^{6,163}

Pet Foods

Polyols are added to the now popular moist pet foods to plasticize the mass, enabling it to retain the desired texture over a long period of time. A typical formulation follows:³¹

SOFT MOIST PET FOOD

Ingredients:	Parts by Weight
Tripe	18.0
Fish (whole cod and smelt)	6.0
Beef cheek trimmings	6.0
Soy flakes	31.5
Dry corn syrup solids (42 D.E.)	21.4
Soy hulls	3.0
Dry non-fat milk solids	2.5
Bone meal	2.1
Dicalcium phosphate	1.4
Propylene glycol	2.0
Sorbitol	2.0
Tallow	2.0
Mono- and diglycerides	1.0
Sodium chloride	0.6
Potassium sorbate	0.3
Minerals, vitamins, color, etc.	0.3

Icings and Toppings

Polyols are of value in the production of icings and toppings as crystallization retarders.^{44,168} A suitable formula illustrating this use follows:

CAKE ICINGS (Low-fat)

Ingredients:	Per cent
Sugar	63.1
Shortening (all-purpose)	17.4
Water	12.5
Corn syrup solids (42 D.E.)	5.0
Crystalline sorbitol solution 70%	2.0

NOTE: The corn syrup/crystalline sorbitol solution 70% ratio may be changed as follows:

Corn syrup solids	4-8%
Crystalline sorbitol solution 70%	2-4%

In cake icings and similar systems where sugar crystals exist in a saturated aqueous media, sorbitol at 1-3 per cent, based on sucrose weight, aids in retarding crystal growth and the development of brittleness and coarse texture associated with large crystals.

Coconut

Propylene glycol, glycerine, and sorbitol are used as plasticizing agents for moist, shredded coconut. While this softening action can be gained from a suitable blend of sugars, the polyols have a decided advantage of contributing color stability. Sugars on coconut undergo a gradual darkening or browning that does not occur with the polyols. The inherent mild sweetness of sorbitol provides a most acceptable end product.^{89,164}

Miscellaneous Food Products

The use of polyols in cereals and edible containers, such as ice-cream cones,¹¹⁸ is claimed to improve firmness and friability.¹⁹ Glycerine has been reported as exerting an anti-staling action on bread.²⁶

A number of fruit and vegetable coatings have been developed containing polyhydric alcohols^{129,155,158} and glycerine has even been reported as an ingredient in an apple spray that favorably influences the color of the apple.¹⁴⁴ A closely related subject is the edible films for wrapping and packaging foods in which glycerine is described as a plasticizer.¹⁷²

The objectionable caking of brown sugar on storage is reported to be relieved by the addition of glycerine⁶³ and sorbitol.⁴⁰

Dairy products are improved by the addition of propylene glycol, sorbitol, or mannitol to milk powder.^{91,127} The keeping qualities of cheese, butter, and dried and condensed milk are reported to be improved by the addition of glycerine.⁸⁴

A pressurized salad dressing containing sorbitol has been described,² as has also a low-moisture pastry dough.⁹⁵ The addition of glycerine and sorbitol to egg whites for preservation and improved whipping action has been reported.^{90,137,138}

Glycerine alone and in combination with sorbitol has been found to be of value in the freeze-drying of foods.¹³¹ Hexitols have also been described as

being of value in the preparation of dehydrated foods.^{28,34,71,117} A possible similar action of glycerine inhibiting the protein denaturation in frozen fish has been described,¹¹⁰ and glycerine has been mentioned as an aid in producing frozen fruits and vegetables and edible emulsions.^{16,77} At the other extreme glycerine has been proposed as a means of elevating the boiling point of a heat-exchange liquid used for the sterilization of canned goods.²³ Glycerine and sorbitol are claimed to aid in the production of dry and powdered yeast.¹

Beverages

Fruit Juices Glycerine, sorbitol, xylitol, and inositol are reported as exhibiting improved flavor and keeping qualities to fruit and vegetable juices.^{36,121,128,154} Sorbitol also has been used in the production of a powdered orange juice.^{119,148}

Low-Calorie Beverages In recent years the general population has become more and more concerned about daily caloric consumption. The food industry has attempted to satisfy this need by marketing low-calorie beverages in both carbonated and fruit-drink forms. In these systems the sugar is reduced or omitted, and synthetic sweeteners are substituted. However, the sugar omission from the beverage reduces both sweetness and "body", presenting a different taste sensation. Synthetically sweetened beverages lack this body. Also, at the levels required in the beverage, the synthetic sweeteners have a slightly different aftertaste, sometimes termed "metallic".^{157,159} It has been demonstrated that a relatively small amount of sorbitol (on the order of 1.0-3.0 per cent) will provide a sense of body as well as an improvement in residual taste.

A few general principles should be considered in formulating a dietetic beverage:

1. Select an acid or acid blend such as citric-phosphoric to obtain proper pH or taste.
2. Add bodying agents to acquire proper viscosity and mouthfeel.
3. Select proper carbonation level.
4. Formulate the flavor to mask the "sugar-free" shortcomings.

TYPICAL LOW-CALORIE CARBONATED BEVERAGE¹⁷⁵

Ingredients:

Lemon Concentrate	
Terpeneless Lemon Oil	1 fl. oz.
Potable Alcohol	42 fl. oz.
Citric Acid Crystals	1.5 oz.
Artificial Sweetener	q.s.
Water, sufficient to make	1 gallon

Procedure:

Step I

1. Mix oil and alcohol and 42 fluid ounces of water.
2. Add sweeteners and citric acid.
3. Add enough water to make one gallon and agitate to dissolve all solids.

Step II

Dilute the above concentrated flavor to use as a bottling concentrate. Take 375cc of flavor concentrates and add water to make one gallon. The "throw" of this solution is one fluid ounce per twelve-ounce bottle.

Step III

Carbonation is achieved by filling each twelve-ounce bottle with carbonated water 3-3½ volumes of gas. Refrigerate at a constant temperature to decrease frothing during bottling and minimize the loss of gas.

NOTE: Bodying agents such as sodium carboxymethylcellulose (0.02-0.05%), sorbitol (1-2%), pectin, and propylene glycol alginate are optional ingredients that can be added to improve viscosity and mouthfeel. They may be incorporated at any step of the formulation.

Wines It has been reported that a low concentration (1-2 per cent) of sorbitol added to a table wine improves taste and also reduces sedimentation tendencies.¹⁸ This is presumably a combination of bodying action as well as sequestration.

Special Dietary Foods

Special dietary foods have been designed to help reduce the consumption level of protein, fat, carbohydrate, and calories.⁵⁶ When conventional foods are modified for dietary purposes, such properties as taste, texture, and body are sometimes adversely affected.

Polyhydric alcohols have been and continue to be investigated as suitable materials that can be added to dietary foods to improve consumer appeal. Over the last several years, such properties as caloric value, sweetness equivalent, noncariogenic potential and the fermentability of polyhydric alcohols have been investigated. Sorbitol, glycerine, and propylene glycol have essentially the same nutritive value as sugars, namely four calories per gram. At least one worker has reported the nutritive value of mannitol at two calories per gram or half that of glucose.⁷ The sweetness values have been determined, and, while propylene glycol and glycerine are described as bitter or bittersweet, sorbitol has been reported to be about 60 per cent as sweet as sugar.¹³⁵ The comparative sweetness of a number of polyhydric alcohols and sugars has been determined in comparison; these data are presented in Table 3.

SUGARLESS CHOCOLATE

Sugar is replaced with sorbitol and/or mannitol in the manufacture of a sugarless chocolate.¹⁰³

Ingredients:	Range, %
Nonfat Dry-Milk Solids	2-6
Vegetable Fat (102°F)	30-35
Sorbitol	30-40
Cocoa Powder (12% fat)	12-20
Mannitol	3-10
Lecithin	0.25-0.30
Flavor	q.s.

Preparation:

1. Mix sorbitol and mannitol with a portion of the vegetable fat. Heat to 100-110°F. *Caution:* Do not exceed 115°F.
2. Add cocoa powder and nonfat dry-milk solids to the fat mixture.
3. Refine to a maximum particle size of 50 microns.
4. Add remainder of the fat.
5. Add the flavor and sufficient lecithin to bring to desired viscosity.

The noncariogenic properties of sorbitol and glycerine have been investigated by *in vitro* methods. There is some indication that, based on the fact that sorbitol is fermented more slowly than sugars, it may be less cariogenic when ingested orally because it is washed off the teeth or diluted with saliva before the critical pH is reached.^{41, 68, 139, 142}

SUGARLESS CHEWING GUM

Ingredients:	Range, %
Gum Base	25-26.0
SORBO (70% Sorbitol Solution)	16-17.0
Crystalline Sorbitol	36-40.0
Mannitol	14-17.0
Glycerine	0.5
Flavor	1.5
Artificial Sweetener	q.s.

Preparation:

1. Feed gum base into horizontal sigma blade mixer and heat with steam for five minutes at 60°C. Avoid overheating gum base.
2. When base has softened, blend in SORBO solution and glycerine.
3. Turn on mixer and steam.
4. Begin adding crystalline sorbitol and mannitol. Add slowly ($\frac{1}{8}$ at a time), incorporating well after each addition.
5. Mix all ingredients until uniform.
6. Add flavors.
7. Remove gum from mixer after flavors have been added.
8. Roll on proper gum roller.
9. Roll gum to 0.075 inch thickness.
10. Dust with mannitol and store at 75°F, 45% R. H. for 24 hours.
11. Wrap as desired.

SUGARLESS HARD CANDY⁵⁰

Ingredients:	
Crystalline Sorbitol	95.0%
Crystalline Mannitol	5.0
Flavor	q.s.
Color	q.s.
Water	q.s.

Preparation:

Dissolve in water using one part water for every two parts dry material, i.e., 300 grams dry powder in 150 grams H₂O. Warm on steam bath until dry powders are in solution; then place on heat and heat to 385°F. Cool to 250°F; stir in color, flavor, and cool to 200°F. Set time will be 10-14 hours.

SUGARLESS MINTS

Ingredients:	
Crystalline Sorbitol	96-98.0%
Magnesium Stearate	q.s.
Flavor	q.s.

Preparation:

1. Granulate sorbitol and screen to particle size that will have good flow properties.
2. Dry blend in lubricant and compress on any suitable tablet machine to desired size and hardness.

DIETETIC ICE CREAM

Ingredients:	
Protein	6.0%
Butterfat	10.0
Stabilizer (pure)	0.4
Carbohydrate (milk sugar)	4.7
Sorbitol Crystalline	10.5
Flavors	q.s.
Artificial Sweetener	q.s.

Procedure:

Normal procedures and equipment for preparing ice cream are satisfactory for the preparation of this product.

SUGARLESS SPONGE CAKE

Ingredient	Grams	Per cent
Flour	150	18.73
Sorbitol	255	31.84
Egg Whites	90	11.23
Egg Yolks	60	7.49
Baking Powder	8	1.0
Vanilla	10 cc	1.25
Margarine	45	5.62
Skim Milk, boiling hot	183	22.84
	801	100.0

Procedure:

1. Sift flour, baking powder, and one-half of the sorbitol.
2. Whip egg whites stiff with one-half of remaining sorbitol.
3. Beat egg yolks with remainder of sorbitol.
4. Melt margarine in hot skim milk and add to No. 3.
5. Add No. 1 to Nos. 3 and 4 and mix well.
6. Fold in egg whites (No. 2).
7. Bake at 375°F for about 22 minutes.

SUGARLESS COOKIE FORMULA

Ingredient	Grams	Per cent
Eggs	100	20.2
Vegetable Oil	55	11.1
Vanilla	10 cc	2.0
Sorbitol	72	14.6
Avicel (Crystalline Cellulose)	19	3.9
Flour (all-purpose)	228	46.2
Baking Powder	8	1.6
Salt	2	0.4
	494	100.0

Procedure:

1. Beat eggs. Stir in oil and vanilla.
2. Sift together sorbitol and Avicel; add to above until mixture thickens.
3. Sift together flour, baking powder, and salt; stir into above mixture.
4. Drop onto ungreased baking sheet.
5. Bake 8-10 minutes or until a light-brown color in 400°F oven.

SUGAR-FREE GELATIN DESSERT

Ingredients (dry blend):	Per cent
Gelatin (225 bloom)	56.2
Sorbitol	19.0 (approx.)
Fumaric Acid	10.6
Artificial Sweetener	q.s.
Sodium Citrate	3.5
Salt	3.0
Flavor and Color, as desired	

Directions for use:

Bring 2 cups (16 oz.) of water to a boil and add package contents (3 oz.). Stir briskly to dissolve completely. Continue stirring for one minute. Gel will be firm in 1 to 1½ hours. Chill in refrigerator.

SUGAR-FREE INSTANT PUDDING^{22,43}

Ingredients (dry blend):	Per cent
Nonfat Dry Milk	60.0
Pregelatinized Starch	18.0
Sorbitol	13.0
Disodium Orthophosphate	3.6
Tetrasodium Pyrophosphate	3.6
Artificial Sweetener	q.s.
Carrageenan	0.7
Flavor and Color, as desired	

Directions for use:

Add the contents of one package (4 oz.) to 2 cups of cold water or milk. Mix well and chill until set.

A variety of other dietetic foods, such as gum drops, fruit packs, and others, are also commercially prepared. In general synthetic sweeteners are substituted for sugar, and sufficient polyol is added to provide the necessary bulking or bodying action.

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