A New World of Functional Sweeteners

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Sweetness is one of the most important characteristics of food. Consumers crave sweet products — something that is established in early childhood. Sweetness enhances other flavor notes, especially fruits, and disguises the bitterness of nutritional supplements. Fruits, sugar and honey have been valued for their sweetness throughout history, and were central to trade around the world. Consider that U.S. per-capita consumption of added sugars is now about 150 lbs., up 30% over the last two decades. Obesity has contributed to a rise in Type II diabetes, which can lead to many health complications in an aging population. We want good-quality sweetness, but the sweetness should contribute fewer calories, less blood-glucose response, less insulin response, good economics and no aftertaste. Nutritive sweeteners are blended for a number of reasons. Honey, molasses and fruit concentrates are often blended with sucrose because of their unique flavor characteristics. Different sweeteners have different temporal characteristics — sweetness intensity over time in the mouth. This also applies to lower-calorie, non-sugar alternatives, so a systems approach is essential. Polyols, sugars and high-potency sweeteners peak at different times and linger to different degrees, characteristics that blending can modify. The use of COMBINATION products is key to obtaining an end product with "just enough" sugars for ideal taste appeal and satiety.

Applying proprietary integration technology designed to maximize performance and versatility of polyols in formulation, the technical team at Corn Products Specialty Ingredients can create customized "performance systems" by combining polyols with various other sweeteners and/or ingredients. The uniform dispersion of these products in both liquid and crystalline form provides exceptional ease of use in a variety of applications. In addition to the functional benefits of each individual element, performance systems deliver further synergistic benefits that can not be achieved using any one sweetener alone. A brief review of the most prominent sweeteners and their characteristics will help to explain the benefits of performance systems.

Group I: Nutritive sweeteners

Nutritive sweeteners are derived from many sources, and include sugar, honey, molasses, fructose, lactose, maltose, maltodextrins and polyols (maltitol, maltitol syrups, polyglycitols, xylitol, sorbitol, isomalt, lactitol and erythritol). Nutritive sweeteners provide calories. With the exception of the polyols, sugars (identified as mono- and disaccharides) are recognized as contributing 4.0 kcal/gram. "Sugar," as we know it, is a highly refined sucrose obtained from sugar cane or sugar beets, a disaccharide consisting of monosaccharide molecules of fructose and dextrose. Sucrose has become the gold-standard sweetener because of its versatility, availability, relatively low cost and range of forms. The most easily recognizable sugar comes crystallized in a range of sizes, but manufacturers can also obtain liquid sugar (sucrose and water), powdered sugar (ground crystals with corn starch), brown sugar (sucrose and molasses) and a variety of specialty products. Invert sugar, a 1:1 liquid mixture of glucose and fructose, results from the inversion of sucrose, and is sweeter than granulated sugar. Honey, available in its pure form or in dried mixtures, is used for its high sweetness and flavor attributes. Honey is a unique sweetener containing about 38.5% fructose, 31.0% glucose, 17.1% water, and smaller amounts of maltose sucrose, other saccharides and minerals, vitamins, and enzymes. As a result, honey provides color, antimicrobial properties, antioxidants, flavoring, texture and gastrointestinal benefits (enhances bifidobacterial growth), and it conveys a natural image. Honey also triggers a much lower blood-sugar and insulinemic response than glucose or sucrose. Brown-rice syrup and barley malt have been used in a number of institutional products, although their carbohydrate distributions would indicate no major differences from typical corn syrups in terms of glycemic effects. Both brown-rice syrup and barley malt, although low in glucose content, contain 40+% maltose, which has a very high glycemic index (GI) relative to glucose. Fruit products, whether dry, concentrated, purée or juice, provide a number of additional benefits beyond sweetness. These include color, flavor, antimicrobials, humectancy and binding characteristics. As an example, cherry-juice concentrate is produced by evaporating cherry juice to 68° Brix, where it contains about 34% glucose and 20% fructose, as well as natural antioxidants

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and anthyocyanins. Various types of corn syrups, maltodextrins, and high-fructose corn syrup are derived from corn starch. Acid and/or enzymes convert starch to a low-dextrose solution. This then undergoes further enzymatic treatment to continue the conversion — refiners control the end product by stopping the conversion at key points to produce the right mixture of sugars, such as dextrose and maltose. Corn syrup is classified on the basis of dextrose equivalent, or DE. The corn syrups most commonly used are 42 DE and 63 DE. High fructose corn syrups (HFCS) are classified according to the fructose content, for example 42%, 55%, 90%. This produces a range of sweetness (Fructose is approximately 25% sweeter than sucrose; dextrose has about 75% of the sweetness of sucrose.), as well as other functional characteristics. On a solids basis, 42% HFCS is considered as sweet as sucrose (42% fructose, 58% dextrose on a solids basis).

Group II: Polyols

Polyols, or sugar alcohols, are a separate group of nutritive sweeteners, derived by hydrogenating simple sugars or corn syrups. Polyols are carbohydrates, but are not regarded as "sugars" on the ingredient legend. Polyols are absorbed more slowly than sugars, resulting in lowered glycemic and insulinemic responses, as well as a lowered caloric value. When formulating a custom sweetener, it is important to note the physical/chemical characteristics of the sweetener beyond sweetness and caloric content. Not all sweetening systems are liquid, so attention must be given to solubility, melting point, molecular weight and heat of solution. Although certain polyols do not have a high sweetness level compared to sucrose, all of these products have characteristics that are more valued in certain applications. Of the polyols, maltitol has the closest characteristics to sucrose in most applications. It has 90% of the sweetness of sucrose, and is available in liquid or crystalline form. We at Corn Products Specialty Ingredients have developed a range of maltitol syrups and polyglycitols for use in any application — the range of products is roughly equivalent to a maltodextrin/corn syrup/high-fructose corn syrup line of products. These maltitol syrups combine the high sweetness of maltitol with the stability of our higher-molecular-weight products, increasing their utility in hard candy, caramels, soft candies, nutritional bars and baked goods. Sweetness levels can be adjusted through maltitol levels and/or addition of high-potency sweeteners." In sugar-free applications, polyols are commonly used to supply the "bulk," or viscosity, required in the product, and additional sweetness is adjusted using a high-potency sweetener. Through similar functional assessments, our technical group can apply the best functional qualities of all of our products (as well as ingredients not in our current line) to customize for specific requirements. The results of some of this work has resulted in product lines such as ERYSTA™ Performance Systems and our GLYSTAR® Performance Systems, which feature functional enhancement of erythritol and sorbitol/glycerin systems, respectively.

The Basics

Where and why are polyols typically used? How do they differ and what is their status? A brief synopsis of each polyol follows:

- Mannitol, a monomer, is the oldest commercially produced polyol, limited in use by its high laxation potential (20 grams/day). Because of its low solubility and nonhygroscopicity, it is used extensively as a tablet excipient and as a dusting agent. Its high melting point (165° to 169°C) led to its use in chocolate coatings for ice cream and confections and as a plastizer and dusting agent in chewing gums. Mannitol is a food additive under Title 21 of the Code of Federal Regulations (CFR), part 180.25.
- Sorbitol, a monomer, is the least-expensive crystalline polyol, and is used extensively in the liquid form in oral care. It is used as a sweetener, plasticizer and as a humectant. Sorbitol has 0.6 times the sweetness of sucrose, and is extremely soluble in water. Sorbitol is GRAS under 21 CFR, pt. 184.1835.
- Maltitol, a dimer, is very similar to sucrose in many of its characteristics, although it has about half the calories (but 90% of the sweetness of sucrose). Crystalline maltitol has been extensively used in chocolate compound coatings for nutritional bars and baked products, in baked goods such as cookies, cakes and crèmes, and in confectionery coatings.
- Xylitol, a monomer pentose, is used primarily for its cariostatic properties and its cooling effect, and it also is as sweet as sucrose. For these reasons, it has been used primarily in oral-care products, chewing gum and mints. Xylitol is approved as a direct food additive for special dietary purposes under 21 CFR, pt. 173.395.

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- Erythritol, a monomer, is lowest in molecular weight, highest in cooling effect, and is relatively insoluble, but is virtually zero calories and is very well tolerated due to its unique metabolism. Erythritol is considered GRAS in the U.S.
- Polyglycitols encompass hydrogenated glucose syrups, sorbitol syrups and maltitol syrups, but for ingredient-legend purposes, polyglycitols are polyol syrups containing less than 50% maltitol; maltitol syrups are polyol syrups containing greater than 50% maltitol. These hydrolysates, like corn syrups, are mixtures of polymers of varying molecular weight. Sweetness is dependent on the maltitol level in the syrup, and may range from 30 to about 80 times the sweetness of sucrose. Polyglycitols and maltitol syrups are self-determined GRAS in the United States.
- Isomalt, a dimer mixture, is lower in solubility, has a relatively high melt point, and 0.4 to 0.6 times the sweetness of sucrose. It has been used extensively for its ability to crystallize and inhibit cold flow in hard candies. Isomalt is self-determined GRAS.
- Lactitol, a dimer derived from lactose, is about 0.4 times as sweet as sucrose, is relatively nonhygroscopic and is low in solubility. Lactitol has been used in panned candies, chocolate compound coatings and baked products. Lactitol is self-determined GRAS.

Group III: Optimizing Sweetness

Non-nutritive sweeteners provide the sweetening power behind a blend. The FDA has approved five low-calorie sweeteners: neotame, aspartame, acesulfame potassium, saccharin and sucralose. Saccharin was the first low-calorie sweetener used, and has been in use for more than a century. The FDA proposed a ban on saccharin in 1977, and Congress placed a moratorium on the ban. In 1991, the FDA formally withdrew its proposal, and in 2000, Congress passed a bill to remove the warning label required on saccharin-sweetened products since 1977. Saccharin is an extremely stable, very economical sweetener, approximately 300 times the sweetness of sucrose, and is probably most known for its use as a tabletop sweetener. Acesulfame potassium (acesulfame-k) is approved for a wide number of uses in approximately 90 countries. The marketing of acesulfame-K incorporates the multiple-sweetener approach, which has been promoted by the Calorie Control Council for a number of years. By itself, acesulfame-K has a bitter, metallic aftertaste, but it is synergistic with a number of other sweeteners, including aspartame. Acesulfame-K is relatively heat-stable, and has a sweetness level approximately 180 times sucrose. Aspartame has an extensive history of use in the United States, primarily in beverages. Aspartame is a dipeptide (methyl ester of aspartic acid and phenylalanine) approximately 180 to 220 times the sweetness of sucrose. It was first approved in 1981, and was approved in 1996 as a general-purpose sweetener. Aspartame does decompose under combinations of high temperature, high pH and high moisture, but its relatively long history of use, temporal profile and economics have made it the most-used high-potency sweetener in the United States (saccharin and cyclamates are used very heavily in other parts of the world). It has generally benefited from blending with acesulfame-K or saccharin for stability. Neotame, approved by FDA in July 2002, is a heat-stable sweetener produced by the hydrogenation of aspartame and 3,3-dimethylbutyraldehyde. Neotame is 30 to 60 times sweeter than its aspartame precursor and 7,000 to 13,000 times sweeter than sucrose. Sucralose, approved by FDA in 1998, is derived from sucrose and has about 600 times the sweetness of sucrose. Sucralose is extremely heat-stable, and has found wide approval in "natural" markets. Sucralose was marketed very well from the outset, with information and samples shared directly with the natural and diabetes management communities. A number of other sweeteners are approved for use at low levels as sweetness enhancers or sweetness modifiers. These include the dihydrochalcones (neohesperidine dihydrochalcone has approval through FEMA), thaumatin, glycyrrhizin, stevioside, maltol and ethyl maltol. All of these can be considered as minor components (generally at the ppm level) of a sweetener/flavor system, because they can add a unique modification to the overall result. Dihydrochalcones are 300 to 2,000 times sweeter than sucrose, and by themselves have a licorice aftertaste. Neohesperidine DHC is about 1,500 times sweeter than sucrose. Glycyrrhizin has 50 to 100 times the sweetness of sucrose, and also has a strong licorice note. Thaumatin is a protein that is 2,000 to 2,500 times sweeter than sucrose. It also has a strong licorice aftertaste, but it enhances sweet and savory flavors. It is approved in the EU, and FEMA-GRAS in the United States at a 0.1 to 0.5 ppm level. Stevioside, extracted from the leaves of a South American plant, has 300 times the sweetness of sucrose, and is often

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used as a dietary supplement or to enhance sweetness. Corn Products International has recently announced the introduction of EnLiten™, a high potency sweetener based on a stevia plant with a high concentration of Rebaudioside A (April 22, 2008 CPI Press Release).

Putting it all together

It is the nature of our fast-paced society to find a system that works (whether sweetener, flavor or stabilizer), then use that system for all applications. There are several reasons for this. Project deadlines, stability comfort, purchasing department approval, supplier relationships, economics, production familiarity with the system — all of these play into formulation decisions. But it does make sense that the sweetener mix would affect overall flavor perception. Through use of performance systems, lingering effects can be minimized while stability is increased, resulting in a much more consistent product. It is too simplistic to say, however, that one combination of sweeteners is "ideal" without considering the whole ingredient system in the product. As a bulk sweetener with 90% the sweetness of sucrose, maltitol can carry much of the sweetness in a sugar-free or reduced-sugar product, and its sweetness characteristics can help to mask off-notes in certain high-potency sweeteners. Maltitol has shown strong synergy with cyclamates and acesulfame-K, and additive sweetness with aspartame. Synergy up to 20% to 30% has been shown in a 50:50 mixture of maltitol and sodium cyclamate.

Blending is frequently done to adjust temporal profiles or to mask off-tastes, but it is often the result of economic or functional considerations as well. An example of an economic or functional blend is the use of sucrose and corn syrup in hard-candy formulation. Typically, sucrose and 42 DE corn syrup are blended 50:50, 60:40, or 70:30 sucrose:corn syrup to take advantage of regional economics and to control crystallization of sucrose. Many products on the market today contain a blending of sweeteners. These sweeteners are chosen for specific reasons, whether for sweetness level or for color, flavor, glycemic effects, viscosity, texture, water activity, humectancy, binding properties, crystallizing properties, freeze-point depression, etc. Examples include sugar-free chewing gums or mints (sorbitol, mannitol, maltitol, xylitol, high-potency sweeteners), nutritional bars (polyols, fructose, corn syrups, maltodextrins, rice syrups, fruit concentrates, sucrose, glucose, maltose, high-potency sweeteners) and beverages (sucrose, corn syrups, maltodextrins, high fructose corn syrups, fructose, fruit concentrates). While one sweetener may predominate, many foods are sweetened by multiple products, whether intentional or not. By interacting more closely with Corn Products Specialty Ingredients, manufacturers can more efficiently use these combinations to individualize their products.

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