When it comes to reducing calories in a food or beverage product, choosing any old sweetener to replace sucrose is not an option. Product designers need to carefully select sweetener systems that deliver the functionality of sugar, as well as its flavor and sweetness intensity.
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The Sweet Life

When early humans wanted to appease their sweet tooth and stoke up on calories, they turned to sweet fruits and berries, sugary sap and honey. Sugar, the now-familiar, cane-based sucrose sweetener, was virtually unknown throughout much of the world until several centuries ago. But it gradually spread from Indonesia, through Asia, to the Middle East and finally reached Europe. And even then, it was a scarce luxury item until the crop took hold in the New World and eventually became affordable for all. In the 1700s, per capita consumption of sugar in England was 4 lbs.; in 1900, it was 90 lbs. The United States consumption followed a similar trajectory, though the amount has declined over the last decade to about 77 lbs. (for all added sugars, including cane and beet sucrose, as well as corn sweeteners and other carbohydrate-derived ingredients), according to the latest USDA calculations.

Why do we have such a hunger for sweeteners? Apparently, it’s a natural inclination that starts young. Scientists for Monell Chemical Senses Center, Philadelphia, have said: “Scientific literature suggests that children’s liking for all that is sweet is not solely a product of modern-day technology and advertising, but reflects their basic biology. In fact, heightened preference for sweet-tasting foods and beverages during childhood is universal and evident among infants and children around the world. The liking for sweet tastes during development may have ensured the acceptance of sweet-tasting foods, such as mother’s milk and fruits. Moreover, recent research suggests that liking for sweets may be further promoted by the pain-reducing properties of sugars” (Current Opinion in Clinical Nutrition & Metabolic Care, 2011; 14(4):379–84).

However, that sweet tooth might be creating a huge problem. On a basic level, our calorie balance is out of whack. Those sugar calories were easily burnt off in the 1900s. But in these sedentary days, not so much. Beyond the simple calories in/calories out imbalance that caloric sweeteners contribute to, currently just about all sweeteners are under intense scrutiny. Sources, processing, composition, health effects, “naturalness,” flavor, technical performance, cost ... the list goes on. Add in consumer perception, fueled by poorly communicated or misunderstood science, foodie and diet fads, public-health initiatives, celebrity “health experts,” and any other issue du jour picked up by media or just someone with access to a computer.

The mission to create ingredients and finished products that satisfy our innate craving for sweets while meeting the various requirements of the consumer and manufacturer is more critical than ever. The solutions are varied and depend on the application and goals. New ways to enhance sweetness perception by tricking the senses, finding sweetener blends that optimize sweetness and flavor delivery, taking apart sweetener ingredients and putting them back in more pleasing combinations, or discovering new sweeteners altogether are all likely to provide sweet solutions for product design.
Companies around the globe are making increasing investments in infrastructure, quality control, regulatory compliance, technology and more, which is driving product development and raising the quality bar. Watch this 20-minute installment of the SupplySide Global Experience Documentary film series, Innovation & Investment in China, to explore several suppliers in China, their ingredient production technologies, quality control measures, supply chain controls, intellectual property portfolios and laboratory testing capabilities to see how best-in-class companies are setting the bar for ingredient sourcing from China.

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Watch Now
Optimizing Sweetness

BY DONNA BERRY
CONTRIBUTING EDITOR

It sounds strange to the average consumer, but sweeteners do so much more than sweeten. Some provide mouthfeel and build viscosity, while others contribute color when heated. Still others deliver a cooling effect or desirable fruity notes. Some make negative contributions, such as bitterness or metallic off flavors. All of them impact the flavor of sweet, which is very different than the taste of sweet.

“Sweetness is a sensory experience that unfolds over time and varies in intensity,” says Alyssa Turner, associate product specialist, Ingredion, Inc., Westchester, IL. This experience varies, and often quite significantly among the many sweetening options available to product designers, from caloric sweeteners to natural and artificial high-intensity sweeteners.”

The “decision tree” can be complex when selecting a sweetening system, according to Thom King, president, Stevia Brands Inc., Portland, OR. “The first decision is between nutritive and nonnutritive sweeteners,” he says. “Nutritive sweeteners, like table sugar, provide energy (calories) in the form of carbohydrates. High-intensity sweeteners fall into the nonnutritive category. Their caloric contribution is negligible.

“Each sweetener will have different physical, chemical and sweetening properties, so finished-product attributes and ingredient functionality are important considerations,” adds King. “Sometimes, the choice of a particular ingredient comes down to how well it plays with others. Though inanimate, ingredients are like people in that they can bring out the best or the worst in each other.”

Reducing sugar impacts sweet flavor

“When trying to reduce sugar, especially in beverages, formulators most often use high-intensity sweeteners,” says Paul Kim, technical manager, Americas, Nutrinova, the food ingredients business of Celanese, Irving, TX.
Frank Adao, director of Magnasweet products, Mafco Worldwide Corp., Camden, NJ, adds, “The main problems with using high-intensity sweeteners are the bitter or metallic aftertaste and an initial sweetness that quickly dissipates.” These issues, however, vary with the sweetener. For example, aspartame has a slow sweetness onset and sucralose has a lingering sweet aftertaste.

Further, consumers tend not to taste the individual taste components of a food or beverage, but rather, taste them as a whole. “Like enjoying a complete symphony, rather than listening to an individual instrument,” says Kim. “The problem is that when you remove sucrose from a product, regardless if you have matched the same degree of sweetness intensity, the overall taste of the whole product changes most of the time. So even when one component has been changed or added and breaks the balance (off taste), that harmony of the authentic taste is broken. The goal with sugar reduction is to build back that overall sucrose taste, not just the sucrose sweetness intensity.”

Steve Rosskam, executive vice president, David Michael & Co., Philadelphia, agrees that nothing beats the sweetness profile of sucrose. “So what we have done is create a trademarked line of flavor modulators that fill in the gaps in the sweetness curve of non-sucrose sweeteners so that the sweetener system more closely mimics the sweetness curve of sucrose,” he says. “These noncharacterizing flavors have been formulated to work in conjunction with whatever type of sweetener is being utilized.

When you remove sucrose from a product, regardless if you have matched the same degree of sweetness intensity, the overall taste of the whole product changes most of the time.

“When used with high-intensity sweeteners, they can also mask lingering aftertastes and smooth out the overall sweetness profile, bringing it closer to that of sucrose,” Rosskam continues. “We discovered when our flavor modulators are used in an application containing sucrose, they enhance the perception of flavor that is typically carried by sweetness. Because of this, total added sucrose can be reduced in a formulation, allowing for a reduction in calories without the need for a high-intensity sweetener.”

These flavor modulators are available in liquid, dry, natural, natural and artificial, and artificial forms. Applications include everything from beverages to dairy products to baked goods,
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anywhere a sweetener is used. “Additionally, combining these flavors with any type of sweetener may even show a cost savings over the use of a full-sugar product,” says Rosskam.

Mafco Worldwide offers a line of ingredients based on monoammonium glycyrrhizinate, a unique compound found only in licorice root. “Its slow onset of sweetness taste and prolongation of sweetness taste can help round out the sweetness profile while at the same time mask any aftertastes associated with high-intensity sweeteners,” says Adao.

**Today, thaumatin has FEMA GRAS status as a natural flavor; it does not have approval as a sweetener in the United States.**

Monoammonium glycyrrhizinate is considered a natural flavor enhancer and is certified as a generally recognized as safe (GRAS) additive. “It is effective at low dosages, which enables product developers to more economically use high-intensity sweeteners in many applications,” says Adao.

Thaumatin is another plant extract recognized for its taste-enhancement properties. Used by West Africans for hundreds of years to sweeten corn breads, sour fruits and also to make palm wine palatable, thaumatin is a protein that is water-extracted from the katemfe fruit (*Thaumatococcus daniellii*) harvested from the West African rainforests, rendering it a natural ingredient.

“In the 1970s, great emphasis was placed on thaumatin’s sweetening properties and, for some time, this defined its regulatory and marketing path,” explains Antoine Dauby, marketing director, Naturex, Avignon, France. Today, thaumatin has FEMA GRAS status as a natural flavor; it does not have approval as a sweetener in the United States. It appears as “natural flavor” on ingredient statements.

“Thaumatin is a multifunctional ingredient that simply improves the taste profile of foods and beverages,” says Dauby. “It masks off tastes, in particular those associated with stevia. It also enhances flavors and improves the taste of sugar and salt replacers. It combines very well with sweeteners, helping extend and enhance the flavor profile and length of delivery.”

Approximately 2,000 to 3,000 times sweeter than sucrose, this natural flavor is water-soluble and stable to heat and pH, making it useful in all applications. It is metabolized by the body the same as any other dietary protein.

“In beverages, thaumatin works with the sweetening system to enhance and round the flavor and sweetness profile,” Dauby says. “In confectionery, it enhances, improves and
prolongs flavors, particularly citrus, berry and mint. It provides a sugarlike taste when used in combination with polyols and high-intensity sweeteners.”

When it comes to the increasingly popular, all-natural, high-intensity sweeteners based on extracts from the stevia plant (*Stevia rebaudiana*), King emphasizes that stevia products are not alike. “All are derived from the stevia plant, but that’s their only commonality,” he says. “Multiple compounds within the stevia leaves—steviol glycosides—have characteristics ranging from sweet to bitter.” The diterpene known as steviol is the aglycone of stevia’s sweet glycosides (the sweet part of the leaf used as a sweetener), he says. A diterpene, a type of terpene, is an organic compound composed of four isoprene units. The glycosides that make up the sweet constituents of the stevia leaf are stevioside (250 to 300 times the sweetness of sugar), rebaudioside A (the most sweet at 350 to 450 times the sweetness of sugar), rebaudioside C and dulcoside A (which is not really used as sweetening agents since they are bitter). There are also rebaudioside B, D and E present, but they are in such small quantities that it isn’t cost effective to extract them.

King notes, that the method used to extract these compounds significantly impacts flavor and quality. Sourcing, processing methods and ratios of steviol glycosides vary widely among suppliers.” All of this impacts the stevia ingredient’s taste of sweet and flavor of sweet. The company recently introduced a highly concentrated stevia extract that contains 98% minimum rebaudioside A, which has intense sweetness, according to King. “The flavor is a sharper, sweet profile in comparison to the softer, smoother profile of our original extract,” he says.

**A systems approach**

PureCircle, Chicago, showcased its next-generation stevia ingredient at the recent Food Ingredients Europe in Frankfurt, Germany. It “represents an evolution for us from a single stevia ingredient solution to blending stevia ingredients for deeper calorie reductions with great taste,” says Jason Hecker, vice president global marketing and innovation. “Rather than providing a one-size-fits-all stevia sweetener, we learned that, to get the best stevia-sweetened product, a blended approach is key. Knowing the particular stevia ingredients that work best in specific food and beverage matrices lets product developers achieve deeper calorie reductions with better taste profiles, achieving a more rounded sweetness than ever before.”

**Multiple compounds within the stevia leaves—steviol glycosides—have characteristics ranging from sweet to bitter.**

Nutrinova invented the high-intensity sweetener acesulfame potassium. The company recently introduced a novel sweetener system designed to bring authentic sucrose taste profiles to all types of reduced-calorie beverages, from...
carbonated soft drinks to flavored milk to cocktails. The products currently in this line are based on acesulfame potassium, sucralose and natural flavors; the system enables beverage makers to balance sweetness and flavor while masking off-notes.

“We asked our customers to tell us about the formulation process for reduced-calorie beverages,” says Diana Peninger, vice president and general manager, Celanese. “They discussed the difficulty in blending various sweeteners and flavors to achieve the desired taste profile and the time involved in the many iterations.” In response, the company set out to develop a sweetener system that sweetens beverages but mitigates taste issues.

“Currently there are two products in the portfolio,” says Kim. “One is designed for partial (30% to 70%) sugar reduction. It lowers calories and added sugars while delivering a full-sugar taste.

“The other is intended for diet or very, very low-added-sugar products,” adds Kim. “It can be used for up to a 100% sugar reduction in carbonated and still beverages, flavored waters, energy drinks, juice-based drinks and more.” Both systems function in a large variety of processing conditions.

A recent ingredient innovation from Ingredion is a line of sweetness and texture systems. “The systems let you capitalize on consumer trends for reduced-sugar and -calorie fruit juices without sacrificing a smidgen of taste and texture,” says Turner. “Now you can trim as much as half the sugar content in juices containing 50% fruit juice and still deliver a drinking experience virtually identical to the full-sugar version.

“The system allows one to dial in the sweetness profile and ensures product functionality (in terms of mouthfeel and body of the beverage) when sugar is removed or reduced,” adds Turner. “A unique flavor modulator in the ingredient systems works synergistically with other ingredients to provide the roundness of flavor consumers find so appealing in full-sugar juices.”

Mary Lynne Shafer, global marketing director, texture, Ingredion, adds, that this technology “will allow juice producers to maintain their brand equity because they won’t be adding anything artificial to their labels when they move to a reduced-sugar formulation.” The company recommends the following declaration on the ingredient statement: “corn starch, calcium and magnesium derived from seaweed, reb A (stevia extract).”

The most recent sweetener to enter the ingredient marketplace comes from monk fruit, the translation for the Chinese luo han guo.
Global concerns about obesity and excessive sugar consumption have driven the development of new products using lower-calorie, alternative sweeteners, including polyols and natural and synthetic high-intensity sweeteners. But the regulations governing their use vary around the world.
This is a fruit grown in Southeast Asia and is now available in a concentrated form for zero-calorie, all-natural sweetening of all types of foods and beverages. The unique zero-calorie sweetness of monk fruit extract comes from naturally occurring compounds (mogrosides) in the fruit that are 150 to 400 times sweeter than sugar, depending on its purification level and the application.

Monk fruit extract works well in systems where there are lingering flavors; for example, tea beverages that have a natural bitterness.

Compared to other sweeteners, monk fruit extract is known for its sugar-like taste and its tendency to build slower to the sweetness. That sweetness also tends to last longer than what one experiences with sucrose. Thus, monk fruit extract works well in systems where there are lingering flavors; for example, tea beverages that have a natural bitterness. It also works synergistically with other sweeteners, in particular, stevia. Together, the two can deliver a balanced sweetness profile in most applications. Further, by using monk fruit extract, less stevia is needed for the same sweetness level. The same is true when monk fruit extract is used with sucrose and other caloric sweeteners.

The preference for sweet is innate and sweeteners can increase the pleasure of eating. Because our sweet tooth is not going to go away, it is helpful that product designers have so many options to deliver the taste and flavor of sweet, and at the same time, reduce added sugars and calories. It is the position of the Academy of Nutrition and Dietetics, Chicago, that consumers can safely enjoy a range of nutritive and nonnutritive sweeteners when consumed within an eating plan that is guided by current federal nutrition recommendations, such as the Dietary Guidelines for Americans and the Dietary Reference Intakes, as well as individual health goals and personal preference.

Donna Berry, president of Chicago-based Dairy & Food Communications, Inc., has been writing about product development and marketing for 20 years. She has a B.S. in food science from the University of Illinois in Urbana-Champaign. She can be reached at donnaberry@dairy-food.com.
## High-Intensity Sweeteners

<table>
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<tr>
<th>Sweetener</th>
<th>Approximate Sweetness Compared to Sucrose</th>
<th>Applications</th>
<th>Characteristics</th>
<th>FDA Approval</th>
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</thead>
<tbody>
<tr>
<td>Sucralose</td>
<td>600</td>
<td>Baked goods and mixes, beverages, dairy products, tabletop use, processed fruits, condiments, syrups, dietary supplements</td>
<td>Taste profile similar to sugar</td>
<td>Approved for general use in 1999</td>
</tr>
<tr>
<td>Aspartame</td>
<td>200</td>
<td>Beverages, chewing gum, confectionery, dairy products, frozen desserts, tabletop</td>
<td>Sugar-like taste</td>
<td>Approved by FDA in 1981</td>
</tr>
<tr>
<td>Neotame</td>
<td>8,000-13,000</td>
<td>Carbonated beverages, chewing gum</td>
<td>Extends sweetness, acts as a flavor modifier, enhances fruit flavors, works well in blends</td>
<td>Approved for use in the United States in 2002</td>
</tr>
<tr>
<td>Glycyrrhizin</td>
<td>50</td>
<td>Flavor enhancer</td>
<td>Tastes like licorice; sweetness is slow and tends to linger</td>
<td>The FDA has only approved glycyrrhizin as a flavor enhancer.</td>
</tr>
<tr>
<td>Saccharin</td>
<td>300</td>
<td>Beverages, tabletop</td>
<td>Bitter, unless combined with other sweeteners, like aspartame</td>
<td>Removed from the GRAS list in 1972, then reinstated in 2001</td>
</tr>
<tr>
<td>Acesulfame K</td>
<td>200</td>
<td>Candies, baked goods, frozen desserts, beverages, tabletop sweeteners</td>
<td>Often used with other sweeteners in order to enhance the sweet taste of foods and beverages</td>
<td>Approved in 2004 for general purpose use.</td>
</tr>
<tr>
<td>Rebaudioside A</td>
<td>200</td>
<td>Beverages, ice cream, yogurt, candies, chewing gum, tabletop</td>
<td>Derived from the stevia plant; considered a “natural” sweetener</td>
<td>Recognized as generally safe for all uses in 2008.</td>
</tr>
<tr>
<td>Luo han guo</td>
<td>300</td>
<td>Juices, flavored milk, ready-to-drink teas, coffee, carbonated beverages, cereals, yogurts, confectionery, baked goods</td>
<td>Also known as monk fruit, this “natural” sweetener is derived from a lemon-sized fruit native to China and Southeast Asia. It has been used for centuries in the countries where it grows.</td>
<td>GRAS status in the United States in 2010</td>
</tr>
</tbody>
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Compiled by Kasia Michalik, associate editor

*Combined, neotame and glycyrrhizin constitute 3.5% of U.S. market

Out with classic granulated sugar and in with all-natural fruit- and plant-based noncaloric sweeteners. As consumers hunt for natural sugar alternatives, the industry is stepping up to the challenge. Stevia is probably the most well-known natural high-intensity sweetener. Its first runway of fame was the juice aisle, according to Euromonitor International, London, as it appealed to health-conscious consumers, “allowing manufacturers to reduce the sugar (and thereby calorie) content without sacrificing either sweetness or naturalness, and even allowed organic low-sugar varieties to emerge.”

In years past, stevia was largely used only as a tabletop sweetener, but this last year, Euromonitor reports more food and drink products that include stevia hit stores, including a reformulated version of Sprite in the United Kingdom and in France. Coca-Cola launched the first Coke sweetened with stevia in Argentina in summer 2013. In 2009, PepsiCo launched Tropicana Trop50, a blend of juice and water sweetened with stevia, which has been extremely successful in the United States. In less than three years, the drink’s value sales reached $149 million, claiming 10% share of off-trade volumes in the nectars (25% to 99% juice) category in 2012, according to Euromonitor.

“For consumers wanting to keep their calorie intake in check while still enjoying a nice glass of ‘natural’ juice with their breakfast, products like [PepsiCo’s] offer the perfect solution,” says Ewa Hudson, global head of health and wellness, at Euromonitor International. “In this regard, monk-fruit extract, by virtue of being derived from a fruit, offers even greater potential. Once this highly promising sweetener manages to overcome the few existing teething problems, low-calorie soft drinks, and in particular the juice category, are set to enjoy another serious boost in popularity.”

The use of monk fruit (Siraitia grosvenorii), or luo han guo, in food and beverage launches has tripled in the past five years, but it still has taste issues to conquer, as well as cost concerns and regulatory hurdles, according to Mintel, Chicago. Interestingly, monk fruit has mainly been used as a standalone sweetener, but more recently it’s finding its way into reduced-calorie blends. Monk fruit is being paired with erythritol, as well as small amounts of sugar and molasses, to create a low-calorie sweetener. A plus to using monk fruit is it’s the only natural, high-intensity sweetener in the United States approved for a “from a fruit” claim, which helps to distinguish it from other natural sweeteners. According to the Natural Marketing Institute’s (NMI) 2012 Health & Wellness Trends Database®, two-thirds of Americans claim their usage of artificial sweeteners (including aspartame, sucralose and saccharin) has not changed in the past year, but upon closer examination, differences in use are evident among certain demographic groups, e.g., women are almost twice as likely as men to have decreased their artificial sweetener usage in the past year. So what sweeteners do Americans like to use? According to NMI, honey and table sugar top the list of alternatives.

—Alissa Marrapodi, associate editor