

## Customizing Sweetness Profiles

By Ronald C. Deis, Ph.D., Contributing Editor

We have come a long way in customizing sweetness in foods since the 1879 discovery of saccharin. We still measure all sweeteners against sucrose, but sugar and caloric reduction are major goals in product development. The challenge has been to deliver a sweetness profile similar to sucrose.

Food manufacturers practiced sweetener blending in the 1960s and '70s. It faded in the 1980s and through much of the 1990s, but increased again through the early 2000s. Now sweetener blending is common in new-product launches. Internationally, varied combinations exist—particularly in beverages and chewing gum—including: maltitol, sorbitol, calcium cyclamate, aspartame and sucralose; sugar, sodium cyclamate, aspartame, acesulfame-K and sodium saccharine; fructose, cyclamate and aspartame K; sodium cyclamate, aspartame and saccharine; maltitol, maltitol syrup, sorbitol, acesulfame-K, aspartame and sucralose.

Why use several sweeteners in one product? A number of reasons exist, although it's impossible to provide a one-size-fits-all road map to success. Sweetener intensity varies according to the formulation—impacted by other ingredients, temperature, shelf life, pH and other factors. Other considerations include cost, functionality, intensity, regulations, claims, synergy, media and/or consumer interest, stability, etc.

“The choice of sweetener has a big impact on a product’s taste,” notes Lauri Rottmayer, marketing director, 21st Sensory, Inc., Bartlesville, OK.

“Because each sweetener interacts differently with every food system, it’s imperative to test the sweetener in the different products in the client product line.”

Sweeteners may also contribute some flavor. Saccharine and aspartame have been called bitter and metallic, respectively. The impurities in natural sweeteners can also carry over as flavor, and the

### Sweetness Sense

*Although food scientists might talk about the sweetness profile as a stand-alone consideration in product development, they know that a product’s sweetness is one part of the consumer’s overall sensory experience. Sweeteners interact with other ingredients in the food matrix, including other sweeteners, to deliver a pleasant consumer experience. Product designers should consider the following factors when determining which sweetener or sweetener blend is best for their formulation.*

*Application: Some sweeteners and sweetener systems are better suited to a particular application than others. If developing a beverage, you don’t want a lingering sweetness—you want a sweetener or a sweetener system that provides a quick onset, clean overall sweetness, with a clean finish. Conversely, if developing a gum base, you want the sweetness to last as long as the flavors.*

*Ingredient matrix: When replacing existing sweeteners, such as sucrose, sweetness is not the only property you are replacing. Sucrose also may provide mouthfeel and texture, bulk, color, and flavor development. A replacement sweetener system needs to provide all of these characteristics, and may include additional ingredients, such as sugar alcohols, gums, bulking agents and flavors.*

*Sweetener synergies: Some sweeteners have a synergistic effect and can enhance and/or complement each other. Some combinations are sweeter than when each ingredient is used by itself and/or they impart improved taste profiles. For example, a combination of acesulfame-K and sucralose might be used to produce a desired sweetness temporal profile while a combination of acesulfame-K and aspartame can enhance sweetness and improve stability.*

*Functional benefits: Today, there is a wide array of sweetener options that deliver a variety of functional benefits. You may want to select a sugar alcohol, such as erythritol, which provides sweetness and bulk, to develop a low-calorie product for weight control. Also, isomaltulose or the new sweetener sucromalt are digested slowly for sustained energy release and lower glycemic response.*

—Paul Kim, team leader, sweeteners and sweetness research, Cargill, Inc.

varying saccharide profile can also affect the sweetener's profile.

For example, brown rice syrup has a mild flavor, often described as "buttery," suiting it to a wide range of applications, including beverages, sports drinks, nutritional bars, etc. These syrups contain maltose and glucose; the content and ratio depends on the type of syrup and its processing. David Janow, president, Axiom Foods, Inc., Los Angeles, notes that the company's syrups are "clear, brown rice syrups naturally processed from sprouted wholegrain brown rice, available from 26 to 70 DE, with sweetness up to that of a 42% HFCS."

### To market

Chicago-based Mintel estimates nearly 3,000 new products have been introduced in the last three years with no-, low- or reduced-sugar claims. The sugarfree market for foods and beverages was worth \$5.9 billion in 2005, and is predicted to grow to \$7.7 billion by 2010.

"While the sugar-free market is expanding, there is concern and confusion among some medical professionals and consumers as to the safety of these products," according to Marcia Mogelonsky, senior analyst, Mintel. "The public is confronted with an array of facts and statistics that elevate health concerns and raise the issue of whether sugar-free is worth the potential risk. The uncertainty is not stopping people from using sugar-free products, but as far as consumers are concerned, moderation is key, once they have chosen the substitute they feel is safest. The majority of consumers believe that some artificial sweeteners are safer than others, giving producers the chance to win customers' trust by focusing on their safety."

Recent product introductions illustrate that designers have become more comfortable with a multiple-sweetener approach. These are usually patented or held as trade secrets. However, resources exist to help product developers better understand what works and what does not.

### Understanding sweeteners

First we need to understand how much of each sweetener to use versus sucrose, or its sucrose equivalence (SE), often given as a percentage. For example, the SE of 200 ppm aspartame in water is 4.2%, which means 200 ppm aspartame and 4.2% sucrose are equally sweet in water.

Plotting the percentage of sucrose versus the concentration of the sweetener gives a concentration-response (C-R) curve. G. E. DuBois et al. posted C-R curves of 19 sweeteners (ACS Symposium Series 450, 1991). They found that sugars and sugar alcohols yielded linear plots, while high-potency sweeteners yielded hyperbolic plots.

For sugar alcohols and sugars, sweetness intensity increases with higher concentration—but at different rates, depending on the sweetener. For high-potency sweeteners, the same effect occurs at low concentrations but, as the concentration increases, the increase in sweetness intensity slows to an eventual plateau.

This gets us to a definition for sweetener potency: the ratio of the concentration of sucrose versus an equi-sweet concentration of the high-potency sweetener. This is the figure, often expressed as a range, usually seen for sweeteners.

But this relative index has little to do with how the sweetener will perform in a particular formulation. Potency depends on the sweetener, the concentration and the matrix—water, beverage, baked good, etc.—in which it

is found. The potency of a high-potency sweetener is lower at high concentrations and in more-complex food systems.

The idea of looking at temporal profiles began over 20 years ago when the appearance time and extinction time of sweetness in the mouth were noted for various sweeteners (for one example, see *Chemical Senses*, 7:237-247; 1983). This led to characterization of temporal-profile curves (intensity vs. duration), allowing researchers to compare area under the curve (AUC), intensity maximum, time of maximum intensity (Tmax) and duration.

Researchers then explored the idea of “quantitative synergy,” an intensity response to a mixture greater than the predicted response based on the temporal profiles of the individual sweeteners. This can get very complex depending on the level of sweetness desired (for an in-depth discussion by Schiffman et al. in *Brain Research Bulletin*, 38(2), see [www.duke.edu/web/tasteandsmell/pdf%20files/203.pdf](http://www.duke.edu/web/tasteandsmell/pdf%20files/203.pdf)). Schiffman states that “synergism permits the blending of low concentrations of sweeteners such as saccharin or acesulfame-K, which are better at higher concentrations with sweeteners without salient bitter components such as aspartame or fructose to achieve a desired level of sweetness.”

Also, in studies reported by Nutrinova, Inc., Somerset, NJ, acesulfame-K’s fast onset, quick clearing and stability complements aspartame’s slower onset, lingering and variable stability. This is an example of advantageous temporal curve use. Qualitative synergy is just the tip of the iceberg. One study of 17 sweeteners used multidimensional scaling techniques to compare intensity and a number of other sensory qualities (*Physiology & Behavior*, 23:1-9; 1979). The report noted that subjects “found it difficult to extract a common quality called ‘sweetness’ from the other qualitative and temporal complexities....” No definitive relationships between molecular structure and sweetness quality could be found. Temporal sweetness of sugars and high-potency sweeteners can be compared in simple media, such as water, to develop a general understanding of how they might complement each other, but the real test occurs in the food system itself.

### A balancing act

Simple sugars and high-potency sweeteners make up part of the solution, but corn syrups and maltitol syrups help balance the flavor. According to Peter Jamieson, manager of technical service, SPI Polyols, New Castle, DE, the key is in the carbohydrate distribution. “Our research in confectionery and chewing gum has shown that the higher-molecular-weight portion of our maltitol syrups extends sweetness in applications while—of course—higher maltitol levels increase up-front sweetness,” he says. “We have used this information to develop our maltitol syrup line toward specific applications.”

Building a system that works in varied applications is the next step. One example of this was the result of a partnership between SPI Polyols and David Michael & Co., Philadelphia. “As a result of having had the opportunity to work closely with SPI and their maltitol syrups in various NSA applications, we have been able to create a vanilla flavor that, in addition to producing a wonderful vanilla flavor, provides a boost to the overall sweetness perception of product made with maltitol syrups,” says Phil Parisi, vice president, technical director, David Michael & Co. “The importance of using this vanilla flavor system is that it creates a total sweetness system that allows manufacturers to avoid the use of any other sweetener systems in combinations with the maltitol syrup.” Vanilla acts as a sweetness potentiator, making it a beneficial addition to NSA sweetener systems.

Multiple sweeteners often display a phenomenon known as “adaptation.” With prolonged exposure to a taste, the tongue loses sensitivity to it—with sweetness, this results in a loss in intensity. Schiffman et al. found that blending two to four sweeteners reduced sweetener loss in repeated sips of product (*Chemical Senses*,

28:219-229; 2003). This can tremendously impact the success of a product—especially chewing gums or a beverage for kids—not to mention the potential for a more-economical use of sweetener.

Projects conducted in 2004 by Leatherhead Food International, Leatherhead, England, reported on the sensory effects of combining bulk sweeteners (sucrose and maltitol) with highpotency sweeteners (aspartame, acesulfame-K, sodium cyclamate, alitame and neohesperidine dihydrochalcone, or NHDC). The scientists developed sensory profiles for the sweeteners singly and in combination. One outcome of this research was the finding that the bitterness and licorice aftertaste intensities of cyclamate were reduced significantly by sucrose, and more so with maltitol.

In a March 2006 paper at the American Chemical Society (ACS) meeting in Atlanta, researchers from The Ohio State University, Columbus, reported on the importance of sweetness quality. In the study, 30 panelists rated overall liking, as well as sweet, sour, bitter and metallic intensities, for 13 sweeteners. The most-preferred sweeteners were those with the least sour, bitter or metallic aftertastes. Sugar ranked highest in sweetness quality, followed by sucralose, xylitol and fructose.

In the same ACS meeting, Christopher T. Simons, sensory research scientist, Givaudan Flavors Corporation, Cincinnati, reported on generating temporal profiles that describe the aftertastes of a range of sweeteners. This enabled researchers to define the sensory attributes contributing to decreased liking of certain sweeteners. A good understanding of these negative attributes allows a better approach to formulating around them.

Jakob P. Ley, of Symrise GmbH, Holzminden, Germany, reported at the ACS meeting on use of flavor nonvolatiles such as polyhydroxylated benzoic acid benzylamides or deoxybenzoins to boost sweetness. Certain compounds that are FEMA GRAS are either high-potency sweeteners or contribute additional sweetness to food products. These include NHDC and stevioside, which enhance sweetness in small concentrations. Formulators have rounded out flavor and boosted sweetness perception with small concentrations of maltol and ethyl maltol for years. Another ingredient, 2,4-dihydroxybenzoic acid, contributes some sweetness at its permitted levels (450 to 500 ppm) and has shown synergy with other sweeteners.

### Planning for the future

Human sweetness perception has been debated for years, with many theories presented, including the AH,B theory presented by Shallenberger and Acree (1967), the AH-B-X theory of Kier (1972), and a multi-point attachment theory presented by Tinti and Nofre (1991). These theories are generally based on sweetness expression through a single receptor and one primary, or “orthosteric,” site. In 2001, experiments by Zuker and Ryba showed that mice possessed a family of G-protein-coupled receptors (GPCRs) that mediated sweet and umami tastes (*Cell*; 106(3):381-90; 2001). Subsequent work at Senomyx, Inc., La Jolla, CA, identified a human sweetener receptor now referred to as T1R2/T1R3 (*Proceedings of the National Academy of Sciences of the United States of America*; 99(7):4,692-96; 2002). This work showed the existence of at least two primary sites, both of which bind certain sweeteners and/or sweetener antagonists.

At the March 2006 ACS meeting, Nancy E. Rawson, associate member, and Hakan Ozdener, research associate, both of the Monell Chemical Senses Center, Philadelphia, reported on the development of taste cells in vitro. This created another breakthrough in sweetener investigation, greatly increasing the speed and accuracy of compound assays. They also reported on sweet-taste inhibition at high concentrations, noting that when subjects rinse a high concentration of a sweetener such as saccharin from the mouth, they note a “sweet water taste,” suggesting that sweeteners bind at low concentrations to a high-affinity site that causes sweetness. At high concentrations, they bind to a lower-affinity site, which results in sweetness inhibition. When rinsing occurs, binding centers on the high-affinity site, again resulting in the sweet water taste.

Paul A. S. Breslin, a Monell geneticist, noted: “The extremely close parallels between the behavior of the human sweet taste receptor and the perceptual phenomenon are remarkable. This two-site model should enable a more-complete understanding of human sweet taste perception, leading directly to studies of how to stimulate, manipulate, enhance, inhibit and create synergy of sweet taste.”

No clear routes lead to the ideal sweetener system, especially across food categories. “Descriptive sensory analysis breaks each product down into perceivable attributes. Sensory and consumer insight provide developmental guidance along the way, shortening the steps to achieve the final goal,” according to Rottmayer. “The results help to understand the total sensory experience of the product. Many companies spend substantial amounts of time— money!—on their research, and yet the product failure rate remains very high. Releasing products into the marketplace too early and expecting the consumer to be the quality-assurance department is a prescription for failure. Systematic sensory analysis provides critical product insight on quality and stability. Failure to study a product fully can ruin a product if a defect is discovered after market rollout.”

Product development is all about innovation. The developments in sweeteners and sweetener enhancers over the last five to 10 years now show many routes to take, whether through high-potency sweeteners, bulk sweeteners, partial use of sugars or use of specially formulated flavors. As with any part of product development, it is best to develop an understanding of the range of what is available, and then formulate to maximize performance.

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