2016 Sweetener Systems Conference Summary

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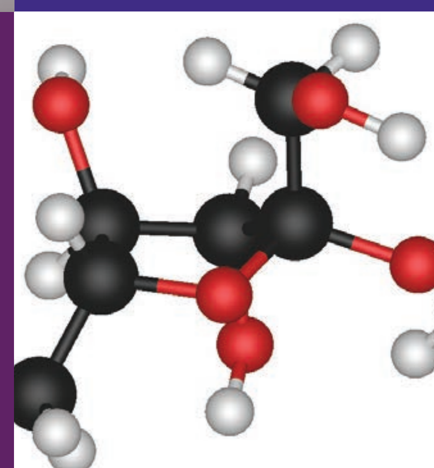

A Global Food Forums® Event

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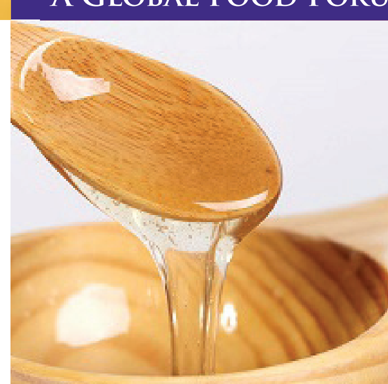

2016 Sweetener Systems Conference Summary

Why hold a conference on sweetener systems?

Sweetness-enhancing components have long been added to recipes, as well as packaged foods and beverages. However, as consumers demand an increasing array of attributes from the products they consume, the food industry has stepped up to deliver sweetener ingredients from a myriad of sources and with wide-ranging properties. Additionally, the perception of sweetness and the impact of any one sweetener ingredient is highly influenced by other ingredients in a food matrix. The need for up-to-date information on sweeteners by product developers has increased. This is because there have been ingredient technological advances; and because there is increased complexity in the sweetener systems used. Other factors include evolving consumer attitudes, progress in nutritional science and, lastly, changes in regulations.

With these issues in mind, Global Food Forums, Inc. launched its first Sweetener Systems Trends & Technologies Conference (since renamed Sweetener Systems Conference) on November 2, 2016, in Lombard, Ill., USA. The event proved successful beyond expectations—with over 160 registrants and an abundance of very positive comments. A brief summary of the excellent presentations from this year's program is provided here.

All presentations and/or adapted versions made available by the speakers are posted at www.GlobalFoodForums.com/2016-Sweetener-Systems/Store.

Please consider attending our 2017 Sweetener Systems Conference, November 7th, at the Westin Hotel, Lombard, Ill., USA. (www.GlobalFoodForums.com/2017-sweetener-systems)

The first Sweetener Systems Conference, held November 2, 2016, had just over 160 registrants, formulator-friendly tabletop exhibits and a sweetener sampling session.

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Insights into Challenges of Labeling "Added Sugar"

Dietary sugar reduction is a global health objective, as per the United Nations' World Health Organization (WHO). Thus, the compliance challenges posed by the U.S. Food & Drug Agency's (FDA) recently published requirement to include "added sugar" as a subhead to the line-item "sugars" on the nutritional label have global implications for all food regulatory agencies.

David Ellingson, MSc, Senior Research Chemist and Project Manager with Covance, an international research laboratory, addressed two issues that should be of primary concern:

1) Industry's inability to discern between naturally present and added sugars; and

2) the need to establish requirements for dynamic sugar concentrations that vary as a function of processing and storage.

"The FDA regulation defines 'added sugars' as either free sugar (mono- and disaccharides), syrups or 'sugars from concentrated fruit or vegetable juices that are in excess of what would be expected from the same volume of 100% fruit or vegetable juice of the same type,'" explained Ellingson.

There are four exceptions:

1) Fruit or vegetable juice concentrated from 100% juices sold to consumers;

2) fruit or vegetable juice concentrates used towards the total juice percentage label;

3) fruit juice concentrates used to formulate the fruit component of jellies, jams or preserves, or the fruit component of fruit spreads; and

4) lactose from milk.

"There are three high-level scenarios with respect to a product analysis: one being where all sugar is added; one being both natural and added; and a third where all sugars present are natural," continued Ellingson.

"Typically, when we do an analysis for sugar in our labs, we are looking for these six: glucose, galactose, fructose, sucrose, maltose and lactose. We utilize HPLC and GC applications," Ellingson noted.

Whereas ion chromatography with pulsed amperometric detection is becoming the norm for HPLC-type applications, "more robust" gas chromatography techniques are still popular—even though they require derivatization of sugars prior to analysis. For quick, in-line production screening, a technology such as Fourier Transform Infrared (FTIR) spectroscopy may be quite adequate. However, he stressed, none of these techniques is capable of distinguishing between "natural" and "added" sugars!

The most difficult analytical challenge is when fruits or vegetables that have innate amounts of sugars are mixed with "added" sugars, such as in juice drinks.

"If a more forensic analysis is needed, laboratories have available a range of analytical techniques to identify the source of a sugar on a qualitative level," explained Ellingson. Although more sophisticated isotope analyses can distinguish between C12 (found in cane and corn sugars) and C13 (found in maple and beet sugars), they cannot pinpoint the source origin of all sugars. Nonetheless, isotope analyses do offer limited use in identifying adulterants in products and ingredients."

Continued Ellingson, "By far the most difficult analytical challenge is when fruits or vegetables that have innate amounts of sugars are mixed with 'added' sugars, such as sweetener syrups, to improve taste or sweetness." This includes products such as juice drinks, breakfast cereals and yogurt beverages.

Providing analytical chemists with a product's formula in advance allows them to analyze the areas under chromatographic peaks and

Old Nutrition Facts Label

Total Carbohydrate 37g	**12%**
Dietary Fiber 4g	**16%**
Sugars 1g	

New Nutrition Facts Label

Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g added Sugars	**20%**

SOURCE: FDA.GOV

Although entailing but a small change to a food or beverage's nutritional label itself, the FDA's recently mandated label change to include "added sugar" poses considerable analytical challenges for processors.

roughly estimate total sugar contents. If the chromatographic profiles conform to the formula provided, all may be well. However, it is much more difficult to determine whether a food, beverage or ingredient has been adulterated—and by how much—using only such techniques. Analysis of carbon isotope profiles and other impurity markers can flag possible adulteration—but not always.

An additional complication is when non-enzymatic browning, fermentation or other processes affect total sugar content during processing or storage. This is an important consideration for heat-treated products rich in amino acids, sweeteners, and fruit and vegetable ingredients, such as soups or sauces.

When asked a question about how one could establish a label declaration for sugar content for products exhibiting starch breakdown during storage due to acid hydrolysis, Ellingson allowed that this could be a complicating factor: At what point in the process or retail distribution of such products can an accurate determination of sugar content and profile be made? Perhaps a petition to the FDA for a labeling exception would be merited in such cases; the FDA regulations do allow companies to petition for exceptions.

[Note: The final, published FDA "added sugar" labeling regulation can be found in: *FDA Federal Register/Vol. 81, No. 103/Friday, May 27, 2016/Rules and Regulations]*.

"Insights into Challenges of Labeling 'Added' Sugar," David Ellingson, MSc, Senior Research Chemist and Project Manager, Covance, David.Ellingson@covance.com

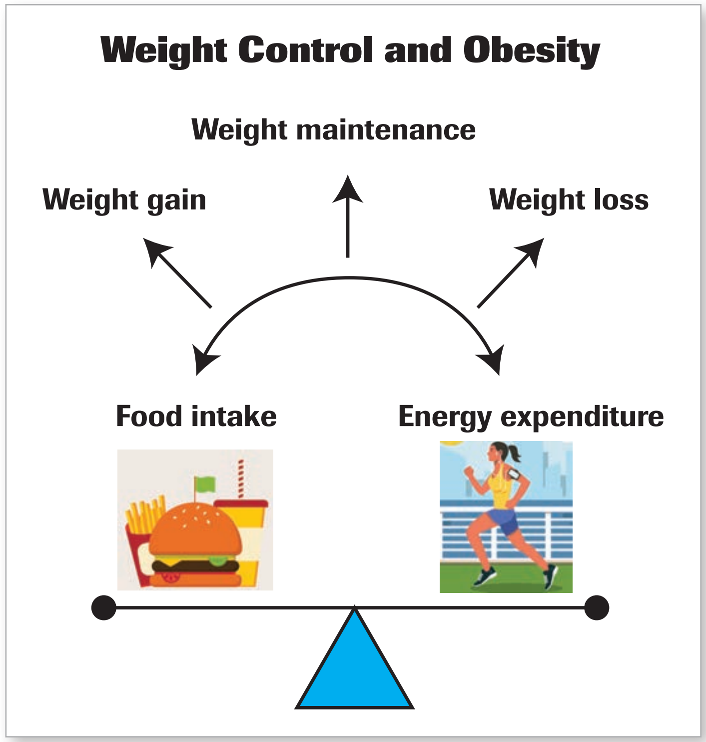
Panel: Sweeteners and Nutrition—New Developments & Reality Checks

Panelist #1: Caloric Sweeteners & Health—What is the Truth?

G. Harvey Anderson, Ph.D., University of Toronto Professor of Nutritional Science and Physiology, got straight to the point: "There is insufficient evidence upon which to make public policy regarding caloric sweeteners consumption—but the horse has left the barn—and we must deal with the consequences."

Caloric sweeteners are under siege. Very recently, the U.S. National Science Foundation's Institute of Medicine (IOM) declared there was insufficient evidence upon which to set upper limits to caloric sweetener consumption, but it nonetheless recommended that they constitute no more than 25% of total calories. This recommendation was based not upon health issue mitigation, but on preventing the displacement of foods that contribute essential nutrients to the diet.

In contrast, the 2015 Dietary Guidelines Advisory Committee declared that caloric sugar consumption should be limited to



Obesity results from a failure to achieve energy balance. It is unclear whether susceptible individuals become obese because their physiological mechanisms of food intake control are compromised, or whether these same control mechanisms are overridden and compromised by environmental factors (e.g., sedentary lifestyles).

no more than 10% of dietary calories, due to "negative impacts" on type II diabetes, cardiovascular health and dental caries. The WHO also supported a policy of limiting caloric sweetener consumption to no more than 10% of the diet and, perhaps, to less than 5% of the diet. "And…there is now talk of imposing world-wide sugar consumption taxes," said Anderson.

"Obesity is the public health concern that started this campaign," explained Anderson. "We know that obesity comes from excess food intake, meaning an energy imbalance, but it remains unclear whether obesity develops from physiological systems that make us susceptible to environmental causes, such as sedentary lifestyles, or from environmental causes alone."

Therefore, caution is warranted.

With respect to the U.S. Dietary Guidelines, for example, "We know that many of the guidelines have proven themselves wrong, over time. We keep shifting around claims, such as fat causes obesity or cardiovascular disease, only to have them later proven wrong." This has hurt the credibility of nutritional policy-making.

Sweeteners are a normal part of life, and humans are exposed to sweet tastes from *in utero* to death. There are also many benefits to sweet foods. They tend to be safe; easy to store; easy to transport; require no preparation; and are relatively inexpensive. In addition, caloric sweeteners can play important roles in rendering highly nutritional products palatable, such as bitter fruit (e.g., cranberry) or high-fiber cereal products (e.g., cereal or granola bars).

So, given all these considerations, what does the evidence say?

Anderson referenced the work of his University of Toronto colleague, John Sievenpiper, MD, Ph.D., FRCPC. Sievenpiper undertook a systematic review of all published studies linking sweetener consumption to health concerns, in order to critically assess whether caloric sweeteners cause diabetes and obesity (as per the U.S. 2015 Dietary Guidelines Advisory Committee). He determined that no studies had been able to statistically link caloric sweetener consumption levels to either obesity or diabetes. Such absences of associations were found for both sucrose and fructose. Certainly, no documented associations were found that could justify public policy-making on caloric sweetener consumption, summarized Anderson.

Sievenpiper also referenced studies that linked the consumption of specific foods to weight gain. Here, a weak but statistically significant association was found between weight gain and sugar-sweetened beverage consumption. But, similar gains were also found for French fries, potato chips, nuts, potatoes and, even, yogurt. In sum, the studies appeared only to prove that increased energy consumption leads to weight gain. "If you eat more, you get fatter," summarized Anderson.

Effects of sugar-sweetened beverage intake on obesity were also more difficult to categorize. Many food intake studies rely upon consumer recall. In general, people can recall their frequency of consumption much better than their quantity of consumption, said Anderson. It also can't be ascertained whether sugar-sweetened beverage consumption levels translate directly into weight gain or serve as markers for other lifestyle factors that relate to obesity (e.g., sedentary lifestyles).

Put together, these results are inconclusive, maintained Anderson, and there remains far more work to be done before public policy-makers can credibly recommend optimal levels of caloric sweetener consumption.

"Caloric Sweeteners and Health: What is the Truth?" G. Harvey Anderson, Ph.D., University of Toronto Professor of Nutritional Science and Physiology, Harvey.anderson@utoronto.ca

Panelist #2: Low-calorie Sweeteners and Health—New Developments and Reality Checks

Prof. Richard Mattes, Purdue University, launched his data-rich presentation with a plea: Given the many terms in use for our topic today, "We need consensus!"

Sweeteners have been charged with being addictive. However, for a material to be addictive, there has to be an active component, and no such components have been identified in food.

Mattes proposed using "low calorie" as the preferred terminology, as it is "easily translatable to consumers."

Low-calorie sweeteners (LCS) have been recurring subjects of controversy ever since saccharine's initial discovery in the late 19th century, said Mattes. More recently, in the "sweetener heyday" of the 1980s, controversy swirled around top-line study claims that suggested LCS were associated with weight gain or long-term weight management. Such were the claims that made news headlines.

Closer critical review of the data indicated that aspartame did indeed benefit consumer weight management, when it was substituted for other energy sources—but this did not lead to resolution of the matter. Many subsequent trials continued to raise concerns but without clear supporting data. In study after study cited in Mattes' presentation, initial top-line conclusions and media headlines ended up being contradicted by either closer examination of the studies' own data or by subsequent studies.

Today, the use of low-calorie sweeteners in the food supply has increased dramatically, coincident with increases in body mass indices (BMI) and claims that the two trends are causally linked. This has not been substantiated, but three new scientific developments have further contributed to debates on LCSs and health in recent years:

1) Elucidation of the gastrointestinal biome's roll in energy management;

2) documentation of sweeteners' effects on dopamine-mediated "reward" mechanisms in the brain; and

3) the discovery of sweet-taste receptors in the gastrointestinal tract and other organs, such as the pancreas and the brain.

The discovery that sweeteners affect reward centers in the brain led to hypotheses that sweeteners render foods "hyperpalatable," triggering reward systems in the brain similar to addictive drugs.

Mattes, after pointing out that overall per-capita sweetener consumption is down in the U.S., decried the use of terms (such as hyperpalatable). When people are hungry, all foods trigger reward signals in the brain, said Mattes.

In order for any material to be addictive, "There has to be an active component," Mattes continued. No such components have been identified in foods. Also, even if one applies criteria for "food addictions" to the population at large, it hardly accounts for the growing prevalence of obesity in the population. Even the term addiction is misused in reference to food: "Dopamine responses to addictive drugs are at least an order of magnitude larger than anything observed with any food-related response," said Mattes.

Mattes cited research purporting to document links between dietary sweeteners, gastrointestinal microflora, obesity and diabetes. Citing two foundational rodent studies for this theory, he once again noted that closer examination of the data refuted the authors' conclusions.

Many of the rodent studies cited involved low-calorie sweetener doses (e.g., aspartame) far in excess of an equivalent human Acceptable Daily Intake (ADI). These studies yield contradictory or insignificant results.

"Whether data like this can translate into anything of practical importance is highly suspect," concluded Mattes. He forensically dispensed with studies postulating that low-calorie sweeteners somehow corrupt brain and appetite "signaling" via alteration of entero-endocrine peptides and receptors. After citing the "intrinsic problems" in using rat models to evaluate human sweet taste perception and energy metabolism (e.g., rats metabolize carbohydrates into fat far more efficiently that humans), Mattes added that "there is no compelling evidence from human studies of any effect of low-calorie sweeteners on entero-endocrine cells."

"Where do we stand now?" asked Mattes. "We know low-calorie sweeteners do affect brain reward mechanisms, but it is not possible to link them to body mass increases. Meanwhile, meta-analyses of epidemiological studies do appear to link low-calorie sweetener consumption to body mass but in a beneficial—rather than problematic—way."

To those involved in selling low-calorie sweeteners, Mattes offered: "The science supports a beneficial role when used properly. LCS can provide a function tool to manage energy intake and body weight."

"Low-calorie Sweeteners and Health: New Developments and Reality Checks," Richard Mattes, MPH, Ph.D., RD, Distinguished Professor of Nutritional Science at Purdue University, Affiliated Scientist at Monell Chemical Senses Center, mattes@purdue.edu

How High-potency Sweeteners Work and What to Do about It

Food scientists have available to them a range of high-potency sweeteners, but are they being used effectively? Maximizing the potential of these ingredients in foods and beverages is of paramount importance to product development. John Fry, Ph.D., of UK-based Connect Consulting, explained, however, that "rather than emphasize how these sweeteners work, I spend a great deal of time talking about how they don't work and offering remedies." To know how to do this, one needs first to understand the physiology of sweetness receptors.

Sweet taste receptors in the mouth are complex protein structures crossing the cell walls of sweet-sensing taste cells. The taste cells are contained within taste buds, distributed in the papillae of the tongue. The buds communicate with the exterior saliva via a taste "pore," within which are tiny projections of the taste cells, called microvilli. The receptor proteins are on the microvilli and comprise four zones:

1) A "Venus fly trap" structure outside the taste cell and in contact with saliva;

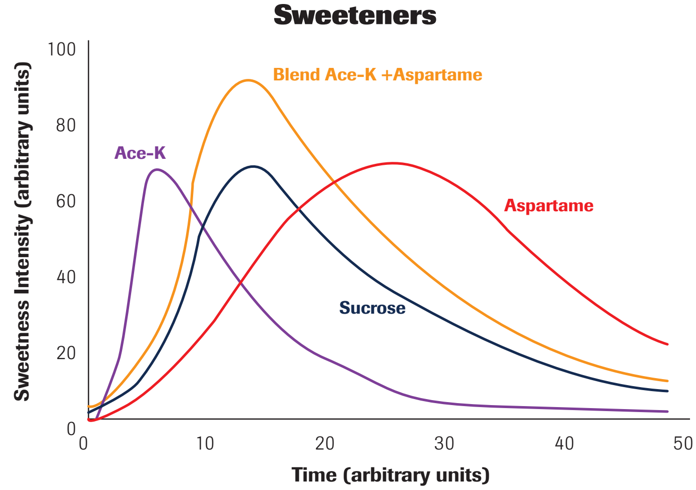
2) an external, cysteine-rich protein chain connecting the Venus fly trap to:

3) a transmembrane zone of seven helical strands of protein, terminating in:

4) an intracellular protein thread that interacts with the taste cell contents and triggers a complex series of biochemical reactions, culminating in a nerve signal to the brain that signifies "sweet."

One of the most successful high-potency sweeteners used by food and beverage manufacturers is a combination of fast-taste onset acesulfame-K (AceK) with the more slow-onset aspartame. Together, they more closely mimic the taste profile of sucrose and exhibit synergistic taste intensity.

Synergies of Low-intensity/High-potency Sweeteners



SOURCE: JOHN FRY, CONNECT CONSULTING; 2016 SWEETENER SYSTEMS CONFERENCE

The primary route for humans to sense sweetness requires two such receptors, T1R2 and T1R3, intertwined. This arrangement affords multiple points where the proteins can interact with the wide variety of substances we experience as sweet. A given high-potency sweetener generally interacts with only one or two such sites on the receptor complex.

There is, in addition, a secondary mechanism by which humans can also detect the sweetness of certain sugars, but this route does not respond to high-potency sweeteners.

Another aspect of so-called "high-intensity" sweeteners, continued Fry, is that they are actually "low-intensity." Few can achieve even 10% sucrose equivalent (the approximate sweetness intensity of many fruit juices and soft drinks) on their own.

In contrast, sucrose itself can deliver much higher sweetness intensities. "This is why I prefer to refer to them as 'high-potency,' rather than high-intensity sweeteners," Fry averred. Providing an example of a typical response curve, Fry indicated the maximum sweetening effect of Rebaudioside A (Reb A) occurs at about 5-800ppm concentration and exhibits a sweetness level roughly equivalent to an 8% sucrose solution.

All high-potency sweeteners have similarly shaped concentration-response curves that plateau at some relatively low sweetness intensity. Continued Fry, "So, if you double the concentration of a high-potency sweetener, you do not get double the sweetness. In contrast, sucrose has a linear response of sweetness to concentration."

In addition, different high-potency sweeteners have different time-intensity relationships that can affect their taste profile. Fry noted that combining acesulfame-K (AceK), which exhibits a quick onset and rapid drop-off of sweetness, with slow-onset, more-lingering aspartame, more closely mimics the sweetness profile of sucrose. This relationship is also "quantitatively synergistic." That is, the combined sweetness from these two sweeteners exceeds that which would have been predicted based on the properties of each sweetener alone. (See chart "Synergies of Low-intensity/High-potency Sweeteners.")

"This suggests that we can get synergistic enhancements of sweetness by combining high-potency sweeteners that react at different parts of the receptor structures," concluded Fry. Nevertheless, while none of the available high-potency sweeteners alone generates sweetness intensities greater than that of about 15% sucrose solution, synergistic effects between different molecules also disappear around this level. Despite the fact that synergism will not furnish true high intensities, the effect is much used to maximize the effectiveness and taste quality of zero-calorie sweeteners in foods and beverages.

As Fry explained, use of high-potency sweeteners at levels approaching their sweetness plateau is a costly waste. In addition, at these elevated concentrations, many sweeteners exhibit intrinsic off-tastes (e.g., a bitter-metallic taste for saccharin). Blends allow product developers to keep individual sweeteners below the thresholds for off-taste development, while achieving quantitative synergies and, thus, minimizing cost.

Fry addressed other factors that can enhance the effectiveness of high-potency sweeteners, particularly in relation to typical issues of slow onset and lingering sweetness. Citing the "non-specific binding" hypothesis, he noted that increasing the osmotic pressure of food and beverage systems "compresses the time-intensity profiles of sweeteners," thus speeding onset and reducing linger to produce more sucrose-like taste dynamics with almost any high-potency sweetener.

Hydrocolloids, sometimes used to remedy mouthfeel losses when sugars are removed, can also benefit the dynamics of sweetness perception by reducing the impact of non-specific binding. However, "perhaps the ultimate solution to the different taste qualities of high-potency sweeteners is not to use them at all," suggested Fry. He pointed to a relatively new category of compounds, known as positive allosteric modulators (PAMs), that have no sweetness or flavor of their own but can greatly enhance the sweetness intensity of conventional sweeteners, such as sucrose. Reduced-sugar formulations could thus be made that still deliver full sweetness and with all the taste qualities of the original sugar.

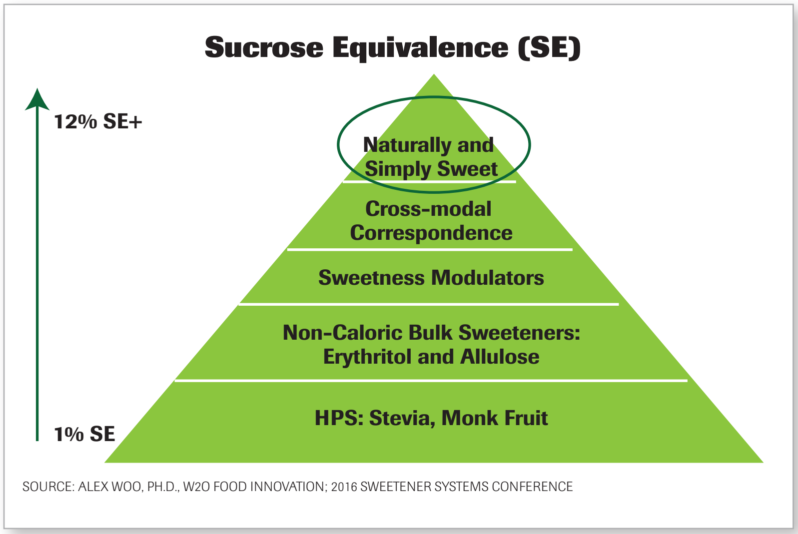
"How High-potency Sweeteners Work and What to Do about It," John Fry, Ph.D., Director, Connect Consulting, j.fry@connectco.biz

Simply Sweet: Updates on How to Make Foods and Beverages Sweeter with Sight, Smell, Sound and Touch

"How do you make food and beverages sweet without using sugar?" asked Alex Woo, Ph.D., CEO and Founder of W2O Food Innovation. Answering his own question, he continued, "You can do this by combining a basic understanding of neuroscience and ingredient technology."

Woo began his presentation by expanding upon conventional concepts of "flavor," setting the stage whereby to show how to systematically achieve a 12% sucrose-level of sweetness typically associated with carbonated, sugared beverages. He proposed a pyramidal approach to using low- or no-calorie sweetener alternatives.

First, said Woo, flavor is not just about the five primary tastes. "Flavor is also 80-90% influenced by smell in the nose." Touch receptors in the mouth let us distinguish between grainy, creamy or crunchy foods. Sound has been labeled "the forgotten flavor



Working up the pyramid of ingredient and sensory modalities allows one to achieve a 12% sucrose-equivalence (SE) in food or beverage products using high-potency sweeteners (HPS). A 12% SE is similar to that of conventional, sucrose-sweetened carbonated beverages.

sense" by one academic researcher. "So, when we are talking about flavor in foods, we are really talking about the full integration of all five senses…smell, taste, sight, touch and hearing." Each of these senses is called a "modality."

Woo briefly summarized the different taste receptors in the mouth. "We are hard-wired to make no mistakes in detecting primary tastes, in large part, for survival reasons." Signals from different taste and other receptors are integrated into perceived flavors by the brain.

In order to remove sugar from a product while protecting its sweet taste perception, Woo proposed "a methodology similar to stacking layers onto a pyramid in order to achieved the desired sweet taste intensity."

First, there is a foundational layer comprising a high-potency, plant-based sweetener (HPS), such as stevia. If the stevia is stacked with monk fruit (not yet approved in the EU) in a 2:1 ratio (200-100ppm), this achieves about 6% sucrose equivalence (SE) in sweetness. This is equivalent to about a 50% sucrose reduction for most beverages in the market, said Woo.

The next step is to add a bulk non- or low-caloric sweetener, such as erythritol or allulose, to boost the sweetness by an additional 2% to approximately 8% SE. "Less is more," counseled Woo. You want to add just enough of each sweetener to maximize its sweetness effect without contributing off-flavors. In addition, there are the time-intensity curves to be considered, as addressed by John Fry, Connect Consulting, in his presentation.

The next step on the pyramid relies upon "cross-modal correspondence." This refers to the integration of multiple signals from all five senses in the brain.

Of these, the most important is smell. "We have about 400 smell receptors in the nose that can detect up to 1 trillion different odors" which interact with taste to create flavors. Phantom flavors are those that operate below their own taste detection level but serve to enhance the sweetness of sweeteners. Congruent flavors are aroma molecules above the detection level that are typically associated with sweetness. These include sugar, honey or molasses distillates, tomato aroma, tea distillates or vanilla aroma.

Combined, this achieves about 10% SE. But for carbonated diet beverages, one will need a 12% SE. This requires "cross-modal modulation," involving the interplay between the other sensory modalities.

Touch, including temperature sensations and carbonation (a pain agent), can mute differences between different artificial, high-potency sweeteners, making them more like sucrose. Lower temperatures make stevia more potent, while higher temperature increases sweetness perception in chocolate.

Sight: shape (roundness) is associated with sweetness. Symmetrical and minimal features serve to enhance sweetness perceptions by 10-30% (in chocolates, for example). Such associations also exist in nature, where round fruits are associated with sweetness. The color red is also associated with sweetness. Woo noted that both Coke and Pepsi's carbonated beverages emphasize round shapes and red colors in their packaging.

Sound has been easy to overlook, but there is considerable documentation linking it to sweetness perception. High-pitched music has been associated with increased sweetness, whereas low-pitched music suggests increased bitterness.

Combined, this pyramidal combination of ingredients based on neuroscience serves to attain the 12% SE target for sweetness.

"Simply Sweet: Updates on How to Make Foods and Beverages Sweeter with Sight, Smell, Sound and Touch," Alex Woo, Ph.D., CEO and Founder of W2O Food Innovation, Alex.Woo123@gmail.com

The Science Behind Sugar Reduction: Ingredient Functionality Beyond Taste

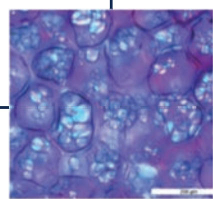
What if the development or reformulation of a product was entirely predictable? What if it was a process informed by science, rather than "gut feel"—allowing consistency and quality to be controlled on a global scale, regardless of differences in processing, packaging or the ingredient supply chain?

This was the objective sought by Leatherhead Food Research (UK) Professor Kathy Groves, Head of Science and Microscopy.

How do you make a blueprint?

Ingredient functionality
Foam or emulsion interface
Thickening, gelling
Water binding
Are they friends?

Texture
Instrumental measure, fracture mechanics
Viscosity & rheology (solidness) with shear
Complex texture and flavor (sensory)



Chemistry
Nutrition
Stability
Flavor

Structure
Complexity of structure
Location of ingredients
State of ingredients

SOURCE: KATHY GROVES, LEATHERHEAD FOOD RESEARCH; 2016 SWEETENER SYSTEMS CONFERENCE

Product blueprints provide historical R&D and quality checklists for addressing formula, quality and process adjustments. Up-front investments in product blueprint development are also cost-effective in the long run, especially for products with high-volume sales and strong brand equity.

"If you want to reduce sugar in foods and—this is important—make high-quality products anywhere in the world, then you need to have a proper blueprint of your products," said Groves.

"Blueprint" refers to a technical map that tells a product developer or food scientist how a product is affected when specific parameters are changed: the effect of formula or process changes on product state, process, structure, texture and sensory properties, for example. While acknowledging that developing such a blueprint is not an easy proposition without access to the relevant technical skillsets, "not doing so for a product (with mass market appeal) can create significant inefficiencies in your product development process. The cost of not doing a blueprint far outweighs the cost of doing one," said Groves.

How does one begin to develop such a blueprint? Begin by laying out the various parameters that define product performance and quality attributes, such as texture, chemistry, nutritional ingredient functionality and nutritional value, to cite a few examples. Each parameter is, in turn, defined by a list of specific attributes or other variables, such as "foam or emulsion interface" under ingredient functionality, or "viscosity and rheology" under texture. Such a blueprint provides a checklist for product and process developers whereby to address product-related issues in a systematic manner.

To demonstrate the concept, Groves provided the example of a biscuit's (i.e., cookie) microstructure and its relationship to texture and other quality parameters. She began by showing a crumb structure as seen under a conventional stereomicroscope, emphasizing that the observable crumb structure has "everything to do with your experience when you eat it."

If one cuts a thin slice through the crumb, one observes "a matrix of starch, protein, sugar and fat throughout the crumb structure." Transmitted cross-polarized light through the slice causes anything with ordered crystallinity (e.g., sugar, fat) to appear white and, when stained, the matrix becomes much clearer, further distinguishing the positions of starches and proteins in the matrix.

The next step is to zoom into the structure with a scanning electron microscope. Air gaps become evident, which affect the fracture mechanics "when one bites into the product," said Groves. Changing the type of detector in the electron microscope brings out the (white) fat in the image. Fat distribution can affect taste perception–i.e., a creamy mouthfeel associated with fat particles that are broadly distributed over the crumb surface. Such microstructure data can then be linked with other techniques, such as texture or audio analyses, to determine chewing properties or brittleness, in order to further enhance the blueprint.

What happens to the product blueprint if we replace sugar in the biscuit with a typically used alternative bulk sweetener? Whereas the sugar formula exhibits evenly distributed sugar, fat, starch and protein, these fat, protein and starch interactions are very different in the biscuit crumb with the alternative bulk sweetener. Also, the structure (viewed under a scanning electron microscope) appears very uneven; large gaps and major differences in fat distribution were evident.

"All these observed differences contribute to very different eating sensations," said Groves. Texture analysis reveals that the sugar formula results in a harder biscuit than with the alternative bulk sweetener product.

It is clear that removing sugar has enormous implications for a biscuit's microstructure, which in turn has implications for texture, flavor and shelflife. Developing a blueprint for a product's ingredient function, chemistry, nutritional value, texture and other values provides a map for product formula and process adjustment, or new product development.

"Once you start doing this, it gets better, it gets easier, you become more informed—and you can extend that accumulated knowledge to other product applications," concluded Groves.

The Science Behind Sugar Reduction: Ingredient Functionality Beyond Taste," Prof. Kathy Groves, Head of Science & Microscopy and Consultant, Leatherhead Food Research, Kathy.Groves@LeatherheadFood.com

Emerging Research in Aromas and Sweetness Enhancement

The presentation by Thomas Colquhoun, Ph.D., Plant Biologist at the University of Florida (Gainesville), built further on the concept of multi-modal sweetness perceptions developed by previous speakers. The focus was on the potential role of volatiles and, perhaps also color and shape, on sweetness perception.

"I run a plant biotech lab that is affiliated with the UF/IFAS Plant Innovation Center, for which the overarching goal is to better people's lives through better plant products," explained Colquhoun. "We do this by enhancing the aesthetic appeal of plants; increasing flavor and nutritional value; and delivering plant products that consumers actually want."

Colquhoun explained the process used:

"The first step is to test and quantify consumer expectations and perceptions using methods referred to as 'psychophysics.' We try to understand what people's perceptions are of plant products, from taste and flavor to emotion and perceived importance."

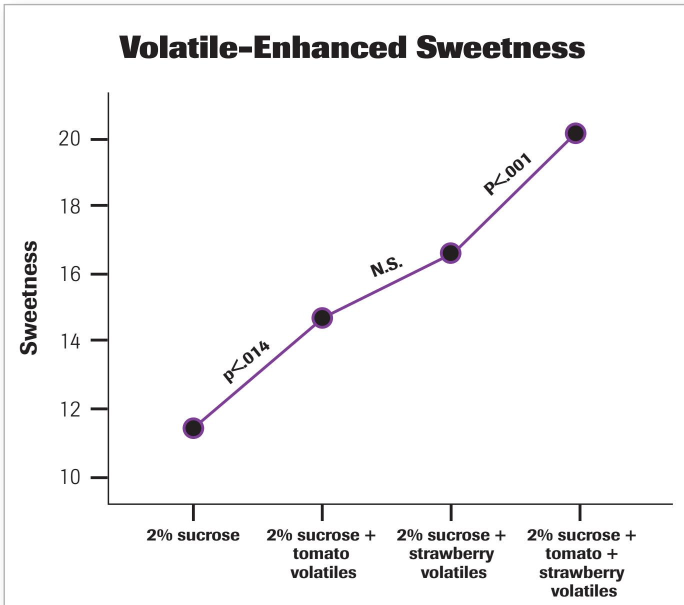
Second, the germplasms of various plants are screened for biochemicals and physical attributes linked to specific, consumer-identified desirability traits. "We link molecular biology, biochemistry and psychophysics," said Colquhoun.

Finally, once the specific plant genes associated with desirable traits are identified, breeding programs are developed to imbed the desired characteristics into the targeted plants.

The laboratory's first application of these methods identified that "sweetness" was the most desirable trait that consumers identified with strawberries. The next step was to categorize all available strawberry germ plasms by their respective combinations of sugars, acids and volatiles (although, Colquhoun noted, geography and growing conditions can also affect these variables within specific cultivars). Sensory analysis, using the psychophysics process, was then used to identify the optimum combinations of these metabolites that consumers associated with sweetness.

"Going through this process, we stumbled upon the phenomenon of 'volatile-enhanced taste,'" observed Colquhoun.

"We identified volatiles that significantly contribute to the perception of sweetness without the presence of sugar on the tongue." This required the use of highly sophisticated and very expensive equipment, such as the laboratory's triple-quad mass spectrophotometer, because when dealing with "human psychophysics data," there is so much variation in the sensory data that it is necessary to obtain the highest resolution available at the biochemical level. Even minute variations in biochemical data may be correlated to specific taste and flavor perceptions. In time, the scientists developed a relational model that was sufficiently and consistently sensitive to be applicable to different fruits across different harvest conditions.



SOURCE: THOMAS COLQUHOUN, PH.D., UNIVERSITY OF FLORIDA; 2016 SWEETENER SYSTEMS CONFERENCE

Additions of tomato and strawberry volatiles associated with sweetness to their respective fruits to 2% sucrose solutions incrementally increased the perceived sweetness of the sucrose solutions by as much as 75%.

"When we applied a hierarchical cluster analysis to strawberries, tomatoes and blueberries, something very interesting popped out," said Colquhoun. All three of these fruits' consumer profiles clustered out according to perceived sweetness; but, when clustered on the basis of their chemistry, they grouped out on the basis of their fruit identity. Thus, an important discrepancy was identified between the fruits' basic chemical compositions and their perceived sweetness.

The question of "why?" necessitated building complex, multivariate models capable of associating specific and minute metabolite concentrations to specific sensory attributes. The researchers found there were specific metabolites associated with "sweet" taste; and others associated with salty and bitter tastes, as well as "overall liking" and "overall fruit flavor" perceptions. Most compelling were the following two responses linked to sweetness:

1) The overall sweetness perceptions for blueberries were considerably lower than those for strawberries, at a fixed sugar content; i.e., it required a 2-3-fold higher sugar content in

blueberries to match the perceived sweetness of strawberries. This result appears to support data, presented in an earlier presentation by Alex Woo, Ph.D., of W2O Food Innovation, indicating that red colors strongly evoke sweetness perceptions in foods and beverages.

2) Adding specific volatiles gleaned from strawberries and tomatoes to a 2% sucrose solution incrementally increased the sweetness perceptions of the sucrose solutions by 25-75%.

In conclusion, the roles of volatiles in modulating perceptions of sweetness are very real and substantial, as are the challenges of manipulating and measuring the presence of the same volatiles in the fruit. Thus, even tiny changes can offer enormous payoffs.

"Emerging Research in Aromas and Sweetness Enhancement," Thomas Colquhoun, Assistant Professor, Plant Biotechnology, University of Florida, ucntcme1@ufl.edu

Consumers believe they focus more on nutrition and performance than they do on flavor. "However, the perceived flavor of the product is more important than the low-sugar claim," Dornblaser said.

KEYNOTE SPEAKER: Understanding Consumer Reaction to Sweetened New Products

The way consumers perceive sweetness can be said to be a "good news, bad news" type of situation.

The bad news: Rising obesity has placed a spotlight on sweeteners, and 70% of consumers are concerned about how sugar impacts their health. The WHO has urged a tax increase on sugary drinks to reduce consumption, and bloggers, celebrities and media outlets have painted HFCS as "the devil."

However, backed by Mintel's market research, which includes gathering the opinions of 30,000 consumers each month and tracking consumer spending in 3,000 markets across 34 countries, Lynn Dornblaser, Director of Innovation & Insight at Mintel, has good news to report. Taste and value still drive the consumer mindset; a healthy percentage of people are willing to pay a premium for natural sweeteners like stevia; and, in short, consumers still care about indulgence.

"Even consumers who are looking for healthfulness and sugar restriction aren't eating that way 100% of the time," Dornblaser said. "The good news is there's room for everything in the marketplace."

New product introductions that make low- or reduced-sugar claims are on the rise since 2012, "and at a faster pace than new product introductions in general," according to Mintel data. In the "snacks/cereal/energy bars" category, consumers consider low-sugar options as "unique" and "premium," but are less likely to purchase them—because they aren't considered "good value" or "tasty."

"When you dig down, it's not about the sugar," Dornblaser said. Many of the products are from smaller companies, and consumer trust tends to be higher with bigger brands. Old Orchard's Cran-Naturals Cranberry Apple Juice got a 57% purchase intent score compared to the 17% for Saluu's "exciting" and "innovative" *Aloe vera* drink.

Consumers believe they focus more on nutrition and performance than they do on flavor. "However, the perceived flavor of the product is more important than the low-sugar claim," Dornblaser said.

In terms of HFCS, half of consumers say they avoid it, according to Mintel, which may explain the recent drop in new product introductions with HFCS. Bakery products are still the biggest segment for HFCS; when Mintel dug deeper into cookies, they found consumers prefer cookies with this sweetener because of taste and value. However, cookies with an HFCS-free claim on the pack consistently score better than cookies without HFCS, simply because of perception.

"The point I took away from this data is HFCS doesn't especially impact purchase intent, but if you're going to take it out—tell people, because it makes a difference," she asserted.

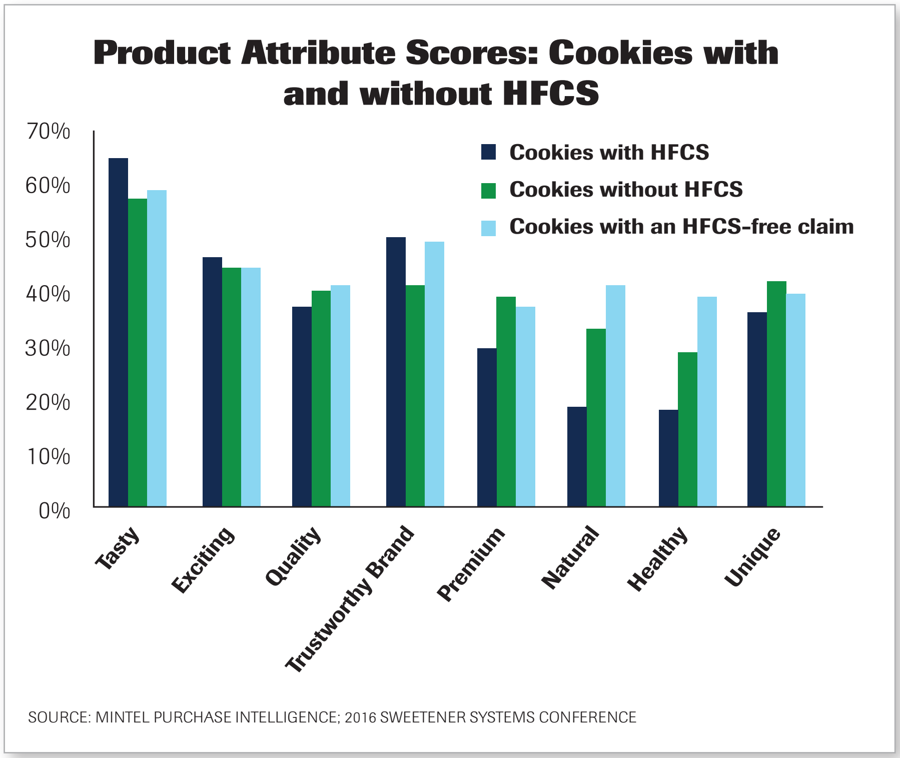
This is likewise true for clean label claims, like "natural" and "organic." Some 43% of internet users say they research sweeteners before using them, and 61% want more natural sugar substitutes, according to Lightspeed GMI and Mintel. However, 65% are confused about which substitutes are natural.

The confusion doesn't stop there. Some 36% of U.S. consumers have cut out certain foods or ingredients they think they shouldn't consume, compared to the 53% who worry about potentially harmful ingredients in food they buy.

"Consumers have been taught that certain things—artificial colors, artificial flavors, HFCS—are in foods and they shouldn't be consuming them—even though companies are still putting them in," Dornblaser said.

The majority agree that "the fewer ingredients, the healthier it is" and want more transparency—especially Millennials. A full 25% of Millennials and iGeneration are willing to pay a premium for natural sweeteners such as stevia. New product introductions with stevia have shown rapid growth in the U.S. over the past four years—particularly in beverages and yogurt. It's been especially effective in the juice drinks segment, Dornblaser noted, as consumer perception scored higher with stevia across the board.

Consumers aren't buying products simply because of a low-sugar or no-HFCS claim. It needs to have something else going for it—notably good value, taste or a clean label positioning. "Tailor your approach, and sweetener, to your purpose," Dornblaser added.



Consumers trust and like the taste of cookies with HFCS, leading to a high purchase intent score. Those with an HFCS-free claim are more likely to do better than HFCS-free formulations—simply because of the perception of HFCS.

"Understanding Consumers Perceptions to Sweetened New Products," Lynn Dornblaser, Director of Innovation & Insight, Mintel, lynnd@mintel.com

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Additional Resources

2017 Sweetener Systems Conference

Due to the success of its 2016 Sweetener Systems Conference, Global Food Forums will hold its 2017 Sweetener Systems Conference on November 7th, at the Westin Hotel, Lombard, Illinois, USA. (Near O'Hare International Airport). For more information on table top exhibits and sponsorships, please contact Peter Havens at Peter@GlobalFoodForums.com or 630-621-0230.

Go to www.globalfoodforums.com/sweetenersystems for links to past and future Sweetener Systems Conferences.

Other Global Food Forums Events:

Clean Label Conference

See www.globalfoodforums.com/clean-label for links to past and future events.

Protein Trends & Technologies Seminar

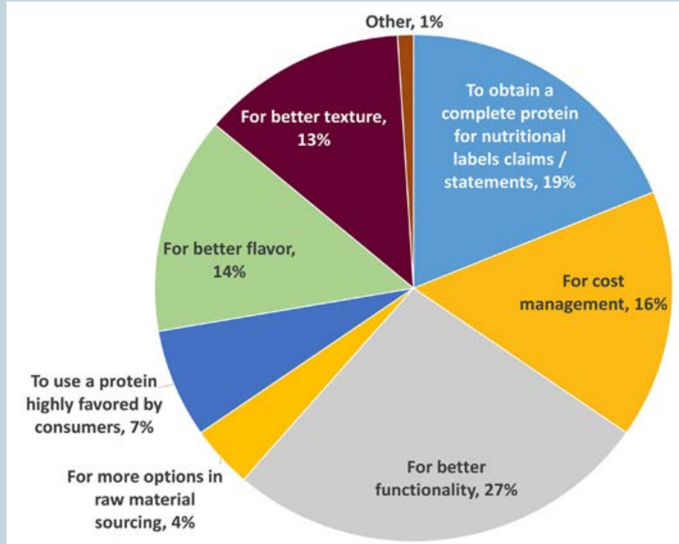
See www.globalfoodforums.com/proteinseminar for links to past and future events.

For all these events, Global Food Forums publishes complimentary downloadable copies of post-conference summaries, as well as copies of presentations, as permitted by speakers. For links to this information, go to the "Store" tab for each archived event as found above or go to www.globalfoodforums.com/store.

New! R&D Report on Protein Ingredients

The new *Global Food Forums® 2017 R&D Report: Protein Ingredients*, conducted by NSM Research, Inc., provides strategic analysis and actionable data on the difficult-to-obtain key drivers of protein ingredient selection. Using Global Food Forums' contact database, 200 food, beverage and nutritional product formulators were asked for their opinions on current and future protein ingredient uses and needs.

For example, when respondents currently formulating health bars, infant formulas or dietary supplements were asked why they



Source: Global Food Forums R&D Report: Protein Ingredients

blended proteins, all mentioned nutritional reasons, but none said "for better flavor." Just some of the other subjects delved into include:

- Which health trends will influence protein ingredient selection?
- Which protein categories will experience the greatest growth?
- What protein characteristics and functions are considered most important?
- How important are traceability, organic, non-GMO and local sourcing among other characteristics and certifications?
- How does R&D rank the value of various supplier services?

For more information, go to www.globalfoodforums.com/PIR or contact Peter Havens, Peter@globalfoodforums.com, 630-621-0230, or scan the QR code.

Source: Global Food Forums®, Inc.

Website Traffic

www.GlobalFoodForums.com averaged 1,198 views per day in January 2017, up from an average of 932 views per day in 2016. "We're expecting continued robust growth this year for several reasons," says Claudia O'Donnell, Co-owner, Global Food Forums. "Most importantly, we will be spending more resources on useful content for the product development community." Look forward to good things to come!

2017 Sweetener Systems Conference
November 7, 2017
Westin, Lombard, IL. USA

MAIL OR FAX REGISTRATION TO:
Global Food Forums, Inc.
P.O. Box 1421, Saint Charles, IL., 60174
FAX: 1-208-246-2242

NOTE: Online registrations can be made at:
www.GlobalFoodForums.com/2017-Sweetener-Systems

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REGISTRATION & FEES (fees effective until expiration of Super Early Bird Discount on September 1, 2017)

☐ **Food & Beverage Manufacturer-$695.00** ☐ **Ingredient/Services Supplier-$795.00**

Attendees will receive a registration receipt confirmation email. Please contact Jenny for registration questions at Jenny@globalfoodforums.com or 1-800-799-9671.****A $20.00 processing fee will be added to all credit card transactions.**
Registration includes receptions on Monday, November 6th (6:00-7:30 p.m.) and Tuesday, November 7th (5:00-6:30 p.m.), all general sessions, meals, networking events and an attendee bag and binder.

I plan on attending: ☐ **Monday Night Reception** ☐ **Tuesday Night Reception**

Official Hotel-Westin Lombard, 70 Yorktown Shopping Center, Lombard, Illinois, 60148 USA. www.westinlombard.com A limited number of discounted rooms have been reserved at $145.00, plus tax, for Monday evening, November 6, 2017. For hotel reservations call 1-888-627-9031 and mention the **2017 Sweetener Systems Conference** or visit www.GlobalFoodForums.com/2017-Sweetener-Systems (Registration & Fees tab). The cut-off date for discounted room reservations is October 23, 2017. **Cancellation & Substitution Policy-**Cancellations must be received in writing. For refund details or to update your reservation details visit www.GlobalFoodForums.com/2017-Sweetener-Systems. Alternative parties may be substituted at any time without penalty.

New 2017 R&D Report: Protein Ingredients

New market research conducted by NSM Research, Inc. surveys R&D and food application formulators on their attitudes, formulation issues and future trends, as related to their use of protein ingredients. This 87 page *Global Food Forums® R&D Report: Protein Ingredients* is now available. For more information go to: http://goo.gl/WEJ4KQ or contact Jenny Stricker at Jenny@GlobalFoodForums.com or +1.800.799.9671 ext. 1.

PROTEIN TRENDS & TECHNOLOGIES SEMINAR

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