Executive Summary

- Formulating low-sodium products without losing flavor.
- Tools for replacing the functions of salt, beyond flavor.
- An ingredient-systems approach to lowering sodium.

Flavorful Sodium-Reduced Foods

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With the media continually reporting that Americans consume too much salt, keeping sodium content low is a priority for most food designers.

The science of salty

Sodium and salt are not the same. The ingredient commonly known as "salt" is sodium chloride with 39.34% sodium and 60.66% chloride on a molecular-weight basis.

Sodium is found naturally in many foods. In addition, prepared and processed foods often contain salt or other sodium-containing ingredients, such as the leavening agent sodium bicarbonate, also known as baking soda.

To reduce sodium in convenience foods consumers want and still keep them tasting good—the No. 1 criterion for purchase—food technologists must gain a better understanding of the basic taste of salty.

"Salty is one of the five basic tastes, which also include bitter, sour, sweet and umami," says Joseph Formanek, associate director, business development and application innovation, Ajinomoto Food Ingredients, Chicago. "Salty is one of the 'positive' taste attributes. Sweet and umami are the others. Bitter and sour are considered negative. The theory is that the body adapted to recognize foods in nature that are nutritious and beneficial, and such foods typically exhibit the positive taste attributes. Sour and bitter tastes are usually exhibited in foods that are poisonous, have perished or are not as nutritious as those with positive tastes."

However, the problem with defining saltiness, adds Mariano Gascon, vice president of research & develop-

ment, Wixon, Inc., St. Francis, WI, "is similar to the layman's attempt to define a specific color. The difference is that colors can be scientifically described by a particular wavelength, but such reference does not exist when it comes to taste. Thus, taste can be simplified as a chemical sense that is caused by chemical reactions, and we have established chemical reference substances that serve to demonstrate them.

"By this definition, saltiness is a demonstrable taste, and it is clear that table salt has been established as a chemical reference substance that serves to demonstrate saltiness," Gascon continues. "No other compound seems capable of identically duplicating the saltiness character of sodium chloride. This makes it very difficult to find a substitute that elicits the same taste characteristics. Though this is an oversimplification from the chemical point of view, from the psychological view, when certain substances are combined, they can create a 'new' taste in the same sense that mixing colors leads to a new shade of a known color. They are close, but not exact. This analogy helps explain the enhancing properties that salt has on other food flavors."

At the 2011 IFT Annual Meeting & Food Expo in New Orleans, Leslie Stein, senior research associate and director of science communications, Monell Chemical Senses Center, Philadelphia, gave a presentation entitled, "Foundations of Salt Perception to Build Your Research." She started out by saying, "Salt is a magic ingredient in food."

In the presentation, Stein confirmed what the food industry knows: "We still don't know how the salty taste works, but we are getting closer." And, to answer the question why humans like the salty taste, she said: "Because it tastes good! Humans evolved to like the taste of salt."

Meredith Bishop, principal development scientist, Spicetec Flavors & Seasonings, Omaha, NE, adds: "Early on, humans learned that salting foods preserved them by retarding spoilage and making the food last—and taste good. Scientists are just starting to learn how humans perceive sodium chloride on the tongue. We seem to have an innate response to salt—we just like the taste."

Two major types of taste receptors are associated with our taste buds. "There are the ion channels and the G-protein coupled receptors," Robert Pan, senior flavorist, Bell Flavors & Fragrances Inc., Northbrook, IL, explains.

"Salty and sour, which is also referred to as acid, are sensed via the ion channels. Bitter, sweet and umami are sensed via G-protein coupled receptors."

However, much remains to be learned about the ion channels. "We know that the ion channel for sodium is very specific," says Stein. "We also know a second, less-specific salt mechanism exists, which may account for several of the other taste attributes of salt, such as mouthfeel, body and enhanced flavor. But this mechanism remains unknown. We must identify this mechanism to help develop fully functional salt replacers or enhancers."

Potassium chloride comes closest to duplicating the saltiness character of sodium chloride, Gascon notes. But potassium chloride's saltiness is tasted more slowly, and also often has a hint of bitterness. "So the challenge of simulating saltiness by using potassium chloride can be achieved via taste modifiers," he says.

More than saltiness

What makes replacing or reducing sodium chloride extra challenging is that salt does so much more for flavor than give food a salty taste. "Studies show that salt accelerates the release of some flavor compounds and selectively filters some unpleasant tastes, such as bitterness and metallic notes," says Pan.

Barbara Zatto, executive chef and sales manager, West region, Mizkan Americas Inc., Mount Prospect, IL, explains: "We have learned that sodium can increase the volatility of certain chemical compounds, allowing them to release more easily and enhance the olfactory part of the flavor experience. Since salty is an intrinsic flavor on our tongues, the addition of salt to a food brings out this flavor. Further, salt aids in the ability to layer or support other flavors in food and allows the other ingredients to shine through."

In addition, sodium chloride makes many flavors taste brighter. "It makes them come alive in the mouth," Bishop says. Sodium also enhances mouthfeel and, in turn, the viscosity of a reduced-sodium food impacts the taste of salt.

Product viscosity also plays a role in sodium reduction in a soup, sauce or dressing. "Formulators must select the

right hydrocolloid or emulsifier system so that the salt taste is properly and effectively released," explains Mark Purpura, technical service manager, Advanced Food Systems Inc., Somerset, NJ. "In an overstabilized product, flavors are not properly released, and to achieve the right taste, more sodium is required. On the other hand, if a product is understabilized, it may not have enough viscosity to keep it in the mouth long enough for the tongue to detect or process the flavors."

A systems approach

In other words, to lower sodium content and keep a food tasting good, it takes an ingredient-systems approach.

"Simplifying the process, one would need a taste modifier that 'speeds up' the reaction time of potassium chloride's saltiness, another taste modifier that masks the bitterness and a third taste modifier that enhances the saltiness so it can be recognized more like salt," says Gascon. "As you can imagine, like mixing colors, the number of combinations is many, but only a few, or maybe even only one, can give the right salty taste to a specific application."

It's also not a one-system-fits-all process. For example, salt tastes differently on chips than it does in processed meat or a salad dressing, says Gascon. Wixon has developed sodium-reduction solutions "based on a mixture of salt, potassium chloride and a combination of taste modifiers," he says. "In the final application, the solution can look like salt, taste like salt and behave like salt, but with only 50% of the sodium. It works well as a direct replacement for sodium chloride in topical applications. In other applications, particularly those with complex matrices, such as a processed meat, or with high amounts of fat, such as salad dressing, sodium reduction becomes more complex, because salt can enhance or diminish certain tastes. Such applications require a more-customized solution of taste modifiers and potassium chloride."

Without a doubt, it is important to look at the whole product and end application when trying to reduce sodium content.

"We concentrate on enhancing the flavor of the food and making it taste better—not salty," says Bishop. "Part of our customized solution is a patent-pending, very fine salt that delivers the expected salty flavor to topical applications such as snack foods, but at a lower application rate."

Formanek says: "We have a system that fools the tongue into perceiving more salt than what is actually present. We deliver specific levels of the other tastes, which tricks the tongue into tasting salt without the sodium. The presence of a low level of umami is important to our sodium-reduction system. Of course, the use of monosodium glutamate (MSG), which contains one-third the sodium of salt, can deliver great flavor while still reducing sodium in a system. We also have nonsodium glutamates—monoammonium glutamate and monopotassium glutamate—that deliver umami without additional sodium."

Umami is a Japanese word for the savory taste of proteins that have been broken down into amino acids and nucleotides. Umami is plentiful in foods like cheese, meat, fish, tomatoes and virtually anything fermented, brewed or aged. Umami can amplify the perception of salt. The taste of umami can be enhanced through processing or cooking steps, such as caramelizing onions or cooking mushrooms, to free up the amino acids that provide umami.

"Our approach to improving the flavor of sodium-reduced foods is by applying natural umami," says Joe Leslie, national industrial sales and marketing manager, Midwest sales manager, Kikkoman Sales USA Inc., Oak Brook Terrace, IL. "Foods with lowered sodium content are usually perceived to have a bland or unbalanced flavor profile. Umami brings out the inherent flavor of food, including the salty taste.

"Approaching sodium reduction by the use of added umami allows food manufacturers to maintain, and even increase, the flavor intensity and flavor pleasantness of food while keeping sodium content significantly lower," Leslie adds. "We can typically reduce sodium 30% to 50% while maintaining equal flavor preference to the full-salt version of the food." Kikkoman has a line of natural flavor enhancers, derived from the fermentation of wheat and soybeans, that offers umami-rich amino acids. "They are neutral in color and flavor, and work well in combination with salt replacers, helping to mask any off-flavor notes," he says.

Umami can also come from a fermented-black-garlic flavor. "It enhances umami in savory applications, allowing for a reduction in sodium without reducing flavor," Pan says. "This is because the fermented-black-garlic flavor amplifies the entire flavor profile of an application. At the same time, it provides depth of flavors and improved mouthfeel. It will boost already-occurring umami notes in naturally high-glutamate foods."

In recent years, scientists have discovered what some believe is a sixth taste called *kokumi*. Others say it does not

actually have a taste. Rather, it enhances taste by triggering calcium receptors on the tongue.

"*Kokumi* is Japanese for 'heartiness' and includes the other five basic tastes, as well as feeling factors such as body and richness, to deliver a more complete flavor profile," says Formanek. "Certain fermentation-based ingredients contain peptide components that have been found to be involved in the *kokumi* response. When using these ingredients in savory applications, it is possible to eliminate additional sodium."

Replace or substitute

Without a doubt, partial sodium-chloride replacement with potassium chloride is the most-common approach to lowering sodium content. For many applications, other ingredients must be considered when using potassium chloride, such as the inclusion of flavors, herbs and minerals, or even alternative cooking processes, such as grilling and caramelizing. Some formulators have found that specialty sea salts are the solution.

"Technically, all salt is sea salt. Some salt comes from seas that existed thousands of years ago, and some is derived from living seas that exist today," says Bishop. "It's the location of the deposit or sea that determines the mineral content and amount of impurities. This is what gives unrefined sea salt its characteristic colors and flavors.

"Potassium chloride has long been used as a salt substitute, and some sea salt is naturally high in potassium," continues Bishop. "Use too much, though, and you may taste bitter off notes. Magnesium and sulfur are other important minerals present in some sea salts that may help enhance the flavors of food. Each food application is unique in the amount of sea salt that may be used to replace refined salt."

The problem with using sea salt for sodium replacement is that, by weight, sea salt and table salt contain roughly the same amount of sodium chloride—not enough difference to use as a 1:1 replacement. However, the sodium replacement concept with sea salt is based on the added flavor produced by higher mineral content, so less salt is used.

Many ingredients are available to assist in low-sodium product development, including flavors that can enhance savory notes in soups and sauces. "The sodium content of such high-salt foods can often be reduced when savory flavor notes are enhanced," says Judie Giebel, technical services representative, Briess Malt &

Ingredients Co., Chilton, WI. "Our roasted potato flour gives soups and sauces an umami-type flavor that clearly enhances palatability, enabling the reduction of salt. It is used in low percentages and is minimally processed, preserving the all-natural integrity of the potato."

Another line of salt replacers, blends of either refined salt or sea salt with potassium chloride and various flavors, "are designed for direct replacement of sodium chloride in a formulation and allow for a 50% reduction in added salt," Purpura says. "We also offer a line of salt substitutes that contain almost no added sodium. They are designed to be combined with salt." These salt substitutes are KCl-based, he says, and contain other ingredients, such as natural flavors, that help to bring out salty taste and minimize any off flavors, such as metallic or bitter notes. Both product lines deliver clean flavor and minimal bitterness, and can be used in a variety of applications.

Another option to reduce salt is the use of flavor enhancers. "Even though many flavor enhancers contain sodium, they can be used at very low levels to help increase flavor perception without adding a significant amount of sodium," notes Purpura. "For example, we offer cheese and savory flavor enhancers to help formulators reduce the amount of high-salt ingredients, such as cheese and hydrolyzed vegetable protein, without affecting the flavor."

Studies have shown that adding low concentrations of vinegar to foods may enhance the flavor of saltiness and allow food manufacturers to reduce sodium without affecting taste. "We offer a wide variety of vinegars, wine reductions, cooking wines, and natural vinegar and balsamic-vinegar powders," says Zatto. The all-natural vinegars and reductions are ideal for companies that seek clean-label ingredients. The vinegar powders can be used in dry seasonings or food-coating applications.

Mizkan featured a tangy traditional barbecue sauce with a more than 50% reduction in sodium at this year's IFT Expo. "Traditional grocery-store-branded sauces have an average of 240 mg of sodium per serving; the Mizkan barbecue sauce only had 105 mg," says Zatto. "This was accomplished by removing the kosher salt in the recipe and balancing the flavor through the addition of more apple-cider vinegar with the slight addition of more sugar. The sauce had a full flavor with half the sodium."

Other organic food-grade acids can also help increase the "sting" or the "bite" associated with the taste of salt. "They also help increase the longevity of perceiving the salt sensation," says Pan. "Increasing the amounts and types of seasonings and spices can also help lower the sodium in some applications. Some of my favorites are garlic and onion as sulfur spices, and bonito, mushroom, seaweed and tomato for umami notes."

Indeed, for centuries chefs and food technologists have added tomatoes to a wide variety of foods to enhance and improve flavor profiles. Food scientists at LycoRed, Beer Sheva, Israel, have been able to separate out and concentrate all the taste-enhancing components that exist naturally in tomatoes (which have umami and *kokumi* flavor characteristics, among which is free glutamic acid), liberating a natural flavor enhancer suitable for a wide range of applications. In many cases, the natural tomato concentrate can be used to enhance flavor and, thereby, reduce the amount of salt added to a product, as well as reduce the use of expensive flavorings, according to the company. Because it's a tomato-based product, LycoRed says food manufacturers can include it in a clean-label product.

"The current 'back-to-basics' trend encourages food manufacturers to minimize the number of ingredients, reduce sodium and avoid E-numbers in the European market, while making it as tasty as ever," says Ehud Zach, food applications manager, LycoRed. "The good news is that, in some cases, you can save up to 10% to 20% of product cost just by replacing expensive ingredients, while at the same time reducing sodium and enabling a clean label."

Sam Bernhardt, director of new food ingredients, LycoRed, adds, "At the same time, the ingredient can create cost-saving opportunities due to the reduction in traditional formulary ingredients, spices, artificial flavors or tomato paste."

A wide range of successful salt replacers that enhance taste are on the market or in development. But, ultimately, sodium-reduction technologies will typically impact the finished-product cost, given that salt is just about the least expensive ingredient used in food. Leslie says that any salt replacer or sodium-reduction tool has a negative economic impact on the end product. "There is no ingredient that can compete with the price of salt."

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