Once a flavorist develops a desirable flavor system, the flavor has to be delivered to the product developer—and ultimately to the consumer—in a form that can be incorporated into a food or beverage manufactured commercially. That is where the flavor-delivery specialist comes in. The flavor-delivery specialist uses a unique set of skills and tools—including encapsulation technologies, material science and physical chemistry, delivery systems and processes—as well as proprietary knowledge to meet specific flavor-delivery challenges. These technical challenges all start with and are critically dependent on flavor perception.

Basics of Flavor Perception
All foods, whether fast foods, home-cooked dishes, restaurant cuisine, or commercial products, are characterized by their flavor, that is a combination of flavor aromatics with taste or gustatory components. As a food is eaten, the receptor cells clustered in the taste buds and the neural sites in the olfactory epithelium generate a series of biochemical signals. These signals combine to ultimately yield organoleptic perception.

The flavor response is the combination of sensory stimuli integrating aromatic character (flavor compounds), gustatory components (sweet, sour, salty, bitter, umami), and chemical “heat,” along with the food’s physical properties of temperature and texture.

- **Aromatics** are specific multicomponent volatile chemicals that characterize a unique flavor. They stimulate the olfactory epithelium in the nasal cavity and send a complex set of signals to the brain, which it interprets as a specific flavor or flavors.
- **Taste components** are water-soluble compounds which stimulate receptor cells of the tongue taste buds.
The receptors are highly discrimina
tory, responding to specific molecular geometries that bind to the individual subcellular sites. The binding of sweet, bitter, and umami agents and the transport of cations through selective ion channels for salty (Na⁺) and sour (H⁺) agents initiate biochemical signal cascades that are ultimately interpreted by the brain as taste.

• **Chemical heat principals** generate the sensation of heat, or burning, as a result of chemical irritation or overstimulation of vanilloid receptors in the taste buds. The most common agents generating the chemical heat sensation are the capsicum compounds in pepper and the allylisothiocyanates present in horseradish, wasabi, and mustard.

• **Texture**—the physical characteristics of a food matrix as it is masticated to release flavors and tastes—is an important contributor to the total sensory process. Specific foods are associated with specific textures; e.g., crispy potato chips are preferred over soggy chips, thereby setting an expectation standard for this product.

• **Temperature** of the food plays a significant role during formation and volatilization of aromatics, which ultimately influence taste and flavor. Freshly baked bread has a distinctive and desirable aromatic character. Unfortunately, as the bread cools, the metastable flavor chemicals change and the bread rapidly loses its most desirable character. It is only in a bakery that a fresh-baked-bread aroma persists. Not surprisingly, many upscale supermarkets and fast-food retailers are now baking their breads in-house.

As the food industry delves further into the subcellular realm of flavor perception, research at universities and institutes such as the Monell Chemical Senses Center is expanding our understanding of the biochemical and biophysical domains of flavor perception. Progress in clarifying subcellular signal cascade pathways initiated by specific molecules continues with the expectation that knowledge of these pathways will further clarify sensory characteristics of flavor and taste.

Although the product developer does not have to be an expert in these newly emerging fields of taste perception and physiology, flavor suppliers continue to follow these emerging fields carefully to improve their ability to supply high-quality functional flavors to the product developer and ultimately the consumer.

**Flavor Development Pathway**
A product developer’s request to a flavor supplier usually addresses highly specific development needs. In starting a project to meet such requests, the flavorist must undertake a holistic approach to identify issues such as product attributes, process impacts, product stability, flavor attributes, flavor stability, off-flavor development, shelf life, and labeling constraints before developing a technical strategy. Then a delivery system for the specific flavor application can be identified, characterized,
Flavor Delivery and Product Development

developed, and integrated into the development process.

In most cases, the flavor house has experience in meeting customer product development needs. Many different skills and technical functions are required and applied to reach a successful technical solution. Figure 1 is an interactive flow diagram of the specialists, functions, and technical activities that are employed when a major flavor-delivery project is undertaken. The process is one of continuous feedback as individual specialists work in concert to meet identified objectives. In this diagram, the double lines indicate an immediate “feedback” loop between the functions. The single arrows (green ovals) signal input from a service function.

The functions and specialists indicated in Figure 1 are coordinated within a matrix environment. While the customer may only interface with the sensory and applications groups, many technical specialists contribute directly to the flavor-delivery objective.

Any flavor-delivery project starts with the flavorists. These individuals specialize in one of the general flavor categories, i.e., savory, fruit, beverage, sweet-brown, or reaction flavors. One or more flavorists are assigned to the project team to initially identify the required flavor characteristics. The flavorist utilizes a number of flavoring agents in preparing a specific flavor (Figure 2). These agents include pure flavor chemicals, essential oils, oil extracts, essences, reaction flavors, oleoresins, and flavor extracts. After a compounded or reaction flavor is prepared initially, it may undergo several reformulations or iterations to achieve optimum character.

Supporting the flavorists are analytical chemists with expertise in isolation and identification of flavor components. Use of a gas chromatograph/mass spectrometer olfactometry unit with a sniff port (Figure 3) can simultaneously identify the structure of the individual, unique flavor chemical and its sensory strength and character. This system works well for identifying natural flavor extracts and reaction flavors, as well as for identifying and matching competitors’ flavors. And synthetic chemists are sometimes required to synthesize and commercially manufacture specific flavor chemicals that are not readily available or are extremely expensive.

The flavor is then turned over to a flavor-delivery specialist, usually a self-trained chemist or chemical engineer, sometimes referred to as an encapsulation specialist. After determining the physicochemical characteristics of the system and the needed functional responses, the flavor is married to an appropriate delivery vehicle or encapsulation technology. Each flavor system undergoes a number of stressors as it passes from flavor creation to flavor delivery to ultimate product use. The flavor-delivery specialist must have adequate knowledge of the flavor, product application, and flavor-delivery vehicles to correctly marry the flavor to the proper delivery system. A good description of the issues and technical constraints in the delivery of active ingredients in foods is discussed by Ubbink and Kruger (2006). Their use of “retro-analysis” models formalizes many of the steps in the process of identifying the most suitable route for flavor delivery.

Encapsulation technologies most commonly employed for flavor delivery include spray drying, melt extrusion, melt injection, spray chilling, agglomeration, fat coating, complex coacervation, and cyclodextrin complexation (Madene et al., 2006; Gouin, 2004; Porzio, 2004; Gibbs et al., 1999; Risch and Reineccius, 1988). With each of these encapsulation technologies, proprietary operations are generally part of the specialist’s technology “tool kit.” A flavor-delivery specialist is usually skilled in the use of one or two of the encapsulation technologies. It is rare that one individual can master all of them equally skillfully.

Next, the flavor-delivery system is made available to the applications and sensory groups. The flavor is tested and evaluated in the product for response, stability, and sensory character because a flavor can change as a result of interaction with the food system or as the encapsulation or delivery process changes either the level or ratio of specific flavor agents. The sensory function can guide the applications staff, the flavorist, and the flavor-delivery specialist via targeted sensory methods selected to provide product development guidance. This evaluation process can require a number of iterations. If necessary, preliminary testing in the customer’s product and commercial systems can be undertaken on a parallel track to benchmark the flavor-delivery process while meeting project objectives and marketing deadlines.

The role of the flavorist may be paramount when a flavor-matching or product-improvement project is needed. Here, significant input by the analytical chemist may also be required to isolate and identify a flavor’s unusual chemical components. On the other hand, the customer and flavorist would not be involved if a new encapsulation technology is under development, in which case use of “stock” flavors is adequate to run experiments and test functionality.

Examples of Flavor-Delivery Systems

The food application requiring and utilizing the delivered flavor is the most critical variable in any flavor-delivery development project—it defines the flavor-delivery strategy. The following are a few selected examples of flavor-delivery systems that have successfully met unique product application needs.

- A dried herb ingredient that retains the color and flavor character of the fresh herb can be
prepared using a patented encapsulation process (Aung and Fulger, 1993, 1994, 1995). A fresh leafy herb is blanched in a highly osmotic carbohydrate solution to inactivate enzymes and partially dehydrate the herb in the syrup. Then excess syrup is removed and the coated tissue dried. The resulting dry tissue consists of a glassy carbohydrate coating that encapsulates the herb oil glands and releases the unique volatile flavor characteristics of the fresh herb upon rehydration.

• A fruit-flavored dry drink mix requires incorporating and stabilizing the volatile flavor chemical acetaldehyde as a “freshness” top-note. Encapsulation of free aldehyde is very difficult. Pure liquid acetaldehyde is not completely stable and is potentially explosive in the gaseous state during spray drying. A number of rapidly hydrolyzing acetaldehyde acetal derivatives were developed as an alternative stable form (DeSimmone, 1981). One of these derivatives, 1,2-di-(1´-ethoxy)ethoxy)propane, is available under the tradename Aldemax from Givaudan, Cincinnati, Ohio (www.givaudan.com). This poly-acetal is stable as a liquid at room temperature, can be encapsulated, and will rapidly hydrolyze in water at the acidic pH of a fruit drink to release free acetaldehyde. It is best stabilized in the form of a spray-dried powder for drink mixes. Alternatively, it can be used directly in liquid form in a non-aqueous compounded flavor system.

• An injectable flavor oil with controlled-release properties for application in marinades usually requires encapsulation in the form of a cross-linked complex coacervate that forms a membrane to surround and protect the lipid flavor droplet. A coacervate system composed of gelatin and gum arabic is the only one allowed by the Food and Drug Administration to be chemically cross-linked using glutaraldehyde. This cross-linking imparts structural integrity to the flavor droplet membrane and prevents the membrane from dissolving at process temperatures.

• A series of stable, flavored vinegars were needed to complement a product line of flavored oils. The only practical technical solution was formation of a solubilized flavor oil, i.e., an oil-in-vinegar microemulsion. This thermodynamically stable dispersion of oil nanoparticles was identified and generated by preparing a series of formulations consisting of vinegar, flavor oil, surfactant, and co-solubilizer (usually an alcohol or polyol) and choosing the microemulsion composition from the resulting phase diagram. The result was a pellucid, colored, flavored vinegar (Logan, 2000).

• Large particles of colored, encapsulated flavors that can be utilized in preparation of visually distinct inclusions in hard candies are best delivered by a melt-extruded, milled, sieved, glass-encapsulated flavor matrix. These extruded products are available as the FlavorCell® encapsulated flavor line of McCormick and Co., Hunt Valley, Md. (www.mccormickflavor.com). The selected glassy matrix will not “melt” during the candy-making process, thus retaining particle integrity and visual impact while protecting the encapsulated flavor (Popplewell et al., 1995; Porzio and Popplewell, 1997).

• A stable lemon-flavor powder for use in cake and pudding mixes can be delivered in the form of a complex of beta-cyclodextrin and lemon oil. This flavor-complex protects against terpene oxidation, the normal failure mode for citrus oils (Szente and Szejtli, 2004). The encapsulated lemon oil is said to be exceptionally stable to moisture, light, oxygen, and heat.

Future Needs in Flavor Delivery

A number of flavor-delivery needs are evident as industrial customers request additional flavor functionality for their products from the flavor suppliers.

• Thermally Stable Flavors. Encapsulated flavors that can withstand the thermal stresses of commercial processes such as retorting, aseptic processing, baking, extrusion, and frying while retaining their original flavor character are in continuing demand. The combinations of heat, moisture, and mechanical energy are very rigorous conditions that stress the encapsulated flavor during proces-
Flavor Delivery and Product Development

Many ingredients in complex food systems contribute "natural" flavor enhancement.

(ammomiated glycyrrhizin), vanilla extracts, and specific masking compounds such as 2,4-dihydroxybenzoic acid and the sodium salt of 2-(4-methoxyphenoxy)-propionic acid inhibit cellular signals in the masking of specific tastes.

Masking of bitter agents such as caffeine, polyphenolics, alkaloids, vitamins, nutraceuticals, and pharmaceutical actives remains a major continuing need in both the food and pharmaceutical industries. Roy (1997) discusses in detail a large number of compounds, agents (which can be mixtures, complexes, or unidentified actives), and extracts designed for specific bitter-masking applications. According to a review of the United States patent literature for specific masking agents, a single organization, Bio-Research Inc., Arlington, Va., has 30 patents covering a large number of chemical agents (“tastands”) for masking and flavor modification (USPTO, 2006).

Off-flavor notes in foods are often subjects for flavor masking. These include cereal off-notes, earthy notes (potato), metallic notes (leavening, vitamins), beany notes (soy), rancid notes (fats and oils), liver notes (warmed-over flavor in meat), metallic—bitter taste (potassium chloride), and artificial sweetener aftertaste. A novel, proprietary masking technology recently developed by McCormick & Co. is able to mask a wide variety of the off-flavors noted above in foods and nutraceuticals (Lawless, 2005). These novel agents are employed by the company as proprietary flavor keys and formulated into industrial products such as coatings, flavors, or seasonings. These maskers are not available otherwise.

• Flavor Enhancement. Many ingredients in complex food systems contribute “natural” flavor enhancement. Chefs and product developers have by trial and error identified unique combinations of ingredients that work synergistically to improve flavor character and taste. For example, tomato powder in a simple seasoning brings in significant levels of monosodium glutamate, sugars, acids, and fruity notes. Adding spray-dried cheese solids to the tomato powder yields a mixture that is the precursor for a more complex seasoning base.

As another example, adding low levels of vanilla extracts to flavors or flavor systems provides enhancing properties resulting from the presence of vanillin and other vanillloid species. Also, nucleotides such as MSG, hydrolyzed vegetable proteins, disodium guanylate, disodium inosinate, and autolyzed yeast extracts enhance the brothy and meaty notes in stews, gravies, and other savory flavor systems. Flavor-enhancing functionality can also be supplied by reaction flavors that augment and round out other complex flavor systems.

• Low-Fat Flavor Systems. The development of low- or reduced-fat foods requires improved flavor delivery and textural character. While fat-free salad dressings have had good consumer acceptance, other reduced-fat systems such as baked goods, confectionery, snacks, fried products, and spreads are not as acceptable as their full-fat counterparts.

Because flavors can partition into both the aqueous and lipid phases of a food, the presence of lipids both rounds and extends certain flavor character and delivery profiles. The discovery of the CD36 peptide fat-receptor site for fatty acids in rats and mice opens up another biochemical pathway to explain fat preference (Abumrad, 2005). It is assumed that humans have similar sensory receptors which will be isolated and identified shortly. The model of fatty acids as a taste-enhancing agent can be coupled with the observation that human lingual lipase may release fatty acids from triglycerides during mastication (Pederson et al., 2002). Combined, these two observations could lead to a new paradigm for low-fat flavor delivery.

• Salt Replacement. The need to lower sodium levels in soups, seasonings, and snacks while retaining the distinctive salty, savory character has not been adequately achieved with the current generation of salt substitutes. More than 100 patents have been issued for mixtures of spices, mixtures of sodium chloride with KCl, combinations of KCl with organic acids or with amino acid salts, and use of sodium contributors such as MSG with nucleotides such as adenosine monophosphate (AMP). These mixtures are minimally effective and can also contribute to undesirable flavor notes (bitter, umami, sour, metallic).

Future salt replacers or saltiness enhancers will need to interact through the epithelial sodium channels and activate the G-protein cascade to truly mimic the “sodium” signal of NaCl.

Continuing Challenges in Flavor Delivery

The basic physics and chemistry of flavors and their delivery systems
set limits to what can be accomplished in the flavor-delivery field. In many cases, a successful laboratory solution may encounter hurdles during the commercialization stage. Factors such as capital requirements, return on investment, price–value relationships, availability of unique ingredients, technical training requirements of plant staff, supply-chain issues, regulatory and quality control/quality assurance restrictions, exclusivity, and long-term contract requirements must be considered when moving a new flavor-delivery technology to the marketplace.

From a technical perspective, new breakthroughs in flavor delivery will continue. The rate of technical advancement will depend in great part on the continuing efforts of the flavor houses to support flavor-delivery research. FT

Michael A. Porzio, Ph.D., a Professional Member of IFT, is Distinguished Scientist, McCormick & Co., Inc., 202 Wight Ave., Hunt Valley, MD 21031-1502 (mike_porzio@mccormick.com).

REFERENCES


