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Coffee and Tea in Beverages and Beyond

By Kimberly J. Decker, Contributing Editor

Coffee and tea make rich topics for study, from the chemical constituents of their flavors to their cultivation and processing to debates over brewing techniques, levels of roast and the merits of loose leaves versus bags.

One pleasant side effect of our infatuation with coffee and tea is the understanding we've gained of how to extend their pleasures beyond the cup. Coffee and tea flavor profiles complement so many foods that it's almost unfair not to share them with everything from crème brûlée to barbecue sauce.

Coffee complexity

Coffee is a model of complexity, with the number of identified flavor constituents growing with each improvement in analytical techniques. "Currently, around 1,000 different substances have been identified in coffee," says Ben Kranen, principal flavorist, global flavour creation & technology group, Givaudan, Naarden, the Netherlands. "Using coffee-derived ingredients will give us many of those substances in one pour."

While complexity doesn't necessarily correlate with deliciousness, coffee's chemical intricacy does set it apart from simpler flavors. "You've got amyl acetate in banana. You've got benzaldehyde in cherry. Even in something as complex as strawberry, there's a known number of components that give you each characteristic strawberry flavor," says Paulette Lanzoff, technical director, Synergy, Wauconda, IL. Not so with coffee. "There's so much more going on," she says. "There is no one particular flavor fingerprint." While this may make things more intriguing to the palate, it definitely makes designing coffee flavors "more challenging for the flavor chemist," she says.

Bean there, done that

To understand what underlies coffee's complexity, you have to start with the bean. According to Leigh Ungerbuehler, global category manager, beverages, Givaudan, Cincinnati, two main species give us most of the coffee we drink: Coffea arabica and C. robusta. Robusta, grown at lower elevations, produces a bean with more acidity and less complexity or body than arabica; this suits it to blending, dry-mix applications and products that require a lower price. Arabica, on the other hand, is the "premier species responsible for all of the high-quality espressos and coffees in the world," she says. "Most high-end coffee shops and cafés use only arabica coffee in their drinks."

But even within the arabica species, flavor differences are "seemingly infinite," Ungerbuehler says. One factor is where the beans grow. "Arabica coffee grown at higher altitudes provides a bolder, acidic profile, and arabica grown at lower altitudes has a milder, less-acidic profile," she says. Coffees of African and Arabian origin tend to display medium acidity; spicy, wine-like and cocoa notes; and citrus, berry and "wild flavors," too. Latin American coffees are usually medium to high in acidity, well-balanced, sweet, intense and tangy. And Asian and Indo-Pacific coffees, she says, offer lower acidity, hearty-earthy notes, “power" balanced by smoothness, a flowery character and some bitterness.

Then there’s the effect of processing on the green fresh-picked beans, which have little flavor of their own—at first. It’s only after drying and fermentation that coffee develops the character that fans recognize. As Ungerbuehler says, in areas like Africa with limited water, coffee beans are often left to dry as a whole cherry in what’s known as the “natural" process. “The outside turns almost black, and the dry bean is loose inside the dry hull," she explains. “This gives a fruity, red-berry profile, as the sugar in the cherry ferments during the process." By contrast, the “honey" process involves removing the cherry, or exocarp, while leaving the inner mucilage on the bean to produce the light-brown color and sweet, honey-like flavor that lends the process its name. Finally, the “washed" process, favored in areas of South America, uses friction and water to clean the bean completely of cherry and mucilage prior to drying.

Roasting kicks off a cascade of hydrolytic, caramelization and Maillard reactions that transform coffee chemistry to yield heterocyclic byproducts like mercaptans and pyrazines, as well as glycols similar to those in bacon. According to Kranen, the degree of roast is the pivot in establishing how much bean you actually taste. “It is possible to start with two green beans from entirely different places and roast them to a point where they taste very similar," he says. “The higher the roast, the less it matters what type of bean you’ve started with."

Coffee’s chemical fingerprint

The task of the flavor chemist is to comb through coffee’s thousand-odd flavor constituents to find those that add most to coffee’s character. “We have a pretty good idea now which ones they are," says Kranen. Starting at the base of the profile, you get the “heavy" compounds responsible for body, taste and mouthfeel. In the middle, he says, nutty, roasted, buttery, fruity, chocolate and malty notes emerge. “This is the most-distinguishing part between the different coffee origins and varieties," he points out. “The most-challenging part, however, is the top. This is where you find the very volatile fresh notes that really determine the fresh character and fill the room when brewing coffee."

Alas, these also have the shortest lifespan. “A lot of the chemicals that we find in coffee flavor are not stable molecules," Lanzoff says. “That’s why a fresh cup of coffee has so much more bouquet and flavor than it does after five minutes. A lot of the chemistry of that beautiful aroma is either too volatile to capture or interacts and is destroyed after it sits." Fortunately, flavor chemists have figured out how to pin some of these notes down through encapsulation, replacement with more-stable alternatives, or bonding to solvents “so they’re fixed in a bit more than you’d be able to do by using some oil-soluble or similar heavy solvents," she says.

According to Cindy Cosmos, senior flavor chemist, Bell Flavors & Fragrances, Northbrook, IL, gas chromatography (GC), mass spectrometry, headspace analysis and other tests have helped flavorists zero in on a desired profile’s chemistry. “A summary of the percentages present gives us a good starting point for the framework of the flavor—also known as the fingerprint. Using the analytical equipment, taste, aroma and art of flavor chemistry allows us to refine that flavor, perhaps with ingredients not found in the fingerprint, but that still taste good."

Building flavor from the ground-up

When building a coffee flavor, flavorists might start with a natural coffee extract. These are available in any number of concentrations or forms, including powders, solid extracts and hydroalcoholic extracts that offer stability. Distillates are another part of the build and can capture more of the low-boiling notes important to coffee's profile. "And there are other sophisticated methods," Lanzoff says, "like spinning cones that produce a very realistic coffee profile, or CO2 extracts that also get you a lot of that upfront profile that you can't get otherwise. You may need to use several combinations of those technologies to get the right flavor."

But, notes Jack Fastag, flavor chemist, David Michael & Co., Philadelphia, "the cost of natural coffee extracts may prove prohibitive in many applications." What's more, the same notes that are so fleeting in a cup of brewed coffee are also labile in coffee extracts. Thus, "even when using natural coffee extracts, coffee flavors will often need additional top notes to round off the overall profile."

Lanzoff usually compounds her coffee profiles with heterocyclic compounds like thiazoles, oxazoles and pyranines, which she says "are very important in coffee flavor." Yet she cautions that a little goes a long way. "These are very powerful molecules," she says. "It's very easy to distort the profile by adding a bit too much or too little. So it's a careful balance of using the right pyranines in the right amounts."

On the question of natural versus artificial, it comes down to what the label demands versus what the palate can detect. "I don't think that you can get the strength that you need to flavor a very concentrated food product with a natural coffee extract," Lanzoff admits. Although current technology has produced superior natural espresso and varietal coffee extracts, "we need to add things to boost that flavor," she says. Yet it may not matter much in the end. When the target profile is café au lait and not pure coffee, flavorists might tap artificials for the desired effect anyway. "So we add dairy notes for a cappuccino or latte, or burnt notes for espresso, or chocolate notes for mocha," she says.

Applications in action

When choosing a flavor system for a coffee beverage, Kranen emphasizes finished-product quality. So in a high-quality canned coffee, he explains, "the base brewed-coffee product will already be quite good, so we can focus on those volatile substances that disappear during processing and storage." At the other end of the scale, cost-optimized applications where high coffee content is not an option "will use a flavor that has extract, bitterness, mouthfeel and some acidity built in," he says. "This flavor, when tasted alone, will give a fuller, more-complex coffee character." Finally, specialty flavors can bring out those subtle nuances. "Some high-quality coffees will have notes like berry, citrus and even jasmine," he says. "Our specialty flavors cover these aspects and enable us to turn a standard coffee more toward different bean types."

Marie Cummings, manager, food applications and product development, David Michael & Co., adds that beverage syrups made with a combination of real coffee and coffee flavors improve beverage profiles. But in dairy applications like ice cream or yogurt, all the coffee character will come from the flavor itself "at approximate use levels of 1% to 2%," she says.

Formulators will probably be limited to natural flavors in premium, full-fat ice cream, but the frozen format usually lets you “get a very nice profile, even with a straight natural coffee extract," Lanzoff says, “be it a hydroalcoholic extract or a hydro-fat combined with other natural coffee products."

Ice cream’s fat helps balance the acid in the extract, but that moderating effect is absent in low-fat yogurt, whose acidity heightens the same taste in the coffee. That’s why Lanzoff says “you really have to balance down the acid in a coffee for yogurt." Dairy notes or chemical buffers do the trick, “or we may choose a flavor that’s not as heavily based on an extract," she says. “It would have some extract, but we’d also put in a coffee distillate where the heavy, tart, bitter notes are pushed down by dilution, while still keeping the coffee aroma high."

In bakery applications, heat is the enemy. Increasing the level of volatiles in a cake batter can help, Lanzoff says, “or you can balance the batter and the icing by putting the heavier coffee extracts into your batter and the lighter, more-delicate distillates into the icing." Solubility in propylene glycol or oil is appropriate for icing flavors, whereas the format used in the batter will depend on whether you’re making a dry mix or the finished cake. “Sometimes, instant coffee powder alone is enough to flavor the batter," she adds, especially if you lean on the icing for the main flavor effect.

Chocolate and coffee, as Lanzoff puts it, “play nice together." She’s used oil-soluble extracts expressed directly from the coffee bean as the starting component in chocolate or compound coatings, possibly augmenting the profile to give it “more of an espresso note or more of a latte-type note, if we were looking for that." In flavoring the center of a fondant, she says, “a water-soluble coffee extract will work very well."

All this focus on sweet risks giving savory short shrift. And though combining coffee and savory is still a niche practice, its logic is elementary. Matthew Walter, culinary group leader, Givaudan, Vernier, Switzerland, likens using coffee in savory to using unsweetened chocolate in Mexican mole sauces. “Both rely on the Maillard reaction," he says, “and as this is the key process in rendering meat acceptable to the human palate, the link becomes obvious."

Cummings notes chefs commonly blend coffee grounds and powders into rubs to “enhance the smoky character in beef or pork."

Givaudan created a steak sauce called “The Red Eye" using instant coffee and robusta coffee flavor as key ingredients. “This sauce draws inspiration from the cowboy practice of deglazing the pan used to cook ham steaks with coffee to form a sauce," says Walter. “In addition to the flavor, the coffee gives you a little jolt, removing the red from your eyes."

Reading the tea leaves

You’d be hard-pressed to find cowboys packing tea cozies in their saddlebags, but tea is just as esteemed an eye-opener as coffee—provided, of course, it’s actual tea and not the herbal infusions known as tisanes. According to Luther Leake, global applications technology, Givaudan, Cincinnati, the leaves of the Camellia sinensis plant give us all the principal varieties of real tea: white, green, oolong, black, scented and compressed. What distinguishes a pekoe from a Darjeeling, or a Silver Needle from an Earl Grey stem from where it's grown and what happens to it after harvest.

The first point of influence is the tea's terroir, which "includes all the growing conditions of a particular region, including soil, weather and other geographic elements like altitude," Leake says. "Since all teas come from the same C. sinensis species, the terroir and processing have significant contributions to how differential flavors develop from one region to another."

Green tea, for example, is the product of a simple process whereby you pick the leaves, cut them to a specific size, and dry them to a moisture content that forestalls fermentation. The same steps, more or less, yield white tea. But in the production of oolong-type tea, drying is interrupted by a short fermentation initiated by the leaves' own enzymes. Carry the fermentation further, and you get black tea.

Like coffee, Fastag says, "tea doesn't develop its full flavor or rich aroma until after the drying and fermentation process." It's no surprise, then, that green tea is much blander and herbaceous, whereas black tea "exhibits a more-complex profile that also depends on the origin and processing of the leaves," he says. "These notes may include fruity, floral, vegetal, hay, honey, woody, phenolic, sweet-brown and spicy characteristics."

Flavor fingerprint

When representatives of Givaudan conducted a TasteTrek™ at the Tea Research Institute, Hangzhou, China, they witnessed firsthand how important process is to the development of tea flavor—specifically that of longjing, Hangzhou's famous Dragon Well tea. First, wilting removes 15% to 20% of the leaves' moisture. Then the leaves are fried in tea-seed oil, a process called qingguo. Cooling and moisture regulation follow, after which comes the huigo, or second round in the wok to dry the leaves further. Finally, screening, refining and sorting prep the tea for sale.

"Each phase contributes to flavor development," Leake says. "For instance, during the wilting phase, the moisture is removed from the leaves, and that reduces the tea's green aroma and bitter and/or astringent tastes. During the pan-frying steps, toasted, roasted and nutty notes develop."

Compare longjing to sencha, Kranen adds, and "you can notice these flavor differences even more." While longjing is fried, sencha is steamed, "resulting in a profile high in vegetable, seaweed and green notes."

According to Steve Wolf, director of flavor applications, Robertet Flavors Inc., Piscataway, NJ, a GC or high-performance liquid chromatography (HPLC) analysis will show "literally thousands of peaks" for tea, with the GC picking up the volatile constituents and the HPLC the non-volatiles tannins, polyphenols and caffeine. "Those are all part of the finished impact you expect in a tea beverage," he says, "and one of the reasons that flavor creation has remained an art and a science is that some of those constituents, even if they appear in ppb quantities, are critical to the flavor."

From bush to beaker

So when building a tea flavor from real tea components, flavorists typically use an extraction or distillation reflux process that suits the type of tea and its grade, or cut: whole leaf, broken leaf or fanning, according to Norm J. Matella, Ph.D., manager of beverage solutions, Sensient Flavors, Indianapolis. “Flavor chemists creating tea profiles with chemical components usually incorporate sweet, smoky nuances for black teas; grassy and floral notes for green teas; and woody notes for rooibos. But the nuances are interchangeable and rely heavily on the creative process and considerations mentioned above."

Flavors give product developers access to profiles they couldn’t otherwise use. “Most of the finest teas from around the world are commonly found in limited quantities and may only be available in their local growing area," says Leake. For example, tieguanyin, a premium oolong known as the Iron Goddess of Mercy, is scarce, time-consuming to produce and expensive. By recreating its flavor, “we can provide our customers the experience of its beautiful floral gardenia notes, creamy sweetness and toasty finish."

Even so, tea flavors aren’t without cost constraints. Natural may be the favorite, but the problem, Wolf says, “is when you’re trying to make a million pounds of a certain flavor that’s only present in the tea leaf at a few ppm. It would be economically prohibitive to extract that compound naturally, so artificial flavors might have a slight advantage from a cost issue."

Flavors fit to a tea

In the end, applying tea flavors in foods “is similar in theory to adding coffee flavors," Cummings says. Combining powders or extracts with natural flavors lets formulators boost the tea character of the finished product, with the extracts contributing the base and the flavors accentuating the nuances. “This gives flexibility in emphasizing particular flavor components that the customer may wish to increase."

Wolf points out that tea flavors tend to be more stable than, say, citrus, “which have solubility issues in many systems and are prone to oxidation." For one thing, tea’s antioxidants are built-in; for another, it’s already gone through fermentation, he says, “So it’s not just waiting to react." Even so, tea tannins can coagulate some dairy proteins, and the non-volatiles are liable to foam, making hard candy production messy. Yet that same propensity to foam is a boon in sorbets, where it helps “hold in a lot of air," notes Wolf.

In cake icings, the spice notes of a chai-style tea make a welcome addition to the flavor profile. “These come through the fat of the icing and complement the cake," says Cummings. In a chewing gum, she advises formulators to use flavor—preferably oil-soluble or dry—to achieve most of the tea character, as tea leaves or powders lack the oomph to provide much flavor on their own.

Similar considerations apply to chocolate, Wolf adds. “You have to pick a tea flavor to work with chocolate, because otherwise, a lot of the tea character can disappear behind it." Continually upping the tea flavor only knocks the profile off balance. “What happens is you have an over-flavored candy," he says. “So depending on the type of chocolate and how roasted it is, you have to develop tea flavors to avoid overlapping."

As always, form and function dictate flavor. As Wolf says: “When you’ve made a flavor system, ideally, you’ve got a product that can withstand whatever process it faces and can deliver the character you want over the life of the product. If we understand the application system, we can develop a flavor to survive it."

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