Successful Flavors

From formulation to QC to applications and beyond

Edited by Gerard Mosciano



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Introduction

Gerard Mosciano

A Childhood Dream

I can remember from my earliest years, whenever I was asked what I wanted to be when I grew up, I would proudly respond that I wanted to be a chemist. While other kids wanted to be doctors, lawyers or Indian chiefs, I always wanted to be a chemist. I didn't really know what the job entailed, other than working with some really cool stuff. I came by this desire honestly.

My aunt was the chief bacteriologist for the New Jersey Health Department, the same person who would routinely close the Jersey Shore beaches to bathers and ban shell fishing on the entire length of the shore when bacteria levels were high. Periodically, she would have to work a weekend in order to re-populate her colonies of bacteria. If both my parents had to work that same weekend, I would accompany my aunt to work. I never knew that this experience would make such a lasting impression on me. It was not her job or lab that interested me, however; it was the chemistry labs of the New Jersey Health Department next door that filled me with youthful wonderment. As long as I was quiet and didn't touch much, I could spend the time playing with the lab glassware, the primitive instrumentation, looking at the reagents and otherwise having a ball. This interest led to summer internships and finally to a job as a "food chemist" with the New Jersey Health Department. While my childhood interest lasted many years, my adult interest waned after

just one. The boring, routine analyses of "standard methods" and civil service left me rather flat. I wanted a job that would be more rewarding and never be routine or repetitive, so I took my food chemist title and went job hunting.

Career Beginnings with IFF

A recruiting company in Philadelphia had an opening for a food chemist for a relatively new company called International Flavors and Fragrances (IFF) located along the shore in Union Beach, New Jersey. IFF was the result of the 1958 merger of Van Ameringen Haebler with Polak & Schwarz. Not having any idea of what IFF was, I decided to go for an interview. In 1964, IFF was preparing to go public on the New York Stock Exchange with total sales of $40 million. I was hired as an instrumental chemist in R&D—a flavor chemist.

It was at IFF that I became associated with the first of the many generous people who would have a profound effect on my future career in the flavor industry. Philip DeC. Kratz was the head of IFF's U.S. food flavor research group, a department of one. I became the second member of the group. Our goal was to extract, isolate and identify the components responsible for the flavor of a wide range of natural products, such as wild French strawberries and English dark chocolate. The technology was new, and everyone was rushing to carve a corporate research identity and retain sole application of the components that were being identified. The ingredients we identified would also provide new and more characterizing flavors. These ingredients would then enable the creative flavorists to produce flavors with better flavor fidelity, and thus keep IFF at the forefront of flavor technology and creation.

The work on strawberry started with 20 L of wild French strawberry essence, and took about two and a half years from the initial extraction to the final flavor patents. The main instrumentation available were two of the most primitive thermal conductivity GLCs that were then becoming commercialized by a company called F&M, which was purchased by Hewlett Packard in 1965. The

1/4-in copper columns they used were hand-cut, rolled and packed, and yielded so few theoretical plates that meaningful separations were nearly impossible. This concentrated extraction was first run on the gas chromatograph from which the odor of the individual peaks was recorded. We always hoped to identify key organoleptic areas. Each individual peak was carefully trapped, using dry ice to condense the hot detector effluent, and later rerun by rinsing the trap with solvent and re-injecting on a column of different polarity. These rerun fractions, when tentatively odor identified, were then run on a primitive mass spectrometer that usually insisted we had either identified a new chemical mixture or positively identified water. To really add pressure to the MS analysis, we had to count mass numbers of the individual fragments ourselves, and then compare our data to known references; there was not a hint of computer assistance. The first MS traces were the result of light traces on photographic paper or UV light on UV-sensitive paper. If we took too long to arrive at a positive identification, the tracings would gradually darken and, after a week, became useless. Today, with modern computer-assisted GC/MS instruments, I would expect that the tasks that took us years to complete would take no more than a month, and every component would have at least five potential candidates.

The only good thing about the time it took to complete some of the projects, such as chocolate, was the test samples. For our chocolate research, we initially purchased 50 lb of Cadbury chocolate. In the time it took the instrumentation people to resolve the mystery of the presence of several alkyl pyrazines, I developed a lifelong appreciation for dark chocolate!

After I had been with IFF for about a year, the basic flavor research was moved from New Jersey to the 10th floor of IFF corporate facilities at 521 West 57th Street in New York. This move gave the R&D department a higher visibility, necessitating an upgrade of facilities and equipment worthy of a research and development department located in the world headquarters of a company that advertised that it spent millions of dollars on

research. Of course, the flavor facilities on the 10th floor were clad in linoleum and had steel lab furniture; this contrasted with the perfumery department, located on the sixth floor, which had wall-to-wall carpeting, wooden desks and, on occasion, bouquets of fresh flowers. That disparity was never a point of contention until many years later.

As our facilities were vastly expanded, we purchased a state-of-the-art Hitachi GC/MS. It was so new that Hitachi sent one of its design engineers to oversee the installation. The guy spoke no English, but he knew every screw and nut in that apparatus. By the time he left, the instrument was yielding incredible amounts of new flavor components that greatly expanded our research capabilities; that lead to a corresponding jump in technical papers, presentations and flavor patents.

The New York R&D group included some new and uniquely talented people, such as Carole Pollock and Larry Buckholz. Carole would subsequently go on to further her creative training as a flavorist at Givaudan, and Larry would return to Union Beach, finish his doctoral studies and assume the creative and technical leadership of the savory department. For IFF, Carole was assigned to work on onion and garlic oils, while Larry and I were involved with producing a line of vegetable juice concentrates and essences. I treasure a picture that shows us both using an old sausage stuffer to extract the juice from some chopped vegetable pulp.

One of those experiments was upscaled at our manufacturing facility in Teterboro, New Jersey. When Carole, Larry and I arrived in Teterboro, we thought we would be there to oversee and render assistance to some plant workers, but Tom Bonica, the plant site manager, had other ideas. We were shown a truckload of green celery stalks and told that no plant people could be spared for our effort. So it was our job to pulp a mountain of celery through a hammer mill and express the juice for further concentration. By the time we were finished, we all looked like Jolly Green Giants. I can't tell you how the Jolly Green Giant smelled, but we without a doubt smelled far worse.

Tom was "the mayor of Hoboken" and the person who instilled in us an understanding of "his" plant and "his" facilities. We loaded and emptied reactors and percolators, ran spray driers and used ribbon blenders so we would learn the operation and limitations of all the available plant equipment. Thus, we would know how best to compound flavors from a manufacturing point of view. Tom also had strong views on how formulations were to be written; he made it very clear that he did not want to see a formulation with any subs. I can still remember his matter of fact statement that he would hunt us down if we ever dared to use a shake-well label. While we could do so in the lab, neither he nor our customers had an 800 lb gorilla that would be able to shake a drum of flavor. It was our job and responsibility to prepare formulations that would be clear and not separate on standing. He also made it very clear that there was a big difference between flavor creation and adding one or two more ingredients into an already existing formulation. He used one of the earliest computer print-outs to demonstrate his point. He stood on a ladder and unfurled a raspberry flavor that had contained many pages of ingredients. At the time, Bonica's bark could be heard throughout the facility; and not knowing that his bark was far worse than his bite, we learned fast! To this day I try to avoid using subs.

The R&D facilities in New York were victims of their own success. The accommodations that were once more than adequate became confining, and plans were prepared for a state-of-the-art research facility to house both aroma chemical and flavor research in the front of the old aromatic research and pilot facilities in Union Beach. After the new facilities were completed, we moved into the empty building. Soon, though, we filled every available lab with interesting talented people working on some very important and ultimately fruitful projects.

To train me and give the new group some respect, IFF managed to convince one of their most senior creative flavorists, Louis Strasburger, to put off his retirement and to transfer to New Jersey to begin my training. Lou was a real gentleman as well as being one of the founding members of the Society of Flavor Chemists

(SFC) and a long-time Van Ameringen employee. He was responsible for creating the flavor for the maple flavor tablets that IFF and its predecessor companies supplied to the U.S. military, and was the flavorist responsible for working on drug and pharmaceutical applications in New York. Lou accepted the challenge of training yet another flavorist, and thus began my formal creative flavorist training.

Lou was a most patient and understanding mentor. He undertook research creative flavor projects while also assuming my flavor training. Lou was firmly convinced that flavorists should taste flavor ingredients as a part of their ongoing education, by familiarizing themselves with the necessary tools of the trade. He explained that a novice flavorist might describe any flavor ingredient in simple subjective terms, but with additional flavor experience the descriptions would become more thorough as one's experience broadened. What were just major descriptors would be joined by minor notes, nuances and possible applications. Thus began a personal tasting regime that I have shared with all my co-workers for many years. He never conducted flavor training as a class; rather, he did his work and I would accompany him, or I would compound for him and ask why he did something or why he used a particular ingredient. He openly conveyed his wealth of flavor experience and gave me unbiased responses to each and every question. I thankfully remember, after completing some unsupervised projects, Lou would point out the shortcomings of my efforts in a firm but constructive manner; for that alone I am eternally grateful. Lou retired after two years. As a way of repaying his generosity, I have undertaken the training of other flavor chemists and have attempted in my own way to emulate his generous paternalistic approach to convey my depth of interest and fascination for flavor creation.

To further my creative flavor training, I had to return to New York. This time, I became an IFF junior flavorist working for Carmine Donnarumma, joining a creative staff that included Herb Stein, Judy Joseph, Harvey Farber, Dom Marmo and Alton "Red" Quinn, who focused on tobacco, and an entire supporting cast of

applications specialists. Carmine was the "godfather" of the beverage department. Together we created a broad array of beverage products—both clear and cloudy—for the national and international markets.

When I returned to the 10th floor in New York, it was very different from my previous R&D days. While we still had the steel cabinets and linoleum floors it was now the domain of Charles Grimm. It was during this time that I applied and was accepted as a member of the SFC, due mainly to a personal endorsement by Carmine. I stayed on with Carmine until I grew weary of commuting and an opening had developed back in the R&D department as a research creative flavorist.

This new position was the result of the less than enthusiastic acceptance of the results of all the expanded research efforts. We all had expected that the new R&D ingredients would make their way into an entire line of new, improved and more characterizing flavors, but to no avail. So, if the fruits of R&D were to be commercialized and help to maintain R&D's lead in the industry, it would have to be an R&D function to incorporate them into finished flavors. Since R&D did not have access to salespeople who brought in projects, it was decided that R&D would focus on international projects. Since both national and international divisions were tithed to bankroll R&D efforts, an internationally driven research program was formulated. Various projects were proposed and then winnowed down to a manageable number. These projects were prioritized and assigned. We had periodic presentations and reviews with the heads of the various international flavor groups. Only the international group could determine if a project had met its initial target. This was a contributing factor to my seeking a more challenging position elsewhere; I also wanted to know if I could create flavors without the R&D department's support group. Was I creating flavors or just compounding whatever the instrument told me to incorporate?

My stay at IFF was almost 10 years; it entailed many changes and opportunities that were later greatly rewarding. I made the acquaintances of many remarkable people who would have a

profound effect upon my flavor career and on me personally. I will be eternally grateful to Lou Strasburger and Carmine Donnarumma. They made it possible for me to achieve goals that I would never have dreamed possible without their training, encouragement, assistance and, most of all, their patience.

A New Challenge

At this time an interesting position arose at H.H. Ottens Inc., a company as different from IFF as IFF was from the New Jersey Health Department. Located in the heart of Philadelphia, it was and still is a family-owned enterprise. The gentleman in charge of the lab was Jack Duffy, a boiler operator aboard the USS Indianapolis, the ship whose name was etched in a deep blue tattoo on his arm. Jack ran the flavor lab and plant as he ran the USS Indianapolis engine steam room. Jack's assistant was Jim Raugh. Jack and Jim created and duplicated flavors, did all QC, and saw to it that the facility ran properly, and that the customers' products were prepared properly and on time. Jack brought a determined "can do" attitude to whatever he did. Whatever they lacked in formal technical and flavor training, they made up for with sheer grit and determination.

On my first day of work, I was given the mandatory tour and introduction. It felt very different to go from being a key person in a company of more than 2500 to being a flavorist in a company with less than 25 employees. What was even stranger was when we got back to the lab and I was presented with my own set of volumetric flasks. The stainless steel and copper flasks looked like oversized beer steins. They showed their age, being repeatedly soldered and displaying pour spouts that were well-worn and dinged, indicating a long and arduous length of hard service. The graduated set included a gallon, a quart and pint followed by ounce, dram and the piece de resistance, a minim dropper. The set looked like a leftover from a beer festival, but the ounce and dram containers were cute miniatures of their larger cousins. The minim dropper was a real relic; it was glass and had faded etched graduations on its sides. I looked at Jack, and then I looked back at the containers. It took me a few

minutes to ask Jack why he was so generous in parting with such obvious old friends. He said, "We do everything in volume here, and you will need these to start working." I hesitated a bit, thinking my career here could set a new record for brevity, and told him that I was trained and accustomed to working in weigh. One thing about Jack was he was adaptable. We discussed the merits of weigh vs. volumetric compounding and production, and Jack ordered me a balance that week.

In those days, the Ottens creative facilities were located within the factory floor. This was a great learning experience on how flavors were compounded and the finished flavors completed in the plant. The company was involved mainly in creating flavors for bakery and related fields. It was where I first encountered bakery emulsions. These specialized products were used to flavor and (usually) color entire batches of cakes and cookies. Whereas IFF had a gentler, long range, idealized research creative effort, Ottens was really an "in the trenches" atmosphere. There were no lengthy research meetings, no visiting lecturers and no presentations of newly-approved flavor ingredients. Here, new projects were added daily to an already overflowing clipboard mounted on the wall. We were expected to reduce that pile in the quickest possible time. What Jack and Jim taught me was that there was a customer behind each project request, and that the company that responded to that request with the best flavor in the shortest length of time would ultimately succeed. Even though the customer was one of many on "the clipboard," they only knew about their own request, and I am sure couldn't have cared less if we had a thousand other projects to do. The customer was solely interested in receiving a product that fulfilled their needs.

What IFF achieved through its vaulted R&D, Ottens achieved with customer service. It was not unusual for the lab staff to go into the plant and assist the compounders to facilitate and expedite an urgent customer order if the other compounders were already tied up with other pressing assignments. We also evaluated each other's flavors as well as doing all our own applications. We not only supervised initial plant productions, but we often compounded them as

well. While we had the ability to choose what project we worked on, no project went undone. In retrospect, that was really the most interesting and creative time that produced some very interesting results. We literally ventured where other, saner flavorists would not have attempted. The majority of these efforts resulted in little more than abject failures, but a few produced surprising successes, as well as many rewarding learning experiences.

Chief Creative Flavorist Position

After about three years at Ottens, I accepted a chief creative flavorist position at Food Materials Corporation in Chicago. It took me a while to consider the pros and cons of the offer, and try to realize the depth and breadth of the commitment I would have to make. My family had moved into a new house less than three years before, and our kids had just adjusted to their new school and friends. However, the chief flavorist title and the challenge of Food Materials convinced us that it was a good move.

Food Materials was what I would call a brown flavors products company. It was involved mainly in extracting natural vanilla and preparing maple, butterscotch and other brown flavors that were augmented by the caramel syrups that were prepared, under clouds of steam in some of the largest copper candy cooking kettles I had ever seen. The company had a spray drier that Ottens didn't, and they counted some of the largest food companies among their customers. Accepting the chief flavorist position was a commitment that would be pivotal in my flavor career.

Food Materials was a private company owned by Robert Koch, one of the "good old boys" of the flavor industry. Bob was very different from all my previous bosses. His management style was unique, but ultimately effective. He learned everything that was going on during his daily plant tours. His tours were the most unobtrusive but effective OSHA inspections, because he didn't want his building to look bad. Whatever shortcomings he discovered were instantly given priority and corrected. He had a joke of the day that he tirelessly told and retold to whomever he saw. Not all were that

funny, but still everyone appreciated his dedication and attention to the company and to each worker in "his" company.

One of the funniest stories about Bob took place at an Institute of Food Technologists (IFT) convention in New Orleans. That year we had been sampling a lime green slush. Everyone attending the convention was formally assigned booth duty: opening setup, manning the booth or cleanup at the end. Well, often the best laid plans go astray, and one of the cleanup people did not show. Bob instantly took off his expensive gray silk suit jacket and started to dismantle the lime slush machine. No one gave it a second thought until after Bob had removed the dasher from the coolant barrel and saw the ice dam that had formed. As Bob was thinking about how he was going to clean the machine, the ice dam broke and out came gallons of icy cold bright green slush mixture. Bob didn't say a word; he didn't have to. We all knew how he felt. He left to make himself more presentable for his evening's appointments. After IFT, we held a post-mortem and the only thing Bob suggested was that all personnel who were assigned a job had better show up next year. I doubt if the green stain ever washed out because I never saw that gray silk suit again!

Chicago was not a hot bed of the flavor industry. While the city was home for a significant number of food companies, the major flavor companies were traditionally located on the East Coast in New York and northern New Jersey. Food Materials had a few secret weapons that gave them the ability to compete. One was Alan Post and the other was John Cassens. Alan Post was an industry legend. His territory was predominately General Foods and Thomas Lipton, which were Food Materials' largest customers. John Cassens covered the pharmaceutical industry like a blanket. Together, these two men were the nucleus of a growing sales force and a source of a constant influx of projects.

To be able to respond to all the incoming projects, we had to grow our creative and technical staffs. The first thing we did was bring in some technical management. I recruited Jim Raugh, and he joined me as a creative flavorist, and later as technical director. We

also looked internally with the goal of training in-house flavorists. After evaluating the available staff, I recommended two people who showed great promise. Constantine "Connie" Apostle was a technician who worked in R&D, and Judith Michalski was our sample order compounder. Connie was a long-time employee, though a chiropractor by training. He had worked at Neuman Buslee and Wolfe prior to his arrival at Food Materials, where he had trained under Bill Jaggard. Connie proved not only to be one of the better creative flavorists, but also a master duplicator of flavors. He had the patience and the nose to identify most components in any flavor. A flavor perfectionist, his only shortcoming was he would always want to make one more attempt before completing and submitting a duplication project. His "one more" attempt at times grew into days. What he did duplicate was amazing; his nose easily beat all the mass spectrographs available at the time.

Judith Michalski was as creative a free spirit as I had ever met. She had applied herself as she was compounding flavor samples to the point where she had a good knowledge of the basic ingredients used to compound flavors. She showed a driving curiosity and ambition. Judy and Connie were the first additions in the expansion of the creative flavor group.

As the company grew, it was decided that quality control had to expand to keep abreast of the expanding range of flavors that were being newly created and commercialized. That was when we interviewed a deceivingly demure youthful candidate; Noreen Lally was employed at a large chewing gum company located on the South Side of Chicago. She was the ideal candidate and soon became the flavor counterpart to Seinfeld's "Soup Nazi." As the head of QC, Noreen oversaw every facet of flavor production and nothing escaped or evaded her. Nothing was ever compounded into a flavor or shipped to a customer until it met her rigid approval criteria. Noreen also handled all regulatory as well as kosher matters.

We kept an eye out for creative talent. Being located in the Midwest was not like being on the East Coast where flavorists were in apparent abundance. On the East Coast, flavorists would

just change car pools when they changed jobs! We did manage to add Susie Sadural and Mike Fasano to the creative staffs. Susie had trained at Stephan Flavors with Ira Litman before going to the East Coast and was returning to the area from Biddle Sawyer. Susie is a very prolific flavorist. On our staff she handled the usual flavor project load as well as all of our tropical flavors, because she was the only one who knew what the customers were requesting. Susie was raised in the Philippines, and her parents' garden held every type of "tropical fruit." Mike Fasano had been lured to St. Louis by Werner Jenkinson from a position at Fritzsche Brothers, where he received his flavor training under Frank Fischetti. Mike, a creative generalist, carried a full array of projects, but showed a special affinity for natural vanilla projects. With these additions, the creative staff at Food Materials was second to none. In the following years, the staff helped to reshape Food Materials from a basic brown flavor company to a full-spectrum flavor company that was an able competitor in the national flavor market.

To enhance our creative capabilities and output, we decided we had to enhance our applications capabilities. What began with the small existing dedicated group, was enlarged with the addition of several highly talented application specialists. Leora Hatchwell brought a full spectrum of application expertise that enabled us to better evaluate and then demonstrate to our customers a range of finished flavor products. She was soon joined with a contingent of various specialized applications personnel who enabled the company to demonstrate our enhanced creative and applications capabilities to customers. One of Leora's applications specialists was Deborah Hay, who went on to become a creative flavorist at General Foods in Chicago.

Association Work and a Publishing Opportunity

It was during this growth period at Food Materials that I started to become more actively involved with the SFC and Chemical Sources Association (CSA). When I first approached Robert Koch about the possibility of becoming more active in the industry

associations, he heartily encouraged me. Ever since I became a member of the SFC in 1974, I had been somewhat active in attending meetings, but resisted getting personally involved in its many working groups. That changed when the SFC wanted to begin a tradition that is still carried on today—holding a Midwest meeting, to minister to those brave people who dared venture across the Delaware and head for the open plains! I volunteered to run the Midwest meetings and continued doing so for many years. The Midwest meeting became a showcase for the educational and food companies in the area. This initial effort of volunteering to run the Midwest meeting eventually lead to both the presidency of CSA in 1983-1984 and the presidency of the SFC in 1987-1988. I must say that what effort was ever entailed was more than adequately compensated in meeting and counting as my friends some of greatest people who are coincidently some of the best creative flavorists in the world. It also somewhat salved the guilt trip laid on me by my Italian mother who flatly stated, after I told her of my decision to move my family to the Midwest, that if she known then of my decision to leave New Jersey, she would have never pushed me to go to college!

It was while I was an officer of the SFC that I had a money-making idea that I presented to the board. The SFC was an educational group that was granted tax-free status by the IRS because of an educational mandate. I thought that, as such, we could perform the educational responsibilities of our charter by publishing organoleptic evaluations of flavor materials. Allured Publishing Corporation had expressed interest for me to provide a regular feature in their publication *Perfumer & Flavorist.* My reasoning was that we, as flavorists, could evaluate the flavor ingredients presented at CSA meetings, and Allured Publishing would include them in its magazine. This would provide a consensus evaluation of the descriptors and their potential applications. Unfortunately, the SFC's lawyer and board ruled against it. The idea, while it had meritorious aspects, would run afoul of many of the members' companies. So again Koch came through; he agreed that our group, consisting

of Judith Michalski, Susie Sadural, Mike Fasano and myself, could publish the results of our evaluations with only two caveats: we could not publish any negative evaluations, and we had to donate the writer's fee to charity. We agreed and thus began my long-time association with Allured Publishing.

Food Materials Acquired by BBA

Over time, as Food Materials' product lines grew, the company began to be coveted by several larger flavor companies. When word of its availability spread, these suitors came courting. Koch's original idea of being acquired by a local company and becoming the remaining entity, or at the very least being acquired by an eastern company but keeping the manufacturing facilities Chicago-based, ultimately was not to be. After several months of raging rumors, varying odds on who was perceived to be the potential buyer, and a failed employee buyout offer, it was announced that the company was to be acquired by Bush Boake Allen (BBA). The plant and its entire staff would be retained. Only the flavor research department would be consolidated and moved to BBA's Montvale, New Jersey, location. "Only" meant me. With that shocking announcement, I stood by while the creative staff, so painstaking built, was dismantled and torn apart. Judy went to Danisco; Connie toured the continent for a while and finally ended up at IFF; Susie went to General Foods; Mike remained in Chicago to head the expanding vanilla flavor group; and I meekly transferred back to New Jersey, ending a 16-year stay in Chicago. I was joined in my exile by a flavorist trainee, Richard Bubola. While at Food Materials, Rich was given a great opportunity to really expand his career potential. Together we created a few saleable products at both Food Materials and later at BBA. Today, Rich continues to prove that our initial evaluation of his potential was correct, and his talents are bearing rich rewards.

The BBA creative department consisted of two separate groups: a British group headed by John Wright and a U.S. group headed by Amby Mankoo. While Food Materials flavor sales were larger than

BBA's, they were strictly limited to the United States. BBA's U.S. group was staffed by Aurora Montenegro, Jean Cassidy and Kathie Conley, and was responsible for supplying flavors to the Americas, both North and South. The U.K. group was responsible for the remainder of the world, and also maintained application and flavor modification facilities in most of the former British territories such as Hong Kong, India and Jamaica. The BBA facilities in Montvale, New Jersey, were located in the building previously used by Leuders/Monsanto.

BBA had both flavors and fragrances in one location. At IFF, I was separated from the perfumers by several floors; here we were directly in their midst, and the funny thing is that we co-existed. At times there were petty tiffs about whose odors reeked the most and were the most disturbing to the other, but otherwise we got along. I could never get over the fact that the perfumers required evaluators to tell them how they were progressing on a project. As if only the evaluators could interpret what the customers were requesting and the progress the perfumer was making toward that goal.

The one thing that both perfumers and flavorists had in common was that we used the same instrumental analysis group. Both had great respect for the group in isolating and analyzing our creative targets. The group was headed by Kevin Myung and ably assisted by Odila Zocca. This group would extract flavor or perfume ingredients from a worldwide range of commercial products such as soaps, detergents, beverages, candy, confections, finished beverages, toiletry products, perfumes, cat litter and room deodorizers. Kevin and Odila employed the latest extraction procedures and the newest separation and identification instrumentation available.

One area of intimate cooperation between the United Kingdom and United States, saving an untold amount of time and needless effort, was a database that compiled all the results of the instrumental groups' efforts. With a few queries you could obtain printouts of any product by name and also whose product was examined. Each month Kevin would submit a report of what his group had examined and send it to the United Kingdom; within a week he would

receive a new CD with his latest work as well as that from the United Kingdom incorporated into one vast and thorough database.

It was about this time that it was finally impressed on me that a competent instrumental analysis group was a real asset and had finally come back full circle. At IFF we had one of the best, if not the best, instrumental analysis groups in the flavor business. When I went to Ottens, the organization had no instrumental capabilities, leaving the flavorist to do everything by nose and taste. In my time at Food Materials, we went from having a rudimentary instrumental capability to having one of the best, though we had to perform the extraction and concentration work ourselves. At BBA, they had a group whose only responsibility was to be up on the latest extraction techniques and provide individual assistance to both the perfumers and flavorists. It became a real luxury; when one was assigned creative projects, the flavorist could proceed with one, have another in instrumentation and have yet another in applications. What time savers! The final instrumental report called for a consultation. Kevin or Odila would hand over a spreadsheet with ingredients and concentrations; the discussion then dealt with where some of the ingredients could have originated. The analyses would break down individual ingredients as being derived from an essential oil or other natural product. Kevin and Odila's assistance was very addictive and sadly was soon accepted as routine.

The BBA flavor applications group, headed by British-born Jim Lewis, was a department that contained a broad array of talents and specializations that enabled some truly magnificent accomplishments. The applications group possessed such a depth of skills that the staff could complete creative projects on their own. The group would present finished products to customers that were blends of existing flavors. Its finished products were professionally prepared. Then the marketing guru, Debbie Johns, would incorporate her magic. With the assistance of Union Camps, BBA's parent organization, Debbie would prepare packaging and logos that were duplicates of the customer's present product line. Debbie in fact created packaging to resemble a line extension. When the creative skills

we had were coupled with such marketing skills, the odds of a flavor sale soared.

From a biased and slightly resentful point of view, my initial appraisal of the BBA creative group was that it was not the equal of what I had to leave behind in Chicago. But the more I worked with them, the more I came to respect the company's creative talents. Aurora was charming and coolly efficient, while Jean was every bit the energetic sparkplug firing on all cylinders, ruthlessly breaking down any project into manageable and commercially successful bites. Both these women were marvels to watch as they successfully devoured project after project, turning them into commercial successes. Amby became the enviable management counterpart to Phil Jackson, coaching Michael Jordan and Scottie Pippen.

The U.S. and U.K. creative groups never really had any interaction. I guess we were both too busy with our own customers and problems to have any time left over for anything but a short friendly chat.

The flavor group continued to expand with the addition of Peter Mazieko and Karen Alexander. Peter brought the talents he had honed at PFW, and Karen came on as a junior flavorist. Peter is now at Ottens, and Karen joined the commuting caravan to IFF's Dayton facility.

During my five years at BBA, I grudgingly admitted that the entire flavor group, instrumental analysis, flavor development and applications, worked extremely well as a single entity. But as all good things have to come to an end, so did my enchantment with BBA. I intuitively turned back to the Midwest. This time Chicago offered nothing, and Cincinnati had not yet become the flavor magnet it would within a year or two. That left Indianapolis, the land of plain vanilla, but a refreshing clean slate.

Back to the Midwest at Universal Flavors

Universal Flavors was a subsidiary of Universal Foods, which was based in Milwaukee. Universal Flavors was basically a supplier of beverage concentrates to private label bottlers that supplied many of the larger supermarket chains as well a few national beverage

brands. It was the descendent of Hurdy Peck, an old-line beverage concentrate and bottling institution in a more prosperous lifetime that formed the basis of a mini-flavor conglomerate that included Warner Jenkin colors, the dairy business of Chicago-based Fantasy Flavors and the flavor business of H. Kohnstamm based in New Jersey. All of this was being bankrolled by its parent, Red Star Yeast.

When I joined Universal Flavors as chief flavorist, I was joined by Carl Holmgren and several of the H. Kohnstamm people who accepted the transfer after the New Jersey facility was closed. Among the transferees were Doug Young and Sajid Ahmedi, who were the Kohnstamm savory creative group. They joined Sharon Brandt, who was the backbone of Universal's savory flavor sales. Steve Kudla, a senior creative flavorist, rounded out the newly consolidated flavor group. These creative staff additions enhanced its core of local talent anchored by Gary Eck and John Long. Gary, one of the industry's paramount tobacco flavorists, had trained the remaining flavor staff, which included the unique talents of Pam Vanover, Theresa Cardin and Jerry Keys. Pam and Theresa made easy work of their beverage and general flavor projects, while Jerry Keys, after being encouraged to go solo, which allowed Jerry's creative ability to emerge from beneath his technician's disguise.

At last it seemed that Universal Flavors was poised for growth. It seemed as if the company had finally overcome the difficulty of luring a credible list of creative talent to its Midwest location, and was going to focus on consolidating its position in the flavor industry. But, alas, during my brief tenure there, the growth and successes that should have been achieved, and to a large extent was accomplished by such a creative and applications array, were overshadowed by continuing turmoil caused by persistent management shakeups and the arbitrary loss of key personnel. The departing list included several divisional presidents and vice presidents, heads of research, QC directors, production managers, marketing managers, beverage applications manager and sensory specialists, as well as the core of the creative group: Carl Holmgren, Gary Eck, Doug Young, Sajid Ahmedi and myself. It was an admirable effort to achieve such

chaos and provide a constant flow of creative talent to its competition in the flavor industry.

Retrospective

In reviewing my flavor career, I have dredged up many memories, some good and some bad. The fondest memories I have are of the many people I have interacted with on a daily basis—those people who you could ask for assistance, those who understood the problems you were encountering in progressing on a particular project, and especially those who would take time from their own busy projects to lend you a hand. I am not unique in having been employed by several flavor companies over the course of the last 40 years, nor am I unique in having worked with many other competent creative flavorists. However, I think I have had the unique opportunity to have worked with some of the brightest and most creative flavorists in the industry, not to mention some of the best support staff people as well. A successful flavor company is not composed solely of creative flavorists; it requires a multitude of specialized skills from a broad array of people striving together for one common purpose: satisfying the customer. Without the customer, no flavor company can exist.

The Contributors

The people who created the following chapters represent some of those specialized talents—efforts both in front of and behind the scenes that have enabled the companies I have been associated with to grow and succeed. When you spend time in the trenches with people, you figure out who you can depend upon for support, thus building special relationships based on mutual respect and trust. I would definitely consider my fellow authors the best of the best in my experience. I have a deep admiration and appreciation for their individual talents and am very proud to call them friends. I am very happy that they didn't turn down my request to join me in this effort.

Carole Pollock and I have the longest ties. We both began working at IFF in the late 1960s. She graduated from the City College

of New York with degrees in both chemistry and biology, and furthered her education at Long Island University with an MS in physiology. Carole has been a senior flavorist with David Michael & Co., Naarden (now Quest) and Givaudan, as well as IFF. At Procter and Gamble, she was a section head for the Crush Beverage group. She progressed to associate director, beverage flavor development and chief flavorist for Universal Flavors/Universal Foods. She became a director at Beck Flavors, and finally became director, flavor development and principal flavorist for Wild Flavors USA. She is presently a consultant residing in Las Vegas, Nevada.

Judith Michalski started her flavor career at Food Materials in 1974. She was selected to undergo flavor training and became a junior flavorist in 1976. She progressed through the ranks to senior flavorist by the time BBA purchased Food Materials. Not wishing to leave the Midwest, Judy accepted a senior flavorist position with Danisco Ingredients in Kansas City. She was there for 10 years before she returned to the Chicago area to become senior flavorist at Silesia Flavors. In 2002, she moved to the Edlong Corp. where she is a senior flavorist creating primarily flavors of the dairy persuasion. Judy was in my first taste evaluations group that published in Perfumer & Flavorist, and we still collaborate.

Leora Hatchwell is a flavor applications specialist with more than 25 years experience in flavoring a wide range of traditional, reduced-fat and reduced-calorie food products. She obtained her bachelor's degree from Hebrew University of Jerusalem, majoring in nutrition and diabetics, and has a master's degree in food science from the University of Illinois. She was a product applications specialist at Food Materials for five years, followed by many years at Monsanto's NutraSweet division, where she mentored the Aspartame and Neotame applications efforts.

Michael Fasano's career has taken him from FD&O, in New York to St. Louis and Chicago. He is presently at David Michael in Philadelphia where he is head of vanilla creation.

With a master's degree in chemistry and a PhD in efficiency, Noreen Lally ran the QC lab for Food Materials, and later for BBA

while production was still based in Chicago. No incoming flavor ingredient, flavor intermediate or finished product escaped her critical eye. She wrote the specifications for everything used or made in the plant and saw that those specs were met. She never claimed to be a flavorist, but she knew her flavors. She is presently working for Wm. Wrigley in Chicago.

Jean Cassidy has a bachelor's degree in business management and administration. She started her flavor career in 1976 with PFW Hercules as a flavor technician. She moved to Lautier Aromatiques in 1979 in a flavor applications role. When Lautier was later purchased by Florasynth, a commute to New York was not feasible, so she accepted a position with BBA in 1980 as a flavor trainee. She rose through the ranks to become a senior flavorist. When BBA was purchased by IFF in 2001, she transferred to Takasago where she is presently a general flavorist, concentrating in beverage and confection flavors.

Odila Zocca graduated from the Universidade De Campinas, Sao Paulo, Brazil, with a double degree in biology and chemistry. She started working in the industry with Unilever and Quest in Brazil. She has had subsequent instrumental experience at Ungerer, BBA, Manheimer and, presently, is the chief creative perfumer and technical VP for Premier Specialties, based in New Jersey.

Doug Young was raised in Brooklyn, New York, and received a bachelor's degree in chemistry from the City College of New York in 1972. He has spent more than 30 years in the flavor industry, beginning with T. Lipton's flavor development group. He has specialized in savory flavor development, and has been with Manheimer, Universal Flavors and most recently Symrise, where he is their principal flavorist. Doug and I have collaborated on many evaluations that have appeared in *Perfumer & Flavorist*.

Carl Holmgren, the gentle Norseman, is a very quiet guy with a keen ability to taste. Carl was born in Brooklyn, New York, and graduated from City College of New York with a degree in chemistry. He first started in the flavor industry at Givaudan. He has also been associated with Haarmann & Reimer (H&R), Stange

and Naarden before he joined Procter & Gamble in 1981. He is a consulting creative flavorist working mainly in mint flavors for confections. He started working on mint flavors at H&R and then at the health care division of P&G, where he specialized in mint flavors for the oral care and chewing gum markets. Carl executed the start-up of Brooklyn by Perfetti Ltd., the flavor development arm of Perfetti/Van Mell Corp., in 1998. He is a past president of the SFC. We have collaborated on many evaluations that have appeared in *Perfumer & Flavorist.*

Acknowledgements

As I review my creative career, I will always remember IFF for giving me the opportunity to learn my craft by providing the mentors whose patience and perseverance enabled me to entertain the concept of becoming a flavorist. I'm also grateful to H.H. Ottens for providing the necessary hands-on learning experience, giving me the self-assurance to continue in the flavor industry. I thank Food Materials for its confidence in giving me my first chief flavorist title and providing a most rewarding career. I am grateful to Bush Boake Allen for naming me flavorist of the year in 1992, and to Universal Flavors for introducing me to the grilled pork tenderloin sandwich that has forever placed Indiana on my gastronomic map.

Lastly, I dare not forget to mention my wife, Barbara, without whose constant encouragement, considerable understanding, infinite patience and unconditional support continue to make my home life a tranquil and restful healing retreat from the typical grind of a creative career.

The Role of Organoleptic Descriptive Analysis in the Training of Creative Flavorists

Gerard Mosciano

If you aspire to become a flavorist, you will have a lot of work ahead of you. Like an aspiring painter, you must learn the tools of the trade, the myriad natural and artificial ingredients contained in the ever growing FEMA and GRAS lists. Like a musician, you must spend countless hours rehearsing the various combinations of notes that, when completed, will yield a viable flavor.

If you aspire to become a flavorist, you will become one of two types, depending upon the type of company you work for and the assets that the organization will expend for your training. You will become either 1) a matching flavorist, one that identifies as a flavorist yet can only reverse engineer what his or her GC/MS has chromatographically deconstructed, or 2) a creative flavorist, one who knows the organoleptics of the organic ingredients, the building blocks used to create flavors.

Unfortunately, matching flavorists are all that a lot of companies require and the only type they can train. While flavor matching offers a quicker payback, the commercial gratification of becoming the secondary and lower cost supplier of any flavor is not an enviable

marketing position to which most flavor companies aspire. Flavor companies that employ matching flavorists do so out of necessity. They have no suitable program with the required, experienced mentors that can undertake the costly, lengthy and arduous task of transforming a flavor technician into a creative flavorist. Creative flavor companies aspire to be the primary supplier of any flavor and maintain that position by providing flavor trainees with the required mentoring as well as the requisite technical instrumental backup and flavor applications.

In order to be considered for membership as a creative flavorist, the Society of Flavor Chemists (SFC) has published the following definition of a member on its Web site (*www.flavorchemist.org*):

> Society members are primarily chemists and food scientists, but there are also members from other backgrounds as well. Flavor chemists (also known as flavorists) develop flavors for a wide variety of food and pharmaceutical products, using creative and artistic talents along with various analytical tools including gas and liquid chromatography. To become a certified member of the society, the candidate must complete an approved seven year apprenticeship period as stipulated by our by-laws and then pass a review by the membership. Apprentice members must complete an approved five year apprenticeship period with a review.

The society also provides the following syllabus of material that the flavorist applicant should know after the required mentoring period (T-1).

As one can see, this syllabus is quite extensive; it reflects the knowledge that a candidate should possess prior to applying for either an apprentice or professional membership. The membership requirements are stringent. Verification of the requirements is a two-part process: First is getting the written certification of a certified member that can attest to the candidate's possession of the suitable basic requirements and their ability to creatively employ those abilities for a specific period of time. Second is a requirement to present oneself for a verbal examination dealing with the knowledge that a member should possess. One should think of the flavor mentoring

T-1. The Society of Flavor Chemists' syllabus

Material quoted herein is available at www.flavorchemist.org.

This document is an elaboration of Article II, I, c, of the Society of Flavor Chemists' by-laws which state that applicants for certified membership "must exhibit a working knowledge of...raw materials, laboratory procedures, production processes, legal/ regulatory consideration and the economics involved in the creation, production, and utilization of flavors."

The syllabus is intended to provide support and guidance to training programs. It is the expected knowledge from which the Membership Review Board draws their interview questions.

No attempt has been made to divide the subject matter into Certified and Apprentice SFC membership categories. It is expected that Certified members will have broader and deeper knowledge than Apprentice members, but it is not the intention here to elaborate who should know what. It is not unlikely that anyone will know everything. Since there are no formal courses in Flavor Chemistry, most of a candidate's knowledge and training must come from work experience, trial and error and the counsel of more experienced practitioners of the art. In addition, most people will find it useful or necessary to supplement their experience by consulting various published sources. Some examples of these are:

1. *Fenaroli's Handbook of Flavor Ingredients I and II*
2. *Morrison and Boyd - Organic Chemistry 3rd ed.*
3. Industry periodicals including:

*Cereal Foods World

*Food Chemical News

*Food Engineering

*Food Processing

*Food Technology

**Perfumer & Flavorist* magazine

*Prepared Foods

*Journal of Agriculture and Food Chemistry

4. Steffan Arctander - *Perfume and Flavor Chemicals, Perfume and Flavor Materials of Natural Origin*
5. *Food Chemicals Codex*
6. Ernest Guenther — *The Essential Oils*
7. Henry Heath — *Source Book of Flavors*

8. Joseph Merory — *Food Flavorings: Composition, Manufacture and Use*
9. Code of Federal Regulations

Basic Organic Chemistry

Structures*

Hydrocarbons
Amino acid
Carboxylic acids
Reducing sugar
Alcohols
Ethers
Aldehydes
Isomers: *cis* and *trans*, dextro and leavo
Esters
Furans
Ketones
Salts
Macrocylic compounds
Sulfur compounds
Lactones
Terpenes
Nitrogen compounds
Sequestiterpenes
Phenols

*define each structure and give examples

Reactions**

Acetal formation
Oxidation
Enzymolysis
Polymerization
Esterification
Schiff's base

Fermentation
Strecker degradation
Maillard reaction

**describe which structures are involved, conditions required, and how to accelerate or inhibit the reaction

Instrumental Analysis***

Density meter
Nuclear magnetic resonance (NMR)
Gas chromatograph (GC)
Polarimeter
High performance liquid chromatograph (HPLC)
Refractometer
Mass spectrometer (MS)

***discuss principles and applications

Organizations

Food Chemicals Codex (FCC)
International Life Sciences Institute (IOFI)
International Organization of the Flavor Industry (IOFI)
International Organization for Standardization (ISO)
United States Pharmacopeia (USP)

Trade Groups

American Association of Cereal Chemists (AACC)
American Spice Trade Association (ASTA)
British Society of Flavor Chemists
Chemical Sources Association (CSA)
Flavor and Extract Manufacturer's Association (FEMA)
Institute of Food Technologists (IFT)

National Association of Fruits, Flavors, and Syrups (NAFFS)
Research Chefs
Society of Flavor Chemists (SFC)

Regulatory

Bureau of Alcohol, Tobacco, and Fire Arms (ATF)
Code of Federal Regulations Volume 21 (21 CFR)
Expert Panel
U.S. Food and Drug Administration (FDA)
United States Department of Agriculture (USDA)

Environmental/Safety

Consumption Ratio
Environmental Protection Agency (EPA)
Good Manufacturing Practices (GMPs)
Hazardous Material Identification (HMIS)
Occupational Safety and Health Administration (OSHA)

Procedures and Documentation

Certificate of analysis
ISO 9000
Continuing guarantee
Kosher certification
Department of Transportation
Material safety data sheets
Drug Enforcement Administration
Natural certification
Halal certification
Specifications

Category of Flavoring Substances

Natural — explain physical form, method of production and solubility of:

Absolutes

Essential oils

Concentrates: fruits

Extracts: fluid, solid, CO_2

Concretes

Oleoresins

Distillates: fruit, cocoa, coffee

Resinoids

Enzymatic modified cheeses

Categories — give examples of each:

Floral

Citrus: explain how and why products are concentrated, washed, etc.

Spice

Vanilla: explain standard of identity, extraction, folding

Major chemical component which characterizes aroma/flavor of:

Almond

Dill

Anise

Eucalyptus

Basil

Lavender

Bergamot

Lemon

Bois de rose

Marjoram

Capsicum

Mustard

Caraway

Neroli bigarade

Cassia

Orange
Cinnamon: bark and leaf
Orris
Clove
Peppermint
Coriander
Spearmint

Nature-identical — define and give examples

Artificial — define and give examples

Legal considerations

Labeling-
Flavor declaration:

Artificial
BATF natural:

Natural
Artificial topnote
Natural Flavor Type
Exemptions to topnote limitations
Natural WONF
Potability
Non-characteristic

Solvents:

Types: Water soluble, oil soluble
Advantages/disadvantages/limitations

Acidulants and buffers

Carriers:

Gums
Starches
Salts
Sugars

Colors: FD&C, lakes

Preservatives:

Types:

Antimicrobial
Antioxidant
Natural/artificial

Standard of identity- define and give example

Genetically Modified Organisms-

Allergens-

Organic Foods-

Flavor Forms

Liquid:
Water-soluble
Oil-soluble
Emulsions

Dry:
Plated
Powders

Spray dry
Drum dry

Pastes:
Enzyme modified products

Describe processing procedures. Explain solvents, carriers, etc., used for each and the finished products to which they are applied. Discuss advantages/disadvantages of each, such as shelf life stability.

Organic Chemicals Used in Flavors

Name two chemicals which naturally occur in and characterize the flavor of:
Apple
Grape
Banana
Honey
Blueberry
Lemon
Butter
Orange
Cherry
Peach
Cocoa
Peanut
Coffee
Raspberry
Cream
Strawberry

What chemicals could be used to modify a flavor and make it:
riper?
fresher?
juicier?
sweeter?

What chemicals would fall into the following descriptive categories?

Dairy
Minty
Waxy
Floral
Pulpy
Brown
Green
Spicy
Nutty
Fruity
Fatty
Earthy

program as a master's program followed by an oral examination to determine if a candidate possesses the necessary qualifications for membership in the SFC. In a way, the SFC has become the qualifier of flavorists for the flavor industry. Many job outlines list, as a precondition for employment, that a successful candidate should be a professional member of the society.

The syllabus requirements deal with several areas of knowledge that are considered to be vital for any career as a creative flavorist:

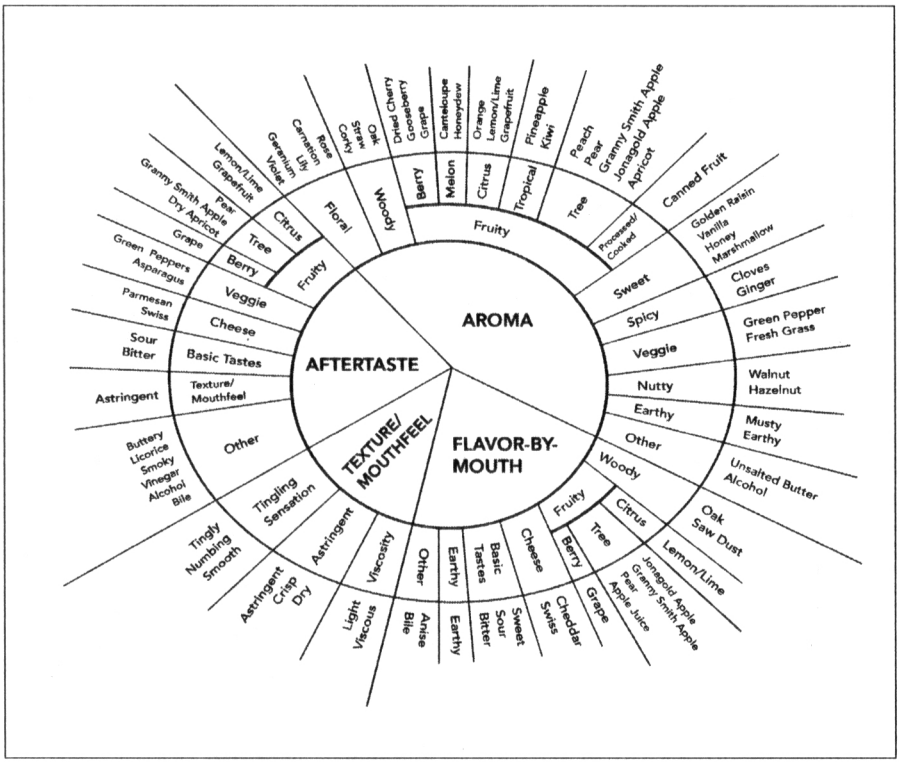
- Regulatory requirements for flavors and the labeling that accompanies each container of flavors. This is even more important today, due to the international nature of the flavor business and the expanding regulatory compliance statutes.
- The various physical forms that a flavor may have, their usual applications and limitations of each.
- The basics of organic chemistry dealing with the various classes of compounds that are used as flavor ingredients.
- Natural flavoring materials, their classification, and some of their characterizing components.

- The principals and applications of the various instruments employed in flavor research and development and quality control.
- Most important of all is that it stresses the need for an effective flavor language or a lexicon of flavor descriptors for the aromatic ingredients that constitute the core ability of a creative flavorist.

A flavor technologist, given adequate time and access to the necessary resources, could pick up much of the necessary knowledge to fulfill most of the above requirements; the last one could become a serious obstacle. Tasting is a subjective sensory experience that becomes a learning experience under the proper conditions and guidance. The sensory language learned during these tastings of flavor ingredients will become the most utilized resource that a flavorist will employ throughout their creative career. It is the task of the mentor or teacher to impart, based on their own experience of having mastered the descriptive analysis of flavor ingredients and their application, that a technologist begins the training process that will eventually enable them to relate his or her sensory perceptions to a either a specific flavor ingredient or to a class of flavor ingredients, be they natural or artificial. A technologist will use his or her descriptive lexicon to establish the organoleptic parameters of a creative project, continuously evaluate the progress of the ongoing creative effort and finally compound the initial flavor for customer submission. When first entering any flavor lab, one is usually stunned by the vast number of shelves crammed with various bottles and jars. Without any previous flavor experience, all of these ingredients appear alike. Similarly, until one personally evaluates the organoleptic potential of each flavor ingredient and outlines their descriptive profile, any flavor ingredient is but a name on a bottle, a Flavor and Extract Manufacturers Association (FEMA) number having a set of physical constants, with no apparent flavor application. There may be some organoleptic information available in various databases on what someone else thought were the ingredients' organoleptic properties. There are several thousand approved FEMA flavor ingredients, all once thought to contribute consequential sensory attributes to a

finished flavor that they warranted FEMA approval. Flavor descriptors are of paramount importance in building a workable library of descriptive terms, a lexicon that will segregate the functionality of flavor components and establish a common language between the mentor and trainee and between the customer and creative flavorist. Or more simply put, will lay the practical foundation for flavor creation.

No two FEMA approved ingredients possess exactly the same organoleptic profile. In fact, any quality control person will attest that even the same ingredient, from the same vendor, may sometimes not possess the same organoleptic profile from lot to lot. Flavor chemistry lies in the organoleptic details that determine which lactone is best suited for butter and which is best suited for an apricot, which



F-1. A graphic outline of flavor characteristics/descriptors — flavor wheel*

*Chardonel wine sensory attribute wheel (Journal of Food Science, Vol. 69, Nr. 6, 2004, S215)

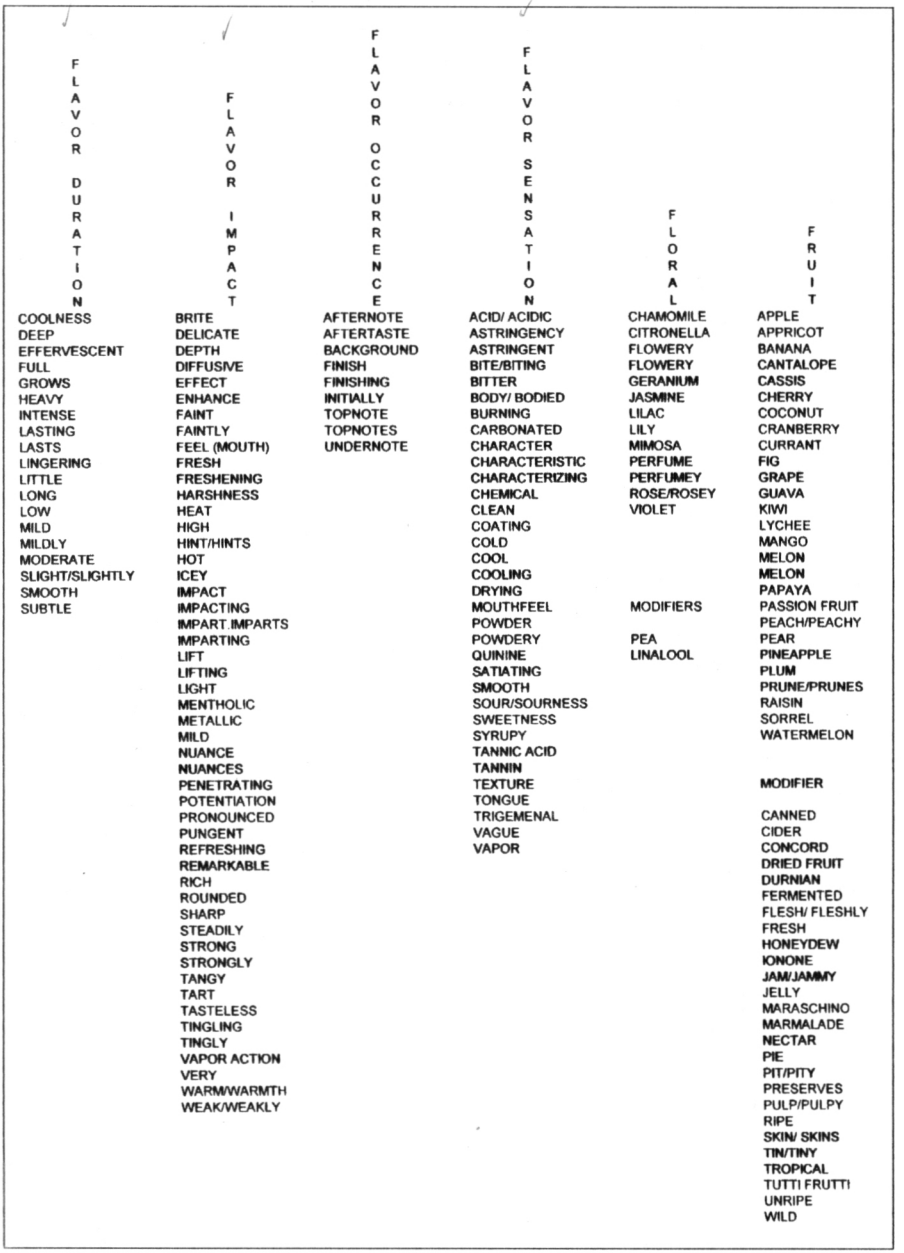
acid is ideally suited for a parmesan cheese and which acid is more typical for mutton flavors. It is only after evaluating many flavor ingredients that one will begin to appreciate the perceptible organoleptic differences in a homologous series of ingredients and thus begin to appreciate the importance of using the proper descriptors.

As a training tool, there are many methods to graphically outline the flavor characteristics or descriptors in any particular food item or compounded flavor. I am including several different versions for your evaluation (T-2 and F-1). As a means of evaluating the flavor profile of any food or beverage, summaries of descriptors are very

T-2. A graphic outline of flavor characteristics/descriptors

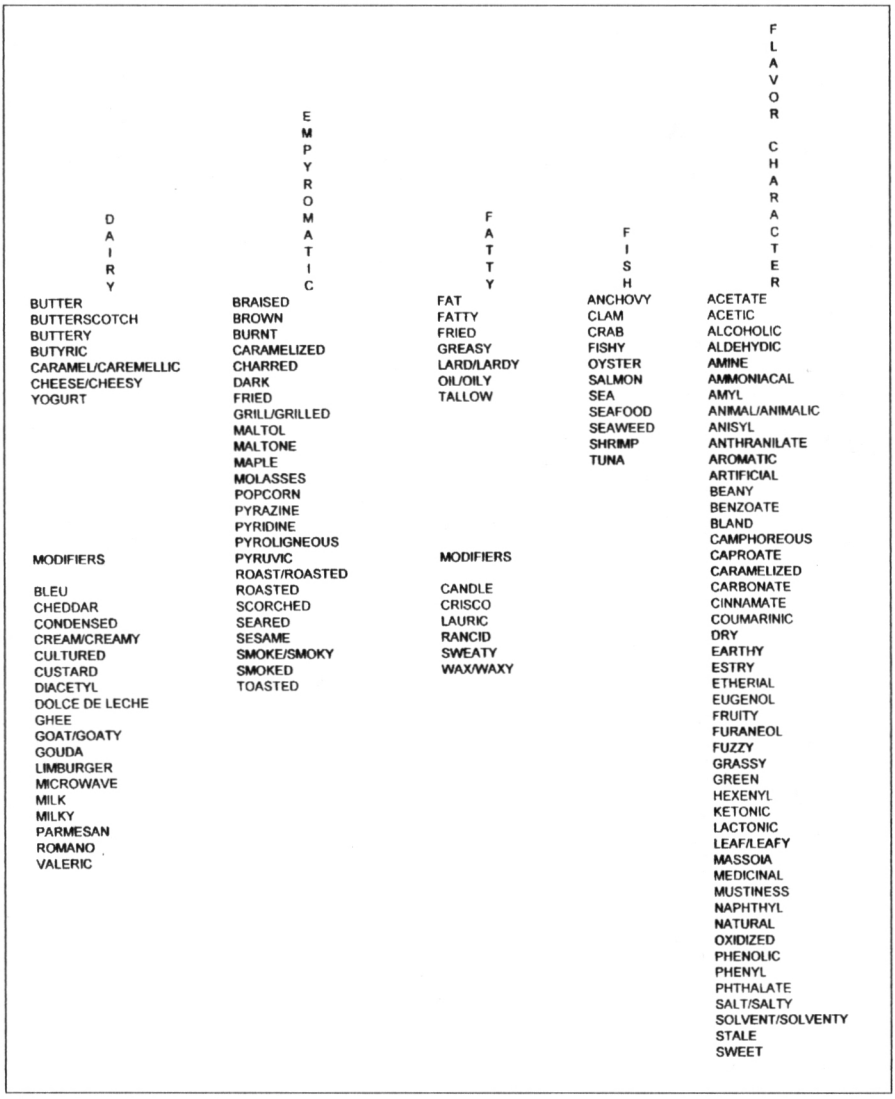
ALLIACEOUS	BOTANICAL	BERRY	BEVERAGE	CITRUS	CONFECTION
ASAFETIDA	AMBRETTE	BLACKBERRY	BEER	BERGAMOT	BRITTLE PEANUT
GARLIC	BALSAMIC	BLACKCURRANT	COCKTAIL	GRAPEFRUIT	BUBBLEGUM
LEEK	CAROB	BLUEBERRY	COCOA	LEMON	BUTTERSCOTCH
ONION	DAVANA	CRANBERRY	COFFEE	LIME	CANDY
ONIONY	FOENUGREEK	STRAWBERRY	EGG NOG	MANDARIN	FONDANT
SCALLION	HAY		ROOT BEER	ORANGE	GUM
SULFUREOUS	INCENSE		SHERRY	TANGERINE	HONEY
	LICORICE		SODA		HONEY
	LOVAGE		TEA		JELLO
	ORRIS		WHISKEY		JORDAN ALMONDS
	PATCHOULI		WINE/WINEY		MARSHMALLOW
	VALERIAN				MINT/MINTY
	VANILLA				TOFFEE
MODIFIERS	MODIFIERS	MODIFIERS	MODIFIERS	MODIFIERS	MODIFIERS
CATTY	CIGARETTE	BLUE	ALCOHOLIC	ALBEDO	BLACK
DISULFIDE	CONCRETE	RED	ASH TRAY	CITRAL	CANDY CANE
FECAL	GLYCYRRHIZA	SEED/SEEDY	ASHY	CITRIC	CHEWING
GASSY	PERU		BRANDY	CYMENE	COTTON
MERCAPTAN	RESINOUS		BREWED	DISTILLED	DENTYNE
METHIONAL	SULFUROUS		CARBONATED	ESSENCE	DOUBLEMINT
SKATOLE	THIO		CASKY	EXPRESSED	JELLO
SKUNK	TOLU		CHAMPAGNE	JELLO	MARIZIPAN
STENCH			COGNAC	JUICE/JUICY	PEPPERMINT
			CORDIAL	JUICENESS	SPEARMINT
			DARK	LEMON GRASS	TERPENIC
			EXPRESSO	LEMONADE	TERPINEOL
			GIN	LINALOOL	TERPY
			GRAPPA	NOOTKATONE	WEED/WEEDY
			HOPPY	PEEL/PEELY	
			ITALIAN	PINENE	
			JAVA	PINEY	
			LATTE	RIND/RINDY	
			LIQUEUR	SQUEEZED	
			MOCHA	STILL	
			MOUTHWASH	TURPENTINE	
			PORT	VALENCENE	
			PUNCH		
			RUM/RUMY		
			TEQUILA		

helpful. These descriptors, as well as the required references, are very important and are often quite interesting. Sometimes the reference materials are so simplistic as to be irreproducible, and other times are so vague as to provide no definitive reference. It is only when



FLAVOR DURATION	FLAVOR IMPACT	FLAVOR OCCURRENCE	FLAVOR SENSATION	FLORAL	FRUIT
COOLNESS	BRITE	AFTERNOTE	ACID/ ACIDIC	CHAMOMILE	APPLE
DEEP	DELICATE	AFTERTASTE	ASTRINGENCY	CITRONELLA	APPRICOT
EFFERVESCENT	DEPTH	BACKGROUND	ASTRINGENT	FLOWERY	BANANA
FULL	DIFFUSIVE	FINISH	BITE/BITING	FLOWERY	CANTALOPE
GROWS	EFFECT	FINISHING	BITTER	GERANIUM	CASSIS
HEAVY	ENHANCE	INITIALLY	BODY/ BODIED	JASMINE	CHERRY
INTENSE	FAINT	TOPNOTE	BURNING	LILAC	COCONUT
LASTING	FAINTLY	TOPNOTES	CARBONATED	LILY	CRANBERRY
LASTS	FEEL (MOUTH)	UNDERNOTE	CHARACTER	MIMOSA	CURRANT
LINGERING	FRESH		CHARACTERISTIC	PERFUME	FIG
LITTLE	FRESHENING		CHARACTERIZING	PERFUMEY	GRAPE
LONG	HARSHNESS		CHEMICAL	ROSE/ROSEY	GUAVA
LOW	HEAT		CLEAN	VIOLET	KIWI
MILD	HIGH		COATING		LYCHEE
MILDLY	HINT/HINTS		COLD		MANGO
MODERATE	HOT		COOL		MELON
SLIGHT/SLIGHTLY	ICEY		COOLING		MELON
SMOOTH	IMPACT		DRYING		PAPAYA
SUBTLE	IMPACTING		MOUTHFEEL	MODIFIERS	PASSION FRUIT
	IMPART.IMPARTS		POWDER		PEACH/PEACHY
	IMPARTING		POWDERY	PEA	PEAR
	LIFT		QUININE	LINALOOL	PINEAPPLE
	LIFTING		SATIATING		PLUM
	LIGHT		SMOOTH		PRUNE/PRUNES
	MENTHOLIC		SOUR/SOURNESS		RAISIN
	METALLIC		SWEETNESS		SORREL
	MILD		SYRUPY		WATERMELON
	NUANCE		TANNIC ACID		
	NUANCES		TANNIN		MODIFIER
	PENETRATING		TEXTURE		
	POTENTIATION		TONGUE		CANNED
	PRONOUNCED		TRIGEMENAL		CIDER
	PUNGENT		VAGUE		CONCORD
	REFRESHING		VAPOR		DRIED FRUIT
	REMARKABLE				DURNIAN
	RICH				FERMENTED
	ROUNDED				FLESH/ FLESHLY
	SHARP				FRESH
	STEADILY				HONEYDEW
	STRONG				IONONE
	STRONGLY				JAM/JAMMY
	TANGY				JELLY
	TART				MARASCHINO
	TASTELESS				MARMALADE
	TINGLING				NECTAR
	TINGLY				PIE
	VAPOR ACTION				PIT/PITY
	VERY				PRESERVES
	WARM/WARMTH				PULP/PULPY
	WEAK/WEAKLY				RIPE
					SKIN/ SKINS
					TIN/TINY
					TROPICAL
					TUTTI FRUTTI
					UNRIPE
					WILD

sensory references are related to individual chemical components that they become informative and definite. While you may or may not agree with their descriptors or their references, they are starting points. This outlining of descriptors is intended to limit the number of potential descriptors to a manageable number and usually includes some sort of reference that is intended as a comparison. Since there are many food items, each in turn would have a standard set of descriptors as well as an accompanying set of references. We as



flavorists will have to eventually create flavors for many food groups, so it would be very difficult to evaluate potential flavor ingredients as a component of a particular food or food group.

Flavorists will also have to deal with many alternative sources of flavor ingredients and how they differ organoleptically from each other. Today we have to deal with natural versions for many of our synthetic flavor ingredients, how they differ from their synthetic versions and how they vary from other comparable natural sources. As a rule, artificial ingredients are usually not source-specific; however,

FUNGAL	GRAIN	HERBAL	LIKE/DISLIKE	NUT	SAVORY
FUNGAL	BARLEY	ALFALFA	BAD	ALMOND	BACON
MUSHROOM	BREAD	CLOVER	BLAND	CASHEW	BEEF
TRUFFLE	CAKE	CHAMOMILE	DELICIOUS	FILBERT	BEEF CORNED
	CEREAL	COSTUS	GREAT	HAZELNUT	BEEFY
	COOKIE	DILL	INTEREST	MACADAMIA	CHICKEN
	COOKIES	GALBANAM	INTERESTING	PEANUT	HAM
	CORN	HERBACEOUS	NICE	PECAN	HAMBURGER
	CRACKER		REAL	PISTACHIO	LIVER
	FLOUR		CHARACTERIZING	WALNUT	MEAT/MEATY
	GRAHAM				MSG
	GRAIN				MUTTON
	GRAINY				PORK
	MACAROON				POULTRY
	MALT/MALTED				ROUX
	RICE				SALAMI
	SOY				SAUSAGE
					STEAK
					TURKEY
MODIFIERS	MODIFIERS			MODIFIERS	UMAMI
		HERBAL			
DAMP	BAKED	LEAFY		NUT/NUTS	
DIRTY	BASAMITI	MOSS/MOSSY		NUTTY	MODIFIERS
EARTHY	BREADCRUST			PYRAZINE	
MILDEW	COOKED			SHELL	AYP
MOLD/MOLDY	CRISP/CRISPY			THIAZOLE	BLOODY
MUSK/MUSKY	CRUST				BOILED
MUSTINESS	DOUGH/DOUGHY				BOUILLON
MUSTY	FROOT(LOOPS)				BROTH
SHITAKI	TACO				BROTHY
	THIAZOLE				BROWN
	TORTILLA				BURGER
					DRIPPING
					DRIPPINGS
					FRIED
					GRAVY
					GROUND
					HVP
					PAN DRIPPINGS
					RUBBER
					RUBBERY
					SAUTEED
					SOUP/SOUPY
					STEWED
					THIAMINE
					THIAZOLE
					VITAMIN

SPICE	VANILLA	VEGETATIVE	WOODY
ANISE	BEANY	AVOCADO	CEDAR
ANISIC		BEAN	FIR
BASIL		BEANS	HICKORY
BUCHU		BEANY	MESQUITE
CARAWAY		BROCCOLI	OAK/OAKY
CARDAMOM		CABBAGE	PINE
CINNAMIC		CARROT	PINEY
CINNAMON		CAULIFLOWER	SPRUCE
CLOVE		CELERY	WOOD
CORIANDER		CHILE	WOODY
CUBEB		CHIVE	
CUMIN		CILANTRO	
CUMINIC		CUCUMBER	
CURRY		JICAMA	
EUCALYPTOL		LETTUCE	
EUCALYPTUS		OLIVE/OLIVES	
EUGENOL		PICKLE/PICKLES	
FENNEL		POTATO	
GINGER		POTATOES	
HORSERADISH		PUMPKIN	
JUNIPERBERRY	MODIFIERS	RADISH	MODIFIERS
MARJORAM		SESAME	
MUSTARD	CREAMY	SLAW	
NUTMEG	CREAMY	SPINACH	IONONE
OREGANO	HELIOTROPINE	SPROUTS	SAWDUST
PARSLEY	VANITROPE	TOMATO	
PEPPER			
PEPPERY			
RUE			
SASSAFRASS			
TARRAGON			
THYME		MODIFIERS	
WABASI			
WINTERGREEN		FRENCH(FRIED)	
		MASHED	
MODIFIERS		RAW	
		ROOT/ROOTY	
BARK		ROTTING	
BLACK		STEM/STEMY	
ESTRAGOLE		TIN	
PEPPER		VINEY	
SPICY/SPICENESS			

natural ingredients are usually very source-specific. Contrary to what many purchasing gurus believe and promulgate, you cannot limit the general availability of flavor ingredients. While it is reasonable to limit the general availability to one synthetic ethyl acetate, usually from a kosher source, you cannot limit the access of your creative people to using just one natural Davana oil or one natural mango juice concentrate or essence or one natural Pyrazine fraction. Today, natural flavor ingredients, flavor isolates and reaction products are readily available from many sources; these tend to be very source-specific, and many of the newer items will contribute unique flavor characteristics and important subtle nuances that their predecessors never could. Over the years, the technology used to produce natural fruit juice concentrates, juice essences and other botanical products and especially today's "naturally derived" flavor ingredients have improved dramatically in both quality and price. If a flavorist was forced to stick with only one source, he or she would lose competitiveness by retaining an inferior ingredient or would be priced out of the competition by remaining with the older higher cost supplier. Another mantra of the purchasing group, that only the lowest cost ingredient should always be preferred, is equally mistaken. The first natural ethyl butyrate available was priced at over $150 per pound. That price is laughable today, but it also means that one must continuously evaluate newer products from a range of sources. QC must maintain rigid alternate source evaluations that are based on comparable organoleptic characteristics and not on cost. Ultimately you should base your usage criterion only on an ingredient's cost in use in the final product, if the ingredient delivers a desired organoleptic effect. Finally, once a product has been accepted by a customer, that final formulation becomes sacrosanct, and the sources for all the ingredients should only be changed to organoleptically approved alternative sources.

To establish a common descriptive language among any flavor group, it is important to encourage maximum participation by the group. The larger the group, the better the discussion of terminology and more sensory organoleptic associations are made. Also, the practical experiences of where ingredients can be used are better

conveyed. I have found that getting a group involved in evaluating ingredients is easy, once you establish several ground rules. Aroma and taste solutions should be prepared ahead of time and a specific time should be set aside for daily tasting. Tasting ballots should be prepared and available for all (F-2). I have found that tasting in the early morning, before the hecticness of the day destroys whatever plans have been set, is the most efficient. Once a routine is established, the evaluation of two or three ingredients per day is easily doable and does not consume an excessive amount of creative time. The evaluation of 100-150 ingredients per year allows the screening of established ingredients as well as the newer sources for existing ingredients and the evaluation of newer natural ingredients and newer sources of flavor ingredients. It also fulfills the flavor training requirements for many technicians.

From my earliest days in the flavor industry, I have been constantly evaluating flavor ingredients. I have always used a hard copy form to record each evaluation and I have tried to involve as many people as possible. The hard copy enabled me to record my own evaluations, but more importantly to record the personal comments from my mentor and later the insightful comments from the others who would participate in the evaluations. I have used many of these comments to later retrieve particularly interesting ingredients. I use the basic odor, taste and potential use fields to record the results of my organoleptic evaluations as well as consensus fields, where common terms are grouped. I have also included several fields that are useful in limiting searches, natural or artificial and natural occurrence. I also record flavor application level and the product code for potential reference. I include fields to list the ingredients source and product code, flavor score, date evaluated and its FEMA and Chemical Abstracts Service (CAS) numbers. I tend to do all my indexing based on FEMA numbers. When you include all the common names as well as their unique commercial names, the FEMA number is a simple but elegant way to retrieve an ingredient. The FEMA number is an ideal basis for assigning raw material numbers. I have often seen the same raw material being assigned two different raw material numbers, based on trivial, trade or chemical names.

- ***Material:*** I list whatever the supplier states on their label.
- ***Synonym:*** These are either common names or supplier-specific designations.
- ***Supplier and product codes:*** These are very important because of source specificity. This information is very necessary to obtain fresh working samples for

FLAVOR MATERIAL EVALUATION

DATE:_____

MATERIAL:_____

SYNONYMS:_____

SUPPLIER:_____ **PRODUCT CODE:**_____

FEMA#_____ **CAS #**_____

NATURAL OCCURRENCE:_____

INDIVIDUAL EVALUATION

ODOR _____ **%/PPM** **TASTE:**_____ **%/PPM**

CONSENSUS EVALUATION

POSSIBLE APPLICATIONS

NOTES:

F-2. Flavor material evaluation sheet

initial flavor compounding. I incorporate the product code after the ingredient's name.

- ***FEMA and CAS numbers:*** These make single ingredient searches very easy and do not rely on chemical or trivial names.
- ***Odor concentration and flavor level of evaluation mixture:*** I usually use alcohol as a dilutent and I taste in deionized water or spring water. When tasting citrus products I will use three to five percent sugar sweetened citric acid acidulated solution. Savory ingredients are best evaluated in slightly salted solutions. Either way, additives in the tasting solution are always noted, to facilitate any subsequent re-evaluations and flavor comparisons.
- ***Individual evaluations for odor and taste:*** These fields are for individual opinions and comments. I use the odor concentration as well as the taste levels as references for future re-evaluations, as well as comparison with other ingredients. The odor and taste fields should include organoleptic, as well as strength, impacting and aftertaste remarks. The concentrations of the odor and taste solutions are important, but appraisals of impact are also very useful. In theory, aroma and taste solutions should be evaluated at several different levels. This is to evaluate the ingredient separately as a major contributor, then at a lower concentration as a minor contributor, and finally at a much lower level to determine its nuance effects. While this might be the best procedure in theory, it is too time consuming, so the choice of evaluation levels should be proportional to flavor strength and character. I odor-evaluate most organic compounds at one percent in EtOH; citrus products, depending upon their folds, I start evaluating at one percent. Sulfur compounds are evaluated at 0.1 percent or less. I usually check on normal usage levels to determine a tasting level. Leffingwell's database provides normal usage level information as well natural occurrence.
- ***Consensus evaluations:*** These fields are to outline what a group of flavor people thought about an ingredient. This is how a trainee can compare his descriptors to what the group comments were and attempt to interpret their descriptors in order to establish a common language among the tasting group.
- ***Possible applications:*** The purpose of tasting with a group is to incorporate the multiple flavor backgrounds and multiple years of flavor experience. The trainee has limited applications concepts while the mentor and the other

members of the tasting group have intimate and practical knowledge of the ingredient and its applications based on their varied creative backgrounds.

- ***Notes:*** This field is reserved for unit cost, kosher status, broker involved, and addresses and phone numbers of any new supplier. I usually include my taste sheet as I apply for a new raw material number.

Years ago when I started my training, a tasting routine was established; I attempted to record the results of my evaluations in a binder. I did not want to lose the minute details of these training sessions. I transcribed each flavor descriptor into as many descriptors that applied. So if a flavor ingredient had several descriptors, such as sweet, estry, fruity, apple, etc., I would re-enter the ingredient under each descriptor heading. If an ingredient had four descriptors, it would have to be entered four times, and I was only dealing with taste. To have dealt with aroma and potential application would have been a nightmare. There had to be a better way of recording such information and making it more complete and readily available. After a while, I had amassed a yard of notebooks, and my penmanship made the information virtually unintelligible. What I wrote in haste became hieroglyphics in a very short time. It was then that I started to search for a computer and a program to store the information.

In the early days of personal computing, it helped if you were computer literate and could do some of your own programming. Not being so inclined, I purchased one of the first Apple Macintoshes. It offered a limited but enjoyable means to write a lot of memos, but no good database. When Filemaker was first introduced, it quickly became the benchmark to which other databases were compared. It has been many years and many revisions since I entered my first organoleptic descriptors of a flavor ingredient. I have since made more than 2,000 additional entries. It is neither rocket science nor fancy, but it provides multiple search capabilities that will retrieve a particular flavor ingredient or a group of flavor ingredients that correspond to either an aroma descriptor, a taste descriptor, or both an odor and taste descriptor, a particular supplier's products, or any ingredient that possess the organoleptic properties that a current creative project demands. The latest of its

many versions, Filemaker 7.0, is available for both the Mac and Windows platforms.

What you don't want in a flavor database is a Google-type response of several hundred hits when queried. I am not interested in 100 responses if I have to reevaluate all of them again. I want a focused response that I can use to begin a flavor project. You want to know which ingredients have a particular set of aroma descriptors as well as desired taste profile and that will be applicable in a product you are interested in creating. Therefore, the more descriptors you use in defining a flavor ingredient's aroma and taste, the more rewarding your queries will be. Do not be fooled into thinking that "green fruity" is an adequate query for the odor of an ingredient; my database will yield over 300 ingredients that share those descriptors. If you could expand the search for green fruity aroma, and a fruity taste and potential applications in apple, you would be still left with over 150 potential ingredients. This result is still too broad and needs a more exacting choice of descriptors so that you are left with a more manageable list of ingredients (T-2).

The overall number of descriptors I have amassed over the years is more than 400. I have broken them down into 21 distinct flavor categories and seven subjective comment categories. Flavor character, flavor duration, flavor impact, flavor occurrence, flavor sensation, like/dislike and similar to are included because they are very important to me. Character is more of a process of grouping like components; flavor duration designates those ingredients that possess unique flavor profiles. Flavor impact will range from the etherealness of ethyl formate to the creamy character of ethyl vanillin. Flavor occurrence outlines where and when the flavor is perceived. Flavor sensation is a trigeminal evaluation for outlining the bite of ginger, the cooling sensation of menthol and the carbonation notes of a Jambu extract. Like and dislike is self explanatory: I will use what I like and won't use anything that I don't like. Sometimes, when working on certain flavor types, you must use ingredients that you would not consider among your favorites. A similar method is used to relate an ingredient to other ingredients, usually in a homologous series, an essential oil or other natural botanical product with a comparable organoleptic profile.

The modifiers I have included as extensions of a category were placed there only for the purpose of clarity. The use of these descriptors is not limited to only one category. Usually a flavor ingredient possesses an array of flavor attributes and nuances that transcend many descriptor categories. In fact, the nuance effects of many ingredients differentiate them from similar ingredients and thus warrant its inclusion into a particular flavor.

I am not offering my descriptors as a set of references. I am stating what I and the various people that I have tasted with over the years have used and have found effective. Over time these descriptors got our ideas across. We understood each other when we asked one another to evaluate the progress of our creative efforts. Each person knew what he or she thought and more importantly the direction that, in their opinion, our further efforts should take.

To summarize, the training of a creative flavorist is a lengthy but rewarding process. One must turn every opportunity into a learning experience. Every inquisitive question must be properly answered, keeping in mind the old adage, "there are no stupid questions, only stupid answers." Most importantly, a tasting routine must be started that will initiate the organoleptic reviews of those flavor ingredients that constitute the essence of a creative flavorist.

Flavor Extraction and Instrumental Analysis

Odila Zocca

Introduction

The flavor industry has become highly specialized. What was once the responsibility of a single flavorist—the analysis or the evaluation of a flavor, its creation or duplication, and its applications evaluation—has given way to a highly specialized, interactive group of technical and focused instrumental, creative and applications personnel. While there are many distinct flavor areas that conceivably could still be accomplished by a "rugged individualist," the technical complexity of today's flavor industry demands the timely use of specialists, ones that can "keep up" with the technical advances in separatory science, instrumental complexity and the various multi-skilled applications specialties.

The range of organics in a sample, such as a flavor, can range from very small to very large. The techniques available to analyze these samples include headspace GC, purge and trap thermal desorption (P&T TD), direct thermal extraction (DTE), solvent extraction, and newer techniques, such as solid phase micro extraction (SPME) and supercritical fluid extraction (SFE). Proper selection of the analysis technique as well as optimization of the system parameters is required to achieve the desired results.

Our objective in this chapter is to discuss some basic principles for extracting flavor compounds from finished products in general. The most common problem one encounters when trying to extract a volatile compound from its finished product, whether the product is

natural or not, is obtaining an extraction free of matrix contaminants.

Sample preparation is required for two main reasons: cleanup and concentration. As a result, depending on the nature of a particular sample, it is necessary to choose a suitable method of extraction. Sometimes, a combination of methods is required to obtain optimal results.

An integrated approach to analyzing flavor compounds includes combining sensory organoleptic evaluation with instrumental methods of analysis. No one universal method exists for isolating the entire flavor-compound spectrum. A more common approach is using particular methods that are more suited for isolating and enriching specific fractions of flavor compounds.

Two methods for sensory analysis, Aroma Extract Dilution Analysis (AEDA) and CharmAnalysis, have been developed to gain more information on flavor and odor activities. These techniques can determine the relative odor activity of single odorants within a more complex mixture of odorants, even though their chemical structures are unknown.

CharmAnalysis, or gas chromatography-olfactometry (GCO), is a method where gas chromatography (GC) is used to separate the flavor component, and a trained flavorist sniffs the effluent of the GC to describe the aroma. CharmAnalysis offers a high-resolution GCO and complementary software, called Charmware. The software takes advantage of a flavor compound database, known as Flavornet, compiled from GCO, AEDA and other methods that have detected odorants.

Another development of the past 10 years is the analytical tool known as "the electronic nose." Electronic sensors emulate human olfactory receptors and a computer system emulates the brain. This method has found a niche as a quality-control tool to spot batch-to-batch differences in raw materials and detection of off notes in packaging materials, though it is difficult to imagine that it will ever replace the highly trained nose of the creative perfumer or flavorist.

Quantities of flavor compounds required for detection are very small, frequently in the parts-per-billion range. The number of flavor compounds present in the sample complicates the analysis of specific

flavors. Chocolate flavor may contain more than 200 components; coffee flavor is estimated to have more than 600.

We intend to cover a broad range of sample preparation techniques, thus being able to analyze most kinds of food samples. Both modern equipment (GC, GC/MS and GC-sniff) and several types of sample preparation (dynamic headspace sampling, liquid extraction, Likens-Nickerson distillation/extraction, SPE, SPME, and vacuum distillation) are among the methods used to analyze natural, nature identical and artificial compounds in finished consumer products and natural products.

Methods

Distillation: The Likens-Nickerson continuous distillation and extraction apparatus is probably the most commonly used method of extraction. The basic advantage of this apparatus is that a large volume of target material is being continuously extracted with a very small volume of freshly distilled solvent, although it produces unwanted by-products due to thermal decomposition. This can be improved by conducting the distillation under vacuum.

In this method, volatile compounds are continuously extracted from the gas phase using an organic solvent and enriched in the extraction medium. The use of strong non-polar solvents may not be suitable for polar, water-soluble compounds. Varying the polarity of the solvent may be an alternative and will produce different results. The solvent is then reduced by controlled concentration in a Kuderna Danish apparatus, and the resulting concentrated extract analyzed by GC and GC/MS or other suitable technique.

This method is very time consuming compared to more modern techniques and utilizes large amounts of solvents, sometimes harmful to individuals and to the environment.

Headspace: Aroma compounds are well suited to the use of headspace methods. Headspace refers to the vapor space formed above a sample, where volatile compounds are collected. These volatile compounds can be "captured" from the matrix, isolated and identified without interference from the matrix material.

Headspace is a technique that has been around for a long time.

It is best suited for the analysis of the very light volatiles in samples that can be efficiently partitioned into the headspace gas volume from the liquid or solid matrix sample. Higher boiling volatiles and non-volatiles are poorly detectable using this technique. In addition, the sensitivity of the technique is limited, typically to concentrations in the ppm to ppt range. However, the technique is a preferred method for the analysis of gases and very light volatiles, which cannot be analyzed by other techniques such as P&T TD. The technique is also a preferred technique when sample automation is required and is used in screening of samples.

Static headspace sampling uses a sealed vessel to collect volatiles, with little or no impact on the sample. Volatiles compounds are adsorbed onto a polymer carrier and then thermally desorbed into the GC and GC/MS injection port. Either dynamic headspace or purge and trap (P&T) concentrates the volatiles by "purging" them onto the adsorbent material. P&T is a better method for liquids, as it entails the bubbling of a purge inert gas through the sample. In both methods, the extracted volatile compounds are adsorbed onto a polymer carrier material and then thermally desorbed directly into the GC and GC/MS injection port, condensation trap or organic solvent.

P&T thermal desorption is also a very popular technique and is routinely used for the analysis of volatiles in environmental samples as well as food samples. Through the proper selection of adsorbent resins such as Tenax TA, water can be eliminated from being introduced into the GC. This is important for the analysis of high water content samples such as food products. The P&T technique is more sensitive by at least a factor of 1000 over headspace techniques. Typical sensitivity is in the ppb range. By purging samples at higher temperatures, higher molecular weight compounds can be detected. However, P&T requires more time for sample preparation and cannot easily be automated. In addition, very light volatiles and gases will not be trapped on the adsorbent resins and therefore will be missed in the analysis. P&T has proven to be the optimal method for the analysis of flavors in food due to its high sensitivity and the ability to eliminate the water from the sample being analyzed. Volatiles

ranging from pentane through the terpenes can readily be analyzed with this technique.

Studies reported that the vacuum headspace method produces the most authentic flavor concentrates and with the highest organoleptic quality. The concentrates obtained with the dynamic headspace method were described as rich in the highly volatile components, but the higher-boiling components were under-represented. This produced flavor concentrates with an unbalanced character.

Solid-phase extraction: Solid-phase extraction (SPE) is an extraction method that uses a solid phase and a liquid phase to isolate one, or one type of analyte (the material you intend to analyze, the components of a flavor) from a solution. It is usually used to clean up a sample before using a chromatographic or other analytical method to quantitate the amount of analyte(s) in the sample.

The general procedure is to load a solution onto the SPE phase, wash away undesired components, and then wash off the desired analytes with another solvent into a collection tube.

Solid-phase extractions use the same type of stationary phases as are used in liquid chromatography columns. The stationary phase is contained in a glass or plastic column above a frit or glass wool. The column might have a frit on top of the stationary phase and it might also have a stopcock to control the flow of solvent through the column. The picture below shows a 3 mL cartridge on a vacuum manifold, which increases the solvent flow rate through the cartridge. A collection tube is placed beneath the SPE cartridge (inside the vacuum manifold for the example in the picture) to collect the liquid that passes through the column. (Solid-phase extraction setup illustrated in F-1.)

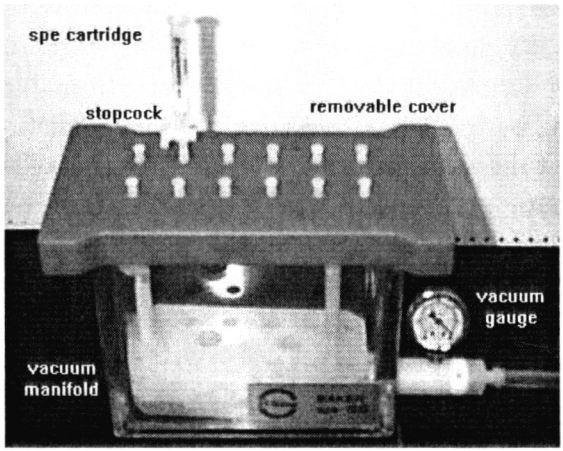
Compared to the classic liquid-liquid extraction using the separatory funnel or the preparative HPLC purification, SPE offers several advantages:

- Reduced lab time
- Easy manipulation
- Lesser amount of solvent required/no disposal of large quantities of organic solvents

- Higher concentration factor
- No problem with the miscibility of solvent
- Easily adaptable for very selective extraction
- Easy automation
- Avoids problems such as incomplete phase separations, less-than-quantitative recoveries and emulsion formation as encountered in liquid-liquid extractions

However, a basic knowledge is necessary of how to perform SPE extractions in an efficient way by selecting the right sorbent (from a variety of reversed, normal or ion exchange phases), conditioning, selective washing and eluting the compounds of interest.

Solid phase microextraction: Solid phase microextraction (SPME) is currently a new and popular technique. It requires minimal accessory equipment (low cost) and is easy to use. Its major shortcomings are the lack of sensitivity and the limited range of volatiles which can be analyzed. It works very well with the less volatile organics, and can be automated.



F-1. Illustration of a solid-phase extraction setup

SPME can be used to adsorb volatile compounds from sample headspace or liquid sampling. SPME is an innovative, solvent-free technology that is fast, economical and versatile; it involves exposing a fused silica fiber coated with a liquid (polymer), a solid (sorbent), or a combination of both, to a sample or its headspace. The absorbed analytes are thermally desorbed in the injector of a gas chromatograph or gas chromatograph-mass spectrometer for separation and quantitation. The fiber is mounted in a syringe-like holder called an SPME fiber assembly, which protects the fiber during storage and penetration of septa in the sample vial and in the GC injector. This device is operated like an ordinary GC syringe for sampling and injection. The extraction principle can be described as an equilibrium process in which the analyte partitions between the fiber and the aqueous phase. Varying the polarity of the coating will allow the adsorption of different compounds.

The fiber coating removes the compounds from the sample by absorption in the case of liquid coatings or adsorbtion in the case of solid coatings. The SPME fiber is then inserted directly into the GC for desorption and analysis. SPME has gained widespread acceptance as the technique of preference for many applications including flavors and fragrances, forensics and toxicology, environmental and biological matrices, and product testing.

This method can be applied to liquid, gaseous or headspace samples. All three sample types can be analyzed on the same instrument without modifications to the GC. The extraction and the sample injection process can be fully automated using a conventional autosampler. The fiber can be used to extract target analytes directly in the field without collecting a sample. All three sample types can be analyzed with an isothermal instrument. Recently, many applications of SPME have been investigated for analysis of semi-volatile and volatile compounds in air, aqueous matrices and in the headspace above dirty aqueous samples, slurries and soils.

To keep up to date with the latest advances in SPME technology and methodology using the internet, search Google using the keywords "Supelco spme" and get their CDs and other informative articles. Or search *www.scholar.google.com* and enter the product you

are interested in, followed by "spme." I searched for "cherry spme" and found a great deal of information. (Google scholar is the technical version of the popular internet search engine Google.)

Solvent extraction: Solvent extraction has been routinely utilized for the analysis of flavors in foods, beverages, confections, medications and other finished products. However, it has several limitations and disadvantages. Since the cost and disposal of solvents is dramatically increasing, other methods will be needed in the future to replace costly solvent extraction. The technique is also limited in the range of volatiles that can be analyzed. During the evaporation or reduction steps in solvent extraction, all of the very volatile compounds and much of the volatile organics will be lost due to evaporation. Proper selection of solvents is required in order to achieve good extraction and separation of the analytes and a wide range of analytes may not be able to be analyzed in one analysis. However, for the analysis of the semi-volatiles and non volatile organics, solvent extraction is probably the method of choice. Detection limits for the non-volatile organics are in the ppb range.

Supercritical fluid extraction: Supercritical fluid extraction (SFE) is also a very popular technique for the analysis of organics in food products. It is an appropriate technique for the analysis of the less volatile compounds, much like solvent extraction. It has limitations for the range of analytes that can be extracted simultaneously. This limits its usefulness for the analysis of food products with 200 or more volatile and semi-volatile compounds. However, if you are looking for a particular semi-volatile analyte or a narrow selection of analytes, this technique is preferable over solvent extraction. This technique can be automated, which also makes it advantageous in many instances.

SFE reduces the time needed for the extraction and concentration of organic compounds. Supercritical fluids have solvent strengths approaching those of liquid solvents. The solvent strength of a supercritical fluid, which is directly related to its density, can be modified by changing the extraction pressure and temperature. Supercritical fluids have lower viscosities and higher solute diffusivities than liquid solvents, thus enhancing mass transfer. The use of supercritical

fluids that are gases at room temperature (e.g., CO_2 and N_2O) makes sample concentration relatively simple. Capillary SFC is a rapidly developing method for the separation and identification of organic compounds that lack sufficient volatility or thermal stability to be separated by GC.

Direct thermal extraction: Direct thermal extraction (DTE) is a new technique which is unique to the SIS Short Path Thermal Desorption System. In this technique, volatiles and semi-volatiles can be thermally extracted from solid matrix samples without the use of any solvents or any other sample preparation. The advantages of this technique are that a wide range of volatiles and semi-volatiles can be analyzed, and the high sensitivity of the technique (typically ppb ranges on samples less than 1 g). Its main disadvantage is the extraction of water into the GC column, which will form an ice plug. Most food products contain a high degree of water, making this technique unpractical. However, for dried food products such as spices and teas, this technique can be utilized. Since no sample preparation is required, the sampling time is small: just weigh the sample into the desorption tube and analyze it. The DTE technique will detect lower molecular weight volatiles than P&T because these volatiles would normally pass through the adsorbent resin in the P&T desorption tube. The DTE technique will also detect higher molecular weight volatiles, because they are extracted directly from the sample thermally at higher temperatures than can be achieved with P&T sampling. Lastly, the DTE extraction technique is more sensitive by at least a factor of 10 to 100.

Today the results of the varied extraction, concentration and separation techniques can result in flood of ingredient information, and the increasing possibility of artifact formation. This flood of data is being exacerbated by the continual trend of using natural, multi-component flavor ingredients to compound finished flavors. Adding to this complexity is the increasing use of many "high potency" flavor ingredients and isolates that are employed at miniscule levels and so you see why it is so important for successful flavor development to have the services of an accomplished instrumental group.

Quality in the Flavor Industry

Noreen Lally

Overview

Because of the many diverse ingredients used in the flavor industry, quality control (QC) is an important and critical area. Many tools of analytical chemistry and sensory analysis are needed to produce consistent products time after time. Also, because many of the ingredients are natural, the ingredients may vary from crop to crop. In some cases this may necessitate the adjustments of production batches and/or product reformulation.

The flavor industry ingredient list is rather extensive. It is very important for the supplier of the ingredients provide proper documentation to the corporate lab as well as to all plants using the material. This documentation includes, but is not limited to specifications and MSDS. If appropriate, kosher certification, certificate of naturalness, and nutritional statements should be on file by both groups.

These are a few of the examples of why quality control in the flavor industry is critical, challenging and technically rewarding. This chapter discusses the many tests used, techniques and problem-solving skills employed to ensure the quality and consistency of finished flavors.

Several different analytical techniques are employed in QC in the flavor industry.

These techniques include wet chemistry, separation sciences, spectroscopy and sensory evaluation. The techniques used vary with the material being evaluated.

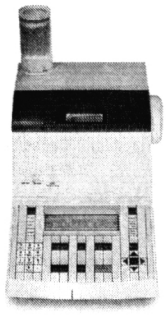
Herein, we will discuss the typical tests used in a QC lab in the flavor industry.

Wet Chemistry

Many traditional wet chemistry protocols provide critical, detailed information to the analysts and developers in the flavor industry. Most flavor chemistry labs include titration, distillation and concentration glassware. Specific examples of the application of these techniques will be discussed where they are most frequently applied.

Specific gravity: Specific gravity is the ratio of the weight of a given volume of a substance to the weight of an equal volume of some reference substance, at a specific temperature. Specific gravity has no associated unit of measure. The density of water is very nearly 1 g/mL. The density of any substance is readily the same numerically as its specific gravity relative to water. Since specific gravity varies with temperature, it is critical to record the temperature at which the specific gravity is determined. Most flavor companies in the United States run all specific gravity tests at 25°C. Flavor manufacturers in Europe run specific gravity tests at 20°C.

Specific gravity is used as an objective test for ingredients, solvents and finished products; it may also be used to determine if a material



F-1. A typical specific gravity-measuring instrument.

complies with a compendium monograph for a material such as the Food Chemical Codex (FCC), signifying a specific purity standard of material. Specific gravity is often cited in a flavor ingredient or finished flavor's specification sheet.

For finished flavors sold to food and pharmaceutical companies, specific gravity can also be used to verify that the customer receives the correct amount of flavor purchased. Since specific gravity is a measure of the weight per given volume, many receiving sites verify the net weight of the container received and do the following calculation:

- Net volume of material received: 53.9 gallons
- Specific gravity of a lot of flavor: 0.943
- Pounds per gallon of water: 8.345 lb per gallon with a specific gravity of 1.00
- Drum at receiving dock should weigh:

  = (specific gravity at 25°C) x (lbs per gallon of water at 25°C) x (number of gallons received)

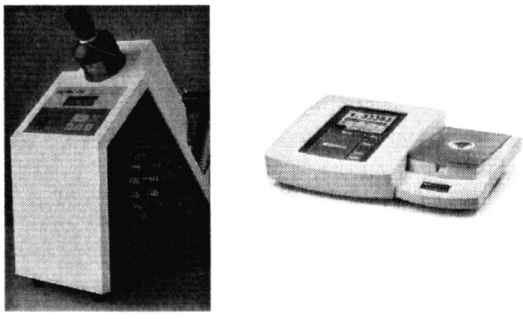
  = (0.9430) x (8.345) x (53.9)

  = 424.16 lbs

Refractive index: Refractive index is another chemical identity test commonly used in the flavor industry. The refractive index is a measure of the degree that a beam of light is refracted as it passes through a given liquid. Refractive index is sensitive to extraneous light, so most devices are equipped with water baths for temperature control or are equipped with temperature compensators to control temperature. Some refractometers supply their own light source, such as the higher priced Abbe's, but some of the simplest, those used for brix or sugar determination, use ambient light. That also holds for temperature control. Abbe's are water cooled, while the Brix meters are similar to singular ocular telescopes.

In the flavor industry, many liquid ingredients are tested for refractive index at 20°C to confirm the material's identity. It can also be used as an indicator of the purity of a specific liquid ingredient by

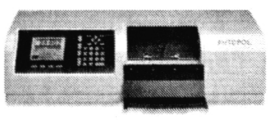
comparing it to literature values or to standard specification sheets. The closer the refractive index is to a standard or a literature value, the purer the sample. For ingredients such as juices, which contain dissolved solids, the refractive index at 20°C can also be correlated to the level of solids in the juice or Brix value.



F-2. Two models of refractometers.

It is important when purchasing a refractometer that the specifications of the device are carefully reviewed. There is a prism in the refractometer that determines the range of materials that can be measured on a specific device. The specification of the refractometer needs to be carefully reviewed to be sure that the instrument being considered covers the range of analytes to be tested.

Optical rotation: Optical rotation is a physical property of substances with a carbon with four different functional groups attached. A beam of polarized light, typically from a sodium source at 589 nm, is passed through a tube containing the material being evaluated. Depending on the structure of the material being evaluated, the light can be rotated to either the left or the right. If the beam is rotated to the left, it is called dextrorotary and is signified by a "+" sign. If the



F-3. A typical optical rotation instrument.

beam is rotated to the right, it is called levorotatory, and it is signified by a "-" sign in the chemical name.

Optical rotation is commonly used in the analysis of essential oils and natural materials. Because of the cost of essential oils and natural materials, optical rotation can be used to verify that the material is natural.

Chromatography

Chromatography is a separation process that isn't new but has made great advances over the years. Chromatography is the class of analytical techniques whereby two or more compounds in a mixture are physically separate by distributing themselves between a stationary phase and a mobile phase. The most important types of chromatography are:

Paper chromatography: This was the first analytical chromatographic technique and was developed around 1855. The interaction between the paper, the stationary phase, the solvent, and the mobile phase results in the separation or partition of components. Today, this chromatography is used to quickly separate and determine color mixtures.

Thin layer chromatography (TLC): As its name implies, a particulate sorbant is applied in a slurry uniformily on a glass pane. Upon drying this slurry forms the stationary phase. Separation is achieved when the plate is partially immersed in a solvent or solvent system in a closed container. The ingredients are partitioned and migrate in proportion to their affinity for the particular solvent used. Visualization of the separated ingredients is aided by reactive oversprays such as sulfuric acid or non reactive methods employing ultra violet additives in the slurry and using UV light to make the separated ingredients visible. This was a standard method to duplicate vanilla flavors.

Column chromatography: Similar to TLC, but using a tall vertical column packed with the same particulate material as the TLC stationary phase and using the same solvents. However, this method allows the solvent to percolate through the column, carrying the adsorbed ingredients down and out of the column into a series of discrete fractions.

Gas liquid chromatography (GLC): Neither one of these two separation techniques was very helpful or informative, since flavor components or ingredients are measured in PPM or PPB regions and they required mg of material. It awaited the advent of gas liquid chromatography to finely elucidate complex flavor mixtures of ingredients thereby making flavor matching feasible and becoming the workhorse instrument in every QC laboratory.

Gas chromatography, in contrast to either TLC or column, uses a carrier gas, usually helium, to convey a volatilized gaseous sample through a column consisting of an inert support and a stationary phase that interacts with sample components. Today, GLC uses very narrow fused silica tubes of 0.1-0.5 μm, bonded to the inner surface and cross-linked to increase thermal stability.

- Inlet: Typically heated to cause the material being evaluated to be instantly volatilized
- Column: Where the separation takes place; there are several types of columns routinely used: packed and open tubular.
- Packed columns contain the column support as a coating on a solid support.
- Open tubular columns contain the column support as a coating on the walls of an inert glass column of multi meter lengths. One of the most popular points of GLC is the ability to choose different polarity coatings to enhance peak resolution and the ability to change operating parameters to speed analysis.
- Detector: Where the effluent is measured; typically a flame ionization detector (FID).
- Data station: Records the information from the detector.

GC: Many very valuable references and courses are available on GC and its application in many industries. This section will briefly summarize the use of GC in the flavor industry.

Because of the complex nature of some ingredients used in the flavor industry, essential oils for example, GC provides the supplier, customer, and consumer a means of evaluating these complex mixtures. Also, finished flavors are complex mixtures, which can also be

fingerprinted and broken down by GC.

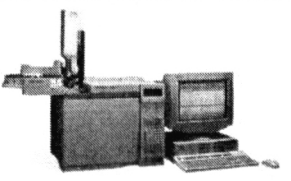
In GC, the sample is injected into a hot inlet where the sample is volatilized. The hardware of the GC system then sweeps the sample (now a gas) onto the head of the GC column. The column is heated in an oven, which is ramped up at a specified rate. The column, which is coated with a thin layer of stationary phase, retains components of the mixture depending on the affinity of the components to the stationary phase as a function of the temperature. As the oven temperature changes, the components of the mixture elute and leave the stationary phase. The gas then sweeps the individual components of the mixture to the detector. The data station records the time the component reaches the detector as well as the concentration of the component.

The column coating in GC determines how the complex mixture is separated. There are many suppliers of excellent GC columns for flavor analysis. Traditionally, the flavor industry uses two columns of different polarities to analyze flavor ingredients, intermediates and finished products.

The column length and film thickness may vary depending on the analysis time one wishes to achieve: the higher the film thickness and/or the longer the column, the greater retention of the components by the stationary phase. These two options will increase the analysis time, but may provide better separation for two components of similar retention by the stationary phase.

Typical columns used are:

- 100 percent methyl silicone 0.25μm, on 0.25 mm x 60 m
- Carbowax-type coating of 0.25μm, on 0.25 mm x 60 m



A typical GC/MS instrument.

The methyl silicon column separates as a function of boiling point of the compound. This is considered a non-polar column. The

Carbowax-type coating separates based on polarity and is considered a polar column. By using columns of different polarity, an analysis can be run on both columns, eluting at different times. Databases can be generated tabulating the retention time of the components on both columns. Prior to the use of GC/MS, databases of retention time indices were used to identify unknowns. Several references have been published on this subject. Today, the majority of GCs use hydrogen flame detection that burns a fraction of the column effluent. This makes it impossible to odorize the eluting compounds. Only a thermal conductivity cell will not degrade the effluent, making it possible to odor evaluate the peaks as they elute.

If today's GLC is the workhorse instrument in any flavor laboratory for both its QC and flavor matching abilities, the most economical and productive utilization of a GC instrument is when it is teamed up with two highly efficient accessories, the auto injector and a mass spectrometer. When configured in this manner the GC becomes an extremely powerful identification work station capable of running unattended for days at a time.

In the mass spectrometer, each peak is fragmented by applying 70 eV to the components. The molecule fragments and concentration (abundance) are recorded. The auto injector provides a carousel that can hold an array of slots for sample vials. The injector provides for syringe cleaning between sample injections and is controlled by its workstation that ensures reproducible runs. The mass spectrometer analyzes each GC peak and stores the information on disk. For QC purposes, the GC/MS outlines the purity of each flavor ingredient in addition it will also identify the minor contaminants present. For flavor duplication purposes, it will graphically outline the results of the chromatographic separation and quantitate them. The GC/MS workstation includes within its software libraries of reference mass spectra. These reference libraries enable the work station to outline the potential identity of a peak and give you the degree of probability of a correct determination. It doesn't get any sweeter than that. For QC the GC/MS can handle the most challenging array of ingredient raw materials and most finished flavors. Its unattended operation and extent of the resulting information is economically advantageous

and efficient. For flavor research and flavor duplication, the combination of the GC/MS superior separation capability using today's columns, with its identification of each eluting peak is nothing short of phenomenal. It has literally leveled the playing field within the flavor industry.

The method for the analysis of flavors typically follows the conditions as noted below:

- Sample size: 0.2 mL
- Inlet temperature: 250°C
- Splitter: 100:1
- Initial oven temperature: 70°C
- Initial hold: 2 min
- Final temperature: 250°C
- Final hold: 12 min

The above conditions typically proved good separation for the components commonly found in compounded flavors.

High performance liquid chromatography: All flavor materials may not be amenable to GC. Because the liquid in GC analysis must be volatilized to a gas, the inlet temperature of a GC must be set fairly high. Typical settings are at 250°C. For those materials that cannot be made volatile at this temperature, this nonvolatile material frequently becomes pyrolyzed in the inlet, and generates false breakdown components.

In high performance liquid chromatography (HPLC), samples are injected at room temperature. The mobile phase in HPLC is a solvent or a blend of solvents. The stationary phases available vary considerably, but many are hydrocarbons chemically bonded to silica. As in GC, there are many suppliers of HPLC columns. The efficiencies of these columns are less than GC columns, resulting in a wide range of specialty columns. Columns frequently are used to separate a specific class of chemical compounds. Reverse phase HPLC columns are frequently used in the flavor industry. These typically are

C8 or C18 hydrocarbons chemically bonded to a silica background. There are many solvents available, but typically an aqueous mobile phase with an organic modifier such as methanol or acetonitrile is used. Also, many detectors in HPLC are not considered universal detectors and frequently are selected based on a chemical or physical attribute of the component of interest.

In flavor analysis, a UV detector is usually used. This detector can be used because many flavor components contain a chromophore, which is sensitive to a specific wavelength in the UV range. Refractive index detectors can also be used in the analysis of flavor materials. These detectors measure the difference in refractive index of the analytes versus air. Refractive index detection is commonly used if a component does not have a chromophore in the UV region. Refractive index detectors are sensitive to temperature fluctuations and need temperature control devices to provide reproducible results.

Organoleptic evaluation: As noted in the previous section, the chemical testing for ingredients, in process, and finished flavors is fairly diverse. However, utilizing all of the above complex techniques does not guarantee the quality of a flavor ingredient and/or finished flavor. The odor and taste of ingredients and finished flavors is a critical part of the QC department of flavor companies.

Odor evaluation: Most QC analysts in the flavor industry evaluate the odor of all incoming raw materials, artificial and naturally derived, in process, and liquid finished flavors using blotters, also used by the flavorists. Typically, a reference and experimental sample are tested.

The strips are typically 0.25 in x 6 in in size. The strips are dipped about 1 in into the liquid under evaluation, as well as the reference. Initially, the strips are fanned to disseminate the liquid. The analyst alternates smelling the blotters from each sample, comparing the odors as they elute. The odors are described by each of the analysts and a conclusion is made as to whether the experimental material and the reference are the same.

This is a skill that is learned by smelling many materials. It is subjective, and remains an art more than a science.

Sensory evaluation: The taste of a flavor and/or ingredient is also

a critical attribute in the flavor industry. Frequently, solutions of individual ingredients are made in sugar water, acidified water or salt water, depending on the ingredient. Again, an experimental sample is tasted versus a reference. Typically, two sample preparations are given to a panelist. After a few quick "bunny sniffs," panelists taste the solutions. Each panelist indirectly records his or her comments for later review by a panel facilitator. The facilitator reviews the comments and a conclusion is drawn.

Panels can be conducted in various forms:

- Side-by-side evaluation
- Duo trio
- Degree of difference
- Descriptive analysis
- Triangle panel

In order for the panel results to be statistically correct an adequately sized panel must be used. In QC, we found the optimum size of an organoleptic panel to be a minimum of 10 tasters. This allowed adequate statistical veracity while not making a single panel a day's work. A QC person presents each taster with the three coded cups and the accompanying ballot. This process was very fast and yielded the QC information required.

Initially, panelists for both odor evaluation and sensory evaluation are screened to be sure they are sensitive to various odors and tastes. The five basic sensory tastes are used as part of the screening process: salty, acidic, bitter, sweet and sour.

In additional, samples are typically prepared with contaminants to see if potential panelists can discriminate the contaminant from the flavor. Sensitivity to odor and taste are critical skills for staff in the QC department of a flavor company.

Ingredients Used

Synthetic pure chemicals: The ingredient list of a typical flavor company is rather extensive. A majority of the ingredients are alde-

hydes, ketones, esters, carboxylic acids, thiols and pyrazines. Several tests, described below, are used for ingredient QC.

GC: Each of these ingredients is analyzed by GC. The purity is verified using an area percent report from the GC data station. Because a low level of impurities may affect a component's performance in a finished flavor, the GC chart needs to be reviewed to confirm that any impurities recorded are at the same retention time and concentration in the material being evaluated. Variation in these impurities could introduce off notes when used in a finished flavor. Retention time is used as a qualitative tool for identifying the component. Dual column analysis—using columns of different polarity—can be employed, if desired, to verify identification on a single column analysis (Some GCs enable a single injection to be channeled to two columns of different polarity while simultaneously facilitating a particular analysis).

Physical attributes: Specific gravity at 25°C and refractive index at 20°C are typically checked to confirm the quality of these ingredients. For powdered ingredients, such as vanillin and ethyl vanillin, melting points may also be run to verify the purity of the material. Typically, the results of the physical attribute tests are compared to an internal specification from a supplier or compendium such as the FCC.

Odor and sensory evaluation: As mentioned before, analytical testing must be supplemented by odor and sensory testing for conformation of consistency of incoming ingredients. It is common practice for a previously approved lot to be compared against an incoming lot, using the blotter technique described above. As the blotters dry, the odor of the material will change. By alternating smelling of the blotter strips, an analyst can confirm that the odor does not change from the control.

Depending on the flavor impact of the material being evaluated, solutions are made to compare an incoming lot versus a control. The strength of the solution to be tested is a function of the ingredients flavor threshold. A lower threshold level requires a weaker solution to produce a suitable tasting solution. For instance, an aldehyde may be tasted at 75 ppm, whereas a thiol may be tasted at 10 ppm. There are many references available that summarize the level of sensory

detection of many flavor materials. For instrumental analysis neat materials are preferred.

Pure natural chemicals: In addition to the testing described for pure synthetic chemicals, natural chemicals may also require additional testing. Natural chemicals used in the flavor industry are more costly and sometimes harder to find. It is important that, in addition to the testing recommended for synthetic chemicals, specialized GC/MS testing be performed to verify the naturalness of the material.

Natural chemicals can be confirmed by very specialized GC/MS systems, which measure the ratio of the various isomers of radio carbon. There are a few specialized commercial laboratories that are equipped to perform this testing. Random samples are sometimes sent to these specialized laboratories periodically to verify the authenticity of natural chemicals.

The supplier should provide certificates confirming the natural status of these materials to the end user.

Essential Oils

Essential oils are derived from the extraction and isolation of many flowers, herbs and spices. The cost of these oils may be very high to the end user because crops may be limited at times of low production due to weather conditions or limited availability of starting materials.

Physical testing: Specific gravity at 25°C and refractive index at 20°C are typically checked to confirm the quality of these ingredients. In addition, optical rotation is commonly run on essential oil samples in the quality laboratories of many flavor companies. In many cases, components of the essential oil may be available from a synthetic source. The optical rotation of the synthetic component will rotate the polarized light in a direction opposite of the natural component found in the essential oil.

Therefore, by testing the essential oil sample for optical rotation, the analyst can confirm the absence of adulteration of the material. If synthetic material(s) had been added to the essential oil being evaluated, the optical rotation result would not be within the predefined specification.

GC: Gas chromatography is also used in the quality control of essential oils to verify that the fingerprint is the same from lot to lot. The GC fingerprint may also indicate whether diluents or adulterants have been added. Typically, the sample is run on a temperature program method previous described.

The chart is compared to a standard to verify the presence of all peaks and the same concentration and ratio as shown by a standard GC run of the material being evaluated. Oxidation of the oil can also be indicated on the GC fingerprint.

Odor and sensory evaluation: Evaluation of essential oils using blotters is critical. Oxidation may also be indicated in the odor evaluation that may not have been detected by the GC.

If sensory evaluation is desired, the essential oil is typically diluted at one percent in 95 percent ethyl alcohol first. A sample of this dilution is then used in sweetened water (at up to 10 ppm). The concentration of the dilution used will vary depending on the strength of the essential oil.

Botanical Extracts

Botanical extracts are but one source of natural flavor ingredients as outlined by the FDA in the code of Federal Regulations has defined "natural flavors" as "the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate or any product of roasting, heating, or enzymolysis, which contains the flavoring constitutes derived from a spice, fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, seafood, poultry, eggs, dairy products, or fermentation products thereof, whose significant function in food is flavor rather than nutrition."

They are made via extraction of many and various bonanical sources species. These extractions use different solvents and are performed at different temperatures. Typically the extractions are standardized with materials such as caramel color, propylene glycol, and glycerin, to name a few.

Physical testing: Specific gravity at 25°C may be run on these materials. In addition, solids are usually run. There are many solids testing procedures. Solids by degrees Brix are sometimes used for

testing of botanical extracts. This may not be a true solids reading, but because it can be read directly from a refractometer, one may find that this is the method of choice for many. Solids may also be run by a loss on drying test. This test uses an oven set at 105°C. The actual time to heat the material varies with the botanical extract.

GC: GC analysis is typically used to measure the residual solvent left in the botanical extract. This is a function of the efficiency of the extractor and concentrator used to process the botanical extract. Legal limits for residual solvent have been set and must be met.

HPLC: Because of the complexity of botanical extracts, many of the components have not yet been identified. With the increased interest in nutraceuticals in the marketplace, some chromatographic methods have been published using HPLC to fingerprint these materials.

A dilution of the botanical extract is usually made and filtered through 0.45-μ filters. It is then injected on a reverse phase column for analysis. In some cases, a marker peak has been identified and quantitated for certain botanical extracts. The marker peak varies with the botanical of interest.

Solvents and Diluents

Flavors are chosen based on the finished product application. The physical form of the flavor, as well as its solubility, is taken into account before the flavor is developed. Frequently, solvents are used to as diluent and flavor carriers.

Some of the common solvents are:

- Propylene glycol
- Ethyl alcohol
- Triacetin
- Benzyl alcohol
- Hydrogenated cottonseed and soybean oil
- Medium chain triglycerides

Physical properties are checked for all of the solvents mentioned above.

GC analysis is typically performed on propylene glycol, ethyl alcohol, triacetin and benzyl alcohol. GC purity is verified against a specification. It is important to verify that the ethyl alcohol has not been denatured in any way. Therefore, it is critical to check the GC chart for impurity peaks.

Odor analysis is important on these solvents. One bad lot of solvent could potentially go into hundreds of batches of finished flavors, causing many QC issues if not picked up by the QC group. Batches of triacetin must be carefully checked to be sure that the degradation component, acetic acid, is not present.

Carriers: Many flavors are liquids. However, some flavors are produced by spray drying, plating and/or dry blending. Some common carriers of flavors are:

- Modified food starch
- Maltodextrin
- Gum arabic
- Dextrose

Typically, moisture, particle size and viscosity are tested on these ingredients.

Moisture can be determined by Karl Fisher titration, or loss on controlled oven drying. It is important that the QC lab runs the material by the same test method for moisture stated on the specification. If the same method is not available in the lab, a correlation study between methods needs to be performed. Viscosity is a critical attribute to measure because it can affect the performance of the material in production. A traditional screen analysis or a particle size counter can run particle size.

Juices and Essences

With the increased emphasis on natural flavors, many flavors are formulated with fruit juices and the essence of fruit juices. The

concentration of the juice will determine the solids or strength of the material.

The QC laboratory typically runs the following tests on fruit juices for flavors:

Solids: The solids content is an indicator of the concentration of the fruit juice. A refractometer set for Brix is typically used for this testing. The Brix range was originally developed for sucrose solutions, but the industry has adapted its use for solids in juice.

Titratable acidity: The measurement of acid in a juice gives an indication of the tartness of the material. The acid measured varies with the fruit being tested. For example, citric acid would be measured for lemon juice. For juices that may contain more than one acid, total acidity is calculated as a result of the titration. The titration is set up using a 0.1 M NaOH solution.

Some juice manufacturers monitor the ratio of solids to acid value to provide batch-to-batch control of their products. The units need to be consistent if this technique is used.

pH: pH is monitored to verify the juice has not been abused.

Color: The initial color of juice is visually evaluated to prevent the production of a finished product that may be considered unappealing to the consumer. The color of some juices changes as a natural reaction of the aging of the juice. In some cases, this does not indicate that there is a quality issue with the juice.

Vanilla Beans

Vanilla is the most popular of all flavors. It is used alone as in vanilla ice cream or is added to many other flavors to provide a synergism between vanilla and another flavor.

The source of vanilla is the vanilla bean. Because of the specific growing conditions needed to produce vanilla beans, the plants are only found in specific areas of the world. The economic conditions of growing areas as well as the variations in weather from year to year have brought about great fluctuations in the quality of vanilla beans. Both traditional chemistry testing and more sophisticated chromatographic testing are used in vanilla bean testing.

Lead number: The Association of Analytical Communities

(AOAC) has many different methods for testing vanilla beans. Lead number (typically abbreviated as Pb number) is a wet chemistry procedure traditionally used to test the strength of vanilla beans. A trial batch of extract is made and reacted with a solution of lead acetate. The lead acetate bonds with the organic acids of the vanilla extract; then the unreacted lead is measured. Typically, EDTA is used as the chelating agent to measure the unreacted lead. Some laboratories have suspended this test in the lab because of safety concerns in disposing of the material after the test is complete.

Vanillin is one of many organic components in vanilla beans. Vanillin can be measured by UV spectrophotometry, but many labs have switched to HPLC for the quantitation of vanillin. Vanillin can be measured by numerous HPLC methods, but the AOAC method is a C8 reverse phase separation using a UV detector. In HPLC, one avoids the interference of components that had been an issue with the UV spectrophotometric method.

Finished Flavors

The QC testing protocol for finished flavors will vary depending on the physical form and ingredients in the product. Odor evaluation and sensory evaluation are critical to all products similar to what has previously been described for ingredients.

The following paragraphs summarize the analytical testing for finished flavors.

Liquid flavors: Typically, liquid flavors are composed of volatile ingredients and a suitable solvent or solvents. It can be fingerprinted by GC. Using a well-developed GC retention time database, identifications can be made. Products containing citrus oil components are analyzed on a methyl silicon column for good separation. Many flavors are adequately separated on a polar Carbowax-type column. If the flavor is fairly dilute, varying the sample size into the GC may help. But, it is always preferable to GC as concentrated a material as possible to produce a more detailed ingredient profile. If a finished flavor is so dilute as to produce a non-detailed chromatogram, it is better to have the flavorist prepare a base oil, containing all the organoleptic ingredients of that flavor as one ingredient, that will

then be cut with diluents in final production. The base oil, being neat, will produce a good chromatogram and will be easily diluted to its final concentration. Alternatively, one could vary the inlet system on the GC and use a splitless inlet. Good chromatographic techniques (i.e. avoiding overloading the inlet system) should be followed at all times.

The physical properties of specific gravity at 25°C and refractive index at 20°C are also run on most liquid flavors. An opaque liquid flavor indicates the flavor may contain botanical extractives. Opaque samples may not be suitable for GC analysis. It is recommended that solids be tested rather than refractive index.

Hydro alcohol extractions: Some flavor formulations are made by processing an in-process material by an alcohol/water extraction process. Because of differences in solubility of components as well as temperature, different profiles may be generated.

If such flavors are being used, it is recommended that the alcohol content be quantified via GC. Most quantitation of this type is done with an internal standard. The AOAC lists a method for the quantitation of ethanol via GC using propanol as the internal standard. This method uses a packed column, but capillary columns under the same conditions have been shown to give similar results.

GC analysis to confirm that the extraction is the same from batch to batch is also recommended. Specific gravity at 25°C and refractive index at 20°C are usually run on these flavors.

Spray dried products: Powdered flavors are produced via the well-documented manufacturing process by spray drying. There are many references explaining this process.

Moisture is very important in process, as well as finished product test for spray drying. Two methods of moisture analysis have been used in the flavor industry: Karl Fisher and loss on drying. The method to be used depends on the flavor that has been encapsulated. Again, method correlation and validation of the method may need to be performed by the laboratory to confirm that consistent results can be obtained.

In order to confirm that the correct amount of flavor has been encapsulated in the spray dry process, a volatile test may need to be

run. A slurry is made of the spray dry to be evaluated. The slurry is then distilled in special glassware equipped with a distillation head and condenser. The condenser is equipped with a graduated tube where the volume of the recovered oil can be recorded. The volume of recovered oil is related to the weight of sample used to calculate the percent volatile oil. In some cases the recovered oil has been fingerprinted by GC.

The QC lab of many flavor companies producing spray dries also typically runs particle size. The traditional ASTM International (originally *American Society for Testing and Materials*) screens can be used, or a particle size counter can be employed.

Blended products: Many flavor companies also produce dry blends of powdered flavors. Many of the same tests used for spray dries are used for dry blends.

Quality Assurance of Flavors

As noted in the previous section, the QC departments of flavor companies employ a wide variety of analytical and sensory testing. However, quality in the flavor industry does not end with QC testing. Several other aspects of quality assurance are also used to provide quality flavors.

HACCP programs: Good manufacturing practices defined in 21CFR110 are the basic rules for all flavor-manufacturing areas. Flavor companies have also implemented hazard analysis critical control points (HACCP) programs to ensure that safe products are produced each and every time,

HACCP ensures that a manufacturer has evaluated its processes and determined the critical points in the process where chemical, microbiological and physical contaminants are prevented from entering the product.

Microbiological testing: Some flavors may be susceptible to microbiological growth. Some microbiological tests may also validate that manufacturing practices are being followed. Typical microbiological tests run in the flavor industry include, but are not limited to, the following:

- Aerobic plate count
- *E. coli*
- *coli* forms
- Yeast and mold
- Salmonella
- *Listera monocytogenes*

Vendor certifications and documentation: Flavor companies need to have a close business relationship with their ingredient suppliers in order to ensure that quality of their finished products. It is important that the vendor and the flavor company agree upon specifications.

The vendors need to provide specifications, MSDS, natural certification (if applicable), kosher status and nutritional statements, as well as organic certification and freedom from allergens, to the flavor companies. It is the responsibility of the flavor companies to review this documentation to create the same documentation and guarantees for their finished flavors.

Storage conditions and shelf life: Flavor companies need to be able to determine accurate shelf life of their finished flavors. The shelf life of a flavor is determined by how it is stored. Refrigeration or temperature warehouses may be needed to guarantee that the integrity of the flavor is maintained.

Plant protocol for incoming ingredients: Most flavor plants are laid out to allow for work to flow from start (incoming ingredient) to finish (finished flavors, packed and labeled for shipment). Typically, incoming ingredients are logged into the plant's inventory in a status that would not allocate these materials for production. Incoming ingredients are quarantined until QC has had an opportunity to inspect the containers, sample the incoming material, perform QC testing, and release to the plant. In most cases, the receiving department of the flavor company is aware that material has been ordered. After the material arrives, the receiving clerk inspects the containers to verify that the integrity of the packaging has not been compromised. If this passes, the receiving clerk takes a count of the number

of containers, their weights, and then documents the vendor lot. A unique lot number is assigned to each supplier manufacturing lot. By assigning a unique lot number upon receipt of the material, this safeguards the finished products should it be necessary to later trace back ingredients to the supplier manufacturing lot number. After QC has completed their work, they release the material, which allows the inventory system to have access to the newly approved material for production. Bar coding and scanners can expedite this process.

In reality, some new materials may be needed immediately upon arrival in production. Some organizations have their inventory systems coded so that the high priority incoming ingredients are marked with red labels. By having this automated, it prevents manual intervention of the receiving staff with the QC staff. In situations of high priority, however, it is important that there are predetermined lines of communication between the receiving clerk and the QC ingredient sampling technician. Teamwork is essential.

Supplier qualification programs: From the business side, it is advisable that more than one vendor be qualified as a source of a given flavor ingredient. This allows the flavor company an alternate source should the primary source be unavailable. Specifications are the blueprint which documents the quality criteria of an ingredient. As QC collects data on various ingredients, they may, after carefully reviewing this data, determine that it is not necessary to run all tests listed on the specification. This "limited testing" program is recommended only after a history of the material has been established. However, in order for alternate sources of material to be qualified, it is critical that all tests listed on the specification be run. It is recommended that three lots of the new source be evaluated prior to approving a vendor. It is also recommended that alternate vendor qualification be performed on samples from one supplier plant. If a supplier has additional plants, it is recommended that alternate vendors be approved on a per plant basis. If an alternate vendor has more than one plant, three samples from the second plant would need to be evaluated.

Supplier relationships: As mentioned previously, the relationships of suppliers with flavor organizations are critical to the success of the

flavor organization. In the flavor industry, it is typical for the flavor organization to audit and inspect the ingredient provided. Various types of scoring systems can be adapted, but the overall process should allow for a score to be determined at the end of the audit. The score typically determines the rating of the supplier. Supplier audit systems need to be formally documented, spelling out specific corrective actions if needed. A formal report to the supplier is recommended. Deadlines should be agreed upon between the supplier and the flavor organization. Should follow-up audits be required, they should be completed in a timely fashion and be documented.

Flavor Applications

Leora Hatchwell

Flavor, whether present naturally or added to a food product, is usually the greatest single factor affecting our choice of foods and whether we will subsequently accept or reject them. People are not willing to put up with foods that are good for them without those foods delivering on the promise of satisfaction and enjoyment that all food is expected to provide. Consumers are not simply seeking reduced fat, cholesterol, sugar or high fiber products; they want products that taste good and appeal to them, or they will not repurchase the product.

This chapter concerns flavor applications—how to attain the flavors in products that will appeal to consumers. It seems appropriate to start off with an explanation of what flavor, odor and taste are and how humans perceive them.

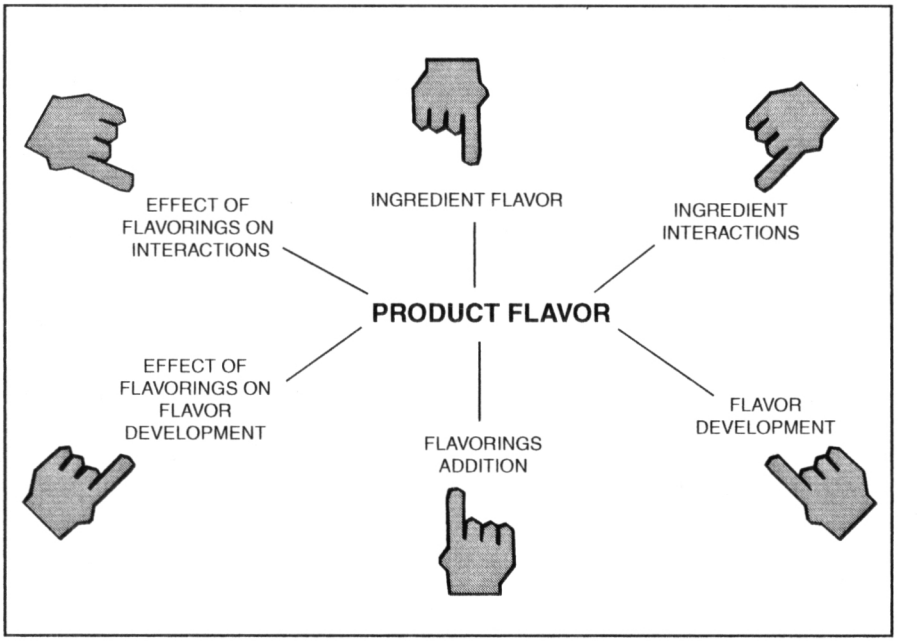
Components of Flavor and Aroma

Flavor is the total impression of taste, odor, tactile, kinesthetic, temperature and pain sensations perceived through tasting. The term "flavor" is generally used to mean a combination of aroma and taste.

Aroma is the collection of volatile aromatic compounds that give foods their identity. Flavor is the combination of these volatile components and the non-volatile components of the base material that are designated as taste.

Holistic Approach to Flavor Applications.

Holism is a theory or doctrine according to which a whole cannot be analyzed simply through an analysis of its discrete elements; in



F-1. Holistic flavor applications

other words, holism emphasizes the organic or functional relationship between parts and wholes. I believe that the most effective way of achieving quality flavor perception in a food is to take a holistic approach to flavor applications. This means that the applications process involves the flavor of the product's basic ingredients, the addition of flavorings to the formulation, and the effect of those flavorings on the flavor interactions and flavor development (see F-1). I believe that to be a good flavor application scientist, one must think outside the traditional constraints of food technology.

Flavor and taste perception: Eating food elicits both physical and emotional reactions. Physically, all the senses are involved: eyes perceive color, gloss and other visual parameters; ears pick up the crunch of foods; the mouth perceives textures and the basic tastes and tactile sensations known as trigeminal responses, while the basic tastes of sweet, salty, sour and bitter are sensed on our tongue. Chemical stimuli and irritation of pain receptors in the mouth, nasal cavity and throat are responsible for the perception of trigeminal factors, such as

the cooling of mint, the bite and pungency of horseradish, ethyl alcohol and ginger, the heat of chili peppers, the metallic note of tomato soup, the astringency of tea tannins and one's favorite cabernet sauvignon and the acidity of vinegar. A unique portion of trigeminal response is the perception of umami, that feeling of fullness and richness that one perceives from MSG, yeast extracts, and other savory and brothy items.

Aroma is broken down into two parts: the reaction to aroma from food before it is placed in the mouth (pre-ingestion aroma), and the odor that reaches the olfactory sensors by way of the pharynx (retronasal aroma). Most of what one perceives of flavor is actually aroma.

Imagine a scoop of high quality vanilla ice cream. Now imagine bringing a spoonful to you mouth. Prior to placing the ice cream in your mouth, you already perceive the bouquet of the vanilla flavor, leading to anticipation and salivation. The ice cream is placed in the mouth and starts to melt; it is mixed with saliva and is warmed, and the basic tastes are perceived on the tongue. As chewing continues, volatiles are released. The food is wetted even further with saliva and further warmed, thus altering the volatility of the aroma chemicals. This affects the intensity and the quality of the perceived flavor. You swallow. A plug of air pushes the volatile chemicals through the pharynx. There it reaches the olfactory bulb and stimulates the nerve endings. Thus, you achieve the full perception of vanilla ice cream.

Other aspects of human food flavor perception are time and intensity. A flavor's temporal profile is the timing of the perception of the aroma and the intensity of that aroma once food has been placed in the mouth. One characteristic of temporal profile is balance: are the flavors integrated and "smooth?" Or can one pick up the various notes of the flavor? Is the flavor harsh? Out of balance? Are some flavor notes too intense and others barely perceptible? All of these aspects must be considered for an acceptable flavor experience. Another feature of temporal profile is the order of the occurrence of the flavor notes. What's tasted first? Is the order appropriate? What flavor notes are being carried into the aftertaste? These are the important features of temporal profile.

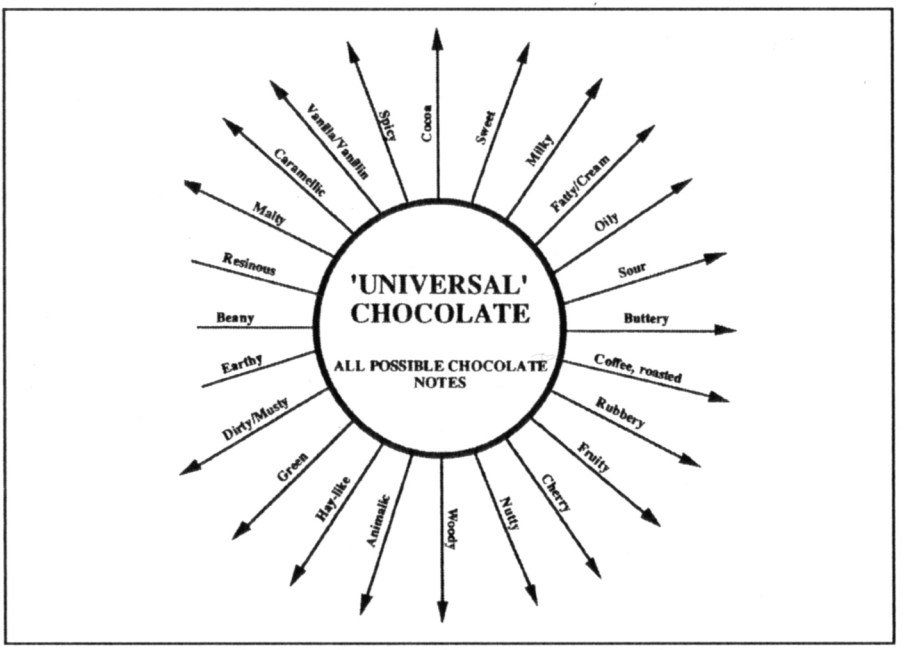
Origin of descriptors: People's attitudes about foods are derived

biologically, psychologically, through experiences, social customs and opportunity of exposure. Biologically, humans have an innate liking for sweetness; people appreciate foods that deliver true calories. Humans have an innate dislike for bitterness, as bitterness and sourness were historically delivered in unripe or poisonous foods. People's disgust at rotting food is learned in childhood, unless one's culture teaches acceptance or even preference. Examples are kimchi, sauerkraut, seviche and lutefisk. Some aromas cause salivation and a greater flow of gastric and pancreatic juices. Food perception is affected by mood at any given time (whether one has a fight with their significant other or is sharing a candlelit dinner). In addition, food tastes different in the morning than it does at night. Flavors are more pleasing at the beginning of a large meal. Private associations with food also affect preference: whether a food once caused stomach poisoning, morning sickness or is associated with a pleasant memory. People have a shared preference for flavoring that reinforces a sense of social solidarity or community.

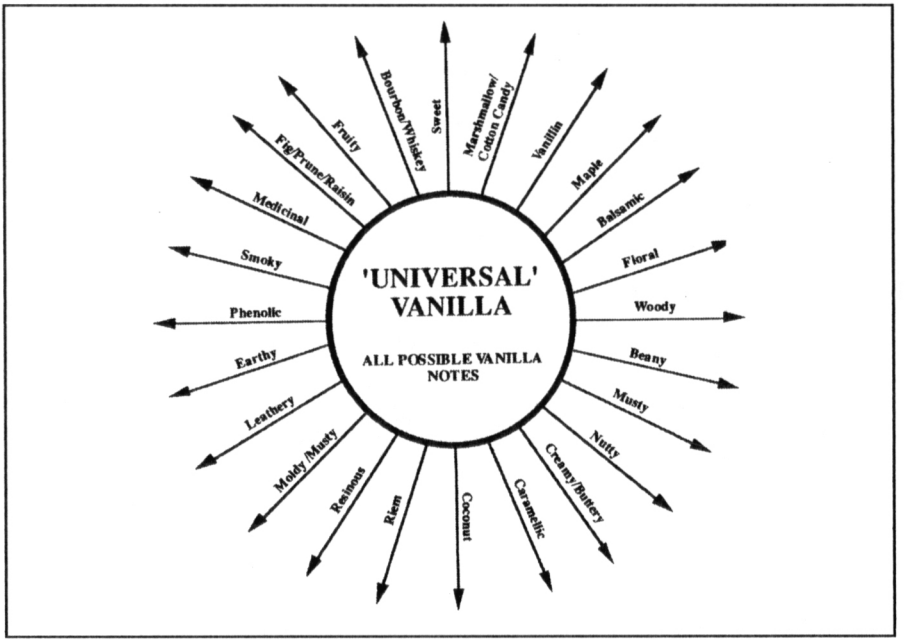
These varied influences form the basis of the vocabulary each person uses to describe the flavor of food. As exposure to new foods and cultures grows, this vocabulary evolves. Professionally, a portion of learning descriptive flavor profiling is anchoring one's perception to references. By agreeing on standards for a particular flavor note, tasting, discussing and compromising, flavorists can develop a common terminology. This common terminology is the basis for developing a method of communicating descriptors that constitute a universal flavor wheel. This is a graphical illustration of all of the flavor notes that comprise a complex flavor such as chocolate, vanilla, cream, etc. (see F-2 through F-5).

What Constitutes "Good" Flavor?

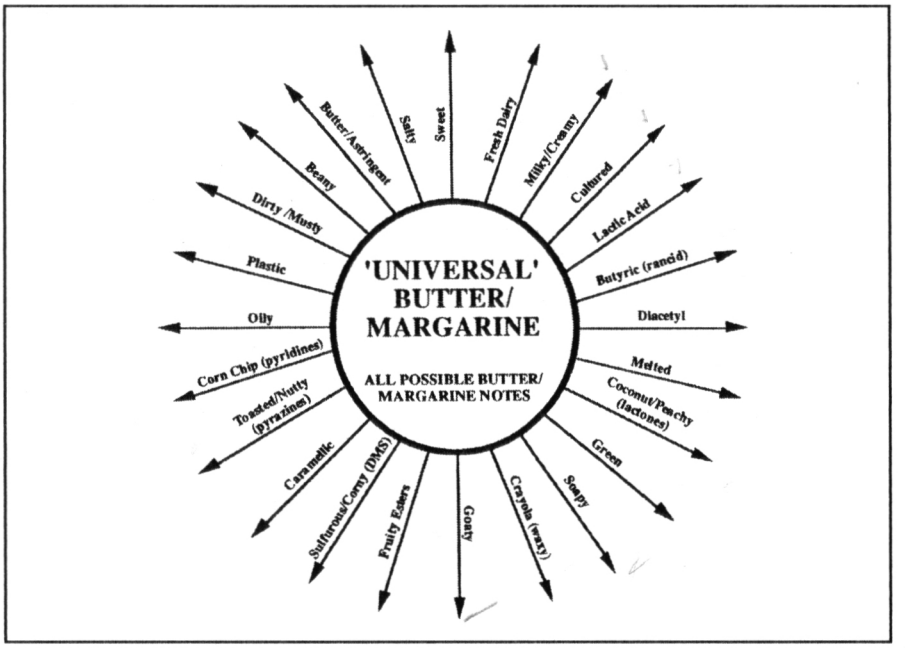
"Good" flavor is comprised of positive aroma, balance, early flavor impact (but not too early), rapid flavor development (so that the flavor lingers and develops throughout the time the product is in the mouth), pleasant mouth sensations, no unpleasant notes, and a well-rounded character with no unpleasant flavor spikes. Anticipation for the next mouthful also must be built while all of this occurs. The



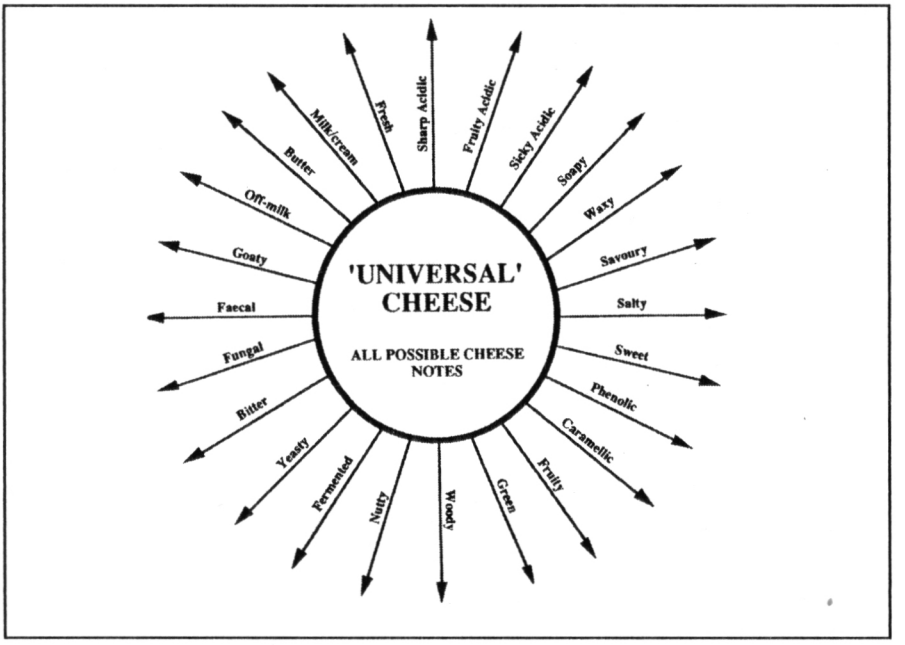
F-2. Illustration of all possible chocolate notes



F-3. Illustration of all possible vanilla notes



F-4. Illustration of all possible butter/margarine notes

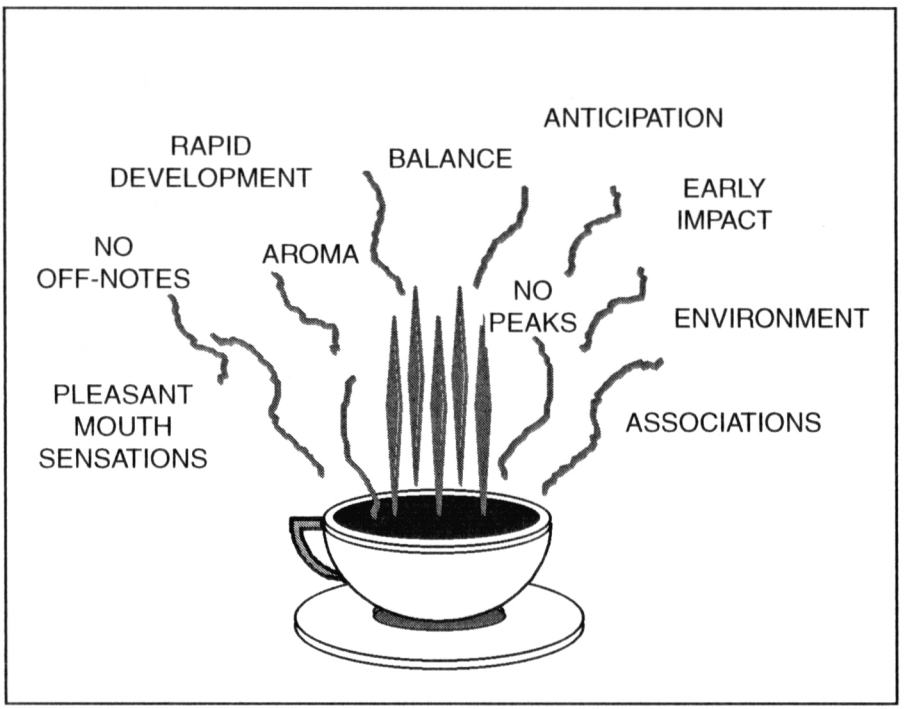


F-5. Illustration of all possible cheese notes

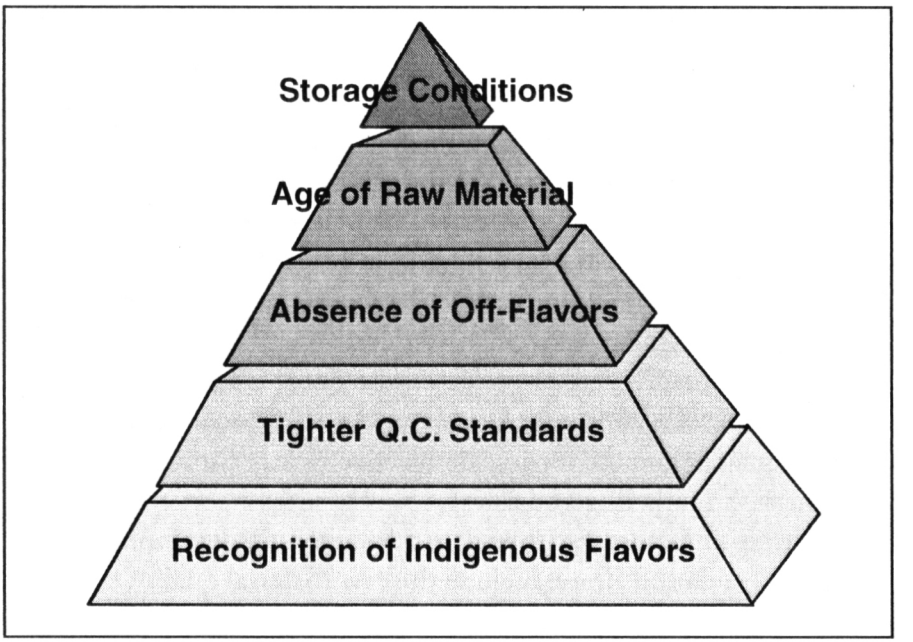
environment in which the food is tasted and the associations that the consumer has made with the food will affect consumer reaction (see F-6).

The first step in flavor application is to define the target. Through the use of descriptive terminology, the taste profile, texture characteristics and flavor aspects are defined. The flavor must be broken apart into its component descriptors. It is not sufficient to say that one wants a chocolate flavor; it must be further defined as being caramellic, bitter, milky, etc. One must understand the traditional product that one is trying to emulate, whether it is full sugar, full fat, etc. What does the consumer like about the traditional product? The flavorist must define the technical objective clearly through communication with marketing and sales.

A variety of factors are important for successful development of a product formulation. These include the raw material quality, the base characteristics, the sweet/salt balance and the flavor system.



F-6. What constitutes "good" flavor



F-7. Raw material quality

The next step is knowing and understanding the food product's ingredients, their functionality, interactions, acceptable flavor profiles and inherent off flavors. Raw material quality is extremely important. This is affected by storage conditions, the age of the material, the absence of off flavors and the recognition of indigenous flavor (see F-7).

Raw material quality is one of the most important aspects of a formulation that a food scientist must appreciate and consider. The window of acceptability for raw materials in non-traditional products, such as reduced fat, reduced calorie or high fiber, is very narrow. Off flavors are more pronounced, and the indigenous flavor of the ingredient is more readily apparent. Abusive and prolonged storage conditions of the raw material can result in undesirable flavors in the finished product. For example, gums and starches develop cardboard notes when exposed to light or aged too long, resulting in a gluey, stale character. Gelatin develops fishy notes when aged; oxidized flavor and bitterness develop through the aging and storage of dry milk

powder. These are but a few reasons that ingredients must be as fresh as possible.

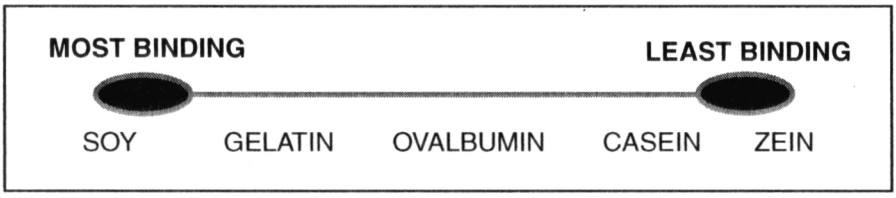
Base characteristics: The quality of the food base on which flavors will be added is very important. The base must be as free of flavor defects as possible. There is no such thing as the total masking of off flavors; the most one can hope for is to obtain flavors that meld with the off flavor to significantly change flavor perception. In comparison, a flavorless base is undesirable. It is very difficult to provide an entire flavor profile to a product via added aroma chemicals without producing an imbalanced, artificial-tasting product. The base must have some of the desired flavor character upon which to build; for example, a dairy character should be built into the base via the ingredients in a reduced fat ice cream mix—the manipulation of non-fat milk solids can alter the profile of the dairy notes, providing an acceptable base ingredient. The balance of sweetness and saltiness is critical. As sugar and fat are reduced in any formula, the relative percentage of water is increased, resulting in decreased saltiness and sweetness. When the saltiness and sweetness are adjusted, the increased or decreased salt and sugar affects flavor balance. This must be taken into account prior to the addition of flavor. Base development must be completed before flavor development can begin.

Flavor Interactions with Base Components

Flavor interaction is one of the important fundamentals that formulators must always keep in mind when flavoring a product. Aroma chemicals may react with base components. This can produce off flavors, may reduce the flavor's impact or render it unavailable for perception.

Protein: Protein interaction is a very complex area due to the heterogeneous structure and composition of proteins. Proteins will bind flavor molecules, making them unavailable for consumers to taste. Denatured proteins have the highest level of binding. This is why many protein drinks are usually provided in powder form.

There are many types of interactions that may occur between flavors and proteins: entrapment of flavor inside the helix of certain proteins; absorption of aroma chemicals onto the proteins via Van



F-8. Protein binding of flavor (dependent on type of protein)

Der Waals interactions; covalent bonding with other hydrophobic sties; and encapsulation and other miscellaneous binding. Proteins can decrease the headspace concentration of volatiles in both aqueous and dry systems. Sometimes, bound flavor compounds may be released, may stay bound, or may undergo chemical reactions with the proteins to generate other compounds during processing and storage. This may generate unusual or undesirable flavors in the food product such as "the beany flavor" that is characteristic of soy bean use.

Any factor that influences protein conformation influences the binding of volatile compounds. This includes the type of processing, pH, time and temperature. Proteins will bind flavor molecules, making them unavailable for consumers to taste. The degree of binding is influenced by the thermal history of the protein. Volatile compounds can bind to proteins only when hydrophobic sites are available. Selective flavor binding is influenced by the type of protein as shown in F-8. Native proteins do not bind a lot of flavor. The flavor components are absorbed into the lipophylic pocket of the protein. As protein is denatured and more hydorphobic sites are exposed, more flavor binding occurs. Binding interactions generally decrease as temperature increases. On the other hand, flavor development increases as temperature increases. One can take advantage of these phenomena by adding flavors prior to processing so that they can aid in flavor development.

pH affects the ionization and magnitude of the net charge on the protein molecule. It alters the attractive and repulsive forces of the proteins and their ability to associate with water. Thus it influences the interaction of proteins and volatile compounds. As these interactions proceed, flavor impact is lost.

Emulsifiers may be able to prevent flavor binding by proteins. Ionic emulsifiers, such as diacetyl tartrate ester of monoglyceride (DATEM) or sodium stearoyl lactylate (SSL), react strongly with proteins. Theories exist that the protein has a stronger affinity for ionic emulsifiers than it does for the flavor's aroma chemicals. Thus the emulsifier interferes with the flavor binding by competing for the same binding sites and winning. In other words, the hydrophobic sites preferentially bind the emulsifier rather than the flavor.

Flavor components or ingredients, especially aldehydes, can react with free amino acids or with the free amino group of proteins and form reversible compounds known as Schiff bases. These Schiff bases can undergo a series of condensation and polymerization reactions and may result in a number of undesirable end products. Emulsifiers and phospholipids preferentially bind to the positively charged amine groups that might bind aldehydic and ketonic aroma chemicals, thus protecting the flavor.

Carbohydrates: Carbohydrates can influence flavor perception directly via chemical interactions or indirectly through physical effects on the system. The types of chemical reactions are hydrogen, hydrophobic, ionic and covalent bonding. All depend upon the chemical structures of the flavor ingredients and of the carbohydrates within the base materials. With simple sugars, one expects little more than hydrogen bonding with volatiles. Sugars may drive volatiles from liquids into the headspace of food products; this is termed salting out. There is a significant salting out effect on hydrophylic aroma chemicals, but little on hydrophobic aroma compounds, thus resulting in a flavor imbalance. An excess of sugars in solution will cause the solution to become more hydrophobic, therefore reducing the aroma release of the hydrophobic compounds. This also results in a flavor imbalance. There is little significant effect on flavor perception by chemical interaction with oligosaccharides.

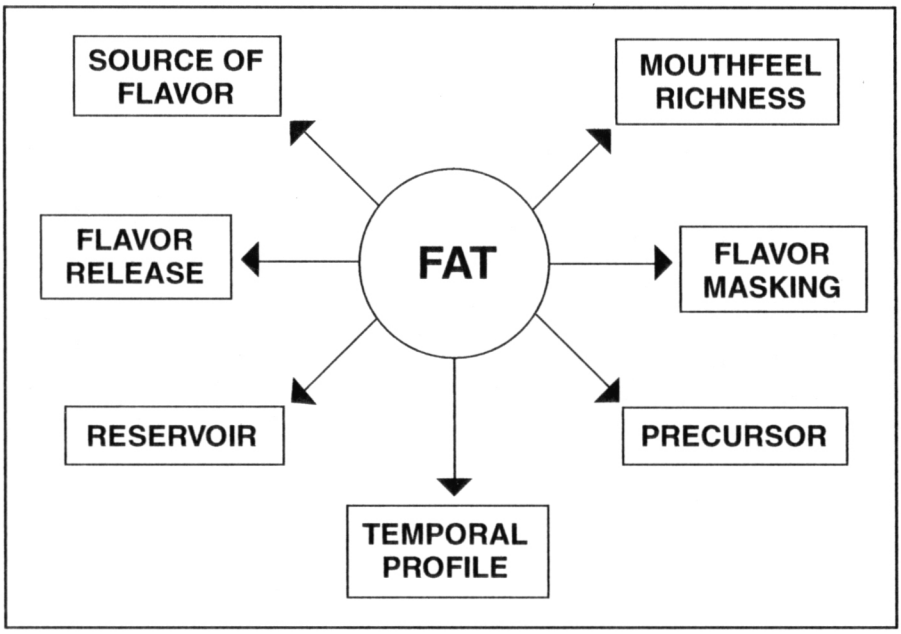
Carbohydrates also have the ability to adsorb/absorb volatiles and retain them. This allows them to act as flavor carriers and encapsulants. The most common of these are sucrose, lactose, gum arabic, modified food starches, maltodextrins and cyclodextrins. This ability of starches, dextrins and sugars to stabilize flavors during preparation

and especially during drying may reflect entrapment, adsorption, binding and/or reduced mass transport effects due to increased viscosity.

Complex carbohydrates exist in two structural variations that are synthesized by plants: linear amylose and branched amylopectins. These are polar structures that do not react or bind chemically with flavors. However, their structure affects how they interact with volatiles. Amylopectin forms soft pastes that are long in structure. They tend to stretch rather than break; they will not form rigid gels. Amylose entraps water, producing opaque stiff gels after cooking and cooling. Amylose forms a long 3-D-shaped coil with the outside of the coil being hydrophylic (water loving) and the core of the helix being hydrophobic (fat loving). Hydrophobic flavor chemicals will reside within the coil. These bound volatiles are not generally released during consumption because the food does not usually remain in the mouth long enough for the salivary enzyme amylase to break down the starch. Therefore, starches with increased amylose content such as corn and potato starch have increased flavor absorption. The lower the fat in a product, the more this reaction takes place. Because the structure of high amylopectin starches (such as tapioca, waxy starches and Chinese glutinous starch) is branched, a helix structure cannot form and therefore no flavor binding occurs. Straight chain emulsifiers (ex. monoglyciderides) can prevent flavor entrapment in high amylose starches. They are able to complex with the amylose and retard flavor binding. In order for this to work, the system needs to be exposed to the emulsifier prior to the addition of flavor.

Fat: Fat plays an important role in flavor perception (see F-9). It is first and foremost a source of rich flavor and mouthfeel. It is also a valuable precursor for further flavor development. It helps to mask off flavor and affects both flavor release and temporal profile.

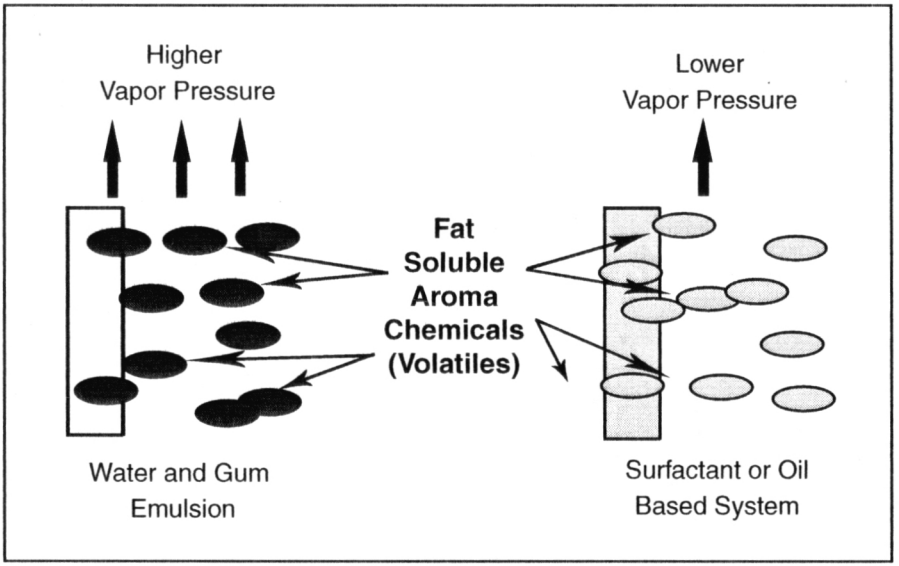
Flavor compounds are inherent in lipid ingredients; these flavors come from a variety of aroma chemicals such as fatty acids, fatty acid esters, lactones, carbonyl compounds and many others. When combined, they produce a range of products from the sweet, buttery, creamy rich flavor that comprises the world of dairy products to the notes peculiar to lard and olive oil. Some of these flavors are



F-9. Role of fat in flavor perception

desirable; some, such as the flavor of emulsifiers, are not. Fats act as precursors to flavor development by interacting with proteins and other ingredients when heated, examples include roasting, baking, frying (other examples include the caramellic notes of a full fat vanilla ice cream or caramel). Fat participates in metabolic pathways to result in the desired flavor components of cultured dairy products, particularly cheeses. The ability of fat to mask off flavors may be due to solubility. Off flavors are not normally perceived in full fat systems because those off flavor compounds are predominately fat soluble. However, in the absence of fat, the vapor pressure of the flavor chemical is increased, building in the headspace and resulting in an intense perception of the chemical.

The key role that fat plays in flavor perception involves the partitioning of aroma compounds. The threshold for flavor change is based on the amount of fat present in the system. Most volatile flavor ingredients have a tendency towards being more oil soluble than water soluble. Ever-growing bodies of research show that the



F-10. Apparent strength difference of identical strength solutions of a fat soluble aroma chemical in water- vs. oil-based systems

vapor of aroma chemicals from the food system is what affects flavor perception. A fat soluble flavor ingredient—such as lemon oil—can be solubilized in one of two ways: in oil, or as an oil-in-water emulsion. Imagine lemon oil in a closed container in a water emulsion, and a second container with vegetable oil and lemon oil. The lemon oil molecules will not be held in solution as much by the molecules of water as they would be by the molecules of surfactant or vegetable oil. That is, lemon oil is hydrophobic or lipophilic. Therefore, the lemon oil is more likely to surface and volatilize in a water system than in an oil system. In the closed container, the headspace of the lemon volatiles will build up. When the container is opened and smelled, the water gum emulsion will appear to be stronger in odor and impact than the oil blend. It will be perceived as being sharper, harsher and over-flavored. The vapor pressure of a non-polar chemical in oil is lower than the vapor pressure in water, and the vapor pressure of a polar chemical in oil is higher than it is in water (see F-10).

Reduced fat systems inherently have less fat and more water. Therefore, aroma chemical may appear to be strong and unbalanced.

Fat effects the duration, or temporal profile, of flavor. For example, skim milk has no fat to hold vanilla flavor, so it emits the strongest vanilla aroma and strong vanilla flavor initially upon drinking. The flavor, however, does not linger in the mouth, demonstrating the difficulty in flavoring no-fat/low-fat products.

All basic food components differ in how they interact with flavors. Taste is an aqueous phenomenon. Salt and sugars must be in solution to be perceived. Aroma depends on volatility and the partitioning of the volatile flavor ingredients. When fat is removed from a food system, it is replaced with water, protein, carbohydrates or minerals. Even if nothing is added to compensate for the reduction of fat, the existing components increase automatically and proportionally. Each of these components interacts with flavor differently than fat would. A combination of fat mimetics may mimic part of the function of fat, but they cannot completely replace fat's functionality, especially as pertains to flavor perception.

Basic Tastes

The basic tastes of sweet, sour, salty, bitter and umami are perceived in the mouth. There is an interrelationship in the perception of the basic tastes, and their perception integrates with aroma to affect flavor perception as a whole.

Sweet: Not all sweeteners possess the same degree of sweetness. Each sweetener has a different flavor and temporal profile, thus affecting flavor perception differently. For example, an identical strawberry flavor will taste different in a beverage containing sugars versus one containing high fructose corn syrup or a high potency sweetener. Without sweetness in a beverage system, the flavor will be poorly received. Sweetness enhances flavors and adds a balance to them. It is very difficult to describe the flavor of sucrose outside of the full context of a food system. It imparts a clean and pure sweet taste; it is also a flavor synergist and a modifier of other components. The amount of sucrose in a formula will determine the amount of flavor needed. Low sugar levels necessitate reduced flavor usage. High levels of sweeteners common in many food products such as ice cream call for increased flavor usage. The flavor of sucrose can

overpower flavors, but in items such as rock candy and donut glazes, strong sucrose flavor is desirable. The flavor of sweetener blends that are commonly used in food formulations are affected by their sweetener components.

Specific sweeteners affect flavor perception and flavor release. Fructose rapidly releases flavors whereas sucrose has a slower impact that lasts longer; because of this difference in timing, certain flavors—fruit flavors as well as some spice and acidic flavors, for example—are better perceived with sugar. Fructose allows flavors to have more impact, even allowing a reduction in acid levels by five percent.

While sucrose enhances flavors, corn syrups can mask flavors. In addition, corn syrup solids, at greater than 25 percent, cause undesirable metallic notes to be perceived. Increased sweetness can reduce bitterness to varying degrees, depending upon the sweetener type. Sucrose and fructose appear to be most effective, whereas dextrose accentuates bitterness. Excessive levels of sweetness can also suppress saltiness and thus be counter-productive.

Sweeteners have varying degrees of heat of dissolution; dextrose has a negative heat of dissolution, which can enhance the cooling effects of flavors such as peppermint oil. Today, sugar-free gums contain sorbitol, xylitol and mannitol, or combinations of them to capitalize on this effect. Sweetness generally reduces the tartness of acids depending upon the type of acid and sweetener used. This can easily be seen by comparing white vinegar to a Japanese seasoned rice vinegar containing 2 percent sugar. Vinegar reduces the sweetness of glucose, but does not significantly reduce that of sucrose. The sweetness of sucrose tends to be intensified by lactic, malic, citric and tartaric acids. Increasing sweetener levels negates some of the perception of sourness.

Corn syrups mask tartness more effectively than does sucrose. Corn syrup contributes its unique flavor profile, as well as an ability to mask off flavors. It takes a 15 percent difference in sweetener concentration in order to see a significant difference in sweetness.

Sour: Acids provide tartness in food products and beverages. Citric and/or malic acid are commonly used with strawberry flavor;

tartaric acid is used with grape flavor impact. Acidulants provide tartness in foods; citric and malic acids are the predominant general purpose acidulants. Fumaric and tartaric acids are also appropriate for general applications. Acetic acid (vinegar), cream of tartar (potassium acid tartrate), phosphoric acid, glucono-δ-lactone, acid phosphate salts, lactic acid and adipic acid are generally considered specialty acidulants.

Sourness can suppress the bitterness and tartness (low pH is why something is acidic) imparted by the organic acids, strongly masking bitterness. Citric and fumaric, lactic, and vinegar are particularly effective. The choice of acid can affect flavor perception. Each acidulant has its unique flavor profile and flavor release characteristic, and each has its own impact on the overall flavor of the system. The choice of the correct acid or blend of acids and the level at which they are used is important to optimize the flavor.

The taste of citric acid has a sharp impact, builds up quickly and is of short duration. It is sometimes described as "bright," or said to "brighten up" the flavor profile of foods to which it is added.

Malic acid has a smooth, tart taste that builds up and diminishes gradually without giving a sensation or "burst in flavor." It does not provide the "pucker note" of citric and carries along with it the inherent flavors of the product to which it was added. It provides a clean, tart taste with no characterizing flavor of its own. The taste of phosphoric acid, a mineral acid, is somewhat flat and quite different from the sharp tartness of most organic food acids. As a consequence, it blends well with non-fruit flavors; it is used in cheese making and in the brewing industry for pH control, as well as for cola beverages.

Fumaric acid is extensively used in non-carbonated fruit beverages. Its greater acid strength allows lower uses than citric; its solubility and rate of dissolution are sufficient for this process. It is also used in gelatin dessert mixes because of its low hygroscopicity. Fumaric acid is used to impart flavor in maraschino cherries. Lactic acid has a mild taste that enhances flavors without contributing any overpowering, delicate nuances.

Of all the food acidulants, lactic acid provides the least amount of flavor at a given pH; today, it is being used to provide acidity to

a new class of cream- and yogurt-containing confections. In frozen confections it imparts a milky tart taste without masking other flavors. Despite the differences between lactic and citric, the exchange basis on a dry basis is 1:1.

Adipic acid provides a delayed acid impact and a lingering high tartness that compliments grape flavors and other products with "delicate" flavors. Adipic functions as a buffer, neutralizing agent, gelling aid and sequesterant. Tartaric acid is an odorless powder with a tart taste and a slight characteristic flavor of its own. It contributes a strong tart taste that enhances fruit flavors. In practice, it is limited to grape flavored products, particularly beverages and candies. It is also used where high tartness is desired in a highly soluble acid. Tartaric acid is the most water soluble of the powdered acidulants.

It is important to use acidifiers that are compatible with the flavors present, such as lactic acid with dairy products, or malic acid with apple flavors. Citrus and berry flavors would be flat and lifeless without at least a touch of tartness. Lemon candies and beverages are traditionally very sour, while orange and cherry are a little less tart. Flavors like strawberry, watermelon and tropical fruits require only a trace of acidity for flavor enhancement

Acid blends are used to modify flavor profiles. Citric acid, which imparts a burst of tartness, can be combined with malic or adipic acid to soften the intensity of the impact of the sour sensation, such as in gelatin desserts. In a barbecue sauce, increased levels of acetic acid will be experienced in the "tail" of the flavor, carrying the spice notes with it. If a "tangier" sauce is desired after pH has been achieved with acetic acid, one should add citric acid. This will provide a more immediate acid impact than the vinegar.

Buffers are commonly used to control pH, and are also used to modify flavor perception. Highly buffered solutions appear to convey greater and more lingering sourness compared to un-buffered acids at the same pH. Buffering agents, such as sodium citrate, reduce the sharpness of the acid taste in beverage if the quantity of acid is relatively large. When desiring a mild sourness, one would choose an acid with a mild flavor. Glucano δ-lactone (GDL), which slowly

hydrolyzes to gluconic acid, imparts the desired results as well as buffering the system.

Taste interrelationships: With simple sugars, there is a reduced need for flavor at low sugar levels. At higher levels, the sugar starts to mask the flavor. With complex carbohydrates, there is an increased flavor need because of the increased viscosity and selective flavor binding. Sugar generally reduces the tartness of acid. The opposite effect may or may not occur depending on the nature of the acid and sugar used. Vinegar certainly reduces the sweetness of glucose, but does not significantly affect that of sucrose. The sweetness of sucrose tends to be somewhat intensified by lactic, malic, citric and tartaric. Sourness suppresses bitterness, two sensations that are often confused by tasters. The tartness and low pH imparted by organic acids such as citric, fumaric, lactic and vinegar are very effective in strongly masking bitterness.

Bitterness: Though the reputation of bitter perception tends to be negative, it holds a rightful place in the flavor spectrum. Without its contribution to the overall flavor profile, cheese, cocoa, caramels, molasses, beef stock, coffee, cola and aperitifs and some cordials would not have their characteristic, familiar and desirable flavor profiles. The bitter components of foods are mostly fat soluble. The lack of bitter perception in high fat foods is due to the slow release of those bitter compounds from the fat. Thus, when fat is removed or reduced in a food product, the bitter flavors are intensified and more readily perceived.

A universal masking agent for bitterness does not exist. Bitterness perception can be influenced by the type of spice used in a system. Bitterness is exacerbated and accentuated by eugenol (clove, allspice and pimento), celery, onion, caraway and dill oils with high carvone contents. On the other hand, bitterness is suppressed by cassia, cumin, ginger and red pepper oleoresin. There is little effect on bitterness from fenugreek, garlic, mace, marjoram, nutmeg or thyme. In some applications, such as pharmaceuticals, bitterness is usually the inherent but unpalatable aftertaste of the therapeutic agent of the formulation.

Since it is difficult to mask bitterness, one must layer the flavor sensations, thus altering the temporal profile and confusing the

senses. This can be done by adding compounds such as cayenne pepper, mint or salt that impart trigeminal responses. Since the effect of these compounds is more pervasive and longer lasting than bitterness, the product becomes more acceptable. Vanilla is also effective in sweetening the product as well as providing a more lingering aftertaste.

Flavoring of juvenile medications, specifically those that must be administered several times per day and for extended periods, is a most challenging project. Since the bitterness-inducing ingredient is also the efficacious ingredient and is being administered in an exacting dose based on the patient's weight, the therapeutic effect of the drug will only be effective if the entire dose is kept down. The creative applications effort for juvenile medications can be facilitated by the use of Bitrex, denatonium benzoate, supposedly the bitterest substance in the world. Substituting Bitrex for the active medicinal ingredient makes possible the ingestion of the base and will lead to a successful flavoring/masking system.

Saltiness: Saltiness has a broad functionality in the spectrum of flavor perception. Remembering that the basic tastes must be in solution to be perceived, the particle size of the salt (ranging from large crystals to flour salt) affects the impact of the flavor profile. The addition of salt enhances the perception of sweetness, decreases the perception of bitterness, and decreases metallic and chemical off notes. Salt increases the perception of fullness and viscosity, resulting in the impression of a less watery or thin product. Salt improves flavor balance; the flavor profile is smoother, fuller, and perceived as being more intense overall. This is partially a result of decreased off notes, enhanced mouthfeel and sweetness, and increased flavor strength perception; it is also a result of a blending of flavor perceptions so that the individual flavor notes are less discreet. Salt enhances the flavor in cheese by controlling the ripening and firming of the cheese and influencing the types of flavor components that develop with aging.

Probably the most unique functionally of salt is its ability to change the order of occurrence of flavor notes in a product. Hollandaise sauces formulated to contain a range of salt levels from 0.5

percent to 2 percent have remarkably differing flavor profiles. The order of occurrence in the sauce with 2 percent salt is salty, bitter, eggy, sour and then lemon. The sauce with 0.5 percent salt has an order of occurrence of lemon, sour, eggy and then salty.

Hydrocolloids: Viscosity and gel type have dramatic effects on flavor profiles. Sweetness is decreased in gum solutions as a function of viscosity. As viscosity is increased, more sweetener is needed for the threshold perception of sweetness. Therefore, the suppression of aroma occurs in thickened systems. There is a chemical interaction with hydrocolloids that results in decreases in flavor and odor intensity that are aroma chemical class dependent and process variable.

No better example of this phenomenon exists than today's light maple syrups. Ever since sugar was replaced with a lower cost high fructose corn syrup, cellulose gums were added to replace the satiating mouthfeel of the sugar. These gums impart a peculiar mouthfeel to the finished syrup. This dual replacement necessitated a significant modification to the flavor system in order to overcome the cellulose gum's apparent viscosity effects.

Bear in mind that the flavor perception with gums is still better than of that with starch, due to the fact that gum levels tend to be much lower than that of starch. Propylene glycol alginate (PGA) is the exception to the rule. PGA has a hydrophobic group that intensifies flavors, particularly citrus notes. Gum type affects flavor release. As the brittleness of a gel increases and the elasticity decreases, flavor release becomes more rapid. Firm, brittle gels, such as gellan gum, readily fracture in the mouth, releasing the flavor quickly; flavor release is very slow in a gelatin system. This quick flavor release is desirable in bakery fillings, pie fillings and dessert type gels. Because these carbohydrates have the ability to absorb volatiles and retain them during drying, they are extremely effective as flavor carriers. This encapsulation aids in stability, prevention of oxidation and attainment of flowable powders.

Flavor Development

A food's flavor is arrived at by a variety of different methods. There is of course the indigenous flavor of the food as derived from

its source, as well as the result of the blending of several of these sources. Flavor develops when ingredients are heated or otherwise processed. This development is usually time and temperature related, whether the process is fermentation, roasting or browning. Flavor production is an important attribute of non-enzymatic browning, such as caramelization. The complexity of this flavor development is dependent upon the type and number of ingredients that are heated. For example, crystalline sugar has no aroma. At 335°F (168°C), sucrose begins to change color, an indication of a change in molecular structure and interaction, as well as flavor development. By 350°F (177°C), the sugar is no longer the disaccharide it started out as, but a complex system of over 300 volatiles, resulting in a rich caramellic flavor. The degree of caramelization and the extent of flavor development are dependent on the time it takes to reach temperature and the stopping point in the range of 335°F to over 350°F. If at this point heavy cream is added, many new aroma chemicals are formed due to the Maillaird reaction, resulting in a much more complex system. The first process results in a caramelized sugar, while the second results in caramel.

Roasting, baking, frying, extrusion, broiling, boiling, poaching and any other heating processes utilize at least these two types of reactions. To appreciate the subtleness and impact of such thermal effects you have only to taste the difference between a can of sweetened condensed milk and a can of dulce de leche, a South American standard. In sweetened condensed milk, the cooked character could be considered an off note, while in the dulce it is the desired characteristic.

Selecting and evaluating flavors: It is most important to know the history of your product: the type of process (process temperature and time); whether evaporation occurs and the types of reactions taking place; the pH of the system; and anticipated storage conditions of light, time, oxidation, spoilage or packaging. One must decide in what form a flavor is needed before selecting one. Is a natural, artificial, natural and artificial, WONF or nature identical flavor desired? What physical form will work best in the system: water soluble, oil soluble, emulsion, spray dried or other forms of flavor encapsulation,

plated, or paste? Are there religious restrictions for your marketplace (kosher or halal)? Are there legal or regulatory constraints for the composition of your final product (GMO, allergy issues)? Finally, will it undergo further processing by the consumer, such as microwaving, boiling, frying, etc.?

The developer must define and refine the language used in communicating with other formulators and with flavor creators and suppliers. A common and mutually understood vocabulary is a necessity so that the flavor company can supply the desired flavor with the least amount of iterations. Since it takes 10 days to two weeks for most products to equilibrate, and much longer for storage studies to be conducted, the lack of need for flavor iterations can reduce the amount of time needed to successfully complete a project.

A common practice when receiving flavors from suppliers is to open the bottles, smell them and make a decision as to appropriateness of the flavor for the product. This is an unfair evaluation and may eliminate many flavors that could solve any flavor issues that exist. A more effective way of evaluating flavors is to try them in a "model system" that closely simulates one's product and process. For instance, in ice cream one might screen the flavors in an ice cream mix. For bakery products, one might add flavors to a generic cupcake formulation prior to baking.

It is important to consider that some flavors may be more effective when added at varying points in the process. A cream flavor added prior to processing provides the flavor precursors needed for flavor development in a reduced fat caramel. On the other hand, it is important to react hydrophobic proteins or high amylose starches with straight chain emulsifiers prior to adding flavor. This will ameliorate binding of the flavor with the ingredients.

Flavor must be considered throughout the product development process. Waiting until formulation and processing are completed prior to considering the flavor results in a frustrating effort to achieve the desired flavor profile. The indigenous flavors of the ingredients, the influence of ingredient or packaging binding or scalping, ingredient off notes, the influence of acids on the flavor profile, and the ingredient masking of flavor by inhibiting access to the palate due to

high viscosity must be considered. Formulators must begin working early and closely with flavor suppliers.

Flavorists should not restrict themselves to working with only one ingredient company, but rather choose a limited series of suppliers. None have *all* the technologies available to solve every flavor issue. Flavor suppliers are most effective when the developer can provide an unflavored base for screening purposes. Flavorists only need basic information about the base, such as whether it is high protein, high in carbohydrates, low fat and/or high mineral, in addition to processing instructions. Flavorists are not interested in developers' exact proprietary formulation, only with providing clients the best means to evaluate their flavor.

Flavor application is more than just opening bottles and adding flavor to formulations. It is a holistic process whereby all flavor aspects of a product are taken into consideration; these include indigenous ingredient flavors, flavor reactions and interactions, processing, storage, and consumer end usage. It is important to document what was successful during the development of the product. It is just as useful to draw conclusions from any failures. This will ensure future successes by drawing on past efforts.

Ruminations on Some Dairy Flavors

Judith Michalski

Introduction

Dairy flavors are a different breed of animal, so to speak. Unlike many types of fruit flavors, with their dramatically different characterizing components, dairy flavors derive their characteristic qualities from the same components, just in differing ratios. These differences, plus the appearance of trace ingredients, make for subtle to dramatic variations in flavor. The trace components also lend themselves to making these differences even more noticeable as signature qualities or off notes, depending on how present they are in the final product.

The rich, fatty notes of dairy products make them highly suitable for a wide array of applications, including sauces, soups, margarine, oils, puddings, frozen dinners, cakes, confections and snacks. Milk and cream flavors, specifically, have the unique functionality of rounding out and deepening the flavor profiles in various applications.

One adjective common to all of the flavors mentioned is "rich." Because richness is a blend of satisfying, fatty, mouth-coating sensations accompanying the flavor, it is left out of all the descriptor charts.

This work will concern itself with milk, cream and butter flavors and offers a compendium of materials from literature and organoleptic data that the flavorist can use in making dairy flavors.

Origins of Dairy Flavors

The flavor of dairy products is due primarily to the flavor components, lipids, sugars and protein naturally occurring in milk. The main pathways that other flavor components are generated through are:

Heat: When milk is subjected to heat, several types of chemical changes can occur that affect its flavor. As more heat is applied, whether by increased time or temperature, these changes become more dramatic.

The most common reaction is the Maillard reaction, which involves amino acids and reducing sugars, primarily casein and lactose, and results in a spectrum of aromatic compounds including pyrazines, pyrones, furans, furanones, aldehydes, and furfurals. The sulfur-containing amino acids methionine and cysteine decompose when subjected to heat, yielding sulfurous compounds that have extremely low odor and taste thresholds. Under heat treatment, the fatty acid portion of milk contributes methyl ketones, lactones, and aldehydes.

Fermentation: In milk and cream products, lactic acid bacteria, primarily lactococci and lactobacilli, are utilized to transform the bland and pleasant dairy products into something more exciting. These microorganisms act on the milk to convert lactose to lactic acid, along with an array of other compounds, such as ketones and other acids.

Feed: The effect of the cow's diet on the flavor of the milk can be quite striking. The classic case is that of the cow consuming or smelling wild onions in the pasturage one to three hours prior to milking. The resulting milk will have an alliaceous note that will detract from its freshness. A more pertinent example is the milk of grass-fed cattle (especially in light of the current organic demand in the marketplace) versus milk from grain-fed cows. Cows allowed to pasture receive more protein in their diets, which produces more free l-tryptophan in the rumen. This leads to powerful, nitrogen-containing compounds present in the milk, acceptable in some markets. This same reasoning has been extended to the presence of phenolic components due to the amino acid l-tyrosine.

Milk Flavors

Fresh milk: One way to express the ideal flavor of milk is to say what it is not. Milk has a bland, pleasant, slightly sweet, pleasingly fatty taste devoid of any outstanding notes. It is not a flavor that usually has the dominant role in a food system. The beauty of a milk flavor lies in its ability to lend richness and to round off a less-than-perfect base. Milk flavors also blend well with more aggressive flavors, enabling the technologist more versatility and creativity in designing flavor systems for applications.

Because of the high concentration of heavier components in milk flavors, they can be well suited to applications involving heat without losing too much impact. Other applications for which they are natural fits are nutraceutical products (to help mask vitamin/mineral notes), soy products, skim and low-fat dairy products, other low-fat products, and baked goods.

Typical core descriptors for fresh milk flavors are sweet, creamy, fresh and, of course, milky (see T-1).

Heated milk: As previously stated, the flavor of milk is transformed when it goes through heat treatment. The degree of flavor

T-1. Fresh milk flavor descriptors

Descriptor	Components
animal	skatole, indole, p-cresol
brown	furaneol, maltol
buttery	diacetyl, acetoinbutyric acid
cereal	furfural, 2-acetyl furan, isovaleraldehyde
creamy	δ-decalactone, δ-dodecalactone, δ-nonalactone, δ-tetradecalactone, *cis*-4-heptenal
fatty	decanoic acid, palmitic acid, oleic acid, myristic acid
fresh	*cis*-4-heptenal
milky	δ-tetradecalactone, 5,6-decenoic acid, 2,3-pentanedione
plastic	2-nonanone
sweet	vanillin, maltol, lactose
waxy	2-tridecanone, nonanoic acid, 2-undecanone, stearic acid

T-2. Cooked milk flavor descriptors

Descriptor	Components
animal	skatole, indole, p-cresol
barny (see animal)	
brown	furaneol, furfural, 2-acetal furan, 5-methyl furfural
buttery	diacetyl, acetoin, butyric acid, 2,3-pentanedione
caramelized	furaneol, maltol, furfuryl alcohol
cereal	furfural, isovaleraldehyde, 2-acetyl furan
cooked milk	sulfurol, 1-octen-3-ol, 2-heptanone, 2-nonanone, hydrogen sulfide
creamy	δ-decalactone, δ-dodecalactone, δ-tetradecalactone, *cis*-4-heptenal, δ-nonalactone
fatty	decanoic acid, palmitic acid, oleic acid, myristic acid
lipolytic	butyric acid, hexanoic acid, octanoic acid, decanoic acid
milky	5,6-decenoic acid, δ-tetradecalactone, γ-butyrolactone
nonfat dry milk	nonfat dry milk
oxidized	2,4-decadienal, 2,4-nonadienal, 2-decenal
phenolic	p-cresol, 3,4-xylenol
waxy	2-undecanone, 2-tridecanone, stearic acid

development increases with temperature and/or time. Creamy notes are intensified as lactones and ketones are formed. In addition, caramellic undertones develop and the product takes on a cooked or scalded quality.

The flavor of condensed milk is richer and more full-bodied compared to fresh milk flavors. These can be used in many of the same applications as fresh milk flavors, in addition to desserts and confectionary products.

Core descriptors for cooked milk flavors are creamy, milky, brown and cooked (see T-2).

Cream Flavors

Fresh cream: Cream, by virtue of its higher fat content, is used to

T-3. Fresh cream flavor descriptors

Descriptor	Components
animal	skatole, indole, p-cresol
blue	2-heptanone
buttery	diacetyl, acetoin, butyric acid
coconut	γ,δ-octalactone, δ-nonalactone, δ-hexalactone
creamy	δ-decalactone, δ-dodecalactone, δ-nonalactone, δ-tetradecalactone, *cis*-4-heptenal
sulfurous	dimethyl sulfide
fatty	decanoic acid, palmitic acid, oleic acid, myristic acid
ice cream	vanillin, maltol
milky	δ-tetradecalactone, 5,6-decenoic acid, 2,3-pentanedione, 2-tridecanone
oily	oleic acid, γ-nonalactone
sweet	vanillin, maltol

endow a flavorful richness and mouthfeel to those products to which it is added.

Likewise, cream flavors also mimic the above qualities in products in which they are incorporated. Cream flavors also serve to tone down harsh notes in bases and, as with milk flavors, impart a luxe/luxurious quality to products, only to a greater extent.

Products in which cream flavors flourish are: sauces, nonfat and low-fat dairy systems, confections, baked goods, soups, and puddings. Typical core descriptors for cream include buttery, creamy, fatty and sweet (see T-3).

Sour cream: The tangy richness of sour cream is notable for the sharp, fresh impact it imparts to foodstuffs. As with its parent, cream, sour cream imparts a lingering, satisfying aftertaste and mouthfeel. Applications that are a natural fit for sour cream are dips, topical coatings for snacks, soups, sauces, and desserts. Typical core descriptors for sour cream include tart, creamy, cultured and fatty (see T-4).

T-4. Sour cream flavor descriptors

Descriptor	Components
buttery	diacetyl, acetoin, butyric acid
cheesy	methyl thiobutyrate, butyric acid, isopentanoic acid, 2-heptanone
cooling	acetaldehyde
animal	skatole, p-cresol, indole
creamy	δ-decalactone, δ-dodecalactone, δ-nonalactone, δ-tetradecalactone, *cis*-4-heptenal
cultured	acetaldehyde, acetoin, lactic acid
fatty	decanoic acid, palmitic acid, oleic acid, myristic acid, γ-nonalactone
fresh	acetaldehyde
blue	2-heptanone, 2-nonanone
meaty	methional, 2-mercaptopropionic acid
milk, nonfat powder	NFDM
phenolic	p-cresol, 3,4-xylenol
scorched	benzothiazole
sulfurous	dimethyl sulfide, 2-mercaptopropionic acid
tart	lactic acid, acetic acid, propionic acid, citric acid

Butter Flavors

There are a myriad of butter types for a vast number of applications throughout the food industry. Fresh butter is prized for its rich, creamy flavor that blossoms on the tongue as it melts in the mouth. Big, bold and brazen is called for in microwave popcorn applications, rich and mellow types are the usual requests for baked goods, and browned notes are highly prized in confections and sauces. In this section, fresh and browned types of butter flavors will be discussed.

Because diacetyl plays such a prominent role in butter flavor, to diacetyl or not to diacetyl is certainly the question of the day in light of its apparent adverse effects to food plant workers. No other material is quite like it. For the sake of argument and this work, the assumption is that this component will remain a part of the flavorist's palette.

T-5. Fresh butter flavor descriptors

Descriptor	Components
animal	skatole, indole, p-cresol
band aid	(see phenolic)
brown	furaneol, maltol, furfural, 2-acetyl furan
buttery	diacetyl, acetoin, butyric acid, acetoin butyrate, 2,3-pentanedione
cabbage	methanethiol
caramellic	furaneol, cyclotene, maltol, 2,3-hexanedione
cooked milk	sulfurol, 1-octen-3-ol
corn, sweet	dimethyl sulfide
creamy	*cis*-4-heptenal, δ-decalactone, δ-dodecalactone, δ-nonalactone, *cis*-6-dodecen-4-olide
cultured	lactic acid, acetoin, acetaldehyde, 2-heptanone
dirty	butyric acid, hexanoic acid
fatty	oleic acid, decanoic acid, myristic acid, palmitic acid
fruity	ethyl butyrate, ethyl caproate
goaty	hexanoic acid, 4-ethyl octanoic acid
green	T-2-hexanal, T-2-hexenol
milky	5,6-decenoic acid, δ-tetradecalactone, butyl undecenoate, γ-butyrolactone
oily	oleic acid, γ-nonalactone
oxidized	2,4-decadienal
phenolic	p-cresol, 3,4-xylenol, 4-ethyl phenol
rancid	butyric acid, heptanoic acid, octanoic acid
soapy	lauric acid, 2-nonanol
sulfurous	dimethyl sulfide, methanethiol
sweet	vanillin, maltol
waxy	nonanoic acid, 2-undecanone, 2-tridecanone, stearic acid

Fresh butter: Because of its water-in-oil quality, the flavor of butter develops quietly on the tongue with a little buttery burst, and blooms quickly to a rich and creamy finish that is elegant and satisfying. Depending on the processing of the product, different

T-6. Browned butter flavor descriptors

Descriptor	Components
animal	skatole, indole, p-cresol
brown	furaneol, maltol, furfural, 2-acetyl furan
butterscotch	(see caramellic)
buttery	diacetyl, acetoin, butyric acid, 2,3-pentanedione
caramellic	furaneol, cyclotene, maltol, 2,3-hexanedione
cooked milk	sulfurol, 1-octen-3-ol, 2-heptanone
corny	dimethyl sulfide
cowy	butyric acid
creamy	*cis*-4-heptenal, δ-decalactone, δ-dodecalactone, δ-nonalactone, δ-tetradecalactone
fatty	oleic acid, decanoic acid, myristic acid, palmitic acid
milky	5,6-decenoic acid, γ-butyrolactone, butyl undecenoate, δ-tetradecalactone
nutty	2-acetyl pyrazine, 5,6,7,8-tetrahydroquinoxaline, methyldihydrocyclopentapyrazine
oxidized	2,4-decadienal, nonanal
phenolic	p-cresol, 3,4-xylenol, 4-ethyl phenol
plastic	(see waxy)
popcorn	2-acetyl pyrazine, 2-acetyl-3,5(&6)dimethylpyrazine, 2-acetyl thiazole
rancid	butyric acid, heptanoic acid, octanoic acid
soapy	lauric acid, 2-nonanol
sweaty	isopentanoic acid, hexanoic acid, 3-methyl pentanoic acid
sweet	vanillin, maltol
toffee	(see caramellic)
waxy	2-undecanone, nonanoic acid, 2-tridecanone, stearic acid

notes can be present, ranging from sulfur impact notes to caramellic. These qualities become "signature notes" and define one brand from another. But no matter what the brand differences may be, the desirable core descriptors of fresh butter remain sweet, creamy, buttery, milky, and slightly sweet corn (see T-5).

Browned butter: As butter cooks, it develops a golden brown color and a rich, nutty aroma, much like that of English toffee. Because of the higher concentration of fatty acids present along with lactose and casein in the aqueous part of the butter, and the prolonged heating period and higher temperatures, the profile becomes much more complex than those of milk and cream. The resultant product is still recognizable as butter, but with nutty, caramellic overtones similar to English toffee, due primarily to the formation of furanones and pyrazines, courtesy of the Maillard reaction.

The core descriptors of browned butter most appreciated are brown, buttery, caramellic, creamy, and nutty (see T-6).

In Conclusion

Milk, cream and butter offer the flavorist a fascinating group of flavors to ponder. Although they all are based on the same aromatic building blocks, dairy flavors become different by virtue of how they are treated, similar to the human condition! These flavors will continue to be a source of inspiration to the flavorist, providing the model for true-to-life renderings, as well as fodder for the exaggerated, fanciful forms of future flavors.

Practical Meat Flavor Creation

Douglas Young

Entering the realm of savory flavors was the last frontier for many flavor houses. Thus, the number of flavorists specializing in this area seems relatively low compared to those creating sweet flavors. I explain this disparity between sweet and savory as the flavor industry's natural response to consumers' basic need for a sense of well being through luxury. This hunger for luxury is well satisfied by sweet indulgence, taking the form of beverages, desserts and confections—the perfect medium for the flavor industry. That need satisfied, the flavor industry eventually turned its efforts to the main course. The late entry of savory flavors and the flavorist needed to produce them was, in the end, an effort to improve and grow the bottom line. (It is important to note that savory is often taken to imply meat flavors, although the segment often includes vegetable and dairy categories. To simplify my examples, I shall limit my discussion to some basic, common meat flavors.)

It seems ironic that, while there are a limited amount of people specializing in meat flavors, more has been written on the subject of the Maillard reaction (one of the principal creative techniques in meat flavor creation) than almost any other flavor subject. Many of these Maillard publications, however, deal with ongoing efforts to understand the chemistry of the reaction, rather than teaching the

creative flavor aspects needed to fulfill continuous improvements in savory flavors. These growing needs are driven by corporate and consumer desires for:

- Improving profit margins
- Improving the flavor of convenience foods (example: microwave food lacking brown and roasted notes)
- Improving pre-cooked foods (covering warmed-over flavor)
- Improving calorie control, low fat foods (fat *is* flavor)
- Improving vegetarian foods (addressing religious, moral and heath concerns)

In the world of creative flavors, meat flavors are commonly made by compounding and/or processing. In general, compounded flavors have the advantage of speed and simplicity, both during the creative process and in actual production. Processed flavors are more energy-, labor- and time-intensive during both the creative and in-production phases, and usually are associated with high capital equipment costs.

Before proceeding further, I should establish that, with all due respect to my international colleagues, I will be speaking primarily from a US perspective as a matter of convention. Thus, the terms "natural" and "permissible ingredients" are defined according to FDA's 21 CFR 101.22 (a) (3) and the Flavor Extract Manufacturer Association (FEMA) and GRAS lists.

Why Processing?

With all these negative cost/time/regulatory factors, one has to question why one would choose to use processing as a technique; after all, many flavor houses have made fine compounded meat flavors for years. The catch, though, is that those flavors are considered "artificial." Marketing and consumer needs for natural flavors in the United States, without an adequate availability of natural chemicals suitable for compounding savory flavors, have left processing as the only way to produce natural meat flavors. Another advantage of processing is that a well-crafted flavor will have improved flavor fidelity, complexity and depth that develops during processing of the ingre-

dients, mimicking the cooking of meat or other commonly cooked products (such as chocolate, coffee, malt and bread).

Chemical manufacturers have been making natural flavor chemicals to service the flavor industry's needs; however, for many years those natural chemicals were more suited to sweet flavors than to savory (the exception being organic acids, such as butyric, used to make esters and cheese flavors). In the late 1990s, natural chemicals such as pyrazines, 2,4-decadienal, methional, 2-methyl-3-furanthiol, and other chemicals more suited to savory began to appear, sparking a resurgence in the compounding of meat flavors.

While compounding and processing have their pros and cons, it is not to say that the two techniques are mutually exclusive; it is quite common to combine compounded flavors with processed flavors to achieve a more complete flavor profile. The compounded flavor or key can supply the strength and characterization, while the processed flavor helps to round out, improve the mouth feel and depth of the flavor.

Compounding Flavor Creation

As with all compounded flavors, creation is all about the flavorist's imagination and being familiar with the chemicals and ingredients that can be used to make the desired flavor profile. The easiest way to begin creating flavors is to use a characterizing ingredient, one that, on its own could be perceived as the desired flavor. The following are common characterizing meat chemicals:

- Chicken or turkey
  1. (E,E)-2,4-decadienal (FEMA# 3135): intense fatty, fried
  2. trithioacetone (FEMA# 3475): light meaty, poultry-like
  3. 2,5-dimethyl-3-furanthiol (FEMA# 3451): metallic, sulfury, brothy note
- Beef
  1. 2-methyl-3-furanthiol (FEMA# 3188): mildly roasted, meaty
  2. 12-methyl tridecanal (FEMA# 4005): soapy, citrusy, tallow-like
- Pork
  1. 2-methyl-3-furanthiol (FEMA# 3188): mildly roasted, meaty
  2. T-2-decenal (FEMA# 2366): fatty, lard-like

- Lamb
  1. 4-ethyl octanoic acid (FEMA# 3800): sweaty, sour, fatty, animalic, goaty
- Seafood
  1. trimethylamine (FEMA# 3241): alkaline and amine-like

Speciation

There is an old adage that fat is flavor; actually, fat provides the characterizing flavor of the meat-speciation. However, the fat (triglyceride) is only the carrier; it is the volatile oxygenated organic compounds (alcohols, aldehydes, ketones, lactones and fatty acids) found solublized within the fat that provide the characterizing notes that distinguish, say, beef from pork from lamb (1). As shown above, 2,4-decadienal is commonly used to characterize both chicken and turkey; the inclusion of 1-octen-3-one (FEMA# 3515) to the decadienal can help develop the flavor into a more characteristically metallic turkey meat note. Similarly, the characterizing differences between beef, pork and lamb lie within the fat-soluble components (12-methyltridecanal, T-2-decenal and 4-substituted octanoic/nonanoic acids).

Characterizing compounds alone do not make very good flavors; it is combination with other notes that rounds out the flavor to completion. I have compiled below a list of chemicals helpful in delivering meaty notes to a flavor.

Meaty Chemicals

- ***2-Methyl-3-furanthiol (FEMA# 3188):*** Found in beef, pork, tuna, hydrolyzed vegetable proteins (HVP), yeasts and, to a lesser degree, chicken.
  - Taste: meaty, brothy, slightly alliaceous, roasted, meaty coffee, HVP-like.
  - Applications: beef broth, roasted meat flavors, shellfish and roasted nut flavors.
- ***2-Methyl-3-(methylthio)furan (FEMA# 3949):*** Found in beef, pork and, to a lesser degree, chicken; also found in HVPs, yeasts and thiamine decomposition products.
  - Taste at 1 ppm: mild meaty, metallic, ethereal-solventy.

- Applications: tropical fruits, chicken or turkey.

- ***2-Methyl-3-(methyldithio)furan; methyl oxycyclosulfide 719; methyl-2-methyl-3-furyl disulfide (FEMA# 3573):*** Found in HVPs; clear yellow liquid.
  - Taste: roast beef, roasted nut, broth, onion-like, reminiscent of cheese, egg or yeast.
  - Applications: roasted meat, beef broth, roasted nut flavors, HVP and coffee flavors.

- ***2,5-Dimethyl-3-furanthiol (FEMA# 3451):***
  - Taste at 0.1 percent: metallic, sulfury, but with a brothy note reminiscent of 2-methyl furan-3-thiol.
  - Applications: light meats such as turkey, chicken and pork; less suited for beef and lamb.

- ***2,5-Dimethyl-3-thiofuroylfuran (FEMA# 3481):***
  - Taste: liver-like, meaty; HVP-like flavor at 0.02 ppm.

- ***Bis-(2-methyl-3-furyl)disulfide (FEMA# 3259):*** Found in beef, pork, HVPs, yeasts, thiamine decomposition products, and to a lesser degree in chicken.
  - Taste at 0.1 ppm: strong, meaty brothy, vitamin-like, slight onion note, slightly nutty/fatty, aged prime rib of beef. Aroma similar to sulfurol. Stronger than the monomer, a bit more roasted, but still having a strong meaty quality normally found in conjunction with the monomer.

- ***Bis-(2-methyl-3-fury)tetrasulfide (FEMA# 3260):***
  - Taste: Braised beef-like.

- ***Furfuryl mercaptan (FEMA# 2493):***
  - Taste at 0.01 ppm: strong roasted, coffee-like. Chemical does polymerize to the dimer (FEMA# 3146), especially in acid solutions.
  - Applications: roasted notes, well done character, easily becomes too coffee-like.

- ***Furfuryl thioacetate (FEMA# 3162):*** Found in coffee.
  - Taste: strong, roasted sulfury coffee-like, but less sulfury than furfuryl mercaptan.

- ***Methyl furfuryl disulfide (FEMA# 3362):*** Found in coffee, cooked pork, wheat bread.
    - Taste at 0.1 ppm: roasted, burnt, sulfury coffee-like.
    - Applications: coffee, roasted meats (beef and pork), roasted nuts, peanut butter; better chemical for meaty roast notes than the traditional furfuryl mercaptan.
- ***Difurfuryl disulfide (FEMA# 3238); 2,2'-(thiodimethylene)-difuran:*** Found in coffee.
    - Taste: roasted coffee-like, very earthy, metallic at 0.1 ppm; becomes more creamy, metallic, meaty more sulfury at higher concentrations.
    - Applications: mushroom, milk, mango, passion fruit, peach, chicken and tallow.
- ***Bis-(2-furfuryl) disulfide; 2,2'-(dithiodimethylene) difuran (FEMA# 3146):*** Found in roasted coffee.
    - Taste: roasted, nutty, meaty, sulfurous and coffee-like.
    - Applications: roasted notes for meat, nut, and caramel; also useful for coffee, maple and onion flavors.
- ***2-Methyl-3-tetra-hydrofuranthiol (FEMA# 3787):***
    - Taste at 0.1 ppm: strong brothy, meaty character reminiscent of 2-methyl-3-furanthiol, though it fades more quickly.
    - Applications: brothy-type flavors.
- ***Spiro-dithiamethyloxabicyclooctane-(oxamethyl)-cyclopentane (FEMA# 3270):***
    - Taste at 0.5 ppm: mild roast meat. Applications: beef, roast chicken and pork.
- ***2-Thienyl disulfide; 2,2'-dithiodithiophene (FEMA# 3323):***
    - Taste: intense burnt sulfury, burnt rubber-like.
- ***2-Thienyl mercaptan; 2-mercapto thiophene (FEMA# 3062):***
    - Taste: roasted, burnt, rubbery.
    - Applications: roast beef and pork, coffee.

- ***2-Ethyl thiophenol (FEMA# 3345):***
  - Taste: burnt, meaty.
  - Applications: meat and fish flavors.
- ***Thiophenol; benzenethiol; phenyl mercaptan (FEMA# 3616):***
  - Taste: strong meaty, brothy, sulfurous character.
  - Applications: poultry-type flavors, especially dark meat.
- ***Benzyl mercaptan (FEMA# 2147):*** Found in coffee.
  - Taste: roasted, burnt, meaty.
  - Applications: roasted meats, burnt notes.
- ***o-Toluenethiol; 2-methylthiophenol (FEMA# 3240):*** Found in coffee.
  - Taste: strong meaty, white meat chicken-like.
  - Applications: seafood flavors such as tuna.
- ***2-Pyridine methanethiol (FEMA# 3232):***
  - Taste: roasted meaty sulfurous.
  - Applications: roast beef, pot roast and roast pork.
- ***2-Pyrazine ethanethiol (FEMA# 3230):***
  - Taste: meaty, roasted, sulfurous, savory, burnt.
  - Applications: beef, pork and chicken.
- ***Trithioacetone (FEMA# 3475):*** Found in cooked beef aroma.
  - Taste at 0.5 ppm: sulfurous, light meaty flavor at low levels.
  - Applications: chicken, poultry, seafood, tuna and egg.
- ***Trithiolane (FEMA# 3475):*** Found in cooked beef aroma.
  - Taste: sulfurous, light meaty flavor at low levels.
  - Applications: chicken, poultry, seafood, tuna, egg.
- ***3,5-Dimethyl-1,2,4-trithiolane (FEMA# 3541):*** Found in cooked beef, pork, lamb, chicken and yeast extracts.
  - Taste: boiled beef in low concentration, and onion at higher levels, chicken-like.

- Applications: light meats such as chicken, turkey, tuna, veal, pork, egg and seafood.

- ***3,5-Diethyl-1,2,4-trithiolane (FEMA# 4030):***
  - Taste at 1 ppm: slightly green onion, sweet, slightly sweet fruity.
  - Applications: red onion, scallion, leek, shallot, and light meaty notes as in chicken, pork, or turkey.
- ***2,4,6-Triisobutyl-5,6-dihydro-tetrahydro-1,3,5-dithiazine (FEMA# 4017):*** Fried bacon-like. One of two major compounds formed in the well-known reaction involving isovaleraldehyde and ammonium sulfide (2).
- ***2,5-Dimethyl-2,5-dihydroxy-1,4-dithiane (FEMA# 3450) (dimer of mercaptopropanone):***
  - Taste at 10-100 ppb: chicken-like, roasted, onion-like.
  - Applications: chicken and meat flavors, and vegetables.
- ***Tetrahydrothio-phen-3-one (FEMA# 3266); 4,5-dihydro-3(2H) thiophene:*** Found in roasted coffee.
  - Taste at 0.5-5 ppm: meaty, brothy and sulfury, metallic note.
  - Applications: roasted meat and HVP replacer flavors; possibly shitake mushroom.
- ***Thiazole (FEMA# 3615):*** Found in cooked beef and pork.
  - Taste: meaty, nutty pyridine-like flavor.
- ***4,5-Dimethyl thiazole (FEMA# 3274):***
  - Taste: meaty, roasted, nutty, green, poultry, fishy, amine-like.
- ***5-Methoxy thiazole (FEMA# 3328):***
  - Taste: roast meat, onion, braised vegetative, nutty, popcorn, bread, toasted cereal.
- ***2-Ethoxy thiazole (FEMA# 3340):***
  - Taste: roast meat, roast peanuts, phenolic and burnt.
- ***2,4-Dimethyl-5-acetyl thiazole (FEMA# 3267):***
  - Taste: meaty, boiled beef, nutty, roasted and sulfurous.

- ***Sulfurol; 4-methyl-5-thiazole ethanol (FEMA# 3204):***
  - Taste at 10 ppm: meaty, vitamin-like. Relatively weak compared to other sulfur compounds.
- ***Tropathiane; 2-methyl-4-propyl-1,3-oxathiane (FEMA# 3578):***
  - Taste: highly aromatic lift, fatty, green, sulfurous.
  - Applications: tropical fruits, peach and possibly poultry fats.
- ***2-Pentyl pyridine (FEMA# 3383):*** Found in french fries and fried chicken.
  - Taste: tallow-like.
- ***2,3-Butanedithiol (FEMA# 3477):***
  - Taste at 0.5-100 ppb: beef broth, roast meat, HVP-like.
  - Applications in beef and HVP flavors.
- ***3-Mercapto-2-methyl pentanol (FEMA# 3996):*** Found in yeast and onion based meat reactions.
  - Taste: sour, animalic-like.
- ***Methionol; 3-(methylthio)propanol (FEMA# 3415):***
  - Taste: sweet, meaty, bouillon at low levels, potato-like in higher quantities.
- ***Methional; β-methiopropionaldehyde (FEMA# 2747):***
  - Taste: powerful, raw potato-like; in lower concentrations onion, meaty, bouillon-like.
  - Applications: potato and tomato flavors; seafood, meat and chicken flavors at very low levels.
- ***3-Mercapto-2-butanol (FEMA# 3502):***
  - Taste at 0.1-1 ppm: sulfury, meaty, bloody with sweet onion notes.
  - Applications: meat, gravy flavors, roasted nut and savory flavors.
- ***3-Mercapto-2-butanone (FEMA# 3298):*** Found in chicken broth.
  - Taste at 1 ppm: burnt matches, rough sulfury, mildly harsh green note, burnt meaty, gun-powdery.

- ***3-Mercapto-3-pentanone (FEMA# 3300):***
  - Taste at 0.1 ppm: strong metallic sulfury, alliaceous brothy character, slightly catty.
  - Applications: peach, apricot, pineapple, currant, tropical fruits, onion and garlic replacers, chicken and turkey.
- ***3-((2-Mercapto-1-methylpropyl)thio)-2-butanol (FEMA# 3509):***
  - Taste at 1-5 ppm: onion, lightly roasted meat, sweet with HVP aftertaste.
  - Applications: roasted meat flavors, HVP and liver flavors.
- ***Methylene bis-(methyl sulfide); bis(methylthio) methane (FEMA# 3878):*** Found in white tuffles, coffee, cooked beef.
  - Taste at 0.1 ppm: strong cooked, vegetative, sulfury, reminiscent of dimethyl sulfide, somewhat corn-like.
  - Applications: corn, broccoli, asparagus, strawberry, durian, tropical fruits and shiitake mushroom.
- ***Dicyclohexyl disulfide (FEMA# 3448):***
  - Taste: slightly green, mildly alliaceous, fading to meaty odor, solventy, seafood, turkey-like aroma.
  - Applications: clam, coffee and cocoa.

Seasonings

Another technique that can be used to reinforce the characterization of a meat flavor is the inclusion of trace amounts (threshold and sub-threshold) of seasoning notes—herbs, spices and vegetative notes. The selected seasoning notes are those commonly associated with a given type of meat; however, this is subject to cultural and regional differences. While real seasoning pieces can be and are used, the use of essential oils and oleoresins is a more convenient way for the flavorist to introduce these notes. If the target flavor is a broth or gravy, the inclusion of a mirepoix (carrot, celery and onion) or the Cajun trinity (green pepper, celery and onion) flavor notes may also be useful (see T-1).

T-1. Seasonings

Chicken	Beef	Pork	Turkey
parsley	black pepper	garlic	parsley
thyme	thyme	sage	thyme
rosemary	onion	clove	sage
black pepper	fenugreek	fennel	marjoram
marjoram	bay	savory	savory
savory			

T-2. Compounding flavor examples*

Ingredient	Chicken Wt percent	Turkey Wt percent	Beef Wt percent	Pork Wt percent
2,4-decadienal, 1 percent	6.00	4.50	-----	-----
T-2-decenal	0.30	0.30	-----	0.60
2,5-dimethyl furanthiol, 1 percent	6.00	3.00	-----	-----
trithioacetone	0.45	0.75	-----	-----
1-octen-3-one, 0.1 percent	-----	0.60	-----	-----
methional, 0.1 percent	-----	1.50	-----	-----
2-methyl-3-furanthiol, 0.1 percent	-----	-----	21.00	0.30
12-methyl tridecanal, 1 percent	-----	-----	0.75	-----
δ-decalactone, 1 percent	-----	-----	4.50	3.00
δ-dodecalactone, 1 percent	-----	-----	6.00	6.00
4-methyl octanoic acid	-----	-----	-----	0.30
triacetin	87.25	89.35	67.75	89.80
Total:	100.00	100.00	100.00	100.00

*taste at 10 ppm in 0.2 percent salt and 0.05 percent MSG

Compounding flavor examples: The simple formulations in T-2 are provided to show how chemicals are compounded to make a basic flavor.

Non-Chemical Compounding

Aside from chemicals, certain food ingredients can be (and often are) compounded and used in combination with a chemically compounded flavor. Those food ingredients typically include such items as meat derivatives, HVPs and yeasts.

Meat derivatives: These materials are obviously the premier way to deliver authenticity to a flavor, creating WONFs when combined with a naturally compounded flavor. Meat derivatives are meat extracts, broth (frozen or dried), dried meat powders and fats. As previously mentioned, fat is flavor (and speciation); the inclusion of fat provides a quick and convenient way to deliver the desired character to a flavor, as it would obviously contain all the specific carbonyl flavor compounds for a given species. Meat powders typically include some intercellular and/or serum fat, which helps with speciation, but also include proteins (soluble and insoluble) that help provide depth and mouthfeel to a flavor. Broths and extracts are the soluble protein fraction of the meat that, similar to the meat powder, provides depth and mouthfeel. The principle difficulties in the use of real meat derivatives are:

- Regulatory concerns (USDA intervention)
- Strength (generally weak flavor contribution)
- Religious (kosher and halal)
- Health (allergen issues)
- Inconvenience (some ingredients requiring cold storage)
- Supply source contamination (BSE [mad cow] and bird flu)

HVPs (or HPP): HVP (or hydrolyzed plant protein) was one of the first processed flavors, developed by a Swiss miller, Julius Maggi, around 1886. In this process, plant proteins are broken down into peptides and reacted with their own carbohydrates by boiling with concentrated hydrochloric acid (approximately 20 to 25 percent) to form savory, meaty-like products. HVPs can be classified as either light (poultry-like) or dark (beef-like). A dark HVP is made into a light HVP by treatment with activated carbon during processing; this removes color and some of the more intense roasted savory

notes, producing a more delicately flavored HVP. HVP peptide bond cleavage typically ranges from 85 to almost 100 percent and results in peptide chain lengths of five or less amino acids. HVPs typically have 40 to 48 percent salt, which results from the neutralization of the acid with an alkali (most commonly sodium hydroxide).

HVPs came under fire in the late 1980s because carcinogenic compounds called mono- and di-chloro propanols (MCPs and DCPs) were found; though these materials were being found at very low levels, many companies began to shy away from them. The compounds were also identified as a source of MSG. Since then, HVPs have been cleaned up to meet guidelines for safe levels of MCPs and DCPs, recovering some favor in the industry. With the GMO (genetically modified organism) issue, some HVPs have again fallen out of favor since some of the common materials used to make HVPs, namely soy and corn, were among the first species to be genetically altered. Wheat and yeast are additional protein sources for HVPS.

Yeast extracts: These materials are water soluble derivatives from yeast that can provide meat flavor much like HVPs, and mouthfeel like inosinate and guanylate salts (known as IMP and GMP). Yeast (whole or extract) can be heat-treated to affect additional flavor changes. Yeast can be considered a naturally occurring process flavor (Maillard) mixture when one considers that yeast is high in protein (and amino acids), B vitamins (especially thiamine) and nucleic acids (source of GMP, IMP and ribose); heat treatment would produce a savory type flavor when heated. When HVPs, MSG, and IMP and GMP fell out of favor, many product developers turned to more expensive yeast extracts to fill the gaps.

There are about 500 yeast species in all; those of the genus Saccharomyces have long been of commercial importance because they are the chief agents in alcoholic fermentation. In addition to yeast's use for fermentation, the cell of and/or extracts of specific strains may be used directly as food (rich in protein [greater than 40 percent], vitamins and nucleic acids) or as savory flavor ingredients. The most important commercial food strains are baker's yeast (*Saccharomyces cerevisiae*), brewer's yeast (*Saccharomyces carlsbergensis*) and torula yeast (*Candida utilis*).

Food yeast can be classified as primary or secondary grown. Primary means the yeast was grown on a clean medium specifically to increase the population to be harvested as a pure, clean, active strain. Secondary yeast is harvested as a by-product of fermentation, the most common source coming from the spent wort of the beer brewing industry. Secondary yeast requires cleaning to remove the bitterness and flavor of the hops; usually alkali washing accomplishes this.

Yeast used as a flavorant comes from both primary and secondary grown sources. After cell inactivation, these are used directly (whole cell) or as yeast extracts. Yeast extracts are classified as either yeast extract or as autolyzed yeast extract. The autolyzed classification indicates that the cells' own enzymes (endogenous) were used in a controlled manner (typically incubation at 40-55°C for 12-36 h). This leads to self digestion of the cells' contents, causing cell death. Through hydrolysis, desired flavor changes occur. This process is followed by extraction to remove only the water soluble matter. Yeast extracts are prepared by first heat inactivating the cell to denature the cells' own enzyme systems, then treating the yeast with exogenous enzymes to affect cell digestion and flavor change. If salt is used for lysis, it is not declared as an ingredient. Rather, it is considered part of the extract and can be as high as 38 percent. Since salt does not have to be used as part of the process, yeast extracts can have salt contents varying from zero to 38 percent.

In the early 1990s, a "60 Minutes" television report named yeast extracts as a hidden source of MSG that the food industry was using to keep MSG in the food systems. The amount of MSG in yeast is not extremely high (≅10 percent, as opposed to HVP at 15 to 30 percent). However, the television report was sufficient to damage yeast's reputation for a few years. Yeast is still a highly favorable ingredient to use relative to using HVPs and MSG.

Process Flavor Creation

Process flavor creation differs from compounded flavor development, in that it depends upon a chemical reaction (usually initiated by heating) to occur before the flavor can be considered completed.

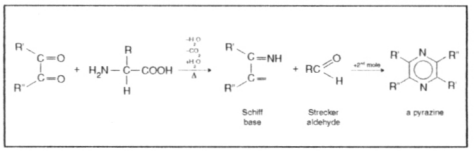
Processed flavors can be subdivided into Maillard and non-Maillard reactions.

Maillard processed flavors (or reaction flavors) are those that involve reducing sugars (or carbonyl compounds) and amino acids or proteins (or active nitrogen compounds). Non-Maillard processed flavors are those that do not involve both carbonyls and nitrogen (amino acids) to initiate the reaction. These can be just simple thermal processing to cook an ingredient or ingredients, i.e. heating onion concentrate with vegetable oil to create a fried onion flavor.

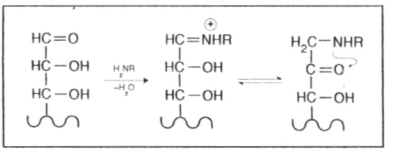
Maillard reaction: The Maillard reaction was first reported by Louis Camille Maillard in 1912 (3). In an attempt to synthesize proteins, he began reacting sugars and amino acids. In the latter half of the 20th century, this reaction was found to be a useful method for creating natural flavors reminiscent of meat, as well as other flavors typically formed through cooking, frying, baking or roasting (chocolate, coffee, malt, bread, etc.). The Maillard reaction relies upon the ready condensation of amino groups and carbonyls forming a Schiff base (-C=N- bond). This reaction can happen at low (room) temperature and is generally referred to as non-enzymatic browning (NEB), and is associated with product darkening with time. The creative flavorist employs heat to increase the rate of reaction (kinetics), and the higher temperatures initiate even more complex reactions (Amadori, Hayes and Strecker).

Common Maillard reactions: No paper on Maillard flavors is complete without reviewing the common process reactions; I therefore include them in an effort to be thorough. While they are useful for those who study reaction pathways, a commercially successful process flavorist does not use them to design or predict the outcome of their reaction. We still largely depend upon our creative artistry. Of the three common reactions, the Strecker degradation is probably the most useful; it is through this reaction that we know amino acids, such as methionine, will break down to methional, or phenylalanine will break down to form phenylacetaldehyde. In short, following the formation of the Schiff base:

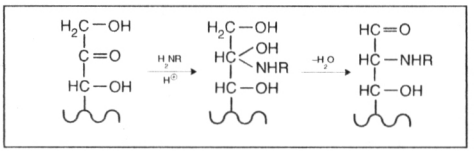
- the Strecker degradation details the formation of aldehydes from amino acids (F-1);



F-1. Strecker degradation: formation of aldehydes (one carbon less) from amino acids and diketones



F-2. Amadori rearrangement: formation of 1-amino-1-deoxy-2-ketones from N-substituted N-glucosylamines



F-3. Heynes rearrangement: formation of 1-amino-2-deoxy-2-aldoses from N-substituted N-glucosylamines corrected heyns to heynes.

- Amadori rearrangement details how aldehydes become ketones (F-2);
- and the Heynes rearrangement details how ketones become aldehydes (F-3).

Four Basic Considerations for Processed Flavor Development

Apart from the specific ingredients of the flavor formulation, varying the processing conditions can develop specific flavor notes. Four basic considerations for processing the flavor's ingredients must be considered beyond just equipment (in which case the developer is limited to what is available). In many ways, creating processed flavors follows the same basic rules of cooking food.

Time: As in cooking, the longer the process times (cooking time), the higher the degree of roast or browning of the flavor. At 121°C (250°F), increasing cooking time from 30 min to 1 h can increase color development by 50 percent. Reaction time affects overall flavor balance, producing more or less of given components. Longer processing time does not compensate for the temperature being below the activation energy for the formation of a given group of compounds; for example, if cooking beef at 212°F (100°C) instead of 350°F (177°C), no amount of added time will make it crisp, brown roast beef.

Temperature: The higher the temperature of the reaction, the more browning or roast development in the flavor. When working with pressure vessels, temperatures above common boiling are possible; increasing temperature is accompanied by increasing pressure. A 10°C rise in temperature may reduce reaction time by 25 percent or more; however, an increase in temperature can also change the profile, because the threshold for the formation of new compounds has been reached. At around 125° – 130°C (257° – 266°F), thermal decomposition of sugars can become quite robust. This decomposition will not only develop roast flavor notes, but considerable carbon dioxide, which in turn can develop extremely high pressures; to reach these temperatures in an aqueous system, a pressure vessel is needed. As in cooking, the higher the temperature, the more roasted the food.

Moisture (water activity): While water activity is often mentioned as a primary factor affecting the Maillard reaction, it is not all that common to have a water activity meter available. I find it more convenient to speak in terms of either moisture or solids. The Maillard reaction begins as a reversible equilibrium condensation reaction. High levels of water will shift the equilibrium and inhibit the Maillard reaction, minimizing browning, roasting and potentially diminishing flavor strength. However, some water is usually needed to help dissolve polar reactants and allow the reaction to proceed. Minimizing water would improve the efficiency of the reaction and subsequent impact of the flavor. The addition of more solid reactants would accomplish this task, but they must be limited: solids can also increase viscosity to the point of becoming unworkable or incapable of allowing even heat distribution during processing. The use of alternative solvents can help solve the moisture and viscosity problems; suitable solvents include propylene glycol and glycerin. Oil can also be used to a limited degree before becoming an oil partition reaction. As a general rule I would recommend 50–60 percent solids as a good starting point for a basic reaction mixture. As in cooking, the more water, the more boiled or stewed the food; less water, the more it becomes roasted.

pH: pH can have profound effects on the flavor of a Maillard reaction. At a lower pH (less than 4.5), the formation of

T-3. Optimum pH taste ranges for selected meats

bacon	< 4.0
beef	5.4-6.0
chicken	5.0-5.5
lamb	4.0-4.5
pork	4.8-5.3
turkey	5.5-6.0

mercapto-ketones, thiophenethiols, 2-methyl-tetrahydro-thiophenone and 3,5-dimethyl-1,2-dithiolan-4-one are favored (4). This accounts for the tendency of low pH reactions to produce harsh, sulfury, metallic flavor notes in the finished product. Low pH can produce undesirably high furfural and methyl furfural notes in high sugar systems. However, the strong sulfury metallic notes do have their place in poultry-type flavors.

At moderate pH (4.5-5.5), the formation of meaty notes are favored, most notably 2-methyl-3-furanthiol, 2,5-dimethyl-3-furanthiol and their corresponding disulfides, which are important to cooked and roasted meat (5). Disulfide formation decreases to near zero as the reaction approaches pH 5.5; beyond pH 6.5, no disulfides are formed. Higher pH (greater than pH 5.5) tends to favor the formation of nitrogen volatiles such as pyrazines (6). The higher pH, the lower the flavor development and the higher the color development. The pigmentation (high molecular weight products) developed during a Maillard reaction are called melanoidins.

Generally speaking, most amino acids are acidic (arginine and lysine being the exceptions), so most reaction mixtures are typically acidic. Also, during the reaction, the pH becomes even more acidic from the breakdown of the ingredients into acidic substances. Adjustment of the pH toward the alkaline side is commonly accomplished using sodium hydroxide, and less often by sodium carbonate (produces CO_2) or disodium phosphate.

While the starting pH is an important consideration before the reaction, it is also important to the post-reaction flavor. The perception for a given species of meat is also a matter of pH. The table provides some recommended pH values for some species of finished flavors (see T-3).

Generally speaking, lower pH reactions produce rare meat qualities, while higher pH (greater than 5.5) gives an old, mature meat quality. So, while a pH of 5.4 to 6.0 would normally be recommended for beef according to T-1, I would favor using a lower pH (less than 5.0) when making a rare beef flavor.

Processing Techniques

The choice of processing equipment used can direct the outcome of the flavor. There are a number of techniques currently used to make processed flavors; these include exotic processes such as extrusion and microwave, but our discussion will be limited to the three most common.

Open kettle heating: This technique is similar to simmering in an open pot, losing water to make a reduction sauce or gravy; this technique includes frying (high temperature reactions). Open kettle processing has the advantage of equipment simplicity, requiring a mixing kettle with some form of heat source. While this process has the advantage of equipment simplicity, it can be less reproducible than other common processes. Flavor reproducibility is dependent upon the amount of water lost during processing, which in turn is dependent upon such variables as batch size, processing time, humidity and atmospheric pressure, all of which would effect the boiling point and evaporation rate of the flavor. Also, during the processing, water lost in the open kettle process tends to increase the rate of reaction and the boiling point of the mixture. As a consequence of so many uncontrollable and complex variables, batch to batch variation can be high if the flavor is not strictly monitored during processing.

Products made this way are generally pastes, and as such, viscosity can be a problem. Kettles used for this process should have heavy-duty (high torque) mixer motors, as well as scrape surface mixing blades to insure even heat distribution during cooking. Products

T-4. Simple example of open-kettle processing

Ingredient	Wt percent
cysteine HCl H_20	1.0
soybean oil	99.0
Total:	**100.0**

made by this process tend to have a sweeter, brown, caramellic roasted flavor, and may have more fatty notes because of open-air oxidation. In addition, the flavors will generally not have very harsh, metallic, sulfury notes generated from cysteine degradation because those notes are oxidized or lost as volatiles during processing.

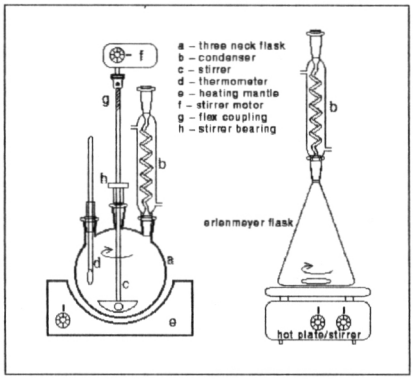
A simple example of open kettle processing (and a non-Maillard process) can be seen in the thermal degradation (frying) of cysteine hydrochloride monohydrate in the fried chicken flavor formulation presented in T-4.

The process: In a beaker, combine the ingredients and heat the mixture on a hot plate to 300° – 310°F for 30 min with good mixing. Allow the mixture to cool. Filter, collecting the oil phase.

Reflux heating: This process is analogous to simmering food in a covered pot, minimizing the loss of water and organoleptically important flavor volatiles. This is similar to the open kettle process, but now with a condenser overhead to prevent water loss. However, a flavor designed using this method has less product variability because of the tighter control over water and volatile loss. Without the water lost during processing (which increases the rate of reaction), as in the open kettle process, processing times for the reflux technique tend to be higher. Like the open kettle process, meat flavors from this process would generally have mild sulfury notes in the finished product; but without the water loss, these flavors would be less likely to generate the same caramellic sweet brown, roasted notes. The maximum reaction temperature achievable in reflux is limited to the boiling point of the mixture, which is dependent upon the composition of the mixture and barometric pressure. Most of the original

work in Maillard processed flavors began with the use of reflux type reactions.

In a laboratory setting, it is common to use a three-neck round bottom flask for development; however, a simple reflux setup can be made using an Erlenmeyer flask, condenser, hot plate and magnetic stir bar. Typically, the process temperature for this type of reaction is the mixture's boiling point (reflux point). The boiling point is used primarily because it is simple to observe and does not require sophistication to control; however, the reaction could be run at lower than the boiling point.



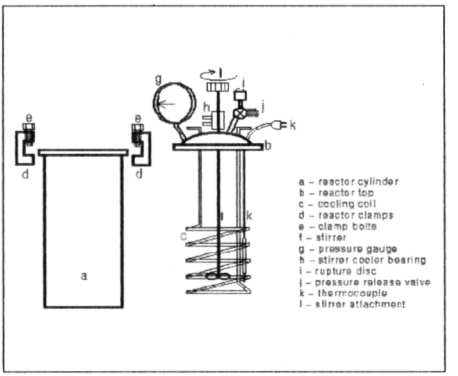
F-4. Two laboratory reflux setups; the left side shows a typical three-neck flask setup, while the right setup shows a simpler setup.

F-4 shows two laboratory reflux setups; the left side shows a typical three-neck flask setup, while the right setup shows a very simple setup. A similar setup to the right side was used to create the example flavor formulations presented later in the chapter.

Closed vessel-retort heating: An important cautionary note: Before venturing into the realm of pressure (retort) reactions, I strongly recommend that the developer be ever mindful of the pressure limits of both laboratory and production equipment.

The retort process is similar to pressure cooking, and will similarly have shorter process times than typical boiling (open kettle or reflux). One of the primary disadvantages to the retort process is the initially high capital cost (even on laboratory scale); vessels must have thick walls and closures to safely handle the high pressures that might develop during processing. Pressure vessels allow the flavorist greater design freedom and control, allowing roast flavors to be developed with less material and less time. By using pressure, the reaction temperature limit is no longer the mixture's boiling point; temperatures above 121°C (250°F) are possible and common. With increased temperature, one may take a reflux reaction formula and decrease the

reaction time. With an increase in pressure, the extent of molecular interaction is increased, which may potentially increase flavor intensity. Products produced by this method will have a tendency to be more consistent than either the open kettle or reflux methods. Since the vessel is sealed, no volatiles are lost during processing; this helps to increase flavor strength, but this can also lead to harsher, more sulfury notes than those seen in either the open-kettle or reflux processes.



F-5. A typical laboratory pressure reactor; the vessel is commonly heated by inserting the reactor cylinder into an electric heating mantle.

A simple technique that can be used in a laboratory setting to study pressure reactions is to use a common household pressure cooker with Ball jars (or media bottles) as the reactor vessel.

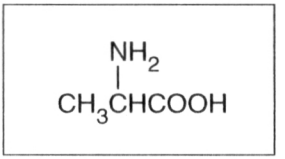
F-5 shows a typical laboratory pressure reactor. The vessel is commonly heated by inserting the reactor cylinder into an electric heating mantle.

Amino Acids and Sugars

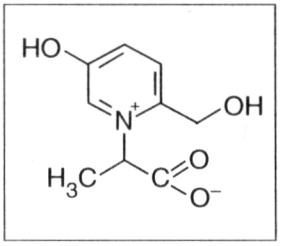
L-Alanine (Ala); $C_3H_7NO_2$; MW: 89.09: This Strecker aldehyde (F-6) is theoretically acetaldehyde. As such, it becomes an important precursor for building low molecular weight Maillard reaction products. Alanine helps smooth out some of the harsh sulfur notes generated by cysteine degradation. Alanine seems to provide weak fruity/ethereal sweetness to flavors.

This may stem from the formation; alapyridaine (N-(1-carboxyethyhl)-6-(hydorxymethyl)pyridinium-3-ol inner salt) is formed from dextrose and alanine. While it is a tasteless compound, alapyridaine does enhance other sweeteners and increases umami notes in meat flavors, especially beef (F-7) (7).

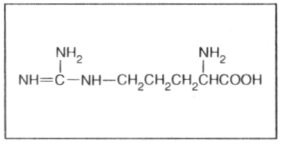
L-Arginine (Arg); $C_6H_{14}N_4O_2$; MW: 174.20: Arginine (F-8) is a



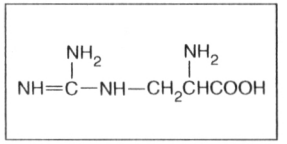
F-6. L-Alanine (Ala)



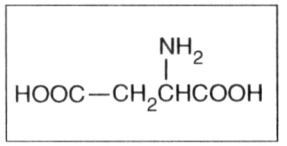
F-7. Alapyridaine enhances other sweeteners and increases umami notes in meat flavors, especially beef.



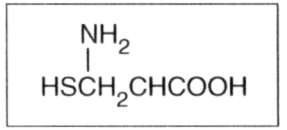
F-8. Arginine



F-9. Asparagine



F-10. Aspartic acid



F-11. A cysteine-free base

very important precursor for beef flavors, probably owing its utility to its structural (guanidine group) similarity to creatine and creatinine (which is found prominently in muscle meat and blood serum). It imparts a meaty, beef stock, brown taste and helps with well-done beef flavors.

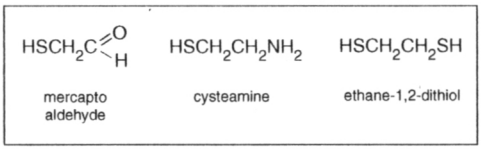
L-Asparagine monohydrate (Asn); $C_4H_8N_2O_3 \bullet H_2$; MW: 150.13: Asparagine (F-9) finds utility as a precursor for pork and beef extract flavors. As an amide, it will release ammonia when treated with alkali or upon pyrolysis. Recently, this amino acid has been implicated as a primary precursor in the formation of the carcinogen acrylamide, so I urge the reader to investigate the most current state of the matter further before considering its use.

L-*Aspartic acid (Asp); $C_4H_7NO_4$; MW: 133.10:* Aspartic acid (F-10) is key to developing well-done brown notes. One of the principle Maillard products produced with dextrose is dimethyl-ethyl pyrazine, which helps provide earthy brown notes for meat, peanut, and baked or fried potato flavors.

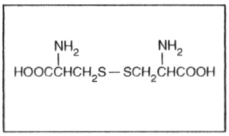
L-Cysteine (Cys); $C_3H_7NO_2S$; MW: 121.15: A cysteine-free base (F-11) is used when the extremely low pH of its hydrochloride salt is undesirable; the salt often requires significant neutralization before and/or after a reaction.

L-Cysteine hydrochloride H_2O; $C_3H_7NOS \bullet HCl \bullet H_2O$; MW: 175.64: Cysteine and its hydrochloride are the cornerstones for almost every Maillard reaction, especially meat- and egg-type flavors

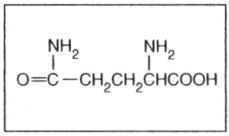
in which they are used at moderate to high levels. (Even at low levels they can support most other reaction flavors.) Cysteine and its hydrochloride are the major precursor sources for the all-important sulfur flavor notes. Decomposition by Strecker degradation or pyrolysis produces six major products (mercatoacetaldehyde, acetaldehyde, H_2S and NH_3, cysteamine, ethane-1,2-dithiol) (F-12) (8). The latter two arise from pyrolysis (roasting conditions [Shigematsu]), as opposed to Strecker degradation.



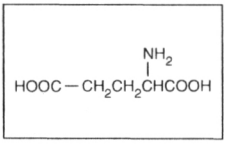
F-12. Decomposition by Strecker degradation or pyrolysis produces six major products (mercatoacetaldehyde, acetaldehyde, H_2S and NH_3, cysteamine, ethane-1,2-dithiol)



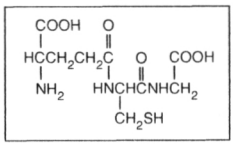
F-13. Thermal degradation of cystine



F-14. L-Glutamine



F-15. L-Glutamic acid



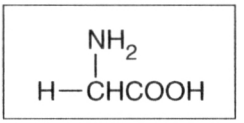
F-16. Glutathione

Coupled with isovaleraldehyde (or leucine) in a reaction, cysteine will produce a Maillard version of the well-known bacon flavor from ammonium sulfide and isovaleraldehyde reaction (2). The harsh sulfury (gunpowder-like) notes of a reaction can be moderated to a meatier (well-bodied) flavor with the addition of decadienal.

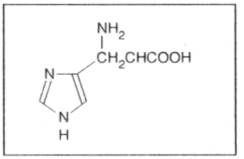
L-Cystine (Cys$_2$); $C_6H_{12}N_2O_4S_2$; MW: 240.30: Thermal degradation of cystine (F-13) produces sharp, crispy, sulfury notes (typically thiazene-type compounds), which makes it useful for fried flavors, especially fried chicken and pork flavors. Depending upon the reaction conditions, this can produce "feathery" notes.

L-Glutamine (Gln); $C_5H_{10}N_2O_3$; MW: 146.15: As an amide, L-glutamine (F-14) is a source of ammonia when treated with alkali. Helps provide burnt, brown, caramelized notes in flavors, and is useful for baked, grain flavors such as bread or malt.

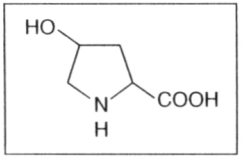
L-Glutamic acid (Glu); $C_5H_9NO_4$; MW: 147.13: This material (F-15) provides a smooth, mild-brown, umami taste upon reaction.



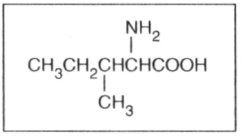
F-17. L-Glycine



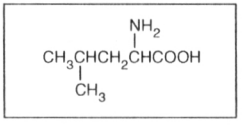
F-18. L-Histidine



F-19.
L-Hydroxyproline



F-20. L-Isoleucine



F-21. L-Leucine

It decomposes rapidly at 121°C. Upon heating, glutamic acid will cyclize to 2-pyrrolidone-5-carboxylic acid (PCA), a proposed precursor for 4-hydroxy-5-methyl-3[2H]-furanone (HMF), itself a precursor for 2-methyl-3-furanthiol.

Glutathione; $C_{10}H_{17}N_3O_6S$; MW: 307.33: Glutathione (F-16) is a tripeptide consisting of glutamic, cysteine and glycine fragments. It is a ready source of sulfur for the Maillard reaction, more so than cysteine; however, its high cost (in natural form) relative to cysteine makes it unattractive for commercial use.

L-Glycine (Gly); $C_2H_5NO_2$; MW: 75.07: L-Glycine (F-17) is the simplest amino acid. The Strecker aldehyde, in theory, is formaldehyde, although it probably does not actually precede it this manner. L-Glycine provides a sweet flavor, with some mild umami effect, which makes it useful for pork flavors.

L-Histidine (His); $C_6H_9N_3O_2$; MW: 155.16: L-Histidine (F-18) provides a brown, bready, baked note to applications. It is useful in pork, beef and baked flavors, but must be used in low quantities (~1 percent) to avoid the formation of bitter notes.

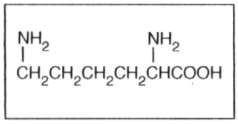
L-Hydroxyproline (Hyp); $C_5H_9NO_3$; MW: 131.13: L-Hydroxyproline (F-19) is useful in developing dry, bakery, brown notes, especially in bread and cracker flavors.

L-Isoleucine (Ile); $C_6H_{13}NO_2$; MW: 131.17: This Strecker aldehyde (F-20) is 2-methyl-butanal, and is useful for chocolate, cocoa, bread and bacon flavors.

L-Leucine (Leu); $C_6H_{13}NO_2$; MW: 131.17: This Strecker aldehyde (F-21) is isovaleraldehyde, very useful for cocoa, chocolate, bacon flavors and baked flavors.

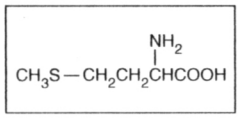
L-Lysine Hydrochloride; $C_6H_{14}N_2O_2 \bullet HCl$; MW: 182.65: Lysine

(F-22) is the most reactive browning amino acid. Provides a deep brown roasted pyrazine or baked quality. Especially useful in grain-based baked flavors such as pretzels, HVP type flavors and nutty flavors.



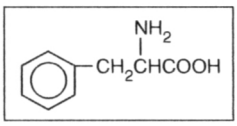
F-22. L-Lysine Hydrochloride

L-Methionine (Met); $C_5H_{11}NO_2S$; MW: 149.21: This Strecker aldehyde (F-23) is methional, a very characteristic potato note. It is useful for vegetable and meat flavors at low levels. Unlike the neat methional, it also provides some mouthfeel by way of its other breakdown products.



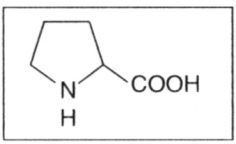
F-23. L-Methionine

L-Phenylalanine (Phe); $C_9H_{11}NO_2$; MW: 165.19: This Strecker aldehyde (F-24) is phenylacetaldehyde, and as such is very useful for making honey and chocolate flavors. It also helps to smooth out some harsh notes in reactions.

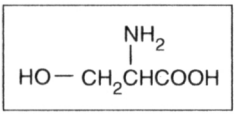


F-24. L-Phenylalanine

L-Proline (Pro); $C_5H_9NO_2$; MW: 115.13: This material (F-25) imparts a sweet brown flavor. This is the classic corn chip precursor given by simple thermal degradation. L-Proline is also key in making furaneol, or maltone, when reacted with rhamnose in propylene glycol (PG). L-Proline is useful in baked flavors because of its sweet brown contribution and rounding out roasted notes, and in malt, chocolate, cracker and bread flavors. Proline reacts with 2-oxopropanal, fructose or yeast extract to produce 2-acetyltetrahydropyridine, a primary odorant in popcorn and secondary important compound in bread crust aroma.

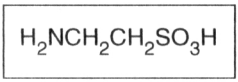


F-25. L-Proline

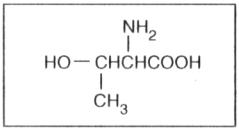


F-26. L-Serine

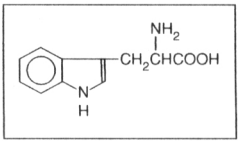
L-Serine (Ser); $C_3H_7NO_3$; MW: 105.09: This Strecker aldehyde (F-26) is theoretically 2-hydroxy-acetaldehyde. Its use level is very low; excessive levels (>1 percent) seem to impart a curious chemical, though not quite bitter, note. Thermal degradation at 120°C yields pyrazine (97.6 percent), methyl pyrazine (6.1 percent) and



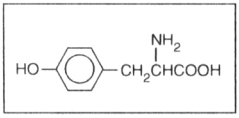
F-27. Taurine



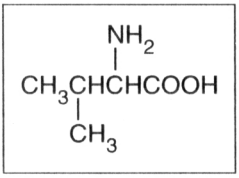
F-28. L-Threonine



F-29. L-Tryptophan



F-30. L-Tyrosine



F-31. L-Valine

ethyl pyrazine (21.3 percent) (9).

Taurine (2-aminoethanesulfonic acid); $C_2H_7NO_3S$; MW: 125.14: Technically, this material (F-27) is not an amino acid. This is a ready source of sulfur and can be invaluable in beef extract flavors.

L-Threonine (Thr); $C_4H_9NO_3$; MW: 119.12: This Strecker aldehyde (F-28) is 2-hydroxy-propanal. In applications it imparts a meaty, umami bottom note and helps round out meat flavors. The material also gives a sweet dark meat character to poultry flavors, and can give a burnt-toasted grain note useful for baked applications. Thermal degradation of threonine produces ethyl-methyl hydroxy furanone and sotolone. Thermal degradation at 120°C yields 2,5-dimethylpyrazine (11.4 percent) and trimethyl pyrazine (10 percent) (9).

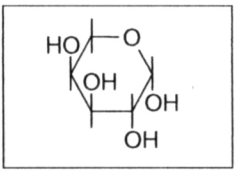
L-Tryptophan (Trp); $C_{11}H_{12}N_2O_2$; MW: 204.22: Reactions with tryptophan (F-29) produce indole-like notes. There is some controversy over the use and sale of tryptophan in the United States. As a result of deaths due to contaminated tryptophan, the US Food and Drug Administration banned the public sale of this amino acid, but its use for specific purposes is still permitted. The reader should review the current laws regarding its permissible use before using this amino acid.

L-Tyrosine (Tyr); $C_9H_{11}NO_3$; MW: 181.19: This theoretical Strecker aldehyde (F-30) is p-hydroxy-phenylacetaldehyde. The material appears useful in supporting vegetable flavors.

L-Valine (Val); $C_5H_{11}NO_2$; MW: 117.15: This Strecker aldehyde (F-31) is isobutyraldehyde. It is very useful for cocoa, chocolate and pork-based flavors. It helps with roasted notes at more extreme reaction temperatures.

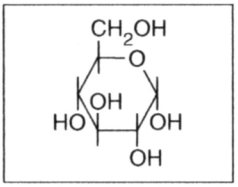
The Role of Sugars in Maillard Reactions

The type of sugar used in a reaction does not drive speciation. It influences the rate of reaction and degree and type (roasted, toasted, burnt, well-done, brown) of cooked notes that are developed.



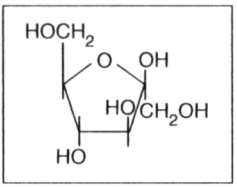
F-32. Arabinose

Relative sugar reactivity (at pH 5.8):
ribose > xylose > arabinose >> fructose > invert sugar >= dextrose > rhamnose >> lactose = maltose > maltodextrin 15 > maltodextrin 10



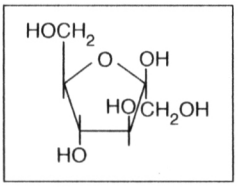
F-33. Dextrose

Arabinose; $C_5H_{10}H_5$; MW: 150.13; mp: 157-160°C: This material (F-32) is useful in providing roast notes to chicken and pork. It is commonly commercially supplied as a 70 percent syrup with the appearance and consistency of molasses, providing better meaty, roasted notes due to sulfur impurities. Slightly less reactive than xylose, about three to four times more reactive than dextrose.



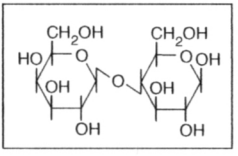
F-34. Fructose

Dextrose (anhydrous α and β forms) (monohydrate α 83°C); $C_6H_{12}O_6$; MW: 180.16; mp: 146-155°C: Dextrose (F-33) is the least expensive, most readily available sugar for the Maillard reaction; it is useful in initiating the reaction and can vary from simple boiled to roasted notes depending on reaction conditions. It is half as sweet as sucrose.



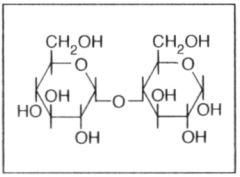
F-35. Inositol

Fructose; $C_6H_{12}O_6$; MW: 180.16; decomposes: 103-105°C: This ketone sugar (F-34) is useful in developing roasted or toasted nutty notes. It is available as crystals or high fructose corn syrup. The material is one and a half times as sweet as sucrose. Fructose can be made from dextrose by treatment with dilute alkali and heat.

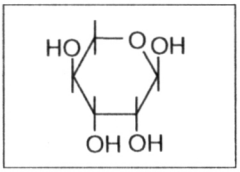


F-36. Lactose

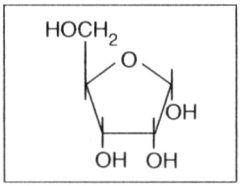
Inositol; $C_6H_{12}O_6$; MW: 180.16; mp: 225-227°C: This is otherwise



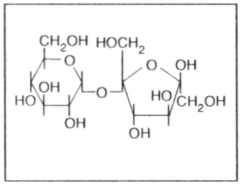
F-37. Maltose



F-38. Rhamnose



F-39. Ribose



F-40. Sucrose

know as "meat sugar," widely distributed in nature (F-35). The material is obtained commercially from corn steep liquor (as phytic acid). Without the carbonyl group present, this material does not participate in Maillard reactions.

Lactose; $C_{12}H_{24}O_{11}$; MW: 342.30; mp: 201-202°C: Also known as milk sugar, this material (F-36) is a reducing disaccharide of dextrose and galactose. It is has α and β forms, and is obtained from whey and cheese production. Lactose is weakly sweet and hydrolyzed to the monosaccharides by acid hydrolysis. It provides more browning and caramelization than roast notes. It is useful in chocolate, baked and beef-type reaction flavors.

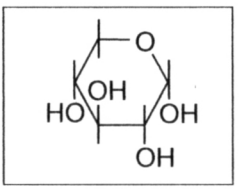
Maltose; $C_{12}H_{24}O_{11}$; MW: 342.30; mp: 102-103°C (monohydrate): Also known as malt sugar, this material (a disaccharide of dextrose) (F-37) is one-third as sweet as sucrose. Some research indicates that this may be the best precursor for maltol production (10).

Rhamnose; $C_6H_{12}O_5$; MW: 164.16; α monohydrate; mp: 82-92°C; β anhydrous; mp: 122-126°C: This (F-38) is very sweet deoxy sugar is the best natural precursor for furaneol production with proline. It provides more of a brown, caramellic or maltone-like flavor, and is very useful for beef flavors.

Ribose; $C_5H_{10}O_5$; MW: 150.13; mp: 87°C: This is the most reactive sugar used in reaction flavors (F-39). The material is very useful in generating both meaty and roasted notes. It is obtained from yeast nucleosides.

Sucrose; $C_{12}H_{22}O_{11}$; MW: 342.30; Dec: 160-186°C; chars and emits characteristic caramel odor: Sucrose (F-40) is hydrolyzed into dextrose and fructose (invert sugar) by dilute acids or invertase.

Xylose; $C_5H_{10}O_5$; MW: 150.13; mp: 144-145°C: This material

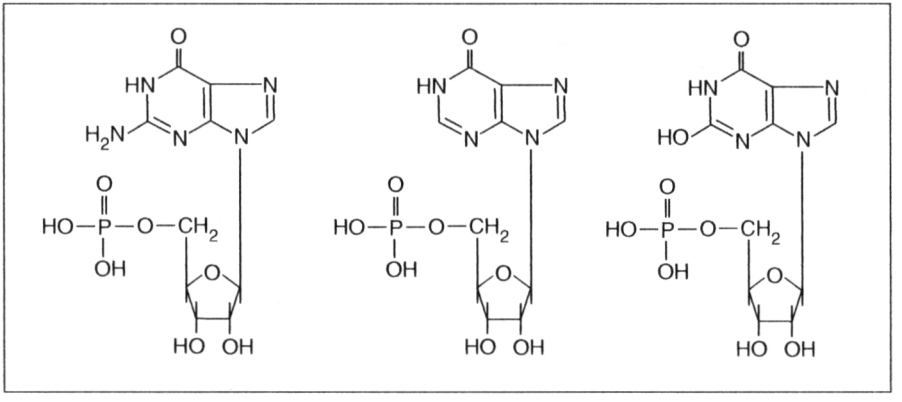


F-41. Xylose

(F-41), also known as wood sugar, is not found free in nature, but rather combined as the polysaccharide xylan and associated with cellulose. It is typically obtained from corn cob hydrolysis. Xylose is the best sugar used for providing well-done or burnt notes to meat flavors, possibly because of its easy production of furfuryl mercaptan (coffee-like) with cysteine. The material is about half as reactive as ribose, and three to four times more reactive than dextrose.

Maltodextrins; $(C_6H_{10}O_5)_n \bullet H_2O$: Maltodextrins are water-soluble hydrolyzed (acid or enzymatic) starches (typically from corn) possessing a dextrose equivalent (DE) less than 20. DEs higher than 20 are considered corn syrups. Pure dextrose is the standard, with an equivalence of 100. In the flavor industry, they are typically used as part of the carrier system or as filler. In the example formulations presented later in this chapter, I treat the maltodextrin 10 as filler, though clearly by definition the maltodextrin has reducing sugar equivalence to 10 percent of pure dextrose.

5'-Nucleotides (11): 5'-Nucleotides (F-42), like MSG, are well known ingredients used to provide umami (mouthfeel) to flavor, but they are also precursors for reaction flavors. 5'-Nucleic acids derived from the enzymatic hydrolysis of RNA or DNA with phospho-diesterase produces 5'-guanosine monophosphate (GMP). Subsequent treatment with deaminase produces 5'-inosine monophosphate



F-42. 5'-Nucleotides

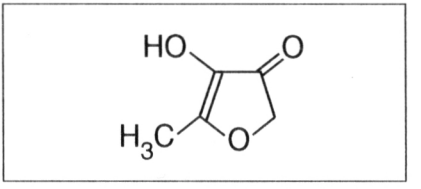
(IMP) from adenosine monophosphate (AMP). GMP and IMP are the most commonly derived nucleotides and are commercially sold as the disodium salts, either individually or in a 50:50 blend. Nucleotides can be typically derived from yeast extracts (yeast being one of the highest sources of RNA). XMP is of no commercial interest as of this writing.

Typical consumption levels for IMP and GMP are 0.005–0.02 percent. When blended together, the mixture is approximately twice the strength of GMP by itself. When blended with MSG, the synergism is even greater; at 10:1 (MSG/[IMP+GMP]) it is ~20 times the strength of MSG by itself, and at 20:1 (MSG/ [IMP+GMP]) ~12 times the strength of MSG alone. GMP is approximately 2.3 to three times the strength of IMP, but less thermally stable. At 100°C after 1 h and normal pH (5-7), 95-plus percent of IMP will survive; GMP 90–95 percent. At 121°C after 1 h, less than 60 percent of either will survive.

5-'Ribotides (especially IMP) break down to ribose 5' phosphate, which are convenient precursors of 4-hydroxy-5-methyl-3[2H] furanone (FEMA# 3635, HMF) for Maillard beef reactions; with cysteine (at <pH 5), HMF will form 2-methyl-3-furanthiol (F-43). IMP is significantly more soluble than GMP.

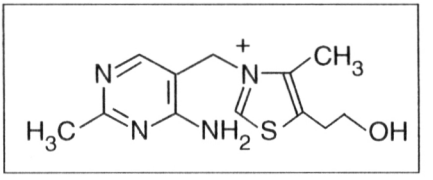
Thiamine

Thiamine hydrochloride is commonly used in flavor reactions. However, as of this writing, no commercial source of natural thiamine is available; thus, its use is limited to artificial and natural & artificial flavors. It provides a sweet, smooth, brothy quality with some mouthfeel.



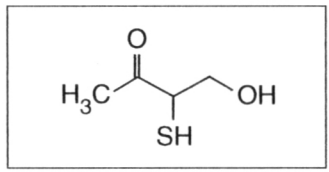
F-43. 5-'Ribotides break down to ribose 5' phosphate, which are convenient precursors of 4-hydroxy-5-methyl-3[2H] furanone for Maillard beef reactions

Thiamine hydrochloride; $C_{12}H_{18}Cl_2N_4OS$ (vitamin B1); MW: 337.28: This material (F-44) occurs in plants and in animal tissue, notably in rice husk, cereal



F-44. Thiamine hydrochloride

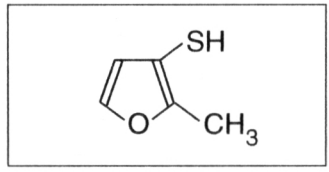
grains, yeast, liver, eggs, milk, green leaves, roots and tubers. Thiamine is relatively heat stable under acidic conditions, but heat labile under neutral or alkaline conditions. In aqueous solution, thiamine can be sterilized at 110°C without loss, but if the pH is above 5.5, it is easily destroyed.



F-45. 5-Hydroxy-3-mercapto pentan-2-one

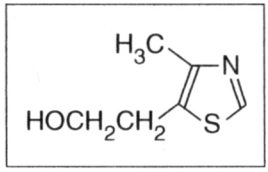
Meaty Compounds from the Thermal Decomposition of Thiamine (9)

5-Hydroxy-3-mercapto pentan-2-one: This material (F-45) is a key intermediate that gives rise to a number of aliphatic sulfur compounds, furans and thiophenes.



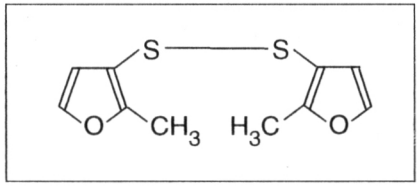
F-46. 2-Methyl-3-furanthiol

2-Methyl-3-furanthiol (FEMA# 3188): This material (F-46) is found in beef, pork, tuna, HVPs, yeasts and, to a lesser degree, chicken. Taste: meaty, brothy, slightly alliaceous, roasted, meaty coffee, HVP-like. Applications: beef broth, roasted meat flavors, shellfish and roasted nut flavors.



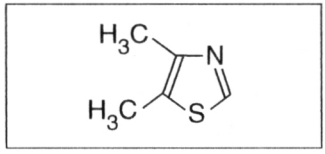
F-47. Sulfurol

Sulfurol; 4-methyl-5-thiazole ethanol (FEMA# 3204): Sulfurol's taste: meaty, vitamin-like.



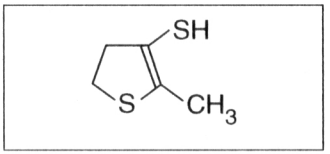
F-48. Bis-(2-methyl-3-furyl)disulfide

Bis-(2-methyl-3-furyl)disulfide (FEMA# 3259): This material (F-48) is found in beef, pork, HVP's, yeasts, and to a lesser degree in chicken. Taste: at 0.1 ppm, strong, meaty brothy, vitamin-like, slight onion note, slightly nutty/fatty, aged prime rib of beef. Aroma similar to sulfurol. Stronger than the monomer, a bit more roasted, but still having a strong meaty quality, normally found in conjunction with the monomer.

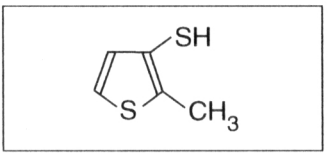


F-49. 4,5-Dimethyl thiazole

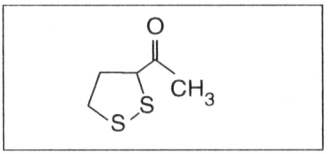
4,5-Dimethyl thiazole (FEMA# 3274): This material's (F-49)



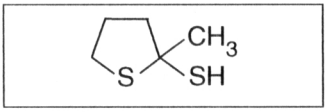
F-50. 2-Methyl-4,5-dihydro-thiophen-3-thiol



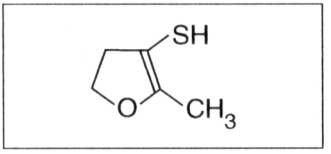
F-51. 2-Methyl-3-thiophene thiol



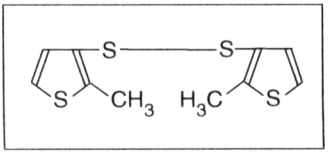
F-52. 3-Acetyl-1,2-dithiolane



F-53. 2-Methyl tetrahydro thiophen-2-thiol



F-54. 2-Methyl-4(5H)-3-furanthiol



F-55. Bis(2-methyl-3-thienyl) disulfide

taste: meaty, roasted, nutty, green, poultry, fishy, amine-like.

2-Methyl-4,5-dihydro-thiophen-3-thiol: This material (F-50) is described as meaty. It is found in HMF and H_2S reactions. It is probably more useful in roast pork flavors than in beef.

2-Methyl-3-thiophene thiol: This material (F-51) is found via a reaction of 4-hydroxy-5-methyl-3(2H)-furanone with hydrogen sulfide, and in cysteine/ribose model systems. It has a roasted, cooked meaty character and possesses an egg-like, fatty, oniony and leek-like aroma. 2-Methyl-3-thiophene thiol possesses a 30-100 ppt (parts per trillion) threshold. Described as roast meat-like, this material is probably more useful in pork flavors than in beef.

3-Acetyl-1,2-dithiolane: This material (F-52) is described as meaty, oniony, shiitake mushroom-like and livery.

2-Methyl tetrahydro thiophen-2-thiol: This material (F-53) is described as meaty, sulfurous, tropical fruity, Buchu and black currant-like.

2-Methyl-4(5H)-3-furanthiol: This material (F-54) is described as roast meaty. It is found in reactions of HMF and H_2S.

Bis(2-methyl-3-thienyl) disulfide: This material (F-55) is described as sulfurous, metallic, rubbery and slightly meaty.

Reaction Flavor Examples

The following simple formulations are provided as examples to illustrate how amino acids and sugars can be used to create a basic flavor. Each example reaction was prepared using a reflux setup similar to the one shown on the right side of F-4.

As stated earlier, the addition of compounded flavors and ingredients such as meat derivatives, HVPs and yeasts will help to improve the quality of the flavor. The chicken flavor example 1B is provided to demonstrate how the inclusion of meat derivations could be accomplished. Also note that the pH of the reaction drops (becomes more acidic) after each reaction. I have also adjusted the pH post reaction in each example to make the flavor more palatable.

The effort in T-5 was to generate a strong, light sulfury character (intrinsic to chicken flavors) with minimal browning and roast development. Water is relatively high in order to lower browning, yet the

T-5. Reaction example formulation 1A; chicken-type flavor

Ingredient	Wt percent	Notes
water	50.00	
cysteine HCl H_2O	2.50	
cystine	0.10	
alanine	2.00	
ascorbic acid	0.10	
glutamic acid	5.00	
methionine	0.10	
lactose H2O	8.70	
salt	10.00	
maltodextrin 10	17.51	starting pH: 2.22
reflux at 104.5° for 2 h		
sodium hydroxide 50 percent	3.99	pH: 1.94 => 5.38
Total:	**100.00**	

Formula notes: dark yellow solution (T-5). Tasted at 0.4 percent with 0.2 percent salt and 0.05 percent
MSG; sulfury, eggy, vaguely white meat-like

content allows thermal breakdown of cysteine. Lactose was chosen because it is a weak reducing sugar, so browning is further reduced. Ascorbic acid is also added to minimize browning. Alanine and glutamic acid are added to aid in the formation of meaty notes. Note how the pH falls from 2.22 to 1.94, which always occurs following a reaction.

For comparison, the inclusion of meat ingredients in the form of chicken broth and chicken fat is demonstrated in the next example (T-6). The formulation is the same as T-5, save the inclusion of the meat ingredients and emulsifiers replacing some of the maltodextrin. Note the difference in pre-reaction starting pH; with the inclusion of chicken broth, the proteins help to buffer the extreme pH of the amino acids as seen in T-5.

T-6. Reaction example formulation 1B; chicken-type flavor

Ingredient	Wt percent	Notes
water	50.00	
cysteine HCl H_2O	2.50	
cystine	0.10	
alanine	2.00	
ascorbic acid	0.10	
glutamic acid	5.00	
methionine	0.10	
lactose H_2O	8.70	
salt	10.00	
maltodextrin 10	4.97	
chicken broth powder 1004 (Ariake)	10.00	
chicken fat (Ariake)	2.50	
xanthan gum	0.20	
Tween 80	0.10	starting pH: 2.90
reflux at 104.5° for 2 h		
sodium hydroxide 50 percent	3.73	pH: 2.59 => 5.24
Total:	**100.00**	

Formulation notes: the finished flavor of T-6 tasted at 0.4 percent with 0.2 percent salt and 0.05 percent MSG, has greater depth, fidelity and mouthfeel than T-5

T-7. Reaction example formulation 2; beef-type flavor

Ingredient	Wt percent	Notes
water	42.34	
cysteine HCl H_2O	2.00	
alanine	2.00	
arginine	2.00	
lysine HCl	1.00	
glutamic acid	5.00	
leucine	0.20	
methionine	0.10	
dextrose monohydrate	3.50	
fructose	3.50	
xylose	0.50	
rhamnose monohydrate	0.50	
salt	10.00	
maltodextrin 10	23.51	
disodium phosphate	0.89	pH: 3.69 => 4.26
Reflux at 105.1° for 2.5 h		
sodium hydroxide 50 percent	2.96	pH: 2.78 => 5.75
Total:	**100.00**	

Formulation notes: dark reddish-brown liquid dry, sulfury, brown, meaty, roast beef-like tasted at 0.4 percent with 0.2 percent salt and 0.05 percent MSG; note the lower amount of cysteine relative to the chicken formulations and the inclusion of arginine and lysine to provide the brown notes found in beef; more reactive sugars dextrose, fructose, rhamnose and xylose are used to improve the browning of the flavor

Microbiological Concerns

When producing a consumable product such as food or flavoring, consumer safety is of paramount importance; one of the principle concerns is the control of microorganisms. Control of microorganisms in food is a tricky balancing act of killing or inhibiting organism growth without adversely altering the host food. For compounded flavors where solvents such as alcohol, PG and oils are used, there is generally no microbiological concern. However, with some savory

T-8. Reaction example formulation 3; pork-type flavor

Ingredient	Wt percent	Notes
water	47.52	
cysteine HCl H_2O	2.34	
cystine	0.08	
alanine	2.00	
arginine	0.66	
glutamic acid	5.00	
leucine	0.06	
lysine HCl	0.32	
methionine	0.10	
ascorbic acid	0.06	
dextrose monohydrate	1.16	
fructose	1.16	
lactose H2O	5.80	
xylose	0.16	
rhamnose monohydrate	0.16	
salt	10.00	
maltodextrin 10	19.80	starting pH: 2.49
reflux at 104.8° for 2 h		
sodium hydroxide 50 percent	3.62	pH: 2.17 => 5.16
Total:	**100.00**	

Formulation notes: orange-brown liquid (T-8); tasted at 0.4 percent with 0.2 percent salt and 0.05 percent MSG; moderately sulfury, light meaty character. This formulation is essentially two-thirds of the chicken flavor (example T-5) and one-third of the beef flavor (T-6)

reaction flavors in which the primary solvent is water and is associated with sugars and proteins, this can be a perfect growth medium. Generally speaking, when a flavor is processed most of the microorganisms are killed or the flavor is outright sterilized. It is during the post-reaction handling of the flavor that recontamination can occur; therefore, care must be taken to minimize microbiological contamination, which can either ruin the product, or worse, cause illness to the consumer.

Controlling Microorganisms

For microorganisms to grow, three factors are required: the right temperature, food and water. By controlling one or more factors one can minimize growth risk.

Water considerations: Water is an absolute necessity for microorganism growth. Water in food can be classified into four categories:

- Type IV: free water is in very high percentages and is generally very fluid
- Type III: loosely bound, the water is typically that which is found within tissue and is generally in the range of 12-25 percent
- Type II: above the monolayer is the moisture that is typically found with dried powders in the range of 3-7 percent
- Type I: tightly bound to the molecular level

No microbial growth occurs in type I and type II water.

Water activity (Aw): Most bacteria require an Aw between 0.9 and 1; some yeasts and mold can grow slowly at Aw as low as 0.65. At 0.7, mold growth is near zero; at ≅ 0.75, yeast growth is near zero; at 0.8, bacteria growth is near zero.

Bacteria:

- Most require Aw (water activity) > 0.91
- Pathogens require Aw > 0.95 (except *S. aureous*)
- Halophiles (salt lovers) can tolerate low Aw (to 0.75)
- Gram-positives tolerate lower Aw more than gram-negatives

Yeasts:

- Can tolerate lower Aw than bacteria
- Osmophilic (pressure hating) yeast grow to Aw 0.61

Molds:

- Can tolerate lower Aw than yeasts

- Likely spoilers of intermediate moisture foods
- Xerophilic molds grow to Aw 0.61

Some general principles related to drying:

- Microbes are more resistant to other stresses in a dry state
- Microbes in foods can survive the drying process
- Contaminants in dried foods can start to grow once rehydrated
- Likely contaminants of dried food are spores of mold and bacteria

Aw:

< 0.9	Most pathogenic bacteria will not grow, except *S. Aureous* requires < 0.86
< 0.75	Halophilic bacteria will not grow
0.7-0.85	semi-moist food (≅ 20 to 50 percent moisture)
< 0.65	mold will not grow (< 20 percent moisture)

Water activity is dependent upon molecular size, hence salt (MW 58.4) is better at lowering Aw than dextrose (172), which is better than sugar (342) on a weight-weight basis. Large molecules such as low DE maltodextrins and hydrocolloids are ineffectual, while high DE corn syrup solids are useful in lowering Aw. Humectants such as PG and glycerine also lower Aw.

BRIX (dissolved solids): Fruits can be preserved by placing them in heavy sugar syrup, while meat can be preserved by placing them in brine solutions. Since microorganisms contain ≅ 80 percent cellular water, immersion in high solute (60–70 percent) solutions causes partial cellular dehydration, which interferes with cellular multiplication. This process is known as plasmolysis and is a result of the osmotic pressure differential across the cell membrane. Yeasts and mold are more resistant to plasmolysis than bacteria.

(Osmotic pressure is a function of the number of molecules or ions in solution; high concentrations of low molecular weight materials exert higher pressure than an equal weight of high molecular weight solutes).

Plasmolysis is commonly employed in the manufacture of yeast extracts. In addition to preservation via plasmolysis, increasing solutes also lowers the Aw.

Sugar solution at 70 percent will stop growth of all microorganisms. Salt solution at 18 to 25 percent will stop growth of all microorganisms.

Temperature Considerations

Heat is the simplest and most common means to control microorganisms (see T-9).

Factors affecting microorganisms' heat resistance:

T-9 Temperature considerations*

°C	°F	Temperature effects
121	250	Steam temp @ 15 psi kills all forms including spores in 15 to 20 min
116	240	Steam temp @ 10 psi kills all forms including spores in 30 to 40 min
110	230	Steam temp @ 6 psi kills all forms including spores in 60 to 80 min
100	212	Kills organisms in vegetative stage quickly, but not spores after long exposure
90	194	Inactivates dry yeast after 1 h of heat treatment
82-93	179-200	Growing cells of bacteria, yeasts and molds are usually killed
66-82	15180	Thermophilic organisms grow
60-77	140-171	Pasteurization of milk in 30 min kills all important pathogenic bacteria
16-38	61-100	Active growing range for most bacteria, yeast and mold
10-16	50-61	Growth retarded for most organisms
4-10	39-50	Optimum growth of psychrophilic organisms
0	32	Freezing; usually the growth of all organisms is stopped

*Note: effectiveness of heat treatment is increased under high acid conditions (< 4.6 pH)

- Some organisms are more heat-resistant than others
- Gram-positive bacteria > gram-negative bacteria
- Bacterial spores > mold spores > vegetative cells
- Bacterial spores will be hardest to eliminate
- Growth phase of cells
- Stationary phase cells are most resistant
- Log phase cells are most sensitive
- Cell numbers matter
- More cells require more heat (longer time or higher temperature)
- Growth temperature
- Thermophiles are most heat-resistant
- Psychrotrophs are least heat-resistant
- Factors that increase microorganism heat resistance
- Low water content
- High fat content
- High protein content
- Neutral pH
- Factors that decrease microorganism heat resistance
- Low solids content
- Acid or alkaline pH

Refrigeration (0-7°C):

- Pyschrotrophs are defined by their ability to grow in the cold
- Many yeast and molds grow at low temperature
- Organisms most likely to spoil refrigerated food are gram-negative bacteria, yeast and mold
- Some pathogenic organisms are known to grow under refrigeration, notably *Listeria monocytogenes*

Freezing controls growth by temperature, but also by removing water through crystallization. Some cells can be damaged by freezing; those damaged will not survive for long, but generally speaking, most organisms survive and will grow out when thawed.

40–140 (°F) (4–60°C) rule: Food may not be stored or held safely within this range for any extended period. Foods should be brought through this range as quickly as possible; USDA specifies within 2 h for meat products.

pH Considerations

At < 4.2 pH, growth of all pathogenic bacteria is arrested; however, yeasts can continue to grow down to pH 2.0. Canned foods with a pH of < 4.6 are considered high acid foods. (C. *Botulinum* will not grow below 4.6; the specification is usually given as 4.0 for the additional margin of safety.)

Generalizations:

Bacteria:

- Prefer pH range around neutrality (pH 5.5–8.5)
- Pathogenic organisms tend to have narrower ranges
- Gram-positive bacteria have a broader range than gram-negatives
- Lactic acid bacteria grow and make acid to pH 3

Yeasts:

- Grow in wider pH range (pH 2–9)

Molds:

- Tolerate the widest pH range (pH 0–11)
- Yeasts and molds are flavored in acid foods
- Bacteria will predominate in neutral foods

Salt Considerations

Microorganisms have a wide range of tolerance to salt concentration; halophilic organisms can grow even up to the saturation point

of salt. Salt concentrations of 9–11 percent will stop most microbes, if the overall solids content is high enough (> 50 percent), and the product is processed and handled with sanitary good manufacturing practices.

Chemical Considerations

Sodium benzoate: Used as a yeast and mold inhibitor in high acid foods (≅ pH 4 and less); 0.04 percent in beverages (in acidic media).

Sorbic acid and salts of: Yeast and mold inhibitor, but has been found to have a broad range of antimicrobial activity; typical Rx: 0.1–0.3 percent. Unlike benzoates, this has a wider usable pH range. Best at < 6.0 pH, ineffectual > 6.5 pH.

Sodium or calcium propionates: Effective in acidic media, up to pH 5; decreased effectiveness at pH 6. Typically used in bread and cheeses. Inhibits molds, but is ineffective against yeast or bacteria. Typical usage 0.1-0.4 (flour wt).

Solvents: In high moisture flavors, ethyl alcohol at 20 percent, not surprisingly, kills and inhibits growth of yeasts, molds and bacteria almost immediately. Propylene glycol at 20 percent, while not as effective as ethyl alcohol in its immediacy, will inhibit ambient growth and, within a week, kill many organisms, including APC, yeast, mold, *Staphylococcus aureous,* salmonella, *Listeria monocytogenes* and *E. coli* O157:H7. PG is slower to kill lactic acid bacteria, taking three weeks to drop three log counts. *Bacillus cereus* is not killed by PG, but neither will it grow out at 20 percent PG. High moisture processed flavors can therefore be made room temperature stable with either a solvent or combination of solvents.

Smoke: Smoke can preserve via three mechanisms:

- Heat: either arresting and/or killing the organisms
- Drying: as a result of heat lowering the Aw
- Chemicals: acid and phenol derivatives act as preservatives

Smoke flavorings do not provide protection use; they contain significant amounts of acids and phenols and are used at sufficient levels.

Creative Considerations and Tips

Secondary physical considerations: The process flavorist must always remember that reaction flavors are dynamic systems. Beyond the critical parameters of time, temperature, moisture and pH, other physical issues need to be considered.

Mixing: Shafts come in many different shapes and sizes. Mixing should be such that the product heats evenly. A high torque, variable speed, scraped surface mixer is the best performer, especially for commercial vessels; such mixers will help minimize burning of the product (especially highly viscous ones) as it is in contact with the hot vessel wall. Other mixers, such as anchor, blade or propeller types, are generally serviceable.

Mixer speed: Should be adequate to maintain even temperature distribution during reaction. Speed also plays an important part in open-kettle reactions; the rate of evaporation of water is directly proportional to the speed of the mixer; increasing speed increases evaporation.

Product viscosity: Viscous solutions may experience poor heat transfer, and therefore uneven temperature distribution in the product. The potential for product burning on the vessel walls increases as product viscosity increases. Increasing mixer speeds in a viscous product is not always the solution; without a scraped surface mixer, the only solution may be to thin out the mixture.

Product mass: Increasing mass (batch size) requires more energy, increases the time it takes to reach the desired reaction temperature. If heating is inadequate to heat the mass to the desired temperature quickly, the increased resonance time experienced at elevated temperatures can cause considerable product variability during scale-up.

Concentrating Flavors

One of the interesting differences between compounding and processing is the ability make a flavor more concentrated. Generally speaking, concentrating a compounded flavor is quite easy—one just proportionally increases the active ingredients. For processed flavors, concentrating is rarely an easy task; increasing the actives is

not a linear effect. Increasing actives can alter such critical factors as moisture content and/or pH. For products that are already low in moisture and high in active ingredients, concentration may not be possible.

Oil and Water

Aqueous-based Maillard reactions, in general, deliver 10 times the impact of oil-soluble reaction flavors. The explanation is simply a matter of solubility; Maillard reaction products are typically polar in nature, and are carried better in polar solvents such as water, propylene glycol or glycerin. However, aqueous Maillard products can have undesirable harsh, burnt or bitter notes; oil-based flavors are generally smoother and less harsh, again owing much to the insoluble nature of the more bitter or undesirable compounds.

Partitioning is one method used to produce oil-soluble flavors. The oil phase is typically added to the aqueous reaction mixture and allowed to mix with the water phase during reaction. Upon cooling the oil phase is drawn off from the product while the aqueous phase is discarded. Clearly there is waste associated with this type of reaction, but it is often unavoidable. A reaction of this type should be carefully optimized to minimize waste.

Another method used to produce oil-soluble flavors is directly reacting the ingredients and thermally degrading them without the presence of water. Typical of this type is the simple degradation of cysteine HCl powder in oil at frying temperatures, developing a fried-chicken-type flavor as outlined previously under the open kettle reaction. Similarly, reaction of leucine and cysteine HCl in oil at lower temperatures (120°C) in a Parr Reactor produces a simple bacon-type flavor. Reaction in a Parr bomb contains much of the flavor volatiles generated, but at frying temperatures may produce objectionable harsh, burnt, sulfury notes. As with the first oil method, there are associated losses, and the oil flavor is usually cleaned up by filtration.

Of the two methods, the latter generally produces stronger flavors, primarily because there is less loss of desirable flavor components due to partitioning in the water phase.

Summary of Some Creative Generalizations

- Sulfur amino acids tend to form meaty notes.
- Methionine tends to form vegetable or stewed notes.
- Proline, hydroxyproline and/or histidine tend to form bread or cracker notes.
- Glutamine generates ammonia under reflux in basic pH.
- Lysine produces the most color.
- Higher reaction temperatures favor pyrazine formation and reduce furan production.
- Maximum pyrazine formation occurs at Aw 0.75–0.84 percent.
- Water-soluble meat extracts contain much of the important reaction precursors.
- Meat speciation is largely due to the lipid source.
- Maillard reactions proceed best under acidic conditions pH 2–7.
- Sensory properties of the finished reaction are greatly influenced by the amino acid precursors rather than the sugar precursors.
- Sugar choice influences the total amount of flavor formed.
- Reaction time affects overall flavor balance, producing more or less of given components, but longer time does not compensate for temperature below the activation energy for a given compound.
- Ribose increases well-done beef character.
- Diacetyl and valine increase roast (nutty, pyrazine formation).
- Beef pH on the alkaline side will take on a more well-done character.
- Arginine base provides a well-done character to meat flavors.
- Lysine will increase color and provide a well done character, in higher concentrations will give a baked (rather than roast) note.
- Fructose gives a nutty, pyrazine-type note.
- Histidine will give a cornbread, popcorn note.
- Juiciness or succulence of a meat product can be supplied by increasing umami either with MSG, HVP or AYEs; malic acid will also improve the

juicy front notes (0.05 percent as consumed); use of methyl furanthiol and its derivatives will also increase juiciness.

- Decadienal added to cysteine based reactions will moderate the harsh, sulfury notes and improve mouthfeel and body.
- Lecithin in a reaction adds fatty, crisp, burnt skin notes.

Some Closing Thoughts

As new natural chemicals become available, the technique of compounding meat flavors will continue its resurgence. However, I do not see process flavors disappearing from the scene anytime soon. The study of Maillard reaction chemistry will continue as a fertile ground for research and doctoral theses, but I'm sure that the artistic approach to creative process flavors will not be replaced by pure science. After all, improvements in analytical techniques (GC/MS used to study volatile flavorings in natural products, for example) have not replaced the flavorist, but rather have served to improve our understanding of our art. Ever-changing consumer trends continue to challenge us; the combination of artistry, innovation and new technology is the answer to fulfilling our customers' needs, and ultimately, the consumers' demands for flavorful, healthy foods, convenience and instant gratification.

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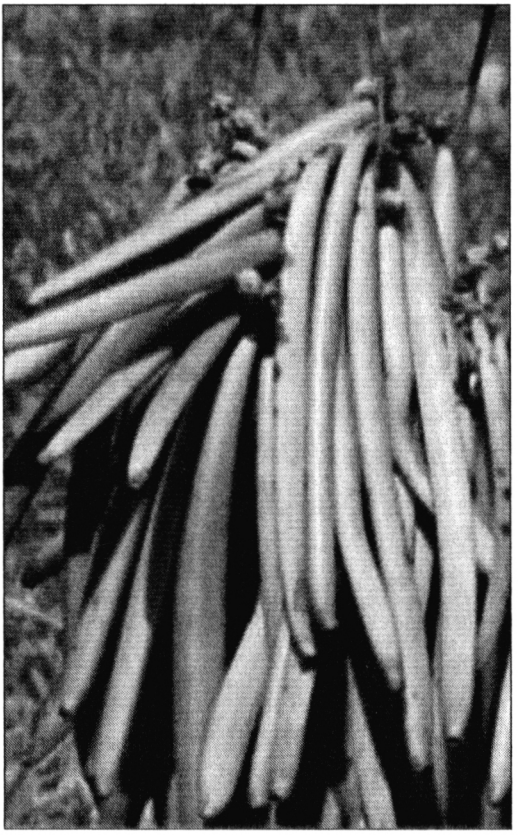
Vanilla: Fruit of the Orchid

Michael Fasano

Before we begin, it is necessary to dispel the myth of "plain vanilla." A recent Internet search for "vanilla" resulted in over two million results. Non-food results included a programming language called Vanilla, a long distance telephone company named Vanilla Inc., the film "Vanilla Sky," and the psychedelic rock group Vanilla Fudge. None, I would say, could be considered "plain." All too often we hear of "simple" or "boring" things referred to as "plain vanilla." Yet vanilla is used in many products specifically because of its *complexity*. The material is found in frozen desserts, baked goods, candies, beverages and many savory recipes. (Vanilla has also become more and more popular in fragrance in recent years. In a novel move, according to an October 6, 1994 article in the Chicago Tribune, the French have begun adding vanilla to their gasoline.)

A Complex History

Little is known about vanilla prior to the Spanish conquest of the Aztecs around 1520. At that time, Cortez was given a drink from Montezuma called *chocolatl*. This beverage consisted of cocoa beans, honey and the dried pod from the vanilla plant called *tlilxochitl*, or black pod. Even then it was known that the flavor of vanilla was developed during a long, slow drying process; the freshly picked beans had no flavor. Shortly after disclosing the recipe of this beverage, Montezuma was executed by Cortez. (Was this the beginning

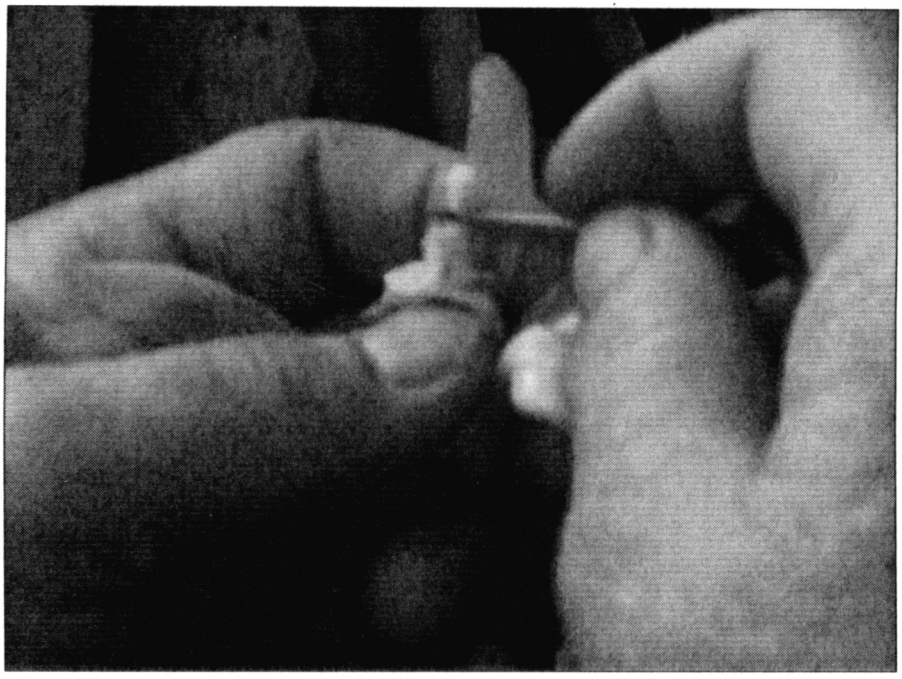


Even in the days of Cortez, it was known that the flavor of vanilla was developed during a long, slow drying process; the freshly picked beans had no flavor.

of non-disclosure agreements between clients and vendors?)

Upon his return to Spain, Cortez brought vanilla back with him. In 1602, vanilla was introduced to the court of Queen Elizabeth by her pharmacist. Sometime during the 1700s, cuttings were taken to France and the Netherlands. While the plants did grow, they would not bear fruit. In 1789, Thomas Jefferson brought vanilla back from France to the United States; this completed vanilla's meandering journey of nearly three centuries from the central Gulf coast of Mexico to its northern neighbor. Between 1819 and 1822, cuttings were taken to Reunion Island, also called the Isle de Bourbon after the Bourbon kings of France. Again, they grew and flowered but would not bear fruit.

The reason vanilla would not bear fruit outside of its native Mexico was discovered about 15 years after introduction to Isle de Bourbon. A Belgian botanist, Charles Morren, was doing research in Mexico. He discovered that a tiny insect, the melipone bee, was responsible for the pollination of the vanilla flower. Indigenous to Mexico, this bee was not found anywhere else the vanilla plants had been taken. Apparently, no insect indigenous to these new places



The vanilla plant does not lend itself to self-pollination. There is a membrane between the pistil and stamen that acts as a barrier, preventing the natural crossover of pollen, thus preventing pollination.

was capable of performing this function. Morren also discovered that the plant did not lend itself to self-pollination. There is a membrane between the pistil and stamen that acts as a barrier, preventing the natural crossover of pollen, thus preventing pollination.

Around this same time, a slave on Reunion Island, Edmond Albius, was given credit for discovering a method of artificial pollination. Using a small stick, Albius physically removed pollen from the pistil and deposited it on the stamen, allowing the vanilla flower to bear fruit.

In the early 1900s, Reunion exported the technique to surrounding islands, including Madagascar. Starting in 1930, production began to exceed demand. At that time, the growing islands of the area formed a pricing cartel. Beyond these islands off Africa's southeast coast, Indonesia is the next prime growing region. Combined, these two regions produce well over 90 percent of the world's vanilla

crop. Other areas where vanilla is cultivated include Uganda, India, Tahiti, Papua New Guinea, Mexico, China, Costa Rica and Tonga.

Growing

The vanilla plant is a vine that is planted alongside a tree that acts as a support. This tree should have a wide canopy as the vanilla vine does not like direct sunlight. The vine, as it grows, is pruned to keep it from getting too wild, allowing the vine to strengthen.

Vanilla grows in a tropical environment, generally within 20° north and south of the equator where the temperature averages between 75°F and 85°F year-round. The plants require high humidity, little wind and good humus-rich soil and adequate drainage. It is said that the vanilla plant does not mind having its feet damp, but it does not like to be standing in a puddle. Ideally, there should be rains between September and October followed by a dry November to stimulate the first flowering. There should be little rain from mid-December to mid-January, followed by a couple of weeks of hot and dry weather to stimulate the second flowering.



Curing begins with the immersion of green vanilla beans in hot water, referred to as the "kill."



It is interesting to note the incredible labor intensity of the vanilla process. From the pollination through picking, curing and sorting, there is no machinery involved.

Harvest and Cure

Vanilla is the only orchid that actually bears fruit. There are over 100 species of vanilla, but only two are used for the manufacture of vanilla extract: *Vanilla planifolia* Andrews, the predominant species for this purpose by far, and *Vanilla tahitensis* Moore, grown primarily in Tahiti. The use of these species for extract production in the United States is codified by statute in the Code of Federal Regulations. No other species may be used for this purpose.

After a vine is planted, it takes about three years for it to be strong enough to bear and support fruit. The productive life of a vanilla vine is from seven to 15 years. The plant blossoms in December and is hand-pollinated as described earlier. This blossom is only open for one day and must be pollinated at that time. However, care must be taken. If too many blossoms are pollinated on any one vine, that vine might not be able to support and nurture all the beans and could die.

After pollination, it takes approximately six weeks for the plant to bear fruit. The fruit is allowed to mature on the vine anywhere from

six to nine months before harvest. Harvest takes place when the tip of the bean turns yellow and splits. Since there are 10-20 beans in one flower, they are not to be picked at once but rather as the tip of each individual bean yellows. The green, uncured beans are 18-20 cm long (7-8 in), are greater than 90 percent moisture and are virtually flavorless.

Curing: Curing begins with the immersion of green beans in hot water, referred to as the "kill." This first step varies by curing station; some might "dip" beans in boiling water or hold the beans for about 3 min at 160°F, while others operate somewhere in between. Regardless of the specific technique, the goal is the same: to stop the ripening process, kill off surface microbes and activate the enzymes that ultimately produce the flavor of vanilla that we know.

The curing process continues by placing the beans on a cloth during the day. At night the beans are wrapped and placed in "sweat boxes." This procedure goes on for only a few days, after which the beans are laid out in the sun during the day and placed on racks at night. This step is repeated for six to eight weeks. During this time the beans are manipulated by hand to facilitate even drying. Beans are then stored on racks for further curing, also called conditioning.

The next step is to sort the beans. Beans are sorted by length, how dry or oily they feel to the touch, whether or not they have split, and by color (some beans are black, some brown and still others have a reddish cast). The beans are then bundled and prepared for shipment. This step takes place about one year after initially flowering.

It is interesting to note the incredible labor intensity of the process. From the pollination through picking, curing and sorting, there is no machinery involved. Everything is done by hand. This labor force is not unskilled: laborers must know how to pollinate, when to pollinate, how many flowers to pollinate, when to pick, how and when to manipulate for moisture distribution, and what to look for when sorting.

The desirable flavor of vanilla develops during its lengthy curing process. The primary component is vanillin, derived from glucovanillin via an enzymatic pathway. Vanillin levels can range between

1 and 3 percent in Bourbon (Madagascar) beans, though a more typical range is a much tighter 1.7–2 percent. (Vanilla's flavor profile is comprised of 250 other volatile constituents, totaling more than 98 percent of the identified components.) The vanillin content is much lower in Indonesian and Tahitian beans.

Standard of Identity

Vanilla extract has a standard of identity in the Code of Federal Regulations 21CFR 169.175. It is the only flavor with such a standard, which technically makes it a food. The standard defines vanilla extract as the solution of sapid and odorous principles extractable from vanilla beans in aqueous ethyl alcohol. The alcohol content must be a minimum of 35 percent by volume, and each gallon of single fold extract must contain the extractives of one unit of vanilla beans. One unit is defined as 13.35 oz of the properly cured and dried fruit pods of *Vanilla planifolia* Andrews or *Vanilla tahitensis* Moore that contain a maximum of 25 percent moisture. So long as the vanilla beans contain 25 percent moisture or lower, one unit equals 13.35 oz. Should the moisture be greater than 25 percent, the weight of a unit is adjusted accordingly. For example, if the moisture is 33.25 percent, one unit would consist of 15 oz of properly cured and dried pods. One unit of vanilla constituent per gallon of extract is one fold of vanilla extract. Single-fold vanilla extract is typically the product found in the grocery store for home use. Multiple folds would simply be multiples of 13.35. (A two-fold would be the extractives of 26.7 oz, or two units, of vanilla constituent.) Vanilla flavoring is also defined in 21CFR 169.177. This product conforms to the definition and standard of identity for vanilla extract except that the alcohol content is less than 35 percent by volume.

Methods of Analysis — Detection of Adulteration

Several methods have been developed in an attempt to determine the authenticity of vanilla extract.

- **Wichmann lead number (AOAC 17th Edition Method 36.2.11):** This test is designed to measure certain organic acids present in vanilla extract. In this

process, neutral lead acetate is added to vanilla to form insoluble lead salts which are then filtered out. The excess reagent is determined by chelometric titration using disodium EDTA. From this titration, and that of a blank reference, the Wichmann lead number is calculated. Extract of vanilla from the various growing regions has different quantities of organic acids. As a natural product, the amounts will vary from year to year. In addition, different parameters of extraction (time, temperature, pressure, etc.) could result in varying quantities of these acids. All of the above make establishing a lead number value indicative of a single-fold extract very difficult. The range of lead number values can be from a low of 0.75 up to 1.1 for a single-fold vanilla extract. Further complications arise because many other products will produce a lead number. The most common adulterant for this purpose is prune juice.

- There are two official AOAC methods for determining vanilla content.
  - First: ultraviolet screening method 36.2.07. The absorbance of ultraviolet light at 348 nm of solutions of vanillin are plotted to obtain a standard concentrational curve. The absorbance of the sample is compared to this curve and the vanillin content read. As other components in vanilla also absorb at this wavelength, the amount of vanillin reported would be slightly high.
  - Second: HPLC method 36.2.05. In this process, vanillin and flavor compounds are separated by high performance liquid chromatography and detected at a wavelength of 254 nm. The absorbance is compared to that of a previously run standard to determine the amount in the extract. This method is also used to determine the quantities of vanillic acid, p-hydroxy benzaldehyde and p-hydroxy benzoic acid. The ratios of these last three components to vanillin and each other can be used to identify geographic origin. This method is also used to determine quantities of select materials used in many artificial vanilla flavors. Unfortunately, neither of these tests can differentiate between the natural components in pure vanilla extract and their synthetic counterparts.

Since the addition of vanillin is the most common method of adulteration of vanilla extract, authentication tests have been developed that focus on ways to identify the source of that component:

- **Stable isotope ratio analysis (SIRA):** The ratio of 13C/12C varies in vanillin depending on its source; ratios are quite specific to each source. Using isotope ratio mass spectrometry (IRMS), the 13C/12C ratio can be determined, and with that the source of the vanillin, whether the source is vanilla beans, clove or a synthetic pathway. The result of this test is only an average. Therefore, isotopically enriched vanillin can be mixed with synthetic vanillin; the results of the test can give the appearance of vanillin from vanilla.
- **Site-specific natural isotope fraction — nuclear magnetic resonance (SNIF-NMR):** This is the latest analytical tool for detection of adulteration. Deuterium is not randomly distributed in natural vanillin. This method was developed to measure the hydrogen/deuterium ratios on all the carbons of the molecule and allows those measurements to be compared to those obtained from vanillin known to be naturally derived. To date, no technique has been developed that can "fool" this procedure into mistaking vanillin not from vanilla for the real thing.

Extraction

Most extractors of vanilla use a variation of a time-honored theme. Hydroalcoholic maceration (soaking) and percolation (solvent circulation) are the most generally employed techniques. Processing parameters vary according to the extractor based on the flavor profile "signature" the extractor is attempting to achieve. The most common parameters varied are: strength of extract (usually between one- and four-fold), time, temperature and pressure.

Multiple washes of beans with fresh solvent are occasionally employed as a way to extract more flavor. Care must be taken in doing this, as it is possible to "over-extract" vanilla by extracting undesirable vegetative and fatty nuances.

Vanilla is extracted by other methods such as supercritical CO_2. This particular technique produces a product that has a higher vanillin content, more oil miscible material, but is not considered a vanilla extract or vanilla flavor as it relates to the Code of Federal Regulation and its vanilla standards.

Natural vanilla is available in other forms as well. These forms include the supercritical CO_2 product mentioned above, oleoresins, absolutes and resinoids. Again, these extraction techniques do not

meet the standard of identity for vanilla extract or vanilla flavor. Use of these different forms in flavor creation will be discussed in brief later.

Flavor of Vanilla

As noted earlier, over 250 volatile flavor components have been identified in vanilla extract, making it anything but plain. Vanilla from different growing regions has variable and recognizable flavor profiles because of growing conditions, curing techniques and, in the case of Tahitian beans, a different species.

The flavor attributes most associated with the different beans are:

- Bourbon: creamy, pruney, beany, caramellic, balsamic
- Indonesian: woody, phenolic, medicinal, smoky
- Mexican: spicy, musky, phenolic, caramellic, creamy
- Tahitian: sweet, anisic, floral, fruity

Using Vanilla

Vanilla all too often is considered only for its characterizing flavor in many food products. But vanilla has a wealth of uses as an ingredient in many other flavors. It can "marry" a flavor, smoothing and rounding out flavor peaks and valleys. It can modify the bitterness of proteins and peptides in savory flavors, in addition to the bitter notes in coffee and chocolate flavors. Vanilla can enhance the flavor of many spices while toning down the heat and bite. It will add creaminess and depth to dairy flavors, enhance and sweeten fruit and brown flavors, and mellow harsh alcohol notes in flavors for alcoholic beverages. Vanilla can also help mask the off notes of artificial sweeteners and overcome the beany notes of many soy products.

Some of the more common uses for vanilla extracts in flavors include:

- One- to four-fold
    - Background in fruit flavors
    - Add creaminess and depth to dairy flavors

    - Enhance sweetness in brown flavors
- Five- to 10-fold
    - Background and modifier—and for sweetness—in cola flavors
    - Mellow harsh alcoholic notes in cordials
- 20-Fold and oleoresins
    - Smooth and enhance chocolate

Oleoresins and critical CO_2 extracts tend to be more oil miscible than hydro-alcoholic extracts. Therefore, they are of value in applications in which water is not desired. Oleoresins and critical CO_2 extracts are also significantly more concentrated than standard extracts, allowing more room in formulations for other ingredients, or for when a flavor needs to be stronger than an extract would allow.

Vanilla absolute is also a very useful tool. This product generally contains between 25 percent and 30 percent vanillin and is more true to vanilla in flavor than straight vanillin. The product is generally used when the need for natural vanillin is high but something more than a simple vanillin note is needed to impart a fuller vanilla profile.

Use of Artificial Components (or Their Natural Counterparts)

With the number of volatile flavor components representing myriad chemical classes contributing to the total flavor profile of vanilla, there is still the occasional need to fortify vanilla extract for a particular end application.

Of course, decreasing the amount of pure vanilla will lead to a decrease of the full, rounded vanilla profile, but that is a necessary evil in some circumstances. Questions of overall flavor strength, solubility concerns and economic considerations are some of the issues that must be reconciled when adding additional flavor materials to vanilla extract. Care must be taken when doing this because the addition of these components means the flavor no longer meets the standards for vanilla extract or vanilla flavor. This might have ramifications on the labeling of the customer's end product.

There are many components that will add back some of the missing nuances of vanilla extract. Looking at some of the most common:

- ***Vanillin***: the component most abundant in vanilla
- ***Ethyl vanillin***: generally considered 2.5 to three times the strength of vanillin, this material (p-hydroxy, m-ethoxy benzaldehyde) has not as yet been found in nature.
- ***Heliotropine***: generally considered twice as strong as vanillin
- ***Propenyl guaethol, or vanitrope***: considered to be 15–20 times as strong as vanillin; not found in nature
- ***Anisaldehyde***: referred to in some monographs as the "classic powdery" note

One ounce of vanillin is generally considered to be equivalent to one gallon of vanilla extract. However, one need only to compare vanillin side by side against pure vanilla extract to see how one dimensional vanillin is against the full bodied, well-balanced flavor of vanilla. The same can be said for any of the other components, whether examined alone or in combination.

Of course, many other materials can be used depending on the final flavor profile desired. These can include lactones for creaminess and milky character, maltol and furanones for brown notes, and guaiacol and other phenols for phenolic and smokey nuances characteristic of Indonesian vanilla. Certain solid extracts can also be employed to add back some of the depth and "natural" qualities of vanilla. But none can capture the total profile of pure vanilla extract.

A New Millennium — and a Crisis

In the first few years of the 21st century, the price of vanilla skyrocketed. What were the causes of this phenomenon? In April of 2000, Cyclone Hudah struck the major vanilla growing region of Madagascar. The eye of the storm had winds exceeding 300 km/h, roughly 250 mph. In comparison, Hurricane Andrew hit Florida

in 1992 with winds "only" in the 130-140 mph range; the destruction was enormous. In the wake of Hudah, damage to vanilla was extensive. Warehouses holding inventory from prior years' crops were damaged; 25-30 percent of the inventory was affected. Damage to vines (producing the 2000 crop), which was due to be picked the following month and cured that summer, was estimated to be 25-30 percent. It is important to note that these vines were the root stock for subsequent years' crops, so the effect of the storm will be felt for years to come. Prices moved immediately.

The next few years saw average crops of fair quality. Prices of beans from all regions were rising, and end users of vanilla began to look for cost-reduced alternatives.

Then it got worse.

Earlier, we described the climate conditions necessary for flowering. In Madagascar in late 2002, things did not happen as they should. Rather than having a hot and dry period to stimulate flowering, the weather was cool and damp, retarding flowering. No flowers, no pollination, no vanilla beans. The 2003 crop—the crop received by extractors in late 2003/early 2004 for extraction and sale in 2004—was only 400 t versus a normal total of 1200 t. Other vanilla-producing regions could not adequately meet the world demand, so prices tripled. Indonesia and the other growing regions followed suit on the price increases simply because they could.

The Crisis Eases

Late 2003 and early 2004 saw a return to normalcy. The replantings from the devastation of Cyclone Hudah were now mature and able to produce fruit. The weather cooperated, allowing full flowering to occur. The crop returned to a more normal size. However, after so many years of instability, quality concerns and high costs, many users of vanilla extract had indeed switched to alternatives where possible and prudent. Due to these cutbacks in usage, the coming vanilla supply is expected to be twice the demand, forcing prices down. As of this writing, we have yet to see the full impact of this convergence of events.

Vanilla — Cures What Ails You

Throughout all of this, vanilla has remained a "feel-good" flavor. Because it is recognizable and associated with so many products in which one might indulge to feel better, it conjures up the proverbial "warm fuzzy" feelings.

During the 16th and 17th centuries, vanilla was considered an aphrodisiac. It was forbidden to young people of passionate and easily aroused temperaments. Clergy were frequently barred from eating chocolate because of the vanilla it contained.

An Aztec version of home remedies called the "Baldianus Manuscript," which appeared in the 1950s, tells how vanilla would "bestow the bodily strength of a gladiator, drive weariness away, drive out fear and fortify the human heart." Vanilla was also deemed effective in cases of dyspepsia, melancholia, hypochondria and anemia in women.

Also, according to a 1991 news release, Sloan Kettering found that its MRI patients, when exposed to vanilla-like fragrance, had lowered blood pressure.

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Mint Flavors Technology

Carl Holmgren

Mints have been prized since ancient times for their clean, refreshing aromas, flavors and therapeutic properties. The name comes from Greek mythology. The nymph Mintho was turned into the herb by Persephone for lusting after the latter's husband, Hades, ruler of the underworld. The plants are believed to have originated in the Mediterranean region.

Mint Oils

Any discussion of mint flavors must begin with the essential oils, since they are the core ingredients. I will give a very basic outline of the industry, but the reader should look elsewhere for a more detailed description. The *Mentha* varieties of importance are *arvensis* (cornmint), *piperita* (peppermint), *spicata* (native spearmint) and *cardiaca* (Scotch spearmint).

Mentha arvensis is cultivated predominantly in Asia, mostly as a source of l-menthol (the variety may contain levels as high as 80 percent). India and China are the major sources. The oil is chilled to precipitate the menthol crystals, which are subsequently washed to remove any residual oil. The dementholized oil (DMO, or cornmint) byproduct is also used commercially in flavors and fragrances. The oil has a peppermint-like character, but is thought to be inferior to *M. piperita* because it tends to be harsher, less creamy/sweet and has a citrusy orange note. Despite these differences, *M. arvensis* contains menthol (~35 percent), menthone/isomenthone (~35 percent), menthyl acetate (~3.8 percent), terpenes (primarily l-limonene [~5.7 percent]), menthofuran (~0.1 percent) and almost 200 other com-

ponents. The usage percentages given in this chapter may vary to a great extent in the oils. *Mentha arvensis* tends to be used at lower levels in US mint flavors than elsewhere.

Mentha piperita oil is produced mostly in the United States, with India and China as the other major players. It is the major US crop grown solely for its essential oil. The composition, cost and flavor of these native oils vary considerably by growing area, agricultural practices, and yield per acre. The major components of the oil are menthol isomers (~45 percent), menthone isomers (~21 percent), menthyl acetate isomers (~4 percent), 1,8-cineole (~7.5 percent), menthofuran (~3 percent), terpenes including l-limonene (~9 percent) and about 220 others. Menthofuran, which has a gasoline-like aroma, is undesirable at higher levels, but adds body to the oil at lower ones and will react over time to form its lactone, which adds a rich creamy note not found in *M. arvensis*. This material occurs at a higher level in the flower than in the leaf oil, so the crop should be harvested before there is too much bloom.

The major producers of spearmint oils are the United States, China and India. L-Carvone makes up about 70 percent of spearmint oils. L-Limonene content is about 9-15 percent. A number of carvone derivatives and sesquiterpenes contribute to both oil varieties' aromas. Scotch spearmint has been reported to be higher in limonene, 3-octanol and menthone, but lower in dihydrocarvone, *trans*-sabinene hydrate, dihydrocarvyl acetate and *cis*-carvyl acetate than the native variety oil. Spearmint plants are harvested and steam distilled locally to obtain these oils.

Mint plants are harvested and steam distilled in the area to yield the crude essential oil, which usually has a sulfurous still note. Most of these oils are purchased by a broker network, each of which removes any residual water, blends and further rectifies the oils (usually via vacuum fractional distillation or steam distillation) into finished products according to customer specifications. These specifications determine the organoleptic characters, FCC, USP, volatile component ranges, physical properties and other standards for the individual oil. A specific percentage of the terpene ("heads") (2-5 percent) or sesquiterpene ("tails") (1-3 percent) fractions may

be removed, resulting in varying degrees of terpeneless and sesquiterpeneless oils. The variation of the process parameters of the rectifications determines the oil's organoleptic profile. The menthofuran content may also be adjusted. It should be noted that the European Union has upper limits on the amount of menthofuran and pulegone allowed in finished products; their levels in the natural oils must be taken into account when creating mint flavors for Europe.

Many consumers, particularly in the United States, consider wintergreen to be a mint flavor. These oil and sweet birch (northern and southern) flavors, which are composed almost entirely of methyl salicylate, suffer from poor availability and questionable authenticity. Therefore, they are only used in natural and WONF flavors. Methyl salicylate is used in most artificial flavors; it blends very well with mints, particularly peppermint, and has the added benefit of being extremely cost effective and readily available.

Coolants

The cooling, refreshing sensation of l-menthol is highly desirable in mint flavors for chewing gum, oral care, confectionery, pharmaceutical and tobacco flavors. The other structural isomers do not possess this quality. Its reasonable cost and ready availability in natural and synthetic versions make it a mainstay in creating mint flavors. However, it also has an olfactory note, in addition to its cooling character, which limits the amount of cooling it can impart to a finished product before it develops a bite/burn, or medicinal/bitter character. Sometime around the 1960s, Wilkinson Sword Co., working on cooling shave creams, developed a number of menthol derivatives that delivered cooling without the off-notes of menthol. Two of these, WS-3 (FEMA# 3455) and WS-23 (FEMA# 3804), are FEMA GRAS and are frequently used to boost the cooling sensations of mint flavors to much higher levels than can be achieved by menthol alone. Since then, H&R/Symrise, Takasago, IFF and Mane Fils have developed and continue to seek new "super coolants." Some of these are:

- l-iso-pulegol (FEMA# 2962, Takasago Coolant P)
- p-menthane-3,8-diol (FEMA# 4053, Takasago Coolant 38D)
- monomenthyl succinate (FEMA# 3810)
- monomenthyl glutarate (FEMA# 4006)
- 3-l-menthoxypropanediol (FEMA# 3784, Cooling Agent 10)
- 3-(l-menthoxy)-2-methylpropane-1,2-diol (FEMA# 3849)
- H&R/Symrise Frecolats — menthol glycol carbonate (FEMA# 3805), menthol propylene glycol carbonate (FEMA# 3806), menthyl lactate (FEMA# 3748), menthone glycerol ketal (FEMA# 3808)

There are a number of patents pertaining to these materials and mixtures thereof, so the reader is directed to perform a patent search before using them in commercial products. To date, I believe that all of these materials are menthol derivatives.

Chewing Gum and Confections

Chewing gums use the greatest volume of mint flavors due in part to the fact that they require a very high level of solvent-free or oil-soluble flavor to achieve a consumer-acceptable organoleptic profile (T-1 through T-3). A stick gum basically consists of a gum base, sweeteners and flavor oil. In a dragee, the gum is formed into a pellet instead of a stick and then covered with a candy coating. Gum bases are highly proprietary formulations of polymers that tend to bind with flavor components, thus preventing them from being fully perceived during chewing. Additionally, the quicker consumption of the sweeteners during chewing greatly reduces their flavor-potentiating effect, resulting in the discarding of the gum before half of the flavor has been extracted. Usage levels in the neighborhood of 2 percent are not uncommon in sugarless gums. The great challenge is to prolong the flavor perception and/or reduce the amount of flavor needed.

Mint flavors for chewing have historically been composed of natural oil blends for most of the industry's history. Peppermint flavor profiles were produced by blending oils from different growing regions, which may have also been further refined through vacuum

T-1. Peppermint flavor for chewing gum

Raw material	Percent w/w
Mentha arvensis oil DMO	10
peppermint oil far west	36.85
eucalyptol FCC	3.5
l-menthol FCC pellets, synthetic	15
l-menthone	4
l-menthyl acetate	4.5
10 percent phenyl acetic acid pure FCC in BA	0.3
thymol crystals FCC	0.05
l-menthol crystals, natural	25
anethole FCC	0.2
germacrene D, natural	0.1
menthyl lactate	0.5
Total	100

T-2. Spearmint flavor for chewing gum

Raw material	Percent w/w
Mentha arvensis oil India	3
spearmint oil far west type	38.55
l-carvone	16
l-menthol crystals, natural	25
spearmint oil Chinese	15
peppermint oil far west USP	2
cis-3-hexen-1-yl butyrate	0.03
phenethyl 2-methylbutyrate FCC	0.02
phenethyl iso-valerate FCC	0.1
cis-3-hexen-1-yl phenyl acetate	0.05
p-anisaldehyde pure	0.05
γ-nonalactone	0.05
iso-amyl phenylacetate	0.05
cis-3-hexen-1-yl iso-valerate	0.1
Total	100

T-3. Wintergreen flavor for chewing gum

Raw material	Percent w/w
methyl salicylate FCC	28
anethole FCC	2
menthol crystals, natural	20
peppermint oil FW redistilled	45
WS-3 (N-ethyl-2-isopropyl-5-methyl cyclohexane carboxamide)	1.2
vanillin FCC	0.5
ethyl salicylate	3
ethyl benzoate	0.2
methyl benzoate	0.1
Total	100

distillation or other means. Cornmint oil, in US regulations, could not be labeled as natural peppermint, thus limiting its use to WONF or artificial flavors. Adding some native spearmint oil to the peppermint blend also increased the consumer acceptance of the gum, but could only be labeled as natural "mint" rather than natural peppermint.

In the 1990s, chewing gum manufacturers developed the "super-cooling" gums and re-introduced coated dragees. Since none of the super coolants are natural or nature-identical, the raw material palette was no longer limited to natural materials. Flavorists could alter the aroma profile of a lower quality peppermint oil to resemble that of a preferred regional oil, or create interesting, more cost-effective, consumer-preferred mint variations. The dragee coating provides an excellent means to increase flavor impact and maximize the cooling sensation because it completely dissolves, thus releasing the entire flavor system in a short time interval. The use of encapsulated flavors and coolants within the chewing gum core can extend the effect somewhat longer, since the volatile components are not in contact with the gum base until it's released when the gum is chewed. This greatly reduces flavor binding. Spray dried flavors may also be dusted

onto sticks to yield a quicker flavor release before chewing adds to the flavor profile.

Mint Flavor Creation for Chewing Gum and Candy

It is best that the flavorist have the gum base that will be used in the finished product to be able to determine how flavor trials will display. The basic skeleton of a natural and artificial peppermint is made by combining one or more *M. piperita* oils, some *M. arvensis* oil, and boosting or modifying the profile with menthol derivatives. The creamy notes can be enhanced with C-7 through C-9 γ-lactones. Sweetness can be increased by adding materials like anethol, methyl salicylate, vanillin, ethyl maltol and furanones. Impact can be boosted with raw materials like eucalyptus, methyl ketones and some conifer notes. Other notes that work well in combination are rose, berry, herb oils, ionone derivatives, citrus, honey and, of course, spearmint. The desired cooling effect is achieved by adding menthol, alone or in combination with one or more other coolants.

Similarly, spearmint flavors are based on a blend of regional and specially processed oils, with the possible addition of peppermint oil and/or l-carvone and its derivatives. Green notes like leaf alcohol and its esters give a more refreshing top note, as do pineapple notes like allyl caproate. Menthol and/or other coolants may also be added to enhance freshness.

Wintergreen flavors are based on methyl salicylate and its homologues, usually with some *M. piperita* oil and menthol. Vanillin, eugenol, lactones, orange oil, anethol, benzaldehyde and some lactones smooth out the profile, particularly if high cooling is desired.

Confectionery flavors are similar in character to those for chewing gum, but are usually more dilute and may need to be modified to withstand processing conditions or spray drying, rather than to compensate for binding to a gum base. Less volatile solvents like propylene elycol, triacetin and triglycerides are commonly used.

Oral Care Flavors

Oral care flavors in many countries outside the United States were once considered to be fragrances, and therefore were developed

T-4. Toothpaste base example 1

Raw material	Percent
dicalcium phosphate	40.88
sodium monoglyceride sulfonate	2.3
sodium lauryl sulfate	0.7
water — glycerin mixture	53
sodium saccharin	0.12
Irish moss extract	2
flavor	1
Total	100

by perfumers. Today, several flavor houses have developed oral care flavor programs and work closely with toothpaste and mouthwash manufacturers to create consumer preferred flavors.

Toothpaste: Toothpastes and gels were originally designed to clean out food particles and polish the teeth. Today, they may also contain materials that prevent or treat caries formation, yellowing, tartar buildup and/or gingivitis, with the inclusion of actives like fluorides, triclosan, baking soda, peroxides, antibacterials, etc. In the United States, those toothpastes/gels that make therapeutic claims are considered drugs and must meet the Food and Drug Administration's (FDA) pharmaceutical criteria for formulation and manufacture.

Toothpaste bases are aqueous pastes made up of insoluble polishing agents, binders, humectants, sweeteners, foaming agents, colors, titanium dioxide and preservatives. Typical polishing agents are calcium carbonates and phosphates. Binders are usually hydrocolloids, like carboxy methyl cellulose, methyl cellulose, xanthan gum, alginate or carrageen, which increase the viscosity and prevent separation of the liquid and give luster and creamy texture to the paste. Humectants such as glycerin work with the binder to stabilize the paste. The common sweetener in the United States is saccharin, which is added at about 0.1 percent; some countries do not permit saccharin. Foaming agents are surfactants like sodium lauryl sulfate, which help to clean the teeth. Preservatives are usually esters of parahydroxy

T-5. Toothpaste base example 2	
Raw material	**Percent**
calcium pyrophosphate	39
stannous pyrophosphate	1
carboxy methyl cellulose	0.7
magnesium aluminum silicate	0.8
glycerin USP	18
sorbitol solution 70 percent	12
sodium lauryl sulfate	1.51
ethyl p-hydroxybenzoate	0.1
water	25.89
flavor	1
Total	100

T-6. Toothpaste base example 3	
Raw material	**Percent**
polyacrylic acid resin	0.6
sodium hyclroxide	0.24
sodium borate	0.08
sodium lauryl sulfate	0.8
sorbitol	30
sodium lauroyl sarcosinate	0.05
sodium saccharin	0.1
water	66.63
flavor	1.5
Total	100

benzoic acid, e.g. methyl paraben, that prevent microbial spoilage. Certified colors give the desired hue, and titanium dioxide adds the opacity (the latter is left out for a clear gel). The base is combined with flavor and any active ingredients to form the finished product.

Formulas I and II are for typical opaque toothpastes, while formula III is a clear gel (T-4 through T-6).

Toothpaste flavors: The function of the flavor is to mask any unpleasant taste and/or astringency of the toothpaste base or actives, give a clean fresh taste, and possibly "signal the efficacy of the product." They should be solvent-free and as "water-white" as possible. Common usage levels for such flavors are in the range of 0.8–2 percent.

Traditionally, there were four main types of flavors—spearmint, peppermint, mint blends and wintergreen (T-7 through T-9)—which usually contained added menthol to increase freshness. The mints were often modified with clove oil/eugenol, cassia oil/cinnamic aldehyde, anise oil/anethole for sweetness, eucalyptus oil/eucalyptol for impact, and lactones for creaminess. Clove bud oil and eugenol have historically been used in dentistry as antiseptics and local anesthetics. Traces of rose notes, ionones, and traces of herbal and fruity notes may also have been added. Wintergreen was based on methyl salicylate with menthol, vanillin derivatives, mint oils, and perhaps some benzaldehyde.

Today, mint oils are still a major component of toothpaste flavors, but prominent herbal, citrus and tutti-frutti blends are also used. The super-coolants too, are often used to increase the sensation to greater

T-7. Typical toothpaste flavor 1

Raw material	Percent
eucalyptol	18
l-menthol crystals	60
peppermint oil FW USP	2.5
anethole FCC	6
anise oil	3
Arvensis oil, India	7.5
thymol crystals FCC	0.2
eugenol FCC	0.2
spearmint oil, native FW	1
basil sweet oil FCC	1
methyl salicylate FCC	0.6
Total	100

intensities.

Mouthwashes: Mouthwashes are low aqueous alcoholic solutions (10 to 30 percent v/v) that may contain carriers, flavors, astringents,

T-8. Typical toothpaste flavor 2

Raw material	Percent
anethole FCC	5
l-menthol crystals FCC	18.5
methyl salicylate FCC	18
phenyl ethyl alcohol FCC	0.4
Scotch spearmint oil	7
spearmint oil, native China	15
WS-23 coolant	12
peppermint oil FW FCC	20
heptalactone, γ	0.2
cis-3-hexen-1-yl acetate	0.05
vanillin FCC	0.1
l-carvone FCC	3.75
Total	100

T-9. Typical toothpaste flavor 3

Raw material	Percent
anethole FCC	2.5
eugenol FCC	2
l-menthol crystals FCC	30
l-carvone FCC	3.5
methyl salicylate FCC	50.05
spearmint oil, native China	2
1 percent guaiacol in benzyl alcohol	0.05
cassia oil China	3.5
cinnamic aldehyde FCC	6.2
vanillin FCC	0.2
Total	100

antibacterial agents, sweeteners and/or coloring. Carriers like glycerin, propylene glycol and sorbitol syrup supplement the alcohol to promote a clear liquid. The flavor can vary from medicinal to clean-fresh-mint to the recent novelties of citrus notes. Flavor levels are usually between 0.1 percent and 1 percent and may have some antibacterial efficacy from components such as thymol, carvacrol, phenol, methyl salicylate, etc. The flavor may also be used as the denaturant for the alcohol under federal regulations for specially denatured alcohols (see formulas 37, 38-B, 38-F and 46, in particular). Astringents like citric acid, zinc chloride and aluminum potassium sulfate coagulate loosened mucous secretions and help to expel them during rinsing. Antibacterial agents are present to kill germs that cause bad breath. Sodium saccharin and sorbitol are the most common sweeteners and are kept at a minimum level because too much sweetness is a consumer negative. Various certified colors and caramel may be used, but they should be evaluated for odor and color stability.

Mouthwash flavors: The traditional medicinal mouthwash flavor is characterized by high levels of menthol and eucalyptus oil/eucalyptol, with thymol, methyl salicylate and anethole modifiers (T-10). Mint flavors are usually peppermint/spearmint blends, with or without winter/methyl salicylate, combined with several common mint modifiers.

Pharmaceuticals: Mint flavors are most frequently used in gastrointestinal remedies, cough/cold products, analgesics, antibiotics and oral care drugs. Pharmaceutical agents in these formulations very often have bad tastes, sometimes accompanied by a foul aroma. Mint flavors can often help mask these undesirable effects. However, some consumers may have doubts about efficacy if masking is too strong, or may fear that a child could overuse a drug if it tastes too good. Formulators should beware of "too much of a good thing." In addition, prescription drugs require that the flavor be tested in the finished product to verify that it has no effect on efficacy or safety. Additionally, a qualitative and quantitative formula must be filed with the US FDA to obtain a new drug approval (NDA). Over-the-counter (OTC) preparations and therapeutic toothpastes/

T-10. Typical mouthwash flavors

Raw material	Percent
anethole FCC	2.5
eugenol FCC	2
l-menthol crystals FCC	30
l-carvone FCC	3.5
methyl salicylate FCC	50.05
spearmint oil, native China	2
1 percent guaiacol in benzyl alcohol	0.05
cassia oil China	3.5
cinnamic aldehyde FCC	6.2
vanillin FCC	0.2
Total	**100**
l-menthol crystals FCC	45
eucalyptol	25
eucalyptus oil	4.5
thymol USP	0.8
methyl salicylate FCC	19.2
anethole FCC	3.5
peppermint oil FW FCC	2
Total	**100**
l-menthol crystals FCC	27
clove bud oil FCC	2.4
methyl salicylate FCC	44.4
cassia oil China	2.5
cinnamic aldehyde FCC	5
anethole FCC	0.3
peppermint oil FW FCC	15
phenyl ethyl alcohol FCC	0.5
50 percent phenylacetaldehyde in benzyl alcohol	0.05
thymol USP	1.2
eugenol FCC	0.6
sweet basil oil	0.8
heptalactone, γ	0.2
10 percent ionone β in benzyl alcohol	0.05
Total	**100**

mouthwashes may also require an NDA.

Pharmaceutical flavor formulations are similar to those shown above, but are specifically modified to mask the off-taste of the finished product. Anise/anethol, methyl salicylate and vanillin sweeten mint flavors and help cover bitterness in antibiotics, antihistamines and antacids. γ-Lactones—in combination with vanillin, lemon notes and some other dairy notes—are effective in masking the chalky, bitter notes in gastrointestinal remedies. Menthol and other coolants also help soothe the burning, bitterness and astringency of many drugs. Furthermore, the possible reaction of flavor components with the actives or incipients must be carefully avoided. For example, methyl salicylate will hydrolyze at the high pH+ of most antacids, and benzaldehyde will often react in cough/cold products.

The flavorist must be fully aware of the drug's dosage recommendations and side effects when working on a project in order to avoid any health damage or physical impairment, which might jeopardize his or her safety. This is particularly true for prescription and new drugs still in clinical testing.

Flavoring Confections

Jean Cassidy

History and Pioneers of Confections

A confection is a sweet-tasting food, traditionally based on sugar. In the 1800s Americans called it "sugar candy." There are several forms of confections, but all types are eaten, except for chewing gum. The history of confections is quite interesting and I would like to present it in two major categories: candy and chewing gum.

Candy

Some of the earliest forms of candy were made by the ancient Egyptians, who mixed fruits and nuts with honey, the source of sweetness. The first commercialization of candy in America occurred in the 1800s and included items such as chocolates by Whitman and Richard Cadbury; candy corn by Wunderle Candy Co. And Goelitz Confectionery Co.; and Tootsie Rolls by Leo Hirshfield of New York. The beginning of the 1900s saw the creation of "The Great American Chocolate Bar" when Milton S. Hershey introduced the first Hershey milk chocolate bar. Milk chocolate was invented by two Europeans, Henry Nestlé, a maker of evaporated milk, and Daniel Peter, a chocolate maker.

The American candy industry was now established and growing, especially when American troops returned after World War I. They had become accustomed to eating the candy that was included in the rations they received. The demand for candy kept rising, and an industry that started on the East Coast in cities like New York, Philadelphia and Boston soon found its way to Midwestern cities like Chicago, closer to the source of raw materials. As the 1900s

continued, new introductions such as Hershey Kisses, Lifesavers peppermint hard candy (and later fruit flavors), and Reese's Peanut Butter Cups (now owned by Hershey) appeared on the market. The Mars family brought us Milky Way, Snickers and Three Musketeers bars, as well as M&M's and Starburst. In the late 1900s Herman Goelitz Co. Introduced Jelly Belly jelly beans, as well as the first American manufactured Gummi Bears and Gummi Worms.

This abbreviated history of America's candy industry illustrates some of the challenges and opportunities for the flavor industry.

Chewing Gum

Chewing gum, the only confection we do not swallow, has also experienced rapid growth. The ancient Greeks were the first to chew a gum-like substance. They chewed a gum called mastiche, made from the resin found in the bark of the mastic tree, indigenous to Greece and Turkey. The Maya chewed chicle, a gum-like sap from the sapodilla tree. Native Americans chewed sap from spruce trees, and introduced this to American settlers. A sweetened paraffin wax later became more popular than the spruce gum.

The true beginning of chewing gum as we know it today occurred in the late 1860s. At that time, Mexican General Antonio Lopez de Santa Anna brought some chicle to America and introduced it to New York City inventor Thomas Adams. While experimenting with the chicle to make rubber, Adams discovered its chewing properties; he went on to establish the first chewing gum manufacturer in America—Adams New York Chewing Gum. The first flavored chewing gum was a peppermint gum called "Yucatan," developed by William White by adding corn syrup and peppermint extract to chicle. Later, Edward Beeman added pepsin powder as a functional ingredient for digestion, calling his concoction Beeman's pepsin chewing gum. Popularity and demand for chewing gum continued to grow in America, and more brands entered the market in the late 1800s. Some of today's most popular brands, such as Wrigley's Juicy Fruit and spearmint, Chiclets, and dentist Franklin Canning's Dentyne gum, were introduced at this time. The American Chicle Co. formed from a merger of Yucatan gum, Adams gum, Beeman's gum and Kiss-Me gum;

American Chicle later purchased Dentyne. The first New York subway vending machines appeared at this time, providing a convenient method to market the sale of the new confection products.

Wrigley's Doublemint Gum and Adams Clove Gum appeared in the early 1900s. Walter Diemer of Fleer Gum formulated Dubble Bubble gum. Topps Gum introduced Bazooka bubble gum, still one of today's best sellers. Leaf Confections marketed Rainblo Bubble Gum. Wrigley created Orbit in the 1940s specifically as a wartime product included in the soldier's rations. Sugarless gum was created mid-century to appease newly health-conscious consumers. The idea is accredited to dentist Bruno Petrulis, who discovered the cariogenic effect of sugar-based gum resulting in tooth decay. Wrigley bought his company and produced Blammo, the first sugar free bubble gum. In the late 1900s major chewing gum, manufacturers continued to introduce more brand leaders, including Wrigley's Freedent (non-stick gum), Big Red, Hubba Bubba, Big League Chew, Extra and Winterfresh. Other successful brands include Hershey's Icebreakers and Adams' Bubblicious and Trident. This sampling of the chewing gum industry demonstrates further creative challenges for the confectionary flavorist.

Confection Types

Confections are commercially available in many forms, and are composed by mixing together any of the following: sugar (sucrose), corn syrup, honey, invert sugar, starches, dextrins, polyols (ex. mannitol and sorbitol), egg albumin, flour, agar, pectin, molasses, gums, milk products, nuts, fruits, chocolate liquor, cocoa butter, vegetable fats, flavorings, food colors, preservatives and food acids.

Chocolate: The most popular candy, chocolate consists mostly of cocoa butter, sugar, chocolate liquor (expressed from cocoa nibs), milk solids, milk fat, flavorings and emulsifiers. Chocolate is a "standard of identity" confection and must meet certain government formulations to be called chocolate. Chocolate coatings are similar, except the fat can be derived from other sources besides cocoa bean (cocoa butter), such as coconut, corn, palm and other vegetable oils. Chocolate bars are made by pouring melted chocolate into molds and allowing it to

harden. Chocolate coating involves a process called enrobing, where melted chocolate is poured over another food and allowed to harden. Another process using chocolate is shell molding, which is used to produce high-end truffles and chocolates with liquid centers.

Hard candy: Hard candy (high boilers), one of the simplest confections, is composed of sugar and corn syrup. The mixture is heated to around 300°F at atmospheric pressure. If a vacuum is applied lower temperatures can be used to produce the same product. Moisture of less than two percent is desired for product stability. Flavorings, food acids and food colors are added as desired and mixed as the candy cools. This mixture is then formed into different shapes — candy balls, sticks and lollipops are a few examples.

Chewy candies: Chewy candies include jellies, gummies, toffees and caramels. Jellies and gummies are made by mixing sugar solutions with a jelling agent, then boiling, flavoring and coloring the solution. After adequate mixing, the solution is poured into various molds and left to set. Caramels, toffees and fudge contain sugar, corn syrup, invert sugar, vegetable fats and milk. The mixture is boiled together with water. The mixture may be flavored, then cooled and cut into pieces. Due to the ingredients present, a flavor is developed during processing due to Maillard browning, which imparts a brown caramellic or roasted flavor.

Whipped candies: Whipped or aerated candies include marshmallows and nougats. They are composed of sugar, corn syrup, invert sugar, gelatin, egg whites, flavors, food colors and vegetable fats. Finished marshmallows contain more moisture than nougats.

Creamy candies: Creams or fondant confections consist of fondant sugar, water, flavorings and food acids. Fondants are generally firmer in texture. Creams typically form the center of another confection like chocolate.

Panned candies: Panned candies are glossy, hard-coated sugar or chocolate on a confection center. Examples include jelly beans, malted milk balls and chocolate covered raisins and nuts. Flavors and food colors are used extensively in forming the shell material. The gloss is produced by a final coating of natural waxes such as carnauba.

Specialized candies: Other specialized candies include licorice

(containing licorice root extract), cotton candy and marzipan (a paste made from almonds and sugar). Flavors as well as food colors may be added.

Tablets: Tablets, which are compressed during manufacturing, are composed of a mixture of sweeteners (dextrose/sucrose), flavors, food colors, food acids and release agents like magnesium or calcium stearate. These release agents prevent sticking during compression. Sugarless tablets may use sorbitol or xylitol to replace sugar. They can give a cooling taste effect. Confection tablets are typically consumed to give one's mouth a freshening flavor, like after-dinner mints.

Chewing gum: Chewing gum is made by mixing gum base, sugar, corn syrup, softeners (glycerin), flavorings, sometimes food acids, and food colors. Sugar free chewing gums replace sugars with sweeteners like sorbitol, xylitol, mannitol and high potency compounds like aspartame or saccharin. Some heat is applied when kneading the ingredients together.

Flavorings

Flavors are a key ingredient for any successful confection. They give flavor impact, long-lasting taste, and contribute to a very pleasant experience for the consumer. They can include fruits, mints, spices, sweet brown flavors like caramel and toffee, and more savory types like coffee and nuts. Some of the earliest flavors for confections were prepared by using plant extracts like peppermint, citrus fruit and spices. These ingredients are very strong and impart a very pleasant flavor in confections. These flavor types are still very popular today, but the advent of synthetic flavoring ingredients allows for flavors of these types as well as new flavoring concepts to be made at lower costs with greater impact and greater survivability during the manufacturing processes. In addition, synthetic ingredients give the flavorist more tools to work with while enabling the end product to maintain a natural taste. When natural and artificial flavors are created, you can achieve very strong and long-lasting confection flavors. Gratefully, flavor labeling for confections is still wide open even though natural flavors are perceived as better by consumers.

Using artificial flavor compounds is necessary, especially when you make berry flavors. Extracts of berries are typically water-soluble and not very strong. They work well for other applications like beverages but are ill-suited for confections. Today, very true-to-life fruit flavors can be achieved thanks to analytical research, molecular chemistry and sensory applications. I use GC/O (gas chromatography/olfactory) as well as GC/MS (gas chromatography/mass spectroscopy) and QDA (quantitative descriptive analysis) to develop more natural tasting flavors. Utilizing a combination of science as well as creativity enables the flavorist to overcome total dependence on natural essential oils for confection flavors. Typical dosages for confection flavors range from 0.25 to 3 percent, with chewing gums requiring the highest use levels.

Flavor Types

Confectionary flavors come in liquid or powder form. The design of the flavor will depend on the final confection type and the customer's production capabilities. The liquid form can be either water-soluble or oil-soluble and sometimes, even an emulsion may be preferred. Again, the confection type determines the most appropriate physical form of the flavor.

Liquid oil-soluble flavors: Liquid oil-soluble flavors can either be very concentrated with little or no solvent or diluted with a vegetable oil or triacetin. Liquid oil-soluble flavors are preferred in most confection products, especially those containing fats and having low moisture. In addition, they perform better when high heat is required (e.g. hard candy) to reduce moisture and prevent tackiness. Oil solublity is preferred in chewing gum where a great amount of the liquid flavor is absorbed into the gum base and keeps the gum soft. This also allows for slower and longer flavor duration.

Liquid water-soluble flavors: Liquid water-soluble flavors for confections are prepared with solvents such as propylene glycol and glycerin. Due to its low flash point, it is recommended to minimize ethyl alcohol use in most confectionery applications. Liquid water-soluble flavors work better in pectin jellies, aerated confections and some creams, but either liquid form can be tried.

Dry flavors: Dry flavors are best for tablets and chewing gums to give initial upfront flavor impact along with the liquid flavor. Encapsulated flavors are preferred over dry powder blends for shelf life as well as controlled flavor release. (Confection flavor types and formulations are presented in T-1 to T-4.)

T-1. Confection Types - Confection Flavors

Confection types	Liquid OS	Liquid WS	Encapsulated
chocolates	X		
hard candy	X		
creams/fondants	X	X	
jellies/gummies		X	
caramels/toffees	X	X	
panned coatings		X	X
marshmallows		X	X
pressed tablets			X
bubblegum/stick gum	X		X

T-2. Citrus flavor formulation in ppm

triglycerides	222
lime oil distilled	440
citral	120
α-terpineol	100
orange oil	100
aldehyde C10	2
aldehyde C8	2
ethyl butyrate	6
ethyl caproate	2
orange light fraction	4
BHT	2
Total	1000

T-3. Mixed fruit flavor formulation in ppm	
triglycerides	143
ethyl butyrate	300
isoamyl acetate	200
Orange oil	180
isoamyl butyrate	50
lemon oil	50
isobutyl acetate	30
cinnamic aldehyde	20
eugenol	10
benzaldehyde	10
vanillin**	5
BHT	2
Total	1000

** For flavor types containing high amounts of powder flavor ingredients (like vanillin for vanilla flavors) you will need to replace some of the triglycerides with triacetin for solubility

T-4. Encapsulated flavor formulation in ppm		
water	600	
maltodextrin M100	256	
gum arabic	64	
flavor oil	80 yield	400 pts

Challenges for a Flavorist

Flavor volatile loss: As temperatures increase during confection production, loss of flavor volatiles increases. Production systems using lower temperatures help, but flavors change as systems change. Flavors have to be balanced for heat loss, and selecting the best solvent helps minimize this problem. Low moisture is critical for

many confections, especially hard candies and chewing gums. The correct flavor form and solvent is also required to minimize flavor volatiles loss in storage. When designing your flavors choose those compounds that are less volatile and still give you a balanced-tasting flavor. Another approach is to increase the lower volatile compounds to compensate for loss. This will be achieved through experimentation. Analytical methods can be used to determine which volatiles are lost, and to what extent they are lost, due to the temperature encountered during the manufacturing process. This approach can also be used to study which compounds are bound up in chewing gum bases. Researchers and flavorists can work together to quantify and reformulate to compensate for flavor losses.

Flavor stability: Flavor oxidation is one of the most common problems associated with flavor stability in a confection. When this happens, the development of flavor rancidity and off notes occurs. Some suggestions to minimize this are the addition of suitable antioxidants, choosing more stable flavor materials, and the encapsulation of the flavor system. This is most problematic are citrus flavorings, and research for ways to improve and extend shelf life is ongoing.

Flavor balancing: There are many reasons that flavors need to be rebalanced or customized for a confectionery base. One is a sugar-based system versus sugar free. In addition to flavor balancing, sugar impression flavors are created to retain authenticity and a pleasant taste when sugar is removed. Masking flavors are used to minimize the bitterness from artificial sweeteners. This balancing and masking process also occurs for the addition of other ingredients, like vitamin fortifiers and other nutraceuticals, as well as the unpleasant taste of chewing gum bases. Active research, both analytical and sensory, is guiding flavorists as to which flavor materials will minimize and alter these off notes and allow for a better tasting confection. Maltol and vanillin have been used for several years as sweetener impressions as well as maskers, but ongoing research is discovering other ways.

Flavor balancing, especially with fruit flavor systems, involves the addition of food acids like citric and malic. These ingredients enhance flavor intensity, authenticity and a full flavor experience. The

balancing of the food acids becomes just as important as the balancing of the flavor.

Global market and regulations: The request for flavorists to create flavors with multinational acceptance has become more popular and important. Flavorists are challenged with taste preferences of a diverse consumer base. Sensory tools are key in determining if submissions will be successful. In addition, a flavorist must be aware of the differences in regulations and may have to design flavors which meet multinational regulations. Allowed components as well as maximum consumption levels will need to be taken into consideration.

Current Trends

Complex flavor types: Flavors with a new twist are the current trend. This includes flavor combinations like fruits 'n' creams, tropical blends, mints and vanilla, as well as sensation additives like cooling, heat, tingling and mouth watering. Sour types continue to be popular, as well as true-to-fruit flavors for a more natural experience. A diverse consumer base demands more choices be available on the store shelves.

True-to-fruit types: The expectation of consumers for more natural tasting confections continues to grow. Analytical research of new and accepted flavoring materials allows for continued identification and synthesis of naturally occurring compounds. As these tools become available, flavorists are able to get closer to recreating nature. I personally have applied GC/O evaluation of extracts made from nature to assist me in flavor creation.

Sugar-free confections: The demand for fewer calories continues to increase. Minimizing the cariogenic (tooth decay) effect is also a consumer desire. This especially applies to chewing gums, which stay in the mouth for longer periods of time. Creating intense flavors, as well as flavor modifiers, are the researchers' and flavorists' approaches to achieving these demands.

Flavoring confections to meet consumer demands and expectations is a job I find interesting, challenging and rewarding when success is finally achieved. My experience has taught me to approach each assignment using logic, knowledge and a team

of specialists. This team includes the flavorist, food technologist, analytical scientist, organic chemist, sensory scientist, marketer and most importantly, the consumer.

The Use of Natural Ingredients in Creating Natural Flavors

Carole Pollock

I became a certified flavorist in 1972 — right on the cusp of a "revolution" in flavor development. In the "old" days, flavor development briefs asked for artificial flavors. These flavors were very concentrated, relatively inexpensive and had been tested for suitability in most food, beverage and snack products.

Starting in the early 1970s, there were increasing marketing demands for natural flavors. "Artificially-flavored" on a product label became something that was looked at as inferior, bad-tasting, economy-priced, unsophisticated or "for children." Nearly all new project briefs that came to the flavorists for creative development requested natural flavors. Natural flavors created at that time were usually formulated using juice concentrates, essences, essential oils—if these existed—and extracts from the named fruit. Natural WONF flavors (with other natural flavors) were formulated using the ingredients stated as well as using natural products of the same type from other fruits and essential oils that reinforced the impact and character of the named flavor. Some flavor types used solid extracts, such as fenugreek and carob, as well as some extracts and distillates from cocoa, coffee, tea and assorted vegetables. Onion juice and cucumber juice were two of the stronger vegetable juices that added green, cooked or sweet notes to natural fruit flavors of the time. These truly

natural flavors were quite weak—requiring 2 percent or more added to the food or beverage. They lacked the stability of artificial flavors and were not suitable for many applications, especially chewing gum, confectionery and baking. Simple citrus flavors and some beverage flavors like colas and lemon-lime "up" types were able to be made from citrus and other essential oils, much as these are today.

There was a great deal of confusion as to what defined a natural flavor and how each flavor needed to be labeled. There was a lot of adulteration going on in the industry as well. Some of it was unintentional—the artificial or "sophisticating" ingredient came along in an essential oil or other product that was labeled and shipped as "natural." Until the 1970s, the major use of essential oils, other than citrus, was in perfumery. The fragrance industry demanded consistency in these essential oils; these were often "standardized" by the manufacturer with artificial components. The perfumery solvents and materials added were often not permitted in flavors at that time. Some of the adulteration came from the confusion as to what ingredients could be used in natural flavors and what ingredients could be used in nature-identical flavors for use in European products. (Confusion is a kind term, as a well-trained flavorist should have known better.) However, the chemicals added had been found in nature, unlike the adulteration that occurred frequently when straight artificial flavors containing all, or nearly all, artificially-derived materials were "blessed" with a small amount of the natural named ingredient and labeled as natural.

The techniques for finding outright artificial ingredients by GLC (gas liquid chromatography) and the "baby days" of MS (mass spectrometry) were growing apace with the adulteration. It was an everyday occurrence for analytical chemists to report that the flavor that needed to be matched contained an outrageous amount of chemicals such as ethyl maltol, ethyl vanillin, ethyl methyl phenyl glycidate and many other ingredients that have not been found in nature even to this day.

The adulteration and mislabeling of flavors and finished "natural" foods and beverages became so widespread that the FDA published definitions and requirements which exist today as CFR title 21

section 101.22. Some of the rules have changed a bit since 1974, but the definition of "natural flavor," the requirements for "certificates of natural" and the criminal penalties for mislabeling remain the same. Every flavorist should read these regulations in their entirety and keep a copy in his/her work area. The definition of "natural flavor," given in the prologue of the original regulations states:

> "...[T]he essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, seafood, poultry, eggs, dairy products or fermentation products thereof, whose significant function in food is flavor rather than nutrition."

The publishing of accountabilities and penalties caused ingredient suppliers and flavor manufactures to clean up their acts. The need for clean essential oils and other materials for flavor use created a lucrative and competitive market. Flavor companies worked with their ingredient suppliers—often their own overseas plants—to provide food-grade materials. The best flavor houses installed regulatory "watch-dogs" to see that there were natural certificates for all their natural ingredients and to ensure that these ingredients were manufactured in a food-approved manner. Flavor manufacturers had to provide natural certificates for their flavors to the food or beverage manufacturer as well. The instances of deliberate adulteration decreased to levels that today are the exceptions rather than the rule. "Sophisticators" are still out there, using analytically challenged methods and inexpensive so-called natural materials from suspect sources.

This definition of flavor ingredients opened the door to the creative manufacture of flavors from "cooking" type reactions, fermentation, and enzymolysis and any physical, rather than chemical, reactions of natural molecules to fashion new natural flavor materials. Therefore, a new generation of flavor materials and creative development was born.

Bottles of essential oils, absolutes, oleoresins, natural extracts and distillates have virtually disappeared from the shelves of flavorists and from the formulations of new flavors. Most of the change in material usage is due to the availability of natural chemicals, created initially in the lab by joining natural pieces through physical means to make most of the chemicals previously used in artificial flavors. Today, the costs of these new natural materials are almost competitive to their synthetic counterparts. That has made it easy for flavorists to convert many of the artificial flavors in their company's database to natural versions. The results are natural flavors that are highly concentrated, slightly more expensive, and taste just like artificial flavors. Flavor analytical chemists have refined their techniques, using vastly improved instruments from those of the 1970s, combined with computers to be able to duplicate flavors from all segments of the market and to deliver tentative formulations that make nearly every flavor easy to match. Soon the flavor collections in all of the flavor industry will all be the same!

Most novice flavorists are not familiar with the use of the other natural products and have very little time to learn them. Few flavor companies are investing time and energy in training new flavorists. Project time has changed from a week or more to a few hours or, at most, a few days to deliver the expected submission. Of course, if the flavorists are "certified," they have to learn the major ingredient in a variety of essential oils to pass the interview for certification in the Society of Flavor Chemists in the United States. However, most use the manufactured chemicals and not the more complex essential oils in their creations and miss out on the subtle and interesting characters of the whole essential oils.

My goal in this paper is to teach how to use these "forgotten" materials to make more interesting and true-to-nature flavors that are affordable, and with the added benefit of being a bit more difficult to duplicate.

Essential Oils

Essential oils are harvested from whole spices or the leaves, bark, fruits, peels, seeds and roots of plants. Most essential oils are col-

lected by distillation—steam or vacuum—of the plant materials in water. Some, especially citrus, are collected by expression and then isolation. Citrus oils are harvested as a by-product from juice production and have some interesting fractions that can be isolated from the juice during concentration. A few essential oils, like rose and other delicate florals, are still done by pressing. There are several good source books that explain each essential oil, its composition, isolation, geographic differences and availability. Please seek them out and use them for this information as I am focusing on their use in flavor creation. Of course, composition and availability affect oil quality and price, so keep all these factors in mind when selecting the essential oil to be used.

In the "old" days, flavorists knew that essential oils, resins and extracts contained the desired flavor characteristics they needed. They used these materials in both synthetic and natural compositions because the isolated chemical components were not available to them. Hence, they used the whole essential oil, which included the major components and the lesser ingredients — whether they wanted these of not. One of my old teachers put some of these materials in the "weighing line" for all his flavors. His favorites included orange oil, coriander oil, onion oil and benzoin resinoid. The orange oil provided aldehydes and terpene lift, the coriander was used for linalool and a mild spice bite, the onion oil provided the richness and sweetness of sulfur compounds, and the benzoin gave earthy notes and acted as a fixative.

These are only *a few* of the many essential oils that I have found useful in adding character and uniqueness to flavor creations; mint oils are covered in another chapter and citrus oils are covered separately within this chapter.

Essential Oils for Creative Flavor Enhancement

Ambrette seed oil: This oil has a musky, earthy, woody character similar to ambrettolide. It is very powerful and will tend to dominate a flavor if not used judiciously. This is a very valuable material for use in berry flavors, especially blackberry and black raspberry at about 1-5 ppm in the finished product. It can be used to advantage in

tropical flavors like pineapple, papaya and guava. It also can be used in vanilla WONF flavors for its woody character.

Anise oil: Anise oil has anethole as the characterizing constituent at about 95 percent. It is primarily used in alcoholic beverages and bakery applications. It is important in root beer flavor and licorice-type flavors. It can add interest in vanilla WONF flavors and even cola flavors when used at 3-5 ppm — below threshold levels. The flavor of anise is long-lasting, and useful in dentifrice and chewing gum applications.

Basil oil: Basil oil taste varies as to geography and variety. The leaves are the part of the plant usually used to obtain the essential oil, but some processors use the whole plant, including the flowers. Methyl cinnamate and linalool are two of the major constituents that are important in flavor creation. The linalool isolate from the Spanish variety still retains some of the fresh, green character of the herb. Basil is a very useful essential oil to include in blueberry and strawberry flavors, as well as in savory compositions.

Sweet birch oil: This oil is distilled from the bark of the silver birch tree, and is very rich in methyl salicylate. The aroma and flavor are quite similar to wintergreen, but lack the musty, green characteristic of this mint. In the early days of natural flavor creation, there was more sweet birch oil produced than there were birch trees because of outright adulteration with wintergreen oil, or worse, synthetic methyl salicylate. Sweet birch is used primarily in root beer flavors and alcoholic beverage flavors. A very low level, about 1-3 ppm, will enhance peach, apple and cherry flavors.

Boise de rose oil: This oil is steam distilled from the chipped wood of the evergreen shrub grown in Brazil, Peru and French Guiana. The oil is primarily used as the starting material for producing natural linalool. The whole oil has a sweet, floral, woody character, which is useful in berry flavors, especially blueberry and red raspberry. It also is interesting in apple and pear flavors.

Buchu leaf oil: Buchu leaf oil is one of the flavor materials that you "love to hate." The aroma is annoyingly pungent, green, camphoraceous, phenolic and sulfurous. It was the source of p-menthan-3-on-8-thiol (p-thiomenthone) that was needed for tropical

and peach flavors before this chemical was available as a natural material. Fractions of buchu leaf oil are available that are rich in this sulfur compound, but a little of the whole oil is quite good in some of the more aromatic tropical fruit flavors.

Carrot seed oil: This oil is herbaceous, fatty and sweet in aroma. It has a unique place in creating mango flavor, adding its own characters, as well as some of the stringy mouthfeel of the mango fruit.

Celery seed oil: Celery seed oil, in addition to limonene and other terpenes, contains more than three percent phthalides. These are potent chemicals typical of celery. They have a warm-spicy and green character helpful in savory flavors. Celery seed oil can also be used in berry flavors and fresh tomato flavor.

Cinnamon and cassia bark oil: These varieties contain 60–85 percent cinnamic aldehyde. However, if the true oils are compared to isolated cinnamic aldehyde, there is a large difference in flavor quality. The cinnamic aldehyde is harsh, burning and lacks the smooth, spicy character of the whole oils. Both cinnamon and cassia oils are produced by steam distillation of the inner bark of the tree or shrub. True cinnamon grows on some of the Indian Ocean islands, India and Southeast Asia. Saigon cinnamon used to be the most valued quality, but it is difficult to get today. Cinnamon is usually sold as the ground spice or as cinnamon sticks as the whole spice. Most of the "cinnamon" in commercial use is cassia from trees grown in China and central Asia. Chinese cassia oil is important in beverages for its use in cola flavors at 5–10 ppm in the finished beverage. It is also used in bakery applications, pickles, cereals, confectionery, chewing gum and in savory flavors. Cassia oil can be used in fruit flavors—black cherry and plum—at 1–3 ppm.

Cinnamon leaf oil: This oil is steam distilled from the leaves and twigs of the true cinnamon shrub. This oil contains nearly all eugenol and only a small amount of cinnamic aldehyde. The phenolic eugenol flavor usually associated with clove bud oil is softened in this oil. It finds application in cola flavors, as a nuance ingredient, as well as in other specialty beverage flavors: "pepper"-type, root beer, "red"-type and even cream soda flavors. It is primarily used in savory and bakery applications.

Cumin oil: Cumin oil contains 60 percent or more cuminaldehyde. The cumin oil flavor differs from the harsh, fatty, "sweaty" character of the isolated aldehyde. Cumin, as the ground spice or as the essential oil, is used primarily in savory flavors—curries and chili. At threshold levels of 0.2–0.5 ppm, it can be used to good effect in tropical fruit flavors contributing a warm, sweet and "meaty" character.

Davana oil: This oil is steam distilled from its flowers, which are cultivated in southern India. It contains unique ketones and lactones that give it a sweet, dried fruit character. It is especially useful in "ripening" and adding body to fruit flavor compositions and finds application in berry, especially "jammy"-type, plum, peach, apricot and tropical fruits. Due to crop variations and weather conditions, this oil is often in short supply and is a target for adulteration.

Refined fusel oil: Refined fusel oil is a product of distillation from various alcoholic beverages. Wine fusel oil and whiskey fusel oil are commonly used in flavor creation. These oils contain mixtures of alcohols from yeast fermentation, primarily isoamyl alcohol, amyl alcohol and butyl alcohol, as well as several aldehydes and ketones. Fusel oil can be used in whiskey flavors and other alcoholic-type flavors, but it also has use in fruit flavors—apple, grape, pineapple and other sweet or "over-ripe" fruits. It can also be used in "brown" flavors such as butterscotch, brown sugar and caramel. It is important to find a source of fusel oil that is consistent or blended to a taste profile.

Galbanum oil: Galbanum oil is produced from steam distillation of the resin obtained from plants grown in Iran. The oil has unique green, herbaceous and green bell pepper character. It is useful in vegetable flavors, especially pepper, green bean and tomato. It can be used in other "green applications," such as green apple and unripe strawberry to give added freshness. The use level as a nuance should be about 0.5–1.5 ppm in the finished product.

Geranium, geranium bourbon, geranium rose and geranium Algerian: These oils are all steam distilled from the same plant grown in North Africa. There are differences in the character of the oils depending on the part of the plant—whole, leaves or flowers—that are processed. In general, the flavor characteristic is rose and to some extent mint. Geranium oil can be used in apple, pear, peach and

apricot flavors. I also like to use it in grapefruit and lime flavors to enhance the floral character.

Juniper berry oil: Juniper berry oil is steam distilled from the ripe but unfermented berries of the juniper shrub. The terpeneless oil is used for flavor creation. The major application is in compounded gin flavors. Other flavor uses are in mint formulations and as a nuance in some berry flavors.

Nutmeg oil: This oil is available in East Indian or West Indian varieties. There are differences in character, but for most applications, cost and consistency are more important. Nutmeg oil is quite high in terpenes; quality is measured as a factor of the myristicin content. Nutmeg oil is used to enhance the ground spice in bakery applications. It is an important component of cola flavors and can be used to give interesting twists to apple and pear flavors.

Bulgarian rose oil or otto rose oil: These oils are carefully distilled from the petals or, in some regions, gathered by pressing the petals through cloth. The major constituent is phenyl ethyl alcohol; there are over 100 other constituents identified. Rose oil is one of the most useful nuance ingredients for fruit flavors, especially apple, pear, cherry, plum, peach and even raspberry. The rose oil should be incorporated at about 0.5–2. ppm to give a hint of the blossom origin of the fruit. A nuanced amount of rose oil can also be used in honey and chocolate flavors.

White thyme oil: This oil is re-distilled from the less stable and harsher red thyme oil. The major constituents are thymol and carvacrol. The aroma is sharp, herbaceous and green—typical of the other herbal oils like oregano, rosemary, sage, etc. What makes thyme oil different is that it can enhance "tangerine-like" character when used as a nuance in orange flavors containing even small amounts of the more expensive tangerine oil.

Valerian root oil: Valerian root oil is steam distilled from young roots. It has a pungent, dirty aroma and was the only source of natural valeric acid that flavorists had before the advent of "natural" chemical materials. It was often used as a tincture (alcoholic extract) directly from the root. It enhanced chocolate, vanilla; nut flavors such as walnut and other brown flavors.

Citrus Oils and Isolates

Just about every fruit flavor and most specialty flavors (cola, ginger ale, "pepper"-types, even cream soda) contain citrus oils as a main ingredient or nuance effect. The oils can be used as single-fold or multi-fold with reduced terpenes. It is difficult to taste and evaluate single-fold citrus oils because of the high content of terpenes. The best way to do this is to make a 10 percent solution in alcohol and taste this at 0.1–0.2 percent in water sweetened with 5–8 percent sucrose, and acidified with 0.1–0.2 percent citric acid. The oils will come to the top very quickly, so the evaluation will have to be done immediately. Five-fold oils with some of the terpenes removed are more soluble in alcohol and much easier to use in flavor creation. The flavor characteristics and quality of citrus oils are different due to variety, geography, isolation techniques, equipment, seasonality and whether the fruit is processed green or ripe. The most commonly used citrus oils are discussed herein.

Sweet orange oil: Peel oil and juice oils are harvested as a by-product of juice production. Oranges are grown for juice in the United States (Florida and California), Brazil, Spain, Italy, Sicily and Israel. The usual collection method is expression from the peel after the juice is removed. There are also oils that are captured from the juice as it is concentrated. These juice oils and orange essence oils contain light aroma compounds that are valuable for flavor materials as fractions and isolates. The major constituents of single-fold peel oil is limonene and mixed terpenes, totaling 95 percent or more. Decanal and other aldehydes, linalool and other aromatic alcohols, and esters are important to orange oil flavor. Enriched fractions of orange oil are widely used in flavor creation. Orange oil and the enriched fractions are used in flavors for carbonated beverages, juices and drinks, alcoholic beverages, cordials and liqueurs, bakery applications, confections, and cereal coatings. Orange oil can be included in other fruit flavors other than citrus to add brightness and aroma. It fits well in blueberry, strawberry and red raspberry flavors. At 10 ppm or less, the orange oil acts as a blender with other flavor ingredients.

Bitter orange oil: The peel oil is the part that is valued in this product. It is grown in the Caribbean, especially on the island

of Curacao. The major use of bitter orange oil is for liqueurs and cordials. It is useful in flavor creation as a modifier for sweet orange flavors and for use in orange flavors for bakery applications.

Lemon oil: This oil is isolated from fruit grown in the United States (California, Arizona, Texas and Florida), Spain, Italy and Sicily. In the United States, the usual method is to harvest the peel oil away from the fruit and to remove it from the water phase by centrifugation. I've seen the oil harvested from the comminuted fruit in Spain and Sicily. A lesser quality oil is produced by distilling the oil from the peel or from the comminuted fruit. The Californian variety is higher, with a light aldehydic note, while the European varieties, higher in citral content, are sweeter and more candy-like in character. Lemon essence oil, rich in aldehydes, is isolated from juice concentration effluent. Lemon oil is used in making clear, "up"-type carbonated beverages, colas, juice drinks, alcoholic liqueurs and cordials, bakery and filling applications, salad dressings and other savory applications, candies and confections, and blended with other flavors in cereal coatings. When lemon oil is included in sweet spice flavors for baking, it enhances the kick of nutmeg. It is also useful in some non-citrus flavors, especially cherry and berry.

Lime oil: The peel oil of fruit grown in Florida and the Caribbean is usually harvested away from the fruit by expression into water and then by centrifugation. It has a sweet, aromatic and fresh quality typical of the lime fruit. Lime oil produced in Mexico, either by expression or distillation from the comminuted fruit, has a much different character. It is high in terpineol and other terpenes and lower in aldyhydes. The flavor is more solvent-like and tastes like lime lollipops; this is the variety most often used in candies, gelatin desserts and bakery applications. Both Florida type and Mexican type are widely used in beverages, including "up"-type lemon-lime clear carbonated beverages and colas. Terpineol is one of the notes that defines "cola" flavor.

Grapefruit oil: This oil is processed from fruit grown in the United States (California, Florida, Arizona and Texas) and Israel. It is expressed from the peel away from the juice. There are some flavor differences among white, red and pink varieties, but for most applications the cost of the oil from each source becomes more important

than the character. The flavor of grapefruit peel oil is quite complex, being sweet and aromatic as well as bitter. Naringen, a bittering agent, is made from grapefruit peel; the intensity of the bitterness of the finished beverage can be modified by adding this compound. The grapefruit essence oil contains nootkatone and sulfur compounds. It also contains menthene-8-thiol and p-mentha-8-thiol-3-one, which give a rich, sweet tropical fruit character to flavor compositions. Grapefruit juice and juice drinks have become more popular of late due to the healthful connotations. Grapefruit oil, especially grapefruit essence oil and isolates from these oils, is quite attractive for adding juicy character to other citrus flavors. It is useful in mango, papaya, guava and other tropical flavors.

Mandarin and tangerine: These are similar fruits. The Darcy variety of tangerine is grown in the United States. The expressed peel oil is the item of commerce. The oil quality is quite like that of sweet orange oil, but has richness attributable to the content of linalool, neral, geraniol and linalyl acetate. Tangerine oil is often blended with orange oil to give a fuller fruity flavor. Mandarins are grown in Spain and Italy. There is a distinct character difference between oils processed from green and red fruit. Mandarin oil contains a small amount of dimethyl anthranilate, which gives the oil a fruity character useful in grape and berry compositions, as well as citrus applications. Mandarin petitgrain oil is made by the distillation of leaves, twigs and unripe fruit. The terpeneless oil contains a large percentage of dimethyl anthranilate and a smaller amount of methyl anthranilate. This material is widely used in grape and berry flavors.

Bergamot oil: This oil is probably the least used of all the citrus oils in flavor compositions, although it is widely used in perfumery. The oil contains bergaptene, a skin sensitizer, which is removed from the expressed oil by vacuum distillation. Most bergamot is used in earl grey tea. It is sometimes added to orange and lemon flavors as a nuance note.

Removing Terpenes from Citrus Oils

Folded oils are more soluble and easier to use. "Folding" means that the oil is concentrated by removing a percentage or most of

the terpenes. The terpenes in citrus oils not only limit solubility, but make the oils susceptible to oxidation. However, the presence of some amount of terpenes enhances the character of the oil and gives freshness and fruit recognition in the finished flavor.

The most common means of folding citrus oil is vacuum distillation. A five-fold oil is one in which 80 percent of the volume is removed as terpenes. For example, if single-fold orange oil containing 95 percent terpenes is concentrated to five-fold oil, 24 percent of the terpenes will still remain in the folded oil. The five-fold citrus oil is more soluble, still has most of the terpene character retained and has reduced potential for oxidation. The oil must still be protected by adding an antioxidant. Mixed tocopherols solution in a neutral vegetable oil is a good antioxidant in keeping with a natural label. Other folds are made as well: ten-fold, twenty-fold and concentrations in between. Some of the higher folds have cooked notes that are useful in some applications, but I prefer the five-fold for its freshness. Soluble alcoholic solutions can be made with folded oils both for tasting and for incorporation into flavor formulas.

There are other methods for removing or limiting terpene content in citrus oils. One of the oldest (and most inefficient) is to make a water and alcohol "wash" of the oil. A solution is made of 5–8 percent single-fold oil, 60–70 percent alcohol and the remainder in deionized water. The solution is mixed for several hours and then chilled for 8–24 h. While keeping the mixture cold, the bottom layer is removed and filtered clear. This method is used for making most clear lemon-lime carbonated beverages. The oil left in the top layer, the "washed oil," although rich in terpenes, still has a lot of flavor left. It is often added to the next batch of oil to be processed until it is exhausted and sold for its terpene content as an industrial cleaner.

Column chromatography, solvent extraction and molecular distillation are other methods used to make citrus oils that are almost completely free from terpenes and sesquiterpenes. These methods use little or no heat, and the oils maintain a fresh citrus aroma rich in aldehydes. These oils are quite soluble and extremely concentrated with a taste threshold less than 1 ppm. These can be used as strong flavor reinforcers in compositions that contain more conventional oils.

Using Citrus Oils in Flavor Creation

T-1. Soluble lemon-lime flavor WONF for beverage use (parts weight)	
lemon oil California five-fold	5
lime oil Persian four-fold	3
citral, natural	0.2
decanal, natural	0.07
octanal, natural	0.02
lemon oil, terpeneless	0.01
alcohol 95 percent	91.7
mix for 3–4 h; chill for 8–24 h; filter cold; use level: 0.03–0.05 percent	

There is no water added to the flavor and no "washing" of the oils. The finished flavor has the taste of the whole oils. Although the terpeneless oil is expensive, the cost contribution is less than $0.04/lb in the flavor. The low use level and low terpene addition will produce a beverage that will be clear at the start and will remain clear on aging. Similar concentrated flavors can be formulated for orange, grapefruit and combination citrus beverages.

Cloudy Citrus Flavors

Cloudy citrus flavors are used in beverages—especially orange, lemonade-type and grapefruit—to give the appearance of juiciness and to enhance the use of color and shelf appeal. This cloudy appearance is achieved through making an emulsion out of the citrus oils. One factor to keep in mind in making emulsions is the specific gravity of the oils and the final beverage. Most citrus oils have a specific gravity of 0.82–0.88, and the beverages have a specific gravity of about 1.05 or more. If the oils were added to the beverage, even "solubilized" in an emulsion form, the oils would eventually rise to the surface making a visible ring around the top. The citrus oils need to be "weighted" to keep this from happening. The specific gravity has to be adjusted to 0.95 or more by mixing the flavor oils with a

material with a specific gravity greater than 1. The most common weighting agent used in the United States is the glyceryl ester of wood rosin, sold as ester gum, and often labeled on the beverage as glyceryl abiatate. This product comes in "kibbled" form and is only soluble in high enough amounts to be useful in terpenes (or citrus oils). It takes hours to dissolve, so for lab use I make a stock solution of 60 percent ester gum and 40 percent orange oil single-fold. Heat should never be used to hurry the process, as it will ruin the citrus oils. Ground ester gum is easier to dissolve, but the ester gum must be freshly ground and kept in a sealed package. The use level of ester gum is limited by regulation to 100 ppm in finished beverages. It gives a musty, cardboard-like flavor if the use level even approaches these limits. Another weighting agent that has been used in Canada, Europe and some parts of Asia, and has been approved for use in the United States, is sodium acetate iso butyrate (SAIB). The limit for its use is 300 ppm in beverages. It is a very thick, viscous liquid, but the addition of 10 percent alcohol makes it easier to pour; it can be purchased in this dilution. A third weighting agent that can be used is brominated vegetable oil (BVO). The use level allowed for BVO is only 15 ppm, but it has a high specific gravity, so a small amount used in conjunction with either of the other weighting agents can have a noticeable effect.

Acacia gum (gum arabic) and modified food starch (formulated especially for beverage emulsions) are two emulsifiers that are commonly used to make citrus beverage emulsions. Acacia gum is a natural product collected as a resin from acacia trees in Africa. The quality of the holding power of the gum will vary due to geography, species of the tree, weather conditions and processing. Reliance on a supplier that checks each batch for emulsion properties is required in order to make consistent flavor emulsions. The modified food starch is factory-made and more consistent in quality. It has good oil holding power at a reduced use level, and produces excellent beverage emulsions. Because of the inconsistencies in quality, availability and cost of acacia gum, I use modified food starch for most emulsions. I still prefer acacia gum for colas and dark-colored beverages that would be packaged in glass or clear plastic since starch emulsions

will sometimes show a slight white precipitate in the container as the beverage ages. Modified food starch is the emulsifier of choice for canned beverages and those packaged in opaque containers.

T-2. Natural orange flavor WONF for beverage use (parts weight)	
deionized water, 100°F	74.7
sodium benzoate	0.1
mix until dissolved; add:	
citric acid, anhydrous	0.2
mix until dissolved; add:	
acacia gum for beverage, agglomerated	18
mix gently until completely dissolved; let stand 4-8 h; add:	
orange oil WONF	7.
mix for 30-60 min; homogenize using a two stage homogenizer at 500-2000 psi for two passes; check particle size on a particle size analyzer; particles size should be 90 percent of particles less than 1.0 μ	

T-3. Orange oil WONF (parts weight)	
orange oil five-fold	29
tangerine oil five-fold	10
decanal, natural	0.1
octanal, natural	0.1
ethyl butyrate, natural	0.5
orange oil:ester gum 40:60	60
mixed tochopherols in soy oil	0.3
mix well; let oils stand overnight before using; add to aqueous gum phase; use level of the emulsion: 0.15-0.20 percent in beverage; add color as needed	

Other Citrus Emulsions

Citrus flavors can be made that are dispersible in applications other than beverages. These include dairy (ice cream, fruit ices, sorbets, yogurt, whipped topping), confectionery (starch-based candy, frosting, syrups), bakery (cookies, cakes, fillings) and topical cereal applications when alcohol solutions are not a good choice due to product ingredients, heat processing or label requirements. Weighting agents are not needed for these applications. Simple emulsions can be made using modified food starch or vegetable gums. Xanthan gum, and to a lesser extent tragacanth gum, are used most often to make these emulsions. Since these emulsions tend to be unstable, the finished emulsions are packed in smaller units that are easier to shake or mix before adding to the finished batches of food.

Citrus flavor oils, either "neat," without solvent, or in a neutral vegetable oil carrier are used for flavoring hard candies, taffies and chewing gum. The basic orange flavor WONF can be enhanced with the addition of citrus fractions, other essential oils and natural flavor materials. These are some ideas for making a "better" orange flavor:

• Orange essence oil three-fold to seven-fold	1–5 percent of the oil
• Orange oil terpeneless/sesquiterpeneless	0.01–0.05 percent of the oil
• Orange flowers absolute	0.01–0.05 percent of the oil
• Valencene, senensal or orange oil carboxyl fraction	0.05–0.10 percent of the oil
• Cassis absolute (0.10 percent in alcohol)	0.01–0.03 percent of the oil
• Natural acetaldehyde	0.25–1 percent of the total flavor*

*Extreme care must be taken when adding acetaldehyde to the flavor. It must be the last ingredient added to a cool batch and mixed quickly. The work area must be ventilated and the worker must wear respiratory safety equipment.

Citrus Oils for 100 Percent Juice Applications

When juices are concentrated, a certain amount of flavor material is removed, as well as the water. This "taste" fraction is often

captured and added back to the concentrate. The "add back" fraction is also available to the flavorist as a material for making "all-natural" named citrus flavors. The finished 100 percent juice beverage is made from the concentrate, water and all-natural flavor derived from the "add back" portion and other materials that are wholly sourced from the named fruit. This can include the peel oil, water phase and oil phase juice oils or fractions of these oils, which will enhance true fruit flavor and replace some of the aroma lost in processing. These flavors are called FTNF (from the named fruit).

Oleoresins

Essential oils possess and impart the aroma of the plant from which they were distilled, but lack the mouthfeel, color, heat principals and general spicy character of the whole plant. Oleoresins result from the solvent extraction of the whole plant and contain these missing factors. The solvent is removed by distillation, leaving only the residue permitted. Acetone has an allowable residual solvent level of 30 ppm; hexane, 25 ppm; isopropanol, 50 ppm; and chlorinated hydrocarbons, 30 ppm. Supercritical CO_2 extraction of the dry plant material produces excellent oleoresins without any solvent residue. The oleoresin is a thick, viscous, usually highly colored liquid. Some of the oleoresins are prized for the deep color, i.e. paprika, but most of the others go through a de-coloration treatment. Often the oleoresin is dispersed in a neutral vegetable oil and standardized with essential oil to replace some of the aromatics lost in processing. Most oleoresins are used to make seasoning blends by plating on salt or dextrose. These are used in bakery flavors, meat flavors, seasoning blends and other dry flavor applications. Oleoresins are often used "straight" in oil-soluble flavor applications as well. The most common oleoresins are paprika, capsicum, turmeric, black pepper, cinnamon, nutmeg, ginger, hops, vanilla and most varieties of herbs. Oleoresins are also used in water-soluble applications by making alcohol or alcohol/water solutions and filtering out the residue. Oleoresin ginger is used to make ginger ale beverage, which has the bite of ginger and can be augmented with the heat of capsicum. Capsicum heat is judged by trained panelists tasting and rating

the capsicum on a scale called Scoville units. It is commercially available at 300,000, 500,000 and 1 million units. Paprika is rated on the amount of red-orange color, and turmeric for its yellow-gold color.

The process for making ginger ale flavor is simple, but time consuming. Ginger ale sodas in the United States have less heat and more citrus character than those in Europe and in the Caribbean, where they are hot enough to bring tears to your eyes. My formula for making ginger ale flavor is less time consuming and allows the developer to adjust the ginger flavor and citrus flavor to meet the beverage profile required (T-4 through T-6).

T-4. Ginger flavor base (parts weight)

oleoresin ginger, African	3
oleoresin capsicum, 500,000 SU	0.2
alcohol 95 percent	98.8
mix for 2 h; add:	
magnesium carbonate	0.5 (helps precipitate the insolubles)
let stand 8-24 h; filter clear	

This formula can be modified to emphasize the heat or citrus contribution by adjusting the ratio between the two parts. Note that the source of each ingredient is identified as to the geography, heat value and process, but the supplier is left to the flavorist. There are differences in oleoresins and essential oils from supplier to supplier due to the quality and processing of the plant materials.

Oleoresins can be used in beverage flavors along with essential oils as part of emulsion systems. Oleoresins contribute the "whole spice" taste and mouthfeel to the beverage. An example is the use of oleoresins in the preparation of a natural cola flavor emulsion (T-7 through T-9).

T-5. Flavor topnotes for ginger ale (parts weight)

lime oil, expressed, four-fold	1
lemon oil, five-fold	1
orange oil, five-fold	0.1
ginger oil, African	2
nutmeg oil, East Indian	0.1
lavender flower oil	0.05
cassia bark oil, Chinese, redistilled	0.05
natural vanillin	1
alcohol 95 percent	94.7

mix for 1–2 h; chill overnight; filter clear

T-6. Ginger ale natural flavor (parts weight)

natural ginger ale flavor base	90
natural flavor topnotes	10

mix for 30 min; the finished flavor may need to be filtered; use level: 0.1–0.2 percent in a carbonated beverage; add to the syrup phase

T-7. Cola flavor oil (parts weight)

lemon oil two-fold, California type	34
lime oil, single-fold, distilled Mexican	47
cassia back oil, Chinese, redistilled	7
nutmeg oil East Indian	4
oleoresin cinnamon	5
oleoresin nutmeg	2
oleoresin basil	0.50
balsam tolu resin	0.50

mix for 3–4 h; allow oils to rest for 24–72 h before using

T-8. Cola emulsion (parts weight)	
water de-ionized	74.7
sodium benzoate	0.1
mix until dissolved; add:	
phosphoric acid, 85 percent	0.2
mix for 20–30 min; add:	
acacia gum for beverage, agglomerated	20
mix until completely dissolved; let stand 8–24 hours; add:	
cola oils	5
mix for 1–2 h; homogenize using a two-stage homogenizer set at 500–2000 psi; check particle size; optimum is 80 percent or better less than 1 μ	

T-9. Cola flavor concentrate with color (parts weight)	
caramel color, acid proof, two-fold	60
solid extract kola nut	1
solid extract St. John's bread roasted	1
vanilla extract ten-fold	0.5
natural vanillin (10 percent in alcohol)	0.5
cola emulsion	37
mix for 2–4 h; let age for at least a week before bottling; use level: 0.2–0.25 percent in a cola beverage containing 93 ppm of caffeine and acidified with phosphoric acid	

Concretes and Absolutes

Concretes are prepared very much like oleoresins in that the plant materials are extracted by solvents, after which the solvents are carefully removed by distillation. The usual materials that are extracted are more delicate, and include jasmine flowers, tuberose, violet leaves,

cassis and aged orris (iris) bulbs. Concretes are thick and turbid, containing the essential oils, waxes and non-flavor plant materials. Most concretes are converted to absolutes by alcoholic extraction, filtration and concentration by removing the alcohol. Sub-critical (low pressure) CO_2 extraction of dry botanicals gives flavor products that are very much like absolutes without going through the concrete stage. Because there are no distillation steps involved in removing a solvent, these are extremely concentrated and have very good flavor quality. Absolutes are much easier to use since they mix well with alcohol and with essential oils. They have strong flavor impact and add beautiful nuances to flavors. The one disadvantage of using these materials is cost. However, their strength and contribution to flavor quality makes their cost well worth it. Some of the many absolutes or concretes that I use in several different flavor compositions are discussed herein.

Boronia absolute: This absolute is prepared by extracting the concrete with ethanol and then concentrating the extract. The concrete is made by extracting boronia flowers with non-polar solvent and then removing the solvent by distillation. Boronia flowers are grown in the marshy areas of Australia. At one time there was more boronia absolute available than there were flowers in Australia. It was the only source of natural β-ionone available to flavorists, and thus in high demand. True boronia absolute contains 12–20 percent β-ionone, as well as methyl jasmonate. Boronia substitutes, made with all-natural materials, are now available. Natural β-ionone is also available, but boronia contributes more desirable character than using the ionone alone. Boronia absolute is used in raspberry and peach flavors

Cassis absolute: This absolute has the aroma that you "love to hate." It has a powerful sulfur chemical aroma with dirty urine-like notes that have been described as "cat box aroma." Before the isolation and manufacture of the various natural mercaptans and other thio-compounds available to the flavorist today, cassis and buchu leaf oil were all we had to give tropical notes to our flavors. I still like to use cassis absolute in berry, peach, grapefruit, some tropical and, of course, in characteristic cassis (black currant) alcoholic beverage flavor.

Jasmine absolute: Jasmine absolute is one of the "workhorses" among absolutes, especially the varieties that have high indol content. It has a strong, earthy, overripe floral character useful in grape, berry, peach, tropical fruit, apple, pear and cherry flavors.

Orris concrete: Made at 1 percent solution in alcohol, it contains several isomers of irone, a potent ingredient useful in blackberry, black raspberry and black cherry flavors, contributing seedy, ripe notes and true fruit character.

Osmanthus absolute: This absolute is produced by extracting the blossoms with non-polar solvent and then extracting the concrete with alcohol. The blossoms have a peach-apricot aroma. The absolute is rich in ionones as well as γ-decalactone and several δ-lactones. It is well suited to peach and apricot flavors, as well as mango and other sweet tropical fruit flavors.

Violet leaves absolute: This absolute was the only natural "green note" available to flavorists of old. The character is more mossy and leaf-like than hexenol and its esters. It is useful in red raspberry, strawberry, currant and other berries to give a green stem-like character.

Fluid Extracts and Solid Extracts

Fluid extracts are made by extracting the plant materials with alcohol and water. The solvent is left in the extract, which is usually concentrated to yield a consistent product with a uniform ratio to the plant material. Fluid extracts are often made of pharmaceutically "active" materials and have found new use in making nutraceutical beverages and tonics.

The most widely used fluid extract is vanilla extract, which is probably the most regulated of all flavor materials. Single-fold vanilla extract is made by extracting 13.35 oz of vanilla beans containing no more than 25 percent moisture in an alcohol/water solution to make one gallon of extract. The finished extract, which must contain at least 35 percent alcohol by volume. "Folds" are made by adding more beans proportionately. Vanilla manufacturers usually make a three-fold vanilla extract, which is then either diluted or concentrated to achieve the desired fold. Vanilla quality and price are related to

the geography of the beans, weather conditions, local politics, plant diseases and other disasters that affect availability. Vanilla extract is used in making vanilla and chocolate flavors, as well as other brown flavors, such as caramel and butterscotch. Another important use is in beverage flavors—cola, ginger ale and natural cream soda flavors. Vanilla acts as a unifier in most fruit flavors, softening and modifying the other flavor materials, as well as making the flavor a little more difficult to analyze and duplicate.

Other "fluid extracts" that have been used for centuries are made from ordinary foodstuffs. These include roasted coffee, black tea (fermented green tea) and roasted cocoa beans, or nibs. These are usually water extracts that are brewed or concentrated to make them strong enough to be used in flavor creation. Alcohol, propylene glycol or glycerin is added after concentration to prevent mold growth.

Solid extracts are made from whole plants by extracting the materials with alcohol, acetone and other polar solvents and then removing the solvent. The result is a thick product containing complex sugars, alkaloids and bittering agents. These products are standardized and solubilized by adding propylene glycol or glycerin and colored with caramel color. Solid extracts add flavor, mouthfeel,

T-10. Natural maple flavor WONF (parts weight)

solid extract fenugreek	5
solid extract St. John's bread	2
solid extract mountain maple	1
propylene glycol	64
mix until completely dissolved; add:	
deionized water	10
maple syrup	10
molasses	4
mix for 20–30 min; add:	
natural topnotes for maple (see below)	4
mix for 20–30 min; let stand 8–24 h	

T-11. Natural topnotes for maple (parts weight)	
propylene glycol	89
natural maltol	2
natural methyl cyclo pentenalone (cyclotene)	3
natural vanillin	1
natural diacetyl	1
natural ethyl butyrate	3
natural furfural	1
mix for 1–2 h until all powders are dissolved	

bitterness, sweetness and/or astringency to flavor compositions. The flavor impact of brown notes of some solid extracts like fenugreek, St. John's Bread, coffee and cocoa are increased by roasting the material before extraction. Some flavors, like maple, are almost entirely based on solid extracts.

Many solid extracts are used for their contribution of bitterness and/or astringency. Some of these are: gentian, quassia, chestnut leaves and black walnut hulls.

Natural Distillates

Fluid extracts can be concentrated by distillation; the flavor-imbued "essence" from the concentration can be used as a flavor material. For instance, the flavor material "coffee distillate" with added alcohol can be distilled, and the essence concentrated further to yield a clear "coffee distillate" that would have strong coffee aroma without the "body" and bitterness of brewed coffee. This can be added to coffee beverages to increase the aroma of the finished drink.

Similarly, natural distillates can be obtained from fruit juices on concentration. Some of these "essences" are added back to the concentrated juices so that the juices retain their aroma on reconstitution, but there are extra essences available for flavor application. In some cases, these distillates are concentrated further by vacuum or column distillation and other processes to yield very strong fruit

T-12. Natural coffee flavor WONF (parts weight)	
deionized water 160°F	43
instant coffee powder	4
mix until completely dissolved; add:	
propylene glycol	34
mix 30–40 min; add the following mixture:	
solid extract coffee	5
solid extract St. John's bread	2
solid extract chickory	1
mix until completely dispersed; add:	
natural topnote for coffee	8
mix 20–30 min; add:	
coffee distillate	2
cocoa distillate	1
mix 20–30 min	

T-13. Natural coffee topnote flavor (parts weight)	
propylene glycol	91.9
methyl cyclo pentenalone	3
natural maltol	2
mix until dissolved; add:	
natural furfural	2
natural furfural mercaptan (1 percent in PG)	1
natural trimethyl pyrazine (1 percent in PG)	0.1
mix for 20–30 min; use a hood when making dilutions	

distillates. These can be used in all-from-the-fruit flavor compositions most popular for products in Europe.

About Solvents

For most natural flavors that are meant to be water-soluble, alcohol 95 percent is the solvent of choice. A stock solution of

alcohol should be "denatured" by adding 2–3 percent natural triethyl citrate, 50 percent propylene glycol, 5 percent citric acid or a small amount of an essential oil. The alcohol needs to be judged as being "non-potable." The formula and samples of the "denatured" alcohol have to be submitted to the Alcohol and Tobacco Tax and Trade Bureau (TTB) in Washington, DC. There, the potability is tested by diluting one's sample to 15 percent alcohol by volume and tasting by a panel. If it is judged to be non-potable, it is assigned a tax number and can be used in formulas without having to submit these for testing.

Propylene glycol is an excellent solvent, especially if solid extracts are used since direct use of alcohol will cause these extracts to precipitate. Some customers, wanting "all-natural" flavors, consider propylene glycol as "artificial" and do not want this used in their flavors. Natural glycerin can be used instead.

For oil-soluble flavors for spice blends and hard candies, vegetable oils or fractionated vegetable oil-medium chain triglycerides (MCT) can be used.

Natural triethyl citrate and triacetin can be used as solvents for both water- and oil-soluble flavor applications; however, these solvents can add unwanted bitterness or a fatty aftertaste.

I've shown some natural WONF flavor formulas that contain essential oils, absolutes, solid extracts, fluid extracts, oleoresins and

T-14. Natural cherry flavor WONF (parts weight)

propylene glycol	80
fluid extract wild cherry bark	4
solid extract gentian	1
black cherry juice concentrate	10
mix for 30–60 min until all the extracts are dissolved; add:	
natural cherry flavor topnotes	5
mix for 20–30 min	

a lot of natural chemical materials. Here are a few more for you to try out for yourselves. Some of the formulas use several dilutions, or "cuts," of the more potent ingredients. If you were writing these for production you would need to make a sub-compound of these lesser ingredients. Otherwise, your production manager would really be annoyed with you since this would cause the operator to make several additional steps in compounding and cause your QC department extra work as well.

These flavor formulations were not meant to be examples of the "best" flavors, but rather to show how all the categories of natural materials can be used to creative advantage. Broadening your knowledge and adding to your "palette" of ingredients will enable you to be the great flavorists of tomorrow!

T-15. Natural cherry topnote flavor (parts weight)

alcohol 95 percent	43
natural benzaldehyde	18
natural isoamyl acetate	5
natural whiskey fusel oil	3
natural phenyl ethyl acetate	3
natural *cis*-3-hexenol	0.5
natural ethyl-2-methyl butyrate	4
natural glacial acetic acid	8
natural β-ionone	0.2
natural maltol	3
rose oil (1 percent in alcohol)	1
jasmine absolute (1 percent in alcohol)	1
ambrette seed oil (0.1 percent in alcohol)	1
natural furfural	1.3
natural ethyl acetate	8

mix for 30–60 min; let stand, covered, for 24 h before using

T-16. Natural red raspberry flavor WONF(parts weight)

alcohol 95 percent	58
glycerin, natural, kosher	20
natural raspberry ketone	3
natural maltol	3
natural vanillin	1
mix until powders are dissolved; add:	
natural raspberry flavor topnotes	3
mix for 20–30 minutes. Add:	
red raspberry juice concentrate	10
apple essence 300-fold	2
mix for 20–30 min	

T-17. Natural red raspberry topnotes (parts weight)

alcohol 95 percent	77
orris root concrete (1 percent in alcohol)	2
natural α-ionone	0.3
natural β-ionone	1
natural *cis*-3-hexenol	2
natural *cis*-3-hexenyl acetate	3
natural ethyl acetate	8
natural ethyl butyrate	3
natural dimethyl sulfide (1 percent in alcohol)	2
jasmine absolute (1 percent in alcohol)	1
violet leaves absolute (1 percent in alcohol)	0.7
mix for 30–60 min; let stand, covered, for 24 h before using	

T-18. Natural peach flavor WONF (parts weight)

propylene glycol	83
solid extract walnut hulls	2
mix until completely dissolved; add:	
peach juice concentrate	5
peach essence	5
mix 30–60 min; add:	
natural peach flavor topnotes	5
mix 20–30 min	

T-19. Natural peach flavor topnotes (parts weight)

alcohol 95 percent	61
natural benzaldehyde	5
natural benzyl alcohol	5
natural ethyl-2-methyl butyrate	5
natural *cis*-3-hexenol	3
natural undecalactone	3
natural ethyl acetate	8
natural ethyl butyrate	4
boronia absolute (1 percent in alcohol)	1
osmathus absolute (1 percent in alcohol)	1
rose oil (1 percent in alcohol)	1
natural thiomenthone (1 percent in alcohol)	1
Add with care:	
natural acetaldehyde	2
mix for 10–20 min; let stand, covered, for 24 h before using	

Natural Chemicals Made for Flavors

Let's go back to the early 1970s to the time that customer marketing departments were demanding natural flavors, and the flavorists truly had limited natural ingredients at their disposal. The new regulations and definition of "natural" left the door wide open for innovative creation of the natural materials so desperately needed by creative flavorists. Most of the larger flavor companies added or expanded their research departments to find sources of new chemicals through physical means, microbiology, fermentation, isolation from natural materials, and cooking or roasting. Many of these discoveries remained "captive," and these companies had the advantage of improved natural flavors. This situation continues to this day, but some of the materials held as captive are now being released to the flavor world at a high price.

Independent chemists formed their own companies, which would sell their developments to whoever wanted to buy them. The first series of chemicals to arrive on the market were natural esters formed by physical reaction of ethyl alcohol and the corresponding fatty acids from fractionation of vegetable oils or by fermentation. There was a lot of soul-searching and discussion as to whether these chemicals were truly natural. Next came the products of fermentation. Some of these, like diacetyl and butyric and other low fatty acids from fermenting milkfat, were easy to accept. Some companies found techniques for "teaching" microbes to produce the desired chemical. More soul-searching was done by flavor creators and flavor users. One company that I know of gave presentations to their customers in which they said they would never use these "natural" chemicals in their flavors. The customers applauded and then bought the new, improved flavors elsewhere. The use of any and all natural materials that were available became an economic necessity. It was no longer possible to rely on the materials that were produced "in-house." The flavorist had to shop at many sources and take chances as to the veracity of the chemicals available. There were the "certificates of natural" that accompanied each new chemical, but if there was still doubt, the material could be sent for carbon-14 dating. Several "natural" chemical suppliers had to clean up their manufacture or

withdraw the chemicals. There are suppliers today for nearly every natural material found in nature. Some still hold many of these captive. When a flavor is analyzed today, it is hard to say that it is "sophisticated" when a chemical is found that is not available as a natural. The flavor company may very well be "smarter" than the rest of the industry.

Natural flavor ingredient suppliers are facing a tight competitive market today. There are new materials available, and established ingredients are being sold at lower and lower cost. The flavorist still has some soul-searching to do. Some of the new materials haven't been shown to occur in nature. New supply markets have opened from laboratories in China and other Asian counties as well as Eastern Europe. Who's there to vouch for the "natural-ness" or even food safety manufacture of these materials?

Natural flavor ingredients made in laboratories have been a large boon to the flavor industry and to the creative flavorist. It has enabled us to go beyond the natural materials available strictly from plants and isolation techniques. However, we cannot forget the many wonderful materials that existed before the 1970s and use only the natural chemicals to make only natural "synthetic" flavors.

Tying it All Together

How do you get to know about all flavor materials, how they are processed and how to use them? "Hands-on" is the only way. Source books can tell you about geography and processing, I can tell you about my perception in smelling and tasting the materials and suggestions of where these can be used, but only your own experience can broaden your knowledge and improve your capabilities. The highlights of my career as a senior flavorist and teacher were the two trips I took to Spain and to Italy and Sicily with the group Women in Flavor and Fragrance Commerce. There, I saw the products growing, visited the manufacturing sites where they were turned into flavor materials and smelled and tasted the fresh products. I saw processing of citrus peel oils, manufacture of paprika oleoresin, terpene fractionation, production of jasmine absolute, and basil oil harvested and distilled. I saw *Cistus labdanum* being processed in the

field using bonfires and oil drums. Most of all, I enjoyed the hospitality and courtesy of our many hosts who invited us into their plants and into their homes. You might not be able to take trips like these, but you could ask your suppliers if they would allow you to visit their facilities. Most would be more than happy for you to do so and to talk to their chemists. In the meantime, try out some of my ideas in your own creations. You might have to use your lunch breaks or stay in the lab after work to do this self-teaching. Just remember to read, smell and taste!

Recommended Sources

All of the flavor formulations and most of the history of the use of natural ingredients come straight from my brain, and this information is often difficult to find in any publication. In addition to references of flavor materials, a flavorist should know as much as possible about flavor applications. Read all the trade magazines that come into your company that are specific to beverage, confectionery, dairy, bakery and other segment marketing. Talk to the sales representatives and technical people from your suppliers to keep up to date on new natural flavor ingredients. Attend meetings of The Society of Flavor Chemists to network with other flavorists. Go to the Food Technology convention and Expo at least every other year.

A flavorist should have the following books and publications available as daily references:

- *Fenaroli's Handbook of Flavor Ingredients, Fourth Edition.* Edit., George Burdock, CRC Press (2002).
- *Allured's Flavor and Fragrance Materials.* Allured Publishing Corp. (2005 or later editions).
- *Perfumer & Flavorist* magazine. Allured Publishing Corp.
- *Food Technology.* Institute of Food Technology.
- *Code of Federal Regulations, Title 21.*

Other suggested sources:

- *Encyclopedia of Common Natural Ingredients, Second Edition.* Edits., Albert Y. Leung and Steven Foster, John Wiley and Sons (1996).
- Brian Lawrence, *Essential Oils.* Allured Publishing Corp.
- *Journal of Food Science*, Institute of Food Technology.
- John Wright, *Flavor Creation.* Allured Publishing Corp.
- *Journal of Essential Oil Research*, Allured Publishing Corp.

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2. Carol Pollock, *WFFC Trip to Italy and Sicily.* Perfum. Flavor., July (2003).
3. Kurt Kulka, *Historical Development of Essential Oils.* Perfum. Flavor., January (1979).
4. David Moyler, *Oleoresins, Tinctures and Extracts.* In: *Food Flavourings.* Edit., P.R. Hurst, Van Nostrand & Reinhold (1991).

Written by some of the most respected flavorists working today, ***Successful Flavors: From formulation to QC to applications and beyond*** covers a broad range of flavor creation. With an extensive introduction written by the editor, Gerard Mosciano, this indispensable resource covers the following topics: the role of organoleptic descriptive analysis, flavor extraction and instrumental analysis, quality in the flavor industry, flavor applications, dairy flavors, practical meat flavor creation, vanilla, mint, flavoring confections and the use of natural ingredients in creating natural flavors. *Successful Flavors* is, above all else, a practical guide for novices and experts alike. Flavor chemistry is one of the few professions that still relies on direct training from an experienced flavorist. *Successful Flavors* assists anyone in learning the craft directly from the leaders in the industry!



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