FUNDAMENTALS OF FLAVOR CHARACTERIZATION

by

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Flavor concerns food, and people. Half of the well-worn saying "we live to eat" is bound up with the highly developed ability in most people to appreciate flavor. Some of us are keenly alive to flavor and are guided consciously by its manifestations; others are profoundly influenced by it even though but dimly aware of its existence until some change in activities brings it to their attention. Flavor is so important that we have two highly cultivated senses devoted to it exclusively, and two others, the senses of feeling and sight, which are useful auxiliaries. Fundamental psychology and genetics are involved in the question of whether we inherit liking for certain flavors and abhorrence for others, or whether these reactions are a product of our environment and experience.

The flavor of food is made up chiefly of two components, odor and the reactions of the taste buds. In addition feelings of softness or hardness, smoothness or scratchiness, and factors connected with appearance are very important to us in total flavor. (18, 19)

Foods appeal to us through several senses simultaneously or nearly so, and the impressions produced by these senses are integrated in the brain as "quality" for an overall acceptance or rejection reaction. Generally, the first sense used is sight. If the article is recognized as like something that gave satisfaction previously, then it may be examined further for flavor and general acceptability. Its appraisal is by then well launched. If the food does not look right, which means customary, some reasoning is then done to find out what is amiss, and whether or not it is considered safe for further testing.

Our present reactions toward foods are really the accumulated wisdom of the ages. (17) That wisdom was acquired mostly before the days of food laws or of adequat refrigeration. Some of it was dictated by wise leaders in the form of a religious code of what was then safe to eat and what not. Crosby Gaige (32) has put it this way, "The science of nutrition comprises the sum total of human experience as to which of nature's gifts from field and forest and stream may be safely and wisely used for the sustenance of human life. That science, originally the most empiric of all, was based upon thousands of years of adventurous experiment. Of late, almost within our own day, it has become a matter of supreme preoccupation for the laboratory, the microscope, the crucible and the test tube. The business of properly cooking and seasoning.........is an art. The sense of taste and the sense of smell govern the palate and mete out for each one of us, according to our merits and our perceptions, the exact degree of enjoyment that we get from our daily bread."

Another writer emphasizes the importance to nutrition of study of the acceptability of food. (36) The reasons that bread may be eaten in large amounts constantly, that some other foods are taken in smaller amounts, habitually, "are not clearly understood. The psychological reactions of human beings to food have been studied very extensively. The importance of taste, texture, odor and color, temperature and habit has been appreciated and studied....It is possible that a better understanding of the physiological effects of food will help explain psychological reactions to food and throw more light on the over-all problem of food acceptance." The last war showed how large a part is played by familiarity and custom as vividly as any recent experience with food.

The new feature about flavor today is the desire to understand it and to apply this understanding to the improvement of foods in a commercial way. In essence, it is the wish to improve dollar volume through better consumer acceptance.(15)

In this paper, we shall divide flavor into its components and consider the physics and chemistry of each, in turn. We will discuss the flavor-detecting organism and arrive at a working philosophy. Then specific matters of organoleptics will be discussed, with methods of tasting and interpretation of findings. Finally, examples will be given of the flavor analysis of specific foods.

II Elements of Flavor

The so-called "chemical" senses involved in flavor detection include smell, taste and part of mouthfeel. The physical senses used are the rest of mouthfeel, hearing and seeing. The terms "chemical" and "physical" in these instances characterize the nature of the stimulus rather than its mode of operation.

As Moncrieff(39) sees it: "Flavor....comprises taste, odor, roughness or smoothness, hotness or coldness, and pungency or blandness. The factor which has the greatest influence is odor.....I think it is legitimate to include roughness or smoothness as a flavor factor....Hotness may be sensed either as a result of applying food at a high temperature....or by tasting ginger....Similarly, coldness may be due to a change in temperature or to tasting peppermint, which has a cooling taste."

The term "flavor" applies to food, medicine, beverage, or smoke, or in general to awareness whenever several senses are involved. It applies to the substance as such plus whatever it may have picked up or developed on handling, holding, processing or packaging. In practice, one form of processing for a food may be preferred over another principally because of better flavor retention. There are many problems of containers, to find those which neither react chemically with the food nor contaminate it with taste or odor. (15, 17, 18, 27)

III Chemistry and Physics of Flavor

Odor

Odor is a general property of chemical substances. Molecules fly off from solid or liquid materials to permeate the air we breathe and those of gaseous materials are already vaporized. With foods, there is usually evaporation of water, and as the molecules of water vapor leave the substance, they help carry off heavy as well as light molecules of odoriferous materials, often where these would not evaporate appreciably without the help of the evaporating moisture. Thus evaporation and steam-distillation processes, which are well known to the chemical engineer, are involved in the production of odors.

The actual quantity of matter required for a smell sensation is amazingly small, something of the order of a millionth of a milligram. Yet small as is this actual quantity of matter, it consists of millions of millions of molecules. Apparently, smelling for man, who is "microsmatic" or relatively poor as a smeller, is a sort of mass bombardment phenomenon, else it would not require such large numbers of molecules to operate it. A compensating factor is that the stimulating particles are individually very minute. In man, the sense of smell, although only moderately keen, still is many time more acute than sensitivity to taste. It is particularly acute to certain chemical radicals, such as the carbonyl group, or to mercaptan sulfur, that component of odor which brings delight with coffee aroma and a quite different reaction with the skunk's effusion.

Scented air has to be brought to the relatively inaccessible odor-detecting areas, which are located high in the nose on either side of the top of the nasal septum. In ordinary breathing, almost no odor reaches the smelling region as air is inhaled, and odor is pretty well stripped from the air by the time it is exhaled. A direct sniff throws some of the inhaled air up into the detecting region and makes smelling possible. The volume of a useful sniff is measurable by the Elsberg air-injecting apparatus,(2) and varies from less than 5 milliliters of scented air for a good smeller through perhaps 20 milliliters for an average smeller to 40 milliliters or more for a poor smeller.(18) A second way of having odor brought to the smelling area is to have it forced up from the throat during the bellows-like action that accompanies the act of deglutition or swallowing. At the time of swallowing, most foods have been warmed, moistened and well comminuted, so that considerable odor is usually present. Actually, this by-way-of-mouth method of smelling is several time as effective as direct sniffing and will find odor readily in nuts, grains and fats, which have but weak odors when smelled directly.

Very little is known about the mechanism of odor detection, but hypotheses or theories are plentiful. It is hoped that some kind of crucial experiment can be devised soon that will show clearly which category or combination of categories of explanation is the true one. Once on the right road with certainty, details can be worked out with more confidence than exists at present. Odor is called one of the chemical senses, regardless of what the mechanism of detection may be, because it is stimulated by chemical substances.

The Crocker-Henderson system of odor classification (18,19,22,39) defines every odor sensation as a composite of four constituent odor sensations: fragrant, acid, burnt, and caprylic, each of which component may be concentrated upon, oblivious of the other three. Every odor is assumed as composed of one to eight degrees of intensity of each of the four components, expressible as a four digit number, such as 7335 for geraniole or 6238 for indole. Whether any odor has actually zero intensity for any component is questionable. Thus, every odor is conceived of as having the capacity for stimulating four kinds of osmic nerves, each responding to a single component only.

Taste

Taste also is of vital importance in flavor. It functions usually after the foods are placed in the mouth, but in a very few instances, as with sulfur dioxide, oil of anise, and oil of limes distilled, we may taste the substance from the air, inhaled by mouth or even by nose.

Four basic or primary tastes are recognized: sour, sweet, salty, and bitter. Sour is due to the hydrogen ion only; salty taste is also a function of ions and is specifically due to monovalent ion combinations; sweet is produced by hydroxy, amino or nitro groups in the organic and nonionic classes, and by certain metallic ions as beryllium, cobalt, and lead; bitter is a sensation influenced by relatively high molecular weight in any series of chemical compounds.(18, 31) There may even be three distinct kinds of bitter, depending on the other taste elements with which they are associated. For instance, stimuli of sweetness tend to taste bitter as well as sweet at high molecular weights, high-molecular salts taste bitter as well as salty, and even some high-molecular acids have bitterness as well as sourness.

Much higher quantities of substances are required for stimulation of taste than that for odor, as shown by a few taste threshold values reported in the literature. (35, 38) Some people are blind to one or more of the fundamental tastes, and this is an inherited characteristic.

Detection of taste is accomplished on localized "buds" or "pits" on the tongue, and not on the palate, gums or cheeks.(1, 6, 7) The substance has to be in solution, in water or saliva, in order to reach the detecting sites and be tasted. Here, as with odor, the actual mechanism of detection is unknown. We can taste either ions or molecules in solution and each one of the four elementary tastes, sweetness, sourness, saltiness, and bitterness, appears to be detected by specific loci, located on limited areas on the tongue. Taste is called a chemical sense because it, like odor, is stimulated (in some unknown way) by chemical substances.

Parker(42) dwells histologically on the "anatomy of the gustatory organ" and gives drawings to show types and locations of taste centers. Apparently the sense of taste decreases as one grows up, for it is stated that infants have more buds than do adults.

Tactual Properties

Mouthfeel is sometimes physical, as when we note temperature or texture of food, and sometimes chemical, as when the stimulus is a chemical ingredient, say of a spice. Mouthfeel is detected by the sense of touch, which involves the temperature factors of warmth and coolness, the contact factor of consistency, and pain. There might advisedly be included certain kinesthetic considerations such as viscosity, toughness or brittleness, which are perceived while masticatory work is being done.

The nerves involved in mouthfeel are apparently the same kinds responsible for feeling all over the outside of the body, although they appear to be especially sensitive when operating in the buccal mucosa. There can also be chemical influence on the temperature-detecting nerves, as when menthol increases the sensitivity to coolness or ginger to warmth. Nearly all strong tastes, including those of acids and spices, have an element of sting or pain as part of the mouthfeel. There is also pain in the nose, called "pungency", noted when certain strong odors are smelled.

The accessory factor of sound, which acts physically, sometimes has important influence on flavor perception. No tasting at all can be done in a very noisy place, although all the din of a nightclub cannot do away entirely with the need of quality in the food served. The eating of foods is often accompanied by sounds which may be used for confirmatory purposes, such as the crisp snap of a fresh cracker, and the crunch of a ripe apple or a stalk of celery.

Appearance, or the application of the sense of sight, is of vital importance in food. Usually it is the first sense applied to the evaluation of quality. If an article is seriously off-color, it fails at the first hurdle, and does not have further opportunity to be judged on its other merits. Appearance takes in not only size and color but obvious cleanliness. For folks sufficiently appreciative, appropriate color schemes and other evidences of consideration of detail may cause immediate reactions, favorable or otherwise.(16,18,25,26,27,28)

IV The Flavor-Detecting Organism

For all practical purposes, flavor detection is done by the human nose and mouth. No mechanical or electrical devices are known, as yet, which give scale or chart readings for any but exceptional instances(23,24,52), and then usually only when the flavor is of many time normal intensity. An article by Lionel Farber, to appear in Food Technology, describes a method by which certain kinds of odors may by accumulated and measured as units of chemical reducing action. Infrared light analysis and the mass spectrograph have limited and specific applications. The human organism is convenient and sensitive, with limitations as well as possibilities, and these have to be taken into account if reliable results are to be obtained. However, it is operative over the entire range of flavors.

The flavor panel has as yet no resort to any instrument such as that recently announced as a stand-in for the eye, especially to distinguish among colors. The Librascope Tristimulus Integrator, recently announced by General Aniline & Film Corporation, is said to distinguish a hundred million degrees of color, and to be able to match any two in 2.5 minutes.(34) Colors can now be designated by a number which characterizes the eye response, and the reflectance and transmittance of any color, in kind and degree. The new instrument integrates continuously over all portions of the visible spectrum.

In lieu of an integrator, the worker in flavor really has just begun, but already has made noteworthy progress in bringing together the sensations of olfaction, gustation, sight, and sense of well-being to a standard of flavor evaluation. As early as 1937 the American Chemical Society held a symposium on flavors in foods(17), and this started off, or at least intensified, a great volume of work on commodity testing. Contributors have come from the ranks of those interested in chemistry and statistics, anatomy and physiology, psychology and genetics, those in the food industry and those chiefly concerned with "the good life."

Recent workers are finding that a large proportion--something of the order of 70 to 75 per cent of people have really good senses of smell and taste, with the relatively taste-blind person the exception rather than the rule(4,5,45,46,53), using the test substance phenylthiocarbamide. Only a small part of this majority of people, however, has the interest, discrimination, concentration, and power of expression to be useful tasters, even though the detecting mechanism is good. Most people are helpless about flavor, knowing well enough what they like but are quite inarticulate in describing it. The only proper attitude to take regarding flavor is to consider that nearly all people are influenced by its quality, and that the mass market is a fussy one.

The physiological conditions requisite to good flavor perception are relatively simple: good health, opportunity to concentrate on smelling and tasting, and a sufficient period of elapsed time since the last meal.(14,16,26,38,40,43,55) The psychological twists are many that may cause one person to choose what another will not have. Choices are often made for reasons unknown to the person, as, for instance, when slightly-scented hosiery is chosen over unscented where the buyer didn't even realize that she had used smell in making a quality judgment.

Appearance, smell, taste, and mouthfell reactions usually are treated simultaneously by the brain in arriving at a quality "Gestalt", or over-all impression, of the sampled food. The impression arrived at is expressed as satisfaction or otherwise, or in the objective sense, as "total quality". This concept of "total quality" has been treated mathematically by Plank,(44) Jakobsen, and others, in attempts to arrive at rational one-figure grades, best when based on the harmonic mean.

V Organoleptics

The famous physicist, Max Plank, in discussing "The Meaning and Limits of Exact Science," concludes: "Among the facts that we do know, and can report to each other, which is the one that is absolutely the most certain, the one that is not open even to the most minute doubt? This question admits of but one answer: 'That which we experience with our own body.' And since exact science deals with the exploration of the outside world, we may immediately go on to say: 'They are the impressions we receive in life from the outside world, directly through our sense organs, the eyes, ears, etc.' If we see, hear, or touch something, it is clearly a given fact which no skeptic can endanger.

"The content of the sense world is, in any case, only something of a subjective character. Every individual has his own senses, and in general the senses of one individual are quite different from those of another, whereas the aim of exact science is to achieve objective, universally valid knowledge. It may seem, therefore, that in adopting our present approach we have been following the wrong track.

"But we must not jump to conclusions. For it will become manifest that considerable progress can be made along the line of advance now open to us. Considered as a whole, the matter reduces itself to the fact that we human beings have no direct access to the knowledge conveyed to us by exact science, but must acquire it one by one, step by step, at the cost of painstaking labors of years and centuries."

The term "organoleptic" means "affecting or making an impression upon an organ or on the whole organism--capable of receiving an impression". This is derived from organon and lambainein--to lay hold of an organ. "Organoleptics", as used in flavor discussions, is the term covering the acquisition of specific information about foods, beverages, smoke, etc. through the senses, primarily through smell, taste and feeling, and secondarily through sight and hearing.

The aim of food workers is to measure, and ultimately, to improve, consumer acceptance.(11,25) Sometimes this means trouble-shooting, and somtimes creation of a new flavor. The food world is so old, however, in a relative sense, that food workers are far more likely to work on the improvement of existing types than they are to be making new ones.

Organoleptics is largely a subjective practice, but, pending the accumulation of data and development of adequate instrumentation, it is the accepted and only means for studying food "acceptability". One can sample the public in a large way to find our whether people will buy a particular product or which one of two they choose.

For most scientific and industrial work, where a close approach to objectivity is desired, recourse can be had to the expert taster, who has been trained to judge intensities and to make quality comparisons in a largely impersonal way. Much use is made of trained individual scorers for dairy products, coffee and wine, but for general laboratory work the preferred testing mechanism is the taste panel rather than the individual, to lessen bias and increase accuracy. For preliminary work this may be a small group of three to five individuals, which makes the first gross evaluations, sets up descriptive terms and becomes practiced in scoring the intensity or quality of the various organoleptic characteristics.

Individuals vary in their ability to taste and smell, both qualitatively and quantitatively, but, so well do they adjust to the physical world, that it usually takes careful tests to find out the reality of any variations. Individuals should be picked with great care for membership in food panels, not only to avoid those who are partially smell-blind or taste-blind, but also those who exaggerate certain characteristics. Even at best, however, everyone has good and bad days and is subject to occasional psychological reactions which make him less dependable than an impersonal instrument. Threshold tests for sensitivity to the basic tastes and to odors may be run, and preference tests to determine consistency of choice, but part of the testing should be done on actual foods. The triangular test or odd-sample test has long been used for determining the reliability of tasters as well as the significance of subjective test results.

The organoleptic testing of food can be carried out for many purposes and in various ways, with all degrees of subjectivity or objectivity. Its success for a particular purpose will depend largely upon the appropriateness of the testing method used. We list a number of types herewith, as examples. Proper use of any one of these can have important commercial application.

1. Inspection according to grade, scoring for points off from an arbitrary standard, for "imperfections". Used for canned fruits and vegetables, milk, butter, cheese, and meat.

2. Quality control by a panel of tasters, insuring constant quality, within minor variations, to preserve product identity. Used for food specialities such as ice cream, candy, chewing gum and beverages, as also for fats, oils, and shortenings.

3. Tasting for purchase or sale of highly variable articles, according to their characteristics and especially flavor. Used for tea, coffee, and wine.

4. Research study, by professional panels, during the running down of troubles and the development of new or improved articles.

5. "Hedonic" rating or pleasurableness score, for esthetic purposes, particularly for anticipating the possible popularity of entirely new articles.

6. Consumer panels, field tests or population acceptance studies, to obtain consumer reactions and estimate sales potential.

<u>Working Conditions</u>

After the panel has been established, the environment of tasting is important. Reasonable quiet, little interruption, a room conditioned for freedom from odor, and with controlled temperature and humidity, if possible. The most important consideration for good working is not the physical details of the environment so much as it is the psychological factors, which means the ability of the tasters to relax and concentrate upon their work. Usually this means comfortable surroundings, good equipment and freedom from telephone calls and visitors during tasting, but always it means a feeling that tasting is the main job at the time and worthy of full attention.

Individual panel booths, neutral in color and with special lighting either to keep the food colors natural or to have them modified by filtered light are described by Dove (27). Most laboratories do quite well without booths. Many workers recommend unrestricted sampling and plenty of time, not only to make the judgment but to allow for aftertaste evaluation. The temperature at which the food is served is important and will vary with the character of the food. The taste buds usually are most sensitive to foods at or near "room temperature".

Perhaps the most important factor in working conditions is experience, on the part of the individuals and with their working together as a panel. Experience has to be gained with each kind of food, too, before findings can have real meaning. An active panel always has a fine <u>esprit de corps</u>, which makes the work more a pleasure than a task. The panel members get to think and express flavors alike. The discussion that follows each tasting session is valuable in building and maintaining the confidence of the tasters and for their general education. Usually, not many observations are available for statistical evaluation, yet the work of a good panel can be highly efficient and of practical utility.

<u>Technique of Organoleptic Examination</u>

Flavor is generally complex, and the desirable first move is to break it down into parts, each of which can be handled easily. Naturally, eye examination comes first, for color and other appearance factors, unless this type of examination is denied the taster by having the sample, often coded, placed in opaque or colored containers, or using dim or colored light (blindfold test). Then comes sniffing, for odor factors. Smelling, like seeing, is not especially tiring and does not call for taking in much of the substance, so that a great deal of smelling can be done. Then comes "flavor by mouth", a combination of tasting, smelling, and feeling. Since smelling was done just in advance of this testing, the features other than odor can be noted, due allowance being made for the odor. Finally, there is a valuable waiting period before the next specimen is tasted during which the taste and feeling senses recover, and aftertaste, if any, can be noted. The attempt is made to taste the food under essentially normal conditions, even if very critically.

In our own company, during the last few years, we have evolved a general method of using panels for solving difficult problems of flavor work.(16) Tasters make the first analysis of the samples and then a seminar meeting determines descriptive terms to use for the aroma and taste, mouthfeel and aftertaste. Subsequent samples are graded according to these terms. Here are used definite descriptive terms, when possible, such as rubbery, eggy, or biting, as well as elementary taste or odor factors. When they can be identified as individuals, specific chemical compounds are referred to, such as phenylacetic acid, indole, dipentene or hydrogen sulfide.

Particular products require special approaches. Sometimes grading a series of products for preference will point out the qualities desired. Sometimes, additions of flavorings have to be made to a neutral master-batch, to find out by cut-and-try what improves it. Again, the nose or tongue is used to track down an off-character. Whenever feasible, classical chemical methods of analysis, and physical methods including use of the mass spectrograph or infrared light analysis, should be used to complement the purely organoleptic work.

Even expert tasters are human, it must be conceded, therefore motivated by preferences. It is therefore recommended by several reporting in organoleptics that different panels be used for evaluating different kinds of food, and that no individual attempt to evaluate too many samples at one time. The taster himself has to conserve his senses. It is best to do all smelling of a set of samples before any tasting; as seen by comparison thresholds, the odor sense recuperates most rapidly. Many smellings may be done in close succession unless strong, paralyzing or irritating odors are involved. Beverage flavors by nature must not tire the senses. These can be tasted in rapid succession. Strong, spiced, or cloying flavors, however, soon dull the tongue, and these and thick or crumbly residues sometimes must be washed from the mouth. Rinsing is not advisable in a routine way, for it may be more harmful than helpful. A dulled condition comes with fatigue; is there not opportunity for rapid habit-formation similar to that met in the "unthinking" consumer who takes the taste of his morning toast for granted?

Meats

We have found that meat flavor is developed during cooking, apparently due to the chemical changes taking place in the fiber rather than in meat juices. (21) "Cooked beef flavor is chemically quite complicated, consisting more of odor than of taste. Indicated as present were hydrogen sulfide; amines of several kinds, including a low, simple form, one of the piperidine type and possibly indole; traces of volatile acids; and the taste elements sweetness and saltiness," from the meat juices.

"Pork, both eastern and choice Iowa, proved to have a fundamental meaty character similar to that of beef, on which was superimposed more sweetness of taste; much more volatile fatty acid content, ranging from acetic to the higher fatty acids; additional bases, including an earthy-potatoey type; and more sulfury ingredients suggestive of chicken. It appeared that either the food or the environment of the animal had imparted certain qualities to the meat, with some types giving a sour-vegetable note unless long cooked.

"Lamb ribs, with a pH of 7, were far more alkaline than beef (pH 6) and pork (pH 6.3), having a marked hexylamine character even when strictly fresh. Also, there was a strong caprylic or pelargonic acid type of odor, characteristic of sheep and goats. Long cooking drove off the unpleasant acidic odor and most of the amine, and the meat had a more delicate flavor, approaching that of beef.

"Chicken flavor was found to be even more complex than that of the red meats, varying considerably between parts of the same bird and from stage to stage in the life cycle. The breast meat tasted sourish and somewhat astringent but was mild in all birds tested. The leg meat of fowl tended to be quite eggy in the upper joint, less so below. On the older birds the leg meat was more prominently sulfury and stronger. The dominant features found in chicken flavor were the eggy odor and flavor, especially noticeable in the skin and dark meat and prominent sweetness and saltiness of taste." (21)

Soybean Oil

Soybean oil, like all other salad oils, with perhaps the exception of olive oil, should by nature be bland-flavored and extremely low in aroma. This oil in storage, or by a comparatively short time after refining, acquires grassy, painty and fishy off-flavors. The causes of these reversion flavors are not yet known, although the literature on the flavor problems of soybean oil is voluminous. Most workers distinguish between oxidative rancidity and reversion, though some do not.(29,54) It has been indicated that certain rancidity factors are due to the formation of the epi-aldehyde of oleic acid, while the volatile reversion factors are unsaturated C_7 and C_8 aldehydes.(54)

Monosodium Glutamate

Much information was brought out by the symposium on monosodium glutamate sponsored by the Quartermaster Food and Container Institute and Associates in 1948.(46) We have since published several papers on the subject.(8,20,50) This neutral salt of glutamic acid is a white crystalline odorless substance which tastes primarily sweet and salty and possesses a persistent mouthfullness.(20) It is compatible with most foods, and when added at levels where it is not identifiable, M.S.G. acts as a seasoning.(8,30,48,49) It blends aroma and flavor by mouth, suppresses rawness and certain undesirable notes, augments saltiness and sweetness,(8,33) reduces sourness and metallic flavors.(8) The appearance of monosodium glutamate has stimulated a wave of flavor consciousness not only among food processors but also among American families.

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