The relationship between odor and flavor

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Recently, a group of French visitors in an English restaurant were served with what were for them foreign dishes—steak and kidney pie, fish and chips and roast beef. Before tackling their first English meal, each one of them carefully smelled the food and discussed its merits for several minutes. Indeed, this was a reasonable thing to do, since they were able to evaluate in advance the flavor quality of the food they were about to eat. A flavorist will automatically do the same thing—that is, smell the product before tasting it. The reason is, of course, that odor and flavor are two facets of the same sensation.

With this in mind, let us discuss the meaning of odor and flavor, examining in particular some of the latest knowledge in the field. The importance of smelling in the evaluation of a flavoring material will become apparent.

Physiology

It will help to define the subject if we outline the physiology of the olfactory process in simple terms. The central feature of the total sensory system is the primary olfactory area. This is in fact a highly sensitive odor detector (or cluster of detectors). Electrical impulses are transmitted to the brain which then acts as a microrecorder for the stimulus created. The data is stored or computerized with other relevant information such as origin of the odor, its name and its relation to other odors. The time taken to identify the stimulus is probably in the order of 100-200 milliseconds.

There are two means of access of the odorous molecules to the primary olfactory area: via the nose (nasal cavity) or via the mouth (buccal cavity). These are connected to each other, allowing free passage of air in either direction over the surface of the primary olfactory area. There is also a secondary passage through the esophagus to the stomach and to the lungs. The flow rate of atmospheric carrier gas is regulated by the pumping action of the lungs. At the same time, the air is heated, filtered and humidified by a mucus layer in the nose. This process is carried out in the region known as the "accessory olfactory area." The odor molecules then pass over the primary olfactory area to the lungs. This operation is known as "smelling" and the stimulus produced, "a smell."

Mere inhalation of odorous air through the mouth does not, in fact, allow the odor molecules to pass over the primary olfactory area. Therefore no sensation is produced. For stimulus to occur, it is necessary to exhale the odorous air through the nose, i.e., to direct the flow of air in the direction opposite to smelling. This is a perfectly feasible, though less usual, operation. It requires a little practice to detect, say geraniol, amyl salicylate or a nitro musk through the mouth, but actually it is one of the best ways of testing the cleanliness of a contaminated pipette or tubing.

Food and drink pass into the mouth where they remain for a few seconds during mastication or are swallowed immediately. In either case, moist, odor-saturated air is exhaled via the nasal cavity as each swallow is made, through the "pumping" action in the throat caused by swallowing. This preconditioned air again passes over the primary olfactory area on its outward journey, and odor sensation is again recorded by the brain. Such a sensation is known as *flavor.* But for some absurd reason, we call the process *tasting,* although logically we should use the expression *flavoring.* Actually, the French have a far more sensible system, for the word "parfum" is used in connection with both smell and flavor.

We see, then, that for flavor response to occur, the odorous air must travel in the opposite direction to that required for smelling. Indeed, if the nasal passage is blocked, no flavor at all will be appreciated by the subject. The old-fashioned practice of holding one's nose when taking unpleasant medicine exemplifies this phenomenon.

There are two other terms whose usage is sometimes confused. The first one is "aroma," which stems from the Greek, and from which we derive words such as "aromatic." It appears that "aroma" is synonymous with "smell"—that is, it is perceived through the nose rather than through the mouth. On the other hand, in modern parlance, it is more commonly associated with the smell of consumables. Its sister synonym is "fragrance" which is associated with the perfumery trade. Needless to say some dictionaries will define "aroma" as flavor, smell and fragrance!

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The second term is "taste," a sensation completey unrelated to olfaction in that it requires direct contact of the chemical to provide stimulus. Taste is synonymous with gustation and relates to certain primary sensations produced on the epidermis inside the buccal cavity of most mammals and fish. It is not my intention to discuss these sensations, rather I draw attention to terms which are also used by the perfumer to describe odors. For example, the term "sweet" as an olfactive description (smell or flavor) is quite a different sensation from the "sweet taste" of sugar or saccharin. The same applies to the terms "bitter" and "sour." (The remaining primary taste sensation is "salt," for which there is no odor equivalent).

It is worth mentioning that we tend to associate certain flavor sensations with specific tastes. This is possibly because of the innate food motivating factor and the fact that such foods have specifc flavor-taste relationships. Most animals are conditioned to these relationships and therefore build up a preference of one food as against another. Thus one might associate beer with a bitter taste, fruit with a sweet taste or sometimes acid taste, and meat with a salt taste.

Animal behavioral response

Turning now to animal responses, the practice of smelling a product before consuming it may be observed among most domestic and wild animals. Indeed, this enables the experienced animal to distinguish between palatable and unpalatable foods. In experiments on rats with hypothalmic damage, Epstein and Teitelbaum in 1963 showed that motivations of taste and smell are psychoenergizers which contribute to the animal's hunger drive.[1] LeMagnen carried out feeding tests with rats in which the food, flavored respectively with citral and cineol, was presented to two sets of animals, each conditioned to accept one or other chemical flavor.[2] He also introduced other additional visual and tactile differences such as color and taste. It was again found that discrimination between the foods was primarily stimulated by olfactory clues rather than taste, visual or tactile factors. In 1967, Rogers and coworkers examined the ability of preconditioned dogs to distinguish foods flavored with beef, fish, liver, and chicken.[3] It was noticed that in these controlled experiments, the dogs primarily used their olfactory system for selection—taste (or flavor) was merely a reinforcement. When presented with six trays containing differently flavored meats, the dogs would first make their selection by odor alone without touching the food. Not until they had smelled all six trays in succession did the dog return to eat from the correct tray, i.e., the one containing the flavored meat which he had been conditioned to accept.

This data has been criticized as being specific to certain mammals and not applicable to other, possibly less sensitive, species such as man. Evidence is accumulating from the work of Laing,[4] and others, which suggests that sensitivity of individual receptors to novel odors is similar in different mammalian species, but that surface area and cell density affect discriminatory ability. Indeed, from tests carried out on a wide variety of species such as rats, rabbits, dogs, and pigeons, it would seem that there is a common mechanism for the detection of odors over a wide species range. Recent experiments by Laing on odor response patterns to n-propanol, n-heptanol, cyclohexanol and pyridine, suggests that there is a similar sensitivity variation of rats and humans to the same novel odors.

Of course it is quite a large step from rats to humans. Comparative studies on sensitivity and discriminatory ability are one thing, but the capacity for learning is quite another. However, some exciting fundamental studies are currently being carried out on the sensory responses of newborn and young babies.

The first important work in this field was by Engen and coworkers, nearly 15 years ago, who observed the effect of olfactory stimuli on the activity, heart rate, and breathing patterns of two day old babies.[5] Each of these 20 newborns, when presented with phenylethyl alcohol, aniseed oil or acetic acid, initially showed an elevated response, e.g. the heart rate increased. Subsequent stimulation to the same smell reduced the response; the child became adapted to that stimulant. When presented with a different smell, the response again increased, showing an ability to distinguish between two different smells.

Recently, Macfarlane, working at Oxford, extended this work to demonstrate the acuity of human neonates' sense of smell.[6] He found that when two day old breast-fed babies were presented with the breast pad of their own mother, a strange mother or a clean breast pad, the babies spent equal time with all pads. But at five days, and significantly at 10 days, the babies showed a definite preference for their own mother's pad which suggests that they rapidly learned to recognize the smell of their own mother and possibly the milk.

We see therefore that there is increasing experimental evidence to show that, in vertebrates at least, the brain is capable of being rapidly trained to distinguish between similar, though highly sophisticated, odors. This learning process can be further extended to discriminating between individual molecular stimuli in a complex mixture. Thus, the odor or flavor of given chemical mixtures, such as foods which cannot be olfactory analyzed by a novice, can be readily broken down by the expert or experienced observer. Both receive the same olfactory stimuli; but it is the expert, by virtue of his experience, who is better able to interpret his olfactory responses. In other words, by being better informed, he analyzes the mixture in greater detail, immediately identifying both single molecules and multimolecular accords.

Flavor evaluation

Let us now examine the ways in which this olfactory skill may be applied to the evaluation of a flavoring material. As an example, we shall take a simplified artificial peach blend, since it has relevance to both perfumers and flavorists (see Table I). It is adapted from a published formulation[7] and, although rather outdated, serves to illustrate a point.

Table I. Imitation Peach Blend

Ethyl valerate	13.0
Ethyl caproate	5.5
Amyl formate	5.0
Amyl acetate	2.5
Amyl butyrate	2.5
Amyl valerate	4.5
Benzaldehyde	0.8
Geraniol	0.1
Cinnamaldehyde	0.1
Neroli synthetic	7.0
Vanillin	24.0
Peach aldehyde	35.0
	100.0

Nasal response The first examination is by nasal response. We smell the liquid blend either in concentrated form or diluted at 5% or 10% in an appropriate solvent, such as ethanol. The latter method is more suitable, since it minimizes the effect of temporary anosmia produced by high concentrations of some chemicals.

Initially we carry out what is virtually a lightening "headspace analysis." In other words, we smell the vapor in the bottle. This enables us to select and identify the most volatile ingredients, namely the ethyl and lower amyl esters—especially the formates. With experience we may even be able to detect the benazaldehyde. Undoubtedly, there will be a strong "background" odor of so-called peach aldehyde, because of its high proportion. Indeed, the very fact that it is noticeable as a "bottle-neck" smell is indicative that it is present in relatively large amounts.

Given the right conditions, we already have a basic odor outline or skeleton of the blend. We can now fill in the details by means of a smelling strip appraisal. It is not my intention here to discuss the details of this technique. However, it is worth mentioning that the most common error encountered is the practice of soaking a considerable length of blotter in the liquid, thereby initially producing an odor effect similar to the "bottle-neck smell" which I have just described. The main purpose of the smelling strip is, of course, to provide a support for the successive fractional evaporation of odorous ingredients—an ideal which, if never actually achieved, can be approached by judicious use of the blotter.

Returning to our peach formula, we can see that some of the lower boiling esters will be detected during the early stages of evaporation and, to the trained nose, many can be selected and identified. Furthermore, the length during which these ingredients remain on the strip may serve as a guide to the proportions in which they occur in the blend. As evaporation proceeds, the relevant concentrations of high boilers such as peach aldehyde and vanillin increases, thereby making the identification of trace materials such as cinnamic aldehyde and geraniol more difficult if not impossible. Finally, after a period of several hours or even days, the presence and approximate concentrations of the peach aldehyde and vanillin can be assessed. In fact, it may take as much as a week or more before the vanillin is "seen."

Of course, you will say that this sounds all very well in theory, but is seldom quite so easy in practice. This is true, and even more so in the case of natural or "perfect" blends where there is no "break" between the odor of one ingredient and the next. But, despite such cases of poor resolution, the more experienced the observer is in his knowledge of aromatic materials and their combined odor effects, the more effectively can he "select" the odor stimuli which he is receiving. This is a brain process which can be switched on or off at will by the observer.

Oral response The final method of evaluating our peach blend is by means of its flavor. This may be done by incorporating it into one or more suitable inert and odorless bases at concentrations above the threshold. Indeed, it is possible to obtain valuable information by evaluating at several different concentrations above and below the threshold of the weakest ingredient—a technique of "selective flavor analysis." As described earlier, with each exhalation of air through the nose, the odorless materials are "steam distilled" over the primary olfactory area, thereby enabling the observer to odor evaluate the whole blend in a slightly different way. Furthermore, by allowing the blend to remain in the mouth for a short period, some of the ingredients may be enzymatically broken down to odorless materials, thus altering the balance and thus producing a different flavor effect from the initial appraisal. Also, some powerful materials such as the peach aldehyde will tend to be absorbed onto the cutaneous surfaces of the mouth, thus producing a residual flavor effect.

Summary and conclusion

We have discussed the meaning of odor and flavor and their physiological relationship, although the way in which the olfactory area responds to odor stimuli is still a mystery despite the many theories which have been propounded during the last 25 years. The interpretation of these responses by vertebrates, and especially mammals, depends on the experience of the observer and upon his learning powers. To illustrate this, we have discussed some of the techniques used by flavorists to evaluate a flavor complex by purely sensory means. Needless to say, although much of this basic, time-consuming work has now been reduced by using modern instrumental techniques of GLC and MS, some form of sensory analysis is still and always will be required.

Unfortunately there is a considerable lack of information, of a kind which would be acceptable in scientific work, on the ability of trained and untrained observers to discriminate odors. Reliable data on odor memory, fatigue and anosmia is still very scanty and inconclusive, although these are significant day-to-day factors in all our practical odor appraisal problems. A lot of work admittedly has been done on animals during the last decade, but there is much more to be understood about odor responses in man.

Possibly the reason for this knowledge gap is that many workers on olfaction at the academic level do not always appreciate the value of the practical know-how of the trained observer when designing experiments. On the other hand, most perfumers and flavorists do not have the time to carry out this sort of work—nor always, to be frank, the ability. However, as Harper and coworkers pointed out some 10 years ago: "One of the most important differences between experts from different disciplines lies in what they consider is fit and proper to investigate."[8] Judging from the wealth of fundamental work on mammalian taste recently it would appear that, at the moment, the flavorists have the day.

The real answer, in my opinion, is to form a professional, multidisciplinary sensory association to advise a program of work and to pool knowledge and resources. In particular there is need for enlightened interpretation and practical application of the results of such experimental work in order to make the best use of the information obtained. Only when such an association is established shall we come to an improved understanding of the subject to the betterment of all.

Acknowledgement

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