HUBER THE NOSE.

The Perception of Foods and Beverages

PASSION FOR SCENTS

The Perception of Foods and Beverages

Introduction

The human perception of food and beverages can be understood as a complex summation of several sensory impressions. Significant components include the senses of smell (olfaction), taste, chemesthesis[1], touch, hearing, vision, and temperature sensation.

For the discernment of flavors, the following aspects are most relevant:

The Sense of Smell

In the animal world, the capacity to smell has become enormously specialized throughout evolution. Salmon, for example, swim thousands of miles to return to their spawning grounds. Insects communicate using specific scents, known as pheromones, that play a crucial role in mating rituals and social behavior. Wildcats track their mating partners over long distances by their smell. And when we compare ourselves to our family dog that has an olfactory mucosa that is 5 times larger (almost 2x4 in^2), and has 2-3 times more types of receptors (man: approx. 350, dog: approx. 1000), we can only be amazed at this veritable olfactory giant!

The external world comes into contact with the human sense of smell in the two nasal cavities. As a sense, it is often considered inferior to the senses of taste, hearing, touch and vision[2]. Nevertheless, the sense of smell is the oldest sense among mammals, and it rivals the others in complexity and capabilities. It enriches our lives substantially. We eat and drink with the nose[3], we judge our environment and our partners with it, and, as the saying goes, "Follow the nose, it always knows". In fact, the sense of smell still plays a key role in the search and checking of food and is an important factor in human relationships, choice of partners and social behavior[4].

When chewing or otherwise moving food and drink around the mouth, volatile molecules circulate to the nasal cavity, via the pharynx, and reach the retronasal olfactory area. The perception of these volatile components (flavors) is the result of a complex interaction between the individual components and the olfactory antennae (so-called cilia), in the upper nasal mucosa that happens while breathing or with retronasal air circulation.

The sense of smell is a chemical sense. The biochemical interaction between the individual scent molecules in the air and the receptor proteins on the cilia stimulate olfactory nerve cells[5], which then trigger further reactions in the brain.

Inside the left and right nasal cavities, there are three layers of scroll-shaped "shelves", the conchae, that are completely lined with mucosa. The actual olfactory epithelium is found in the superior concha. It measures about ¾ x 2 inches and is distributed over both halves of the nose. Below the mucosa, there are about 30 million olfactory cells embedded in supporting cells; these come into contact with the outside world via the protruding cilia. The olfactory cells have, on average, a life span of only one month; newly-formed cells then arise from basal cells. This is unique as, normally, fully grown nerve cells are no longer capable of dividing.

At the other (basal) end of the olfactory cells, thousands of axons are bundled together and continue through the foramina (holes) of the cribiform plate and reach the brain as the left and right olfactory bulbs. Axons from the same type of receptors end in a common gathering point, the so-called glomeruli. In man, there are approximately 5500 glomeruli on each side, which corresponds to about 16 times the number of the 350 functioning olfactory receptor types[6,7]. The glomeruli are connected to each other via the so-called periglomerular cells. Axons of the approx. 30,000 mitral cells further transmit the signal into the olfactory cerebrum. From there, the signal goes to other regions of the brain, including the limbic system, which is responsible for our feelings.

When breathing, eating or drinking, the volatile scent molecules reach the conchae, where they come into contact with the mucosa on the olfactory cell receptors and, depending on how well the scent molecules “fit” into the receptors, evoke nerve signals of different strengths. These signals are then transmitted via the glomeruli into a very old (evolutionarily-speaking) brain region and, only then, with this considerable detour, are they further transmitted to the cerebrum, where they evoke the impression of a scent.

Durio zibethinus

A scent is thus the illusion that the brain creates based on the stimulation of the olfactory bulbs, that itself arises from the interactions of the individual fragrances with the olfactory receptors. This means that scent cannot be physically perceived, only virtually. Precisely how the brain evokes this illusion – the impression of scent – from the olfactory bulb signals is still not fully understood. But one thing is agreed: Stimuli are not simply processed in an additive fashion, but rather in a complex manner, e.g., by an interplay among inhibitory, cancellation and synergy mechanisms initiated by the periglomerular cells.

The Sense of Taste:

Papillae → Buds → Sensory Cells → Receptor Proteins

The sense of taste receives information from the external world via the tongue. On its top (the apical[8] surface), there are about 400 taste papillae, of which three types are distinguished: fungiform, foliate and circumvallate. In its walls and furrows, each single taste papilla, depending on its type, contains 5–100 taste buds[9], totaling 3000. In addition to consisting of both supporting and basal cells, each taste bud contains 10-50 sensory taste cells, representing all tastes. The popular opinion that the various tastes are perceived on distinctively separate areas of the tongue is based on the repeated citation of a questionable interpretation of a 1900 publication by Hänig[10] and is, in fact, incorrect.

The taste cells, on the top surface of the tongue, contain the receptor proteins that are responsible for the various taste perceptions. Here, it should be noted that each taste cell can carry several and even different taste receptors with varying and cell-specific degrees of sensitivity. This means that, for example, one cell reacts strongest to sour, while another perhaps to bitter. It also means that from the activity of a single taste cell, no conclusions can be made about the quality and intensity of the taste. This only becomes possible by "calculating" the activities of several cells. In contrast to olfactory nerves (primary sensory cells), taste nerves do not have axons, i.e. they are secondary sensory cells and supplied by cranial nerve axons. Part of the fibers end together with fibers in the thalamus that are responsible for other sensations, such as pain, touch, or temperature. The other fibers end in the same area as the olfactory nerves (limbic system) and contribute significantly to the emotional components of taste.

Fragraria vesca

Whereas the perceptions of sour (concentration of hydrogen ions), salty (alkali metal ions and a few anions), and umami (nucleic acids and certain derivatives, e.g., MSG), are evoked by comparatively few substances, the perception of sweet and especially bitter are evoked by a great variety of different substance types[11].
These basic stimuli provide helpful information about our food: Sweet indicates something pleasurable, while bitter provokes caution as many toxic substances, especially of plant origin, taste bitter.

The Trigeminal Nerve: Pungency

Our mouth and throat, tongue and nasal cavities are innervated primarily by the trigeminal nerve that is responsible for perceiving both cooling and pungent (a designation including spicy, burning, stinging, biting, tingling) stimuli.
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While Mexican, Indian and Far East foods are typically associated with pungency (chili, ginger, etc.), many Western-style kitchens also “live” from such pungent aspects. For example, the trigeminal nerve is excited by pepper in the mouth or by onions, mustard and horseradish in the nose. The tingly feeling that is evoked by carbon dioxide bubbles and contributes to the enjoyment of certain drinks is also conveyed by the trigeminal nerve. Some trigeminal nerve perceptions, such as spicy or cooling, are slow to develop and may persist for quite some time; this is sometimes recognized as painful when eating spicy foods.

Legal Classification of Flavors

Unfortunately, there are many different classifications and definitions of flavors that are used by various organizations, associations, committees and even countries.

The superceded European Council Directive 88/388/EEC uses the following definitions:

a) 'flavouring' means flavouring substances, flavouring preparations, process flavourings, smoke flavourings or mixtures thereof;

b) 'flavouring substance' means a defined chemical substance with flavouring properties which is obtained:

   i) by appropriate physical processes (including distillation and solvent extraction) or enzymatic or microbiological processes from material of vegetable or animal origin either in the raw state or after processing for human consumption by traditional food-preparation processes (including drying, torrefaction and fermentation),

   ii) by chemical synthesis or isolated by chemical processes and which is chemically identical to a substance naturally present in material of vegetable or animal origin as described in (i),

   iii) by chemical synthesis but which is not chemically identical to a substance naturally present in material of vegetable or animal origin as described in (i);

c) 'flavouring preparation' means a product, other than the substances defined in (b) (i), whether concentrated or not, with flavouring properties, which is obtained by appropriate physical processes (including distillation and solvent extraction) or by enzymatic or microbiological processes from material of vegetable or animal origin, either in the raw state or after processing for human consumption by traditional food-preparation processes (including drying, torrefaction and fermentation);

d) 'process flavouring' means a product which is obtained according to good manufacturing practices by heating to a temperature not exceeding 180 °C for a period not exceeding 15 minutes a mixture of ingredients, not necessarily themselves having flavouring properties, of which at least one contains nitrogen (amino) and another is a reducing sugar;

e) 'smoke flavouring' means a smoke extract used in traditional foodstuffs smoking processes.

Regulation (EC) No 1334/2008, valid in the European Communities since 2011, combines the old definitions of nature-identical (ii) and artificial (iii) flavoring substances under the term, "flavoring substances", and uses for (i) the designation "natural flavoring substances". In addition to the following terms already used in the 88/388/ EEC, "flavoring preparations", "thermal process flavorings " and "smoke flavorings", the following terms are added: "flavor precursors", "other flavorings" and "source materials".

Definitions concerning the term "natural" are stricter than before:

The term, "natural", may only be used if the flavoring substances and/or flavoring preparations used as flavoring components are entirely of natural origin.

The term, "natural", along with the designation of a food may only be used if at least 95% of the flavoring components originate from the named food and the taste cited by the food is easily recognizable. The remaining 5% natural aroma may simply round out the taste impression, or add nuance in a specific way. For example, "natural lime flavor" can consist of at least 95% lime oil and, e.g., 5% lemon oil. The abbreviation, FTNF (From The Named Food), is often used. If the taste of the cited food is easily recognizable, but less than 95% of the flavoring components originate from it, then the term, "natural lemon flavor with other natural flavors" is used (WONF, With Other Natural Flavors).

Appendix I of the Regulation (EC) No. 1334/2008 contains the so-called "Union List" of flavors and source materials that may be used in foods. The Union List is established in a separate Implementation Regulation (EU) No. 872/2012. Each approved flavoring substance has a Flavis number (Flavour Information System). A comprehensive interpretation aid to the European legislation has been composed by the European Flavour Association (effa).

Zingiber officinale

In many countries - in particular, the USA – those flavorings substances classified as safe by the Flavor Extract Manufacturers Association (FEMA) are allowed. Newly-tested flavoring substances are periodically published in the so-called GRAS Lists (Generally Recognized As Safe). Each flavoring substance has a FEMA number.

Most other countries have similar definitions and guidelines. They have published their own positive lists of each flavoring substance that may be used in foodstuffs (including, e.g., China, Japan and Korea). These may also contain limitations to the amounts that may be used or other instructions for use in certain types of foodstuffs.

The International Organization of the Flavor Industry (IOFI) publishes global reference lists. These contain all flavor substances and flavor preparations that, worldwide, have been judged as being safe for use in foodstuffs by at least one government authority.

Sensory Evaluation

Sensory evaluation of foodstuffs by expert panels are frequently carried out within companies in order to harmonize products to consumers' taste. This is a multi-step process in which defined criteria of a test object are evaluated. The results allow the product developers to improve the product in a step-wise fashion. With so-called consumer panels, consumers cite how well they like the presented foodstuff. By comparing the results to products already on the market, one can determine whether the new product will be successful[12].

Sensory evaluation is taken to generally mean the evaluation of a foodstuff (or other products, such as cosmetics or items of use) using several senses. For example, the assessment of cookies is not only important for the taste and olfactory senses, but also the sense of hearing plays a decisive role, because in addition to the sense of touch, hearing also contributes to how "crispy" something is perceived.

A Flavorist's Job

The primary activity of a flavorist is to achieve a flavor in a food or beverage that ideally is perceived as being very close, or identical, to that which nature produces in fruit, vegetables, spices, meat, fish, etc. On the other hand, the flavorist also produces fantasy flavors, such as those that can be found in certain drinks (cola or energy drinks) or chewing gum. Nevertheless, when it comes to this creative or artistic side, the flavorist enjoys significantly less leeway than does a perfumer, who can always create new scents.

References

Endnotes

We would like to point out that this brochure considers and cites many different sources of literature in order to provide a better understanding of our specialty area. Dr. W. Huber AG did not contribute to, or financially support in any way, the independent research or results.

1. Chemesthesis has been called the common chemical sense and is mediated primarily by impulses from the trigeminal nerve; also known as the drilling nerve, it innervates many areas of the head. It is responsible for transmitting impressions of pungency, cooling and the like. Hot spices, such as capsaicin from the chili pepper, can evoke strong impulses via the trigeminal nerve that are perceived as burning and painful. This sense is separate from the actual olfactory sense, as its receptors are found in the oral cavity, in the pharynx and in the nose.

2. Generally, one speaks of five senses: seeing, hearing, touching, tasting and smelling. However, today's scientific community counts more, including the sense of temperature, of pain, of equilibrium, of positional and motional perception, and of awareness of the body and its parts.

3. Please cf. "Sense of Taste" below.

4. In addition to the olfactory organ, most mammals also possess a second organ sensitive to volatile substances. This so-called vomero-nasal organ (VMO) is found in approximately 60% of humans. It is still disputed whether it is actually functional in man, but the general opinion is that it is not. However, in the animal world, this second, separate sense of smell plays an important role. It recognizes those inter-species signal scents that are used for reproduction; these volatile substances are called pheromones. This second olfactory system likewise has its own, separate olfactory bulb; however, in this system, not all the same receptor nerve cells converge in the same glomerulus.

5. Olfactory nerve cells are bilpolar, primary sensory cells. The nasal (apical) end comes into contact with the external world via fine sensory hair cells (cilia) found on the nasal mucosa. The basal ends lead directly to the olfactory bulb in the brain, where they are bundled and finally transmitted to the limbic system via mitral cells. (In contrast, taste cells are secondary sensory cells that, themselves, have no nerve endings but rather are supplied by brain cells.)

6. One particular gene is responsible for the synthesis of each receptor protein. About 30,000 genes are present in man, of which 1000 are responsible for olfactory receptors. However, on average, only about 350 of these are used for the expression of olfactory receptors. Science now assumes that, in man, the biologically-relevant olfactory receptors have remained highly conserved during the evolutionary process, though we still do not know what the functions of the other 650 genes were or are. Nevertheless, 3% of the human genome is reserved for the sense of smell, which shows just how important it is for man, even today.

7. Earlier research was a proponent of the one glomerulus per receptor type theory, where 350 glomeruli were present for each half of the olfactory bulb. However, A. Maresh *et al.*, PloS ONE 2008;3/7):e2640 cite some 5500 glomeruli. The reason for this 16-fold higher ratio of receptor types than glomeruli is not known. But we do know that many receptor types interact with many scents, and that, with stronger scent exposure, as a result of overburdening, additional glomeruli can be stimulated (that also further transmit information about the intensity of the scent).

8. The apical side of the tongue is that which faces the oral cavity. Here, the taste receptors contained in the microvilli (fine dendritical extension of the taste cell at the top of the tongue) interact with stimuli and induce an excitatory signal that is transmitted to the brain for processing (in the thalamus, limbic system, and hypothalamus).

9. According to experimental studies [L.M.Bartoshuk *et al.*, Physiol. Behav. 56, 1165 (1994)], the number of taste buds may vary considerably among individuals. Termed supertasters, certain people have a significantly higher number of taste buds than the average individual. Gender and hormones also play a role: Women are more likely to be supertasters than men, and increased perception of bitterness has been shown for pregnant women. Since many plant toxins are bitter, this may be an evolutionary protective mechanism.

10. D. Hänig, Philosophische Studien [Philosophical Studies] 17, 576-623 (1901).

11. For tasting, the stimulating molecules do not have to be volatile, and in most cases, they are of low volatility and water-soluble (hydrophilic). One exception to this is chloroform, which tastes sweet. This contrasts with the sense of olfaction where the stimulating molecules are highly volatile and poorly water-soluble (lipophilic).

12. One has to keep in mind that the results of such sensory testing, independent of the experience of the tester, may vary substantially among subjects. Therefore, one should not expect such tests to provide strictly reproducible results.

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