Chemical Senses
Taste Sensation and Chemical Composition

CERASELA DORINA SINCAR[1], CAMELIA ANA GRIGORE[1]*, SILVIA MARTU[2], LILIANA LACRAMIOARA PAVEL[1], ALINA CALIN[1], ALINA PLESEA CONDRATOVICI[1], BIANCA IOANA CHESARU[1]

[1] Dunarea de Jos University of Galaþi, Faculty of Medicine and Pharmacy, Dentistry Department, 47 Domneasca Str., 800008, Galati, Romania

[2] Grigore T. Popa University of Medicine and Pharmacy, Faculty of Dental Medicine 16 Universitatii Str., 700115, Iasi, Romania

Taste and smell are chemical senses, which means that the receptors (chemoreceptors) of these senses respond to chemical stimuli. In order for a substance to produce a taste sensation, it should be ingested in a solution or subsequently dissolved in saliva; a solid substance put in the mouth perfectly dry is tasteless. Therefore, taste receptors or taste buds occur only on wet surfaces, more precisely in the oral cavity in land vertebrates; however, in aquatic animals, these receptors are scattered all over the body. There are functionally different types of receptors for each of the primary tastes and the distribution of each type is not even on the surface of the tongue mucosa. The sweet and sour sensitive buds are located mainly on the tip of the tongue, those sensitive to acids are located on the sides of the tongue and those stimulated by the bitter taste are located towards the back of the tongue and in the epiglottis area. Taste may be generated by substances which touch the taste buds through the blood; thus, histamine injected intravenously causes a metallic taste, glucin a sweet taste, whereas jaundice may trigger a bitter taste due to the big concentration of gallbladder constituents in the blood.

Keywords: taste receptors, taste nerves, taste sensation, chemical compostion, inadequate stimuli

Taste receptors

In humans, taste buds are located mainly on the tongue. However, although in small numbers, some of them also occur on the hard palate, pharynx, epiglottis and arytenoid cartilage area. In children, taste buds enjoy a more generous outlay and most of them are located on the front part of the tongue. In adults, there are fewer taste buds on the tip of the tongue and almost none in its middle part. In most fish, the teguments along the whole surface of the body have taste receptors, and in some species they are located in the thread-shaped extensions which originate in the oral region (Atlantic wolffish). In insects (fly, bee), taste receptors are located at the end of the antennae or on the tarsal section of their legs.

Human tongue mucosa exhibits a large number of small projections – lingual papillae – produced by chorion protuberances. Lingual papillae are classified in three main categories: *filiform papillae* (very small cone-shaped formations, which cover the two front thirds of the dorsal side of the tongue and are placed in somewhat parallel rows with the circumvallate papillae rows); *fungiform papillae* are much bigger than the previous ones (round shaped and located mainly on the tip and sides of the tongue); *circumvallate papillae* are even bigger and become very prominent on the back side of the tongue, where 6-12 of them are located in a *V* shape with arms widely open towards the front part of the tongue. A circumvallate papilla consists of a round central projection with perpendicular faces and surrounded by a groove; taste buds are located on the mucosa making up the groove walls. Filiform papillae rarely contain taste buds, yet each fungiform papilla contains 8-10 such buds, which are hosted in the epithelium covering their loose surface.

A cross section through a taste bud is about 70µ long and 50µ wide, with the long axis perpendicular on the epithelial surface. It is made up of a number of elongated support cells placed one next to the other and forming a small oval space which opens on the surface in a circular orifice, the *inner taste pore,* surrounded by the converging ends of the support cells. The *inner taste pore* usually extends into a short channel, which opens on the surface of the tongue through the *outer taste pore*. The taste bud cavity is full of other support cells (central support cells). Taste cells are scattered among them. They are fusiform and have an extension as thin as a hair, which penetrates into the short channel through the inner taste pore. A taste bud contains a variable number of sensory cells (5 and 18) and amyelitic nerve endings surround them in a tree-like pattern.

The tympanic segment of the facial nerve (innervates the taste buds of the two anterior thirds of the tongue) and the glossopharyngeal nerve (innervates the posterior third of the tongue) are the main gustatory nerves. The vagus nerve innervates the rare taste buds occurring in the epiglottis and arytenoid cartilage area. The trigeminal nerve mediates the general chemical sense and tactile sensation, temperature and pressure of the whole oral mucosa; it has no gustatory fibers. Cushing noted that trigeminal ganglion removal does not lead to permanent taste loss; gustatory nerve cutting in animals leads to the degeneration and progressing loss of taste buds. Olmsted showed that the taste buds of Atlantic wolfish reappear when nerve fibers begin to regenerate.

Taste sensations

There are four taste sensations (simple, primary or fundamental): *sweet, sour* (acid*), salty* and *bitter*. They are sometimes accompanied by the *acid* and *metallic* tastes. The other tastes that we know are: the mixture of two or several primary sensations; a combination between the latter and sensations produced by common sensitivity nerve stimulation.

Many of the more subtle taste sensations are actually olfactory sensations and the smell is responsible for many of the sensations that we mistaken for tastes.

* *email: cameliaanagrigore@yahoo.com*

Some substances that we believe we identify through our smell are actually determined by our taste. The sweet smell of chloroform belongs to this category; the vapor in the air we breathe in reaches the taste buds.

The four primary taste sensations do not occur at the same intensity throughout the whole surface of the tongue.

Some substances stimulate two types of taste receptors; thus, sodium salicylate, etc. creates a sweet sensation on the tip of the tongue, but when they are swallowed and come into contact with the circumvallate papillae, they become bitter. On the other hand, ortho benzyl benzoate creates a bitter followed by a sweet taste. Magnesium sulfate and sodium sulfate are salty-bitter, as they create a salty sensation on the tip of the tongue and a bitter taste at the root of the tongue. These findings indicate the existence of certain receptors which, from the functional point of view, are customized and the fact that different types occur in the same fungiform papilla. Circumvallate papillae contain taste buds only for bitter substances.

Theories on taste perception. The findings of the experiments, which recorded the action potentials on isolated nerve fibers when sapid substances were applied on the tongue, strongly supports the existence of four types of specific taste receptors. The quality of a sensation is determined by the central connections of the nerve fiber, in the cortical area reached by the impulses triggered in the receptor organ by an adequate stimulus. The stimulation of different types of receptors, in different degrees, accompanied by the excitation of the non-gustatory nerves of the oral and lingual mucosa, and of the olfactory receptors, may account for the extended range of gustatory sensations that we perceive.

Taste sensation and chemical composition

The sweet taste is mainly related to organic compounds, especially carbohydrates (saccharose, maltose, glucose, etc.), certain polysaccharides, glycerol and other alcohols, aldehydes and ketones in the aliphatic series, saccharin, dulcin and chloroform. Some inorganic substances, such as lead acetate and much diluted alkalines, also taste sweet.

The substances which produce an acid or sour taste are always electrolytes, yet bitter or sweet tastes may be dissociated or not.

There have been several attempts to relate the sweet taste to chemical composition. Oerthy and Myers, having studied a large number of sweet organic compounds, suggested a theory according to which each sweet molecule contains two types of radicals or an atom which the sweet taste depends on: one is called glucophore, the other auxogluc.

Glucophore gives to a certain compound its taste characteristics; when it binds to an auxogluc, the result is a sweet compound. Six glucophores (-CO-CHOH-(H); CO_2 . $CHNH_2$-;CH_2OH . CHOH-;CH_2ONO_2-etc.) and nine auxoglucs ((H); CH_3CH_2; CH_2OH;CH_2OH .CHOH) were detected.

Thus, hexoses contain glucophore (-CO-CHOH-(H) and auxogluc (CH_2OH;CH_2OH .CHOH); glycerol contains glucophore (CO_2 . $CHNH_2$-) and auxogluc (CH_2OH), and aminoacetic acid, glucophore (CO_2 . $CHNH_2$-) and auxogluc (H).

In general, the sour taste is produced by inorganic compounds, especially sodium, potassium, magnesium, ammonium and lithium chloride, by certain sulfates, bromides and iodides, and by sodium and potassium nitrate. The sour taste of these compounds is due to anions (Cl, Br, I,SO_4, and NO_3), which has been proven by comparing their much diluted solutions with identical diluted solutions of sodium acetate.

The dilution which preserves the sour taste is the highest for the chlorine ion, then for the bromine ion and the lowest for the chlorine ion, then for the bromine ion and the lowest for the iodine ion. Nonetheless, the sour taste is not exclusive to inorganic agents. Certain organic compounds like monomethylamine and diethylamine hydrochloride also have this quality.

The sour taste is produced by acids and acid salts. It is generally agreed that the hydrogen ion is the active factor. This statement seems to contradict the fact that the solutions of certain organic acids, such as the acetic, tartaric, citric, etc. acid, have a more acid taste than mineral acid solutions with a much higher hydrogen ion concentration. For instance, the acid taste of an acetic acid solution is almost the same as the taste of a HCL solution in a dilution three times lower. Nevertheless, when comparing the two solutions, the latter is four-five times more concentrated in hydrogen ions, as hydrochloric acid is very dissociable. The stronger taste effect of acetic acid for a particular hydrogen ion concentration is due to its superior ability to penetrate the tissues, thus making it easier for the hydrogen ion concentration to increase in the taste buds.

The astringent taste is due to a much diluted acid, in other words, to a very mild acidity sensation.

Like the sweet taste, the bitter taste is related to organic compounds, especially alkaloids (quinine, strychnine, morphine, etc.), and to certain glycosides. Picric acid, dextromanose and bile salts are other bitter organic compounds; among the bitter inorganic substances we may list magnesium, ammonium and calcium salts. The bitterness of these salts is due to cation. Any slight change of the chemical composition of a substance may change the bitter taste into sweet taste. For example, saccharine is very sweet, yet some of its derivatives are bitter; dulcin is 500 times sweeter than sugar while phenylthio-carbamide, where an oxygen atom in the dulcin molecule is replaced by a sulphur atom, is bitter for most people.

Taste deficiency (taste cecity) in connection with this substance is hereditary being transmitted as a recessive character; many organic compounds which taste bitter contain NO_2 groups. When the molecule contains two such groups, the compound is usually bitter, and when it has three, it is always bitter.

Inadequate stimuli

Among the agents – other than the chemical ones – able to produce a taste sensation, electric current is the most effective. An electric stimulation using direct current through two electrodes placed on the tongue produces a *metallic* aftertaste after the current has been switched off. When an electrode is placed on the surface of the tongue and the other on any body part, a direct current passing through them produces an *acid* or *alkaline* taste, depending on the direction of the current.

When the anode is placed on the tongue, the taste produced is *acid*; when the cathode is the stimulating electrode, the taste produced is *alkaline*. It seems that two factors are involved in *acid* or *alkaline* taste production, namely direct electric stimulation of taste cells and production of H or OH ions in the anode and cathode, respectively, further to oral liquid electrolysis.

The fact that a taste sensation is produced by direct electric stimulation proves that the sensation may be generated more easily by rapid alternating current, which does not have a considerable electrolytic action, unless a direct current is involved.

The taste produced by a direct current is a complex sensation; it often has a metallic bitter component, which occurs when the current is switched off.

The basic taste sensation thresholds are the result of minimum concentrations of the four main groups of sapid substances producing the corresponding sensations:

Sensation	Substance	Concentration
-	sugar	1/200
sweet	dulcin and perillaldehyde ans α-antialdoxin	1/100. 200 1/600.000
salty	NaC1	1/400
acid	HCI	1/15.000
bitter	quinine strychnine	1/2.000.000 ½.500.000

Aftertaste Sensation and Contrasting Tastes

Taste has analogical phenomena with positive post-images and successive and simultaneous contrast; it is well known that the tastes of certain substances (quinine) stick to the tongue. It is highly unlikely that persistent taste is a postsensation comparable to postimage; persistent taste is very likely due to the extended action of the stimulating agent which, once it has penetrated the taste pore, is difficult to wash away by saliva or by rinsing one's mouth. The metallic taste which persists after a single electrical stimulus (when the current is switched off) is a similar example of sensation persistence.

Effects of Drugs on Taste

Certain drugs have an elective action on taste sensations, as they abolish some of them and leave other intact. For instance: when a decoct of Gymnema szlvestre leaves is placed on the tongue, the sweet and the sour are no longer perceived; the salty and acid tastes are preserved, being only slightly depressed. Cocaine abolishes all taste sensations and overall sensitivity; the different sensations disappear in the following order: pain, bitter, sweet, saline, acid and tactile.

Conclusions

In human, chemical sense is limited to areas which are always wet, namely the nasal and oral mucosa, the conjunctiva and anal duct mucosa; the general chemical sense of the first three areas is served by the trigeminal nerve.

The organs perceiving this sense at the mouth and nose level are different than taste endings, and they do not seem identical to the ones serving pain, since pain may be dissociated from the chemical sensation through cocaine, pain being abolished by the former.

References

1.CUSHING, H., Bull.Johns Hopkins Hosp., 1903, 14, 71.
2.OLMSTED, J.M.D., Am.J.Physiol., 1918,46,443,
3.OLMSTED, J.M.D., J Comp. Neurol., 1920, 31,465.
4.OERTLY, E., MYERS, R.G.J. Am Chem.Soc.,1919, 41, 855.
5.JOHN, E.,Hall Ph.D.-Guyton and Hall textbook of medical physiology, 12th edition (2011).
6.SEMPLE, D., SMYTH, R., Oxford Handbook of Psychiatry, 2nd edition, Oxford University Press, 2009.
7.HOWLAND, R.D., MYCEK, M.J., Pharmacology 3rd edition, in Lippincott's Illustrated Reviews, R.A. Harvey and P.C. Champe editors, Lippincott Williams & Wilkins, 2006.
8.GELDER, M., MAYOU, R., COWEN, P., Shorter Oxford Textbook of Psychiatry 4th edition, Oxford University Press, Oxford, 2001.
9.DEHELEAN, L., ENATESCU, V.R, BREDICEAN, C., PAPAVA, I., ROMOSAN, R., GIURGI-ONCU, C., Caiet de Stagiu pentru Psihiatrie Adulþi, Ediþia II, revizuita. Editura Mirton Timisoara, 2013.
10.***American Psychiatric Association, Diagnostical and Statistical Manual of Mental Disorders, Fifth Edition. Arlington, VA, American Psychiatric Asociation, 2013.
11.LAZARESCU, M., BARANESCU, R., Psihopatologie descriptivã. Iasi: Polirom, 2011.
12.GELDER, M.G., ANDREASEN, N.C., LOPEY-IBOR, Jr. J.J., GEDDES Jr. New Oxford Textbook of Psychiatry. Second Edition. Oxford: Oxford University Press, 2009.
13.LAZARESCU, M., ILE, L., Tulburarea obsesiv - compulsiva: circumscriere, modele si interventii. Iasi: Polirom, 2009.
14.*** Revista Interiorul corpului uman, Editura DeAgostini, Bucuresti, 2010

Manuscript received: 26.11.2016