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SEVENTH MEETING OF EUROPEAN MEAT RESEARCH WORKERS
WARSZAWA, 18th to 23rd September 1961.

A PHYSICO-CHEMICAL APPROACH TO THE RELATIONSHIP BETWEEN STIMULI CONCENTRATION AND RESPONSE INTENSITY IN TASTE SENSATIONS.

by

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It is already a widely known fact that the main basis of modern quality evaluation of food is sensory analysis. One of its most employed techniques is taste testing basing both on human physiology and psychology.

The physiology of taste testing was explained for a long time on the basis of Weber's law and Fechner's modifications of this formula. However it is valid only in a limited range of stimuli concentrations/viz. Fig. 1 and Fig. 2/., and is only a general description of existing interrelations without giving exact numerical values.

These difficulties were overcome by the excellent work of Beidler /1,2/, who on the basis of electroneurophysiological measurements found that the response intensity/stimuli concentration relationship in one-component solutions may be described by the formula

$$S = S_m \frac{k \cdot c}{1 + k \cdot c} \qquad /1/$$

where: S- actual intensity of taste sensation

S_m- maximal intensity of taste sensation

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c- stimuli concentration

k- proportionality factor /constant/

For solutions with two different stimuli the total response intensity is given by:

$$S = \frac{S_{m1} \cdot k_1 \cdot c_1 + S_{m2} \cdot k_2 \cdot c_2}{1 + k_1 \cdot c_1 + k_2 \cdot c_2} \quad \ldots\ldots\ldots\ldots /2/$$

We will not discuss the course of reactions which take place in the chemoreceptors of the oral cave. However, we want to stress one important fact i.e. that taste stimuli brought on the tongue act in the form of solutions, whereas the chemoreceptors are in the solid state. This means that in order to evolve taste sensations there must occur some kind of mass transfer due to adsorptive forces.

Starting from the theory of adsorption processes we will derive equations for the concentration /intensity relationship, which are identic with Beidler's formulas thus corroborating his ideas on taste sensations.

Since the adsorption equilibrium in chemoreceptors of the tongue is achieved in a very short time /some /some 50 miliseconds-Beidler[1]/ which is in no comparison to the duration of taste sensations under average assessment conditions, we shall focus our attention only on the statics of this process.

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As is known in the equilibrium state the amount of stimuli being adsorbed within a time interval is equal to that, which undergoes desorption. Putting:

c - concentration of stimuli

n - total number of adsorption sites

x - number of sites already covered by the adsorptive

A - proportionality factor of adsorption/constant/

B - proportionality factor of desorption /constant/

the state of adsorption equilibrium may be described by:

$$A./\,n-x/.c=B.x \qquad ..../3/$$

introducing $k=\frac{A}{B}$

we find

$$x=\frac{k.n.c}{1+kc} \qquad ..../4/$$

Assuming that the response intensity/S/ is directly related to the number of ions or molecules of the stimuli that have reacted with the receptors we see that it is proportional to the number of sites /x/ covered with the adsorptive, i.e.

$$S= a.x$$

where a- proportionality factor /constant/.

If all sites were covered with the adsorptive, we should observe the maximal intensity of response/S_m/ i.e.

$$S_m = a.n$$

Therefore we may write that $S=S_m.\frac{x}{n}$ ..../5/

Introducing the latter into equation/4/ we obtain

$$S= S_m.\frac{k.c.}{1+kc}$$

which is identic with Beidler'sformula /1/.

In a similar way the expression for a multicomponent solution may be derived.The adsorption equilibrium for the first and the i-th component of this solution is described similarly to eqn./3/ i.e.

$$A_1./n-\sum x_i/.c_1= B_1.x_1 \ldots\ldots\ldots\ldots /6/$$

$$A_i./n-\sum x_i/.c_i= B_i.x_i \ldots\ldots\ldots\ldots /7/$$

putting: $k_1= \frac{A_1}{B_1}$ and $k_i= \frac{A_i}{B_i}$

we have herefrom

$$x_i= \frac{x_1}{k_1c_1}.\ k_ic_i \ldots\ldots\ldots\ldots /8/$$

introducing this into eqn./6/ we obtain

$$x_1= \frac{k_1.\ c_1.n}{1+\sum k_ic_i} \ldots\ldots\ldots\ldots /9/$$

which together with eqn./8/ gives

$$x_i= \frac{k_i.c_i.\ n}{1+\sum k_ic_i} \ldots\ldots\ldots\ldots /10/$$

According to eqn./5/ $S_i= S_{mi}.\frac{x_i}{n}$

and therefore eqn./10/ may be rewritten as:

$$S_i= \frac{S_{mi}\ .k_i.\ c_i}{1+\sum k_ic_i} \ldots\ldots\ldots\ldots /11/$$

The above represents the specific response~~x~~ intensity of the i-th component in a multicomponent solution.

Since the total response intensity $/S_t/$ is a sum

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of the specific intensities, i.e. $S_t = \sum S_i$

it may be described by the formula:

$$S_t = \frac{\sum S_{mi} \cdot k_i \cdot c_i}{1 + \sum k_i \cdot c_i} \quad \ldots\ldots\ldots\ldots /12/$$

In the case of a two-component solution the above becomes identic with Beidler's second formula/eqn.2/.

Thus in a different way we came to results which confirms the validity of Beidler's formulas.

In the a/m.equations the factor /or k_i/ has the dimensions 1/% and its value depends only on the chemical composition of the taste stimuli.The value of S/or S_i or S_t/ as well as this of S_m/or S_{mi}/ is expressed in terms of the "just noticeable differences"/jnd/which further will be called "Beidler Units"/abbrev.BØ.All these values are easy to determine e.g.by means of the triangle method.

According to Tilgner and Zimińska [3] the values for k and S_m in mono-component solutions are:

<u>NaCl:</u> k= 1.21 S_m= 33.3 B

<u>sucrose:</u> k= 0.26 S_m= 23.73 B

<u>tartaric acid:</u> k=2.3 S_m= 40.0 B

<u>chinine hydrochloride:</u> k= 2974.0 S_m= 10.4 B

On the basis of the above presented formulas we may now consider the question whether the introduction o of an additive into the solution of a taste stimuli enhances or quenches its response intensity.Pangborn[4]

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recently listed the experimental findings and conclusions in this matter made by different authors and compared them with her results.This list is somewaht confusing because of the contradictory conclusions derived by different authors from similar experiments.

In order to compare the differences in response intensity of a certain stimuli at fixed concentration s solved a/ in pure water, b/in a solution of another stimuli,we have to compare equations /1/ and /11/. From this comparison it becomes clear that in all cases the value of S_1 is less that that of S,which means that an introduction of a second substace into the solution of any stimuli always quenches the response intensity of the latter.This conclusion is in full agreement with the experimented results of Pangborn.[4]

However,the quenching effect of stimuli "2" upon the response intensity of stimuli "1" will be noticeable by the human nervous system only in cases if

$$c_1 \geqslant \frac{1}{2.k_1} . \left[k_2c_2/\,S_{m1} - 1/ - 2 + \sqrt{(k_2c_2\,/S_{m1} - 1/\,-2)^2 + 4./1 + k_2c_2/} \right]$$

For stimuli concentrations less than the above no change in response intensity will be noticeable.

In meat products we often observe a phenomenon known as the effect of saltiness hiding.The importance of this effect may be seen from fig.3,representing the experimental results of one of us[x/] on the salt index

x/ N.Baryłko-Pikielna.

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of canned hams. As we see in extreme cases the organoleptic saltiness of hams is only around 40% of that, which may be expected on the basis of its NaCl contents.

According to Tilgner [5] this effect may be expressed in terms of the salt-index i.e. as the concentration of watery NaCl solutions that induces the same impression of saltiness as the tested sample.

The application of equations /1/ and /11/ in order to elucidate this problem leads to the conclusion that quenching is not responsible for the hiding of saltiness in hams. Most probably there is another reason for it, whose understanding requires further work.

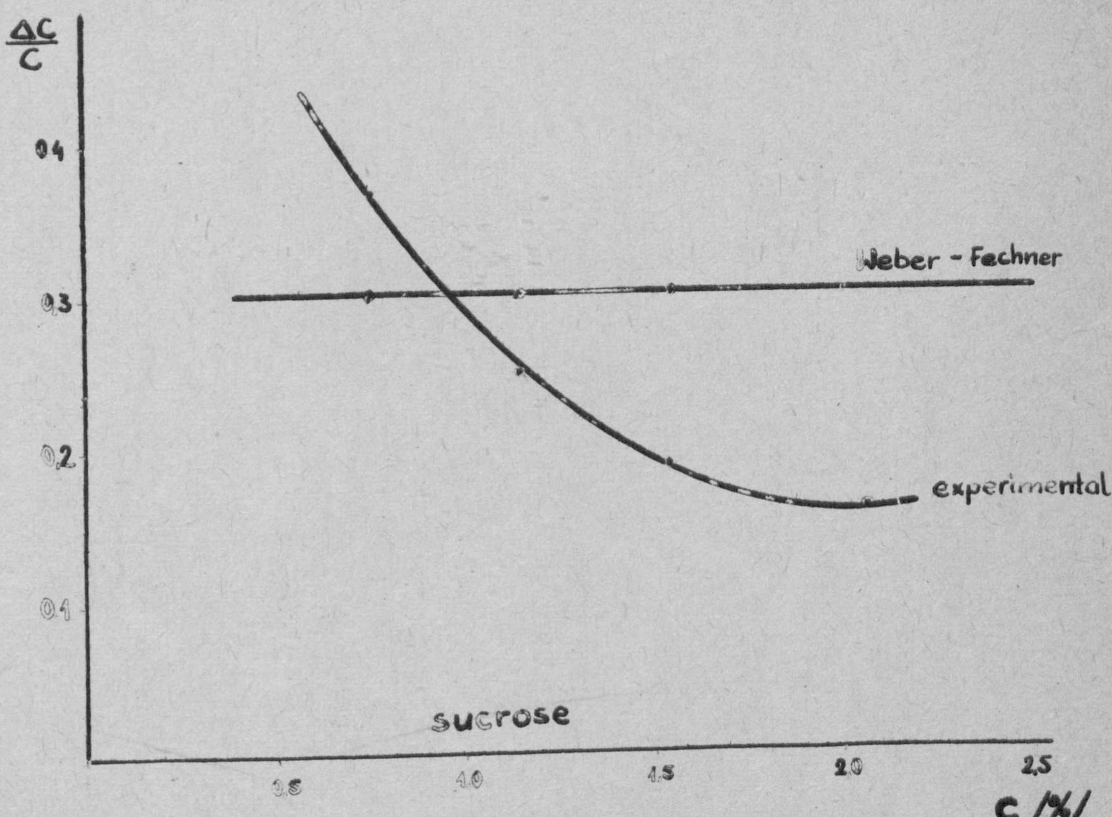
The possibilities of application of Beidler's formulas to further problems of taste testing are now under investigation and will be the subject of another paper.

Acknowledgements.

The authors are highly indebted to Prof. Dr D.J. Tilgner and Mrs. H. Zimińska, M.S. for their kind permission to employ some of their experimental data. We also appreciate the assistance given by the staff of the Quality Control Laboratory of the Polish Meat Research Institute in performing some sensory experiments.

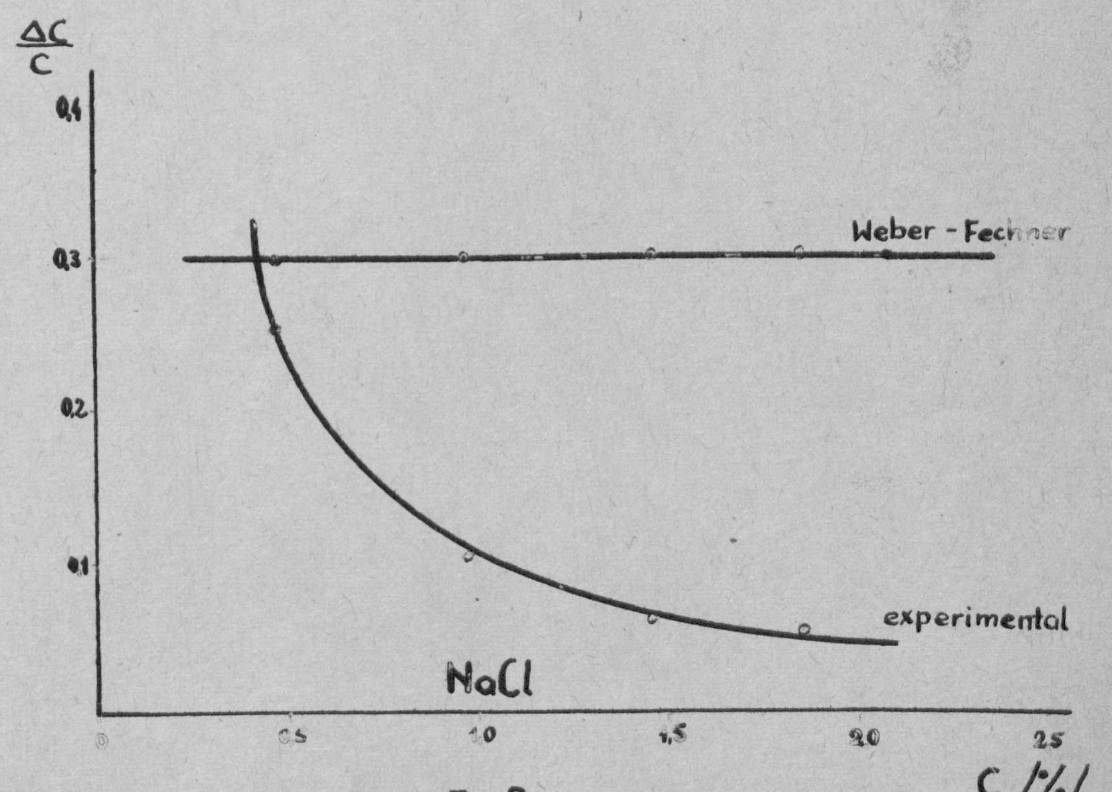
References:

1. Lloyd M. Beidler: The J. of Gen. Phys. Vol. 38/1954/ p. 133
2. Lloyd M. Beidler: "The physiological basis of flavor" in FLAVOR RESEARCH AND FOOD ACCEPTANCE, Reinhold. Publ. Co. New York 1958
3. D.J. Tilgner and H. Zimińska: personal communications.
4. R.M. Pangborn: Food Res. Vol. 25/1960/, p. 245
5. D.J. Tilgner: Przemysł Rolny i Spoż. v. 6/1954/, p. 14



$\frac{\Delta C}{C}$
0.4
0.3
0.2
0.1
Weber - Fechner
experimental
sucrose
0.5
1.0
1.5
2.0
2.5
C /%/

Fig. 1



$\frac{\Delta C}{C}$
0.4
0.3
0.2
0.1
Weber - Fechner
experimental
NaCl
0
0.5
1.0
1.5
2.0
2.5
C /%/

Fig 2.

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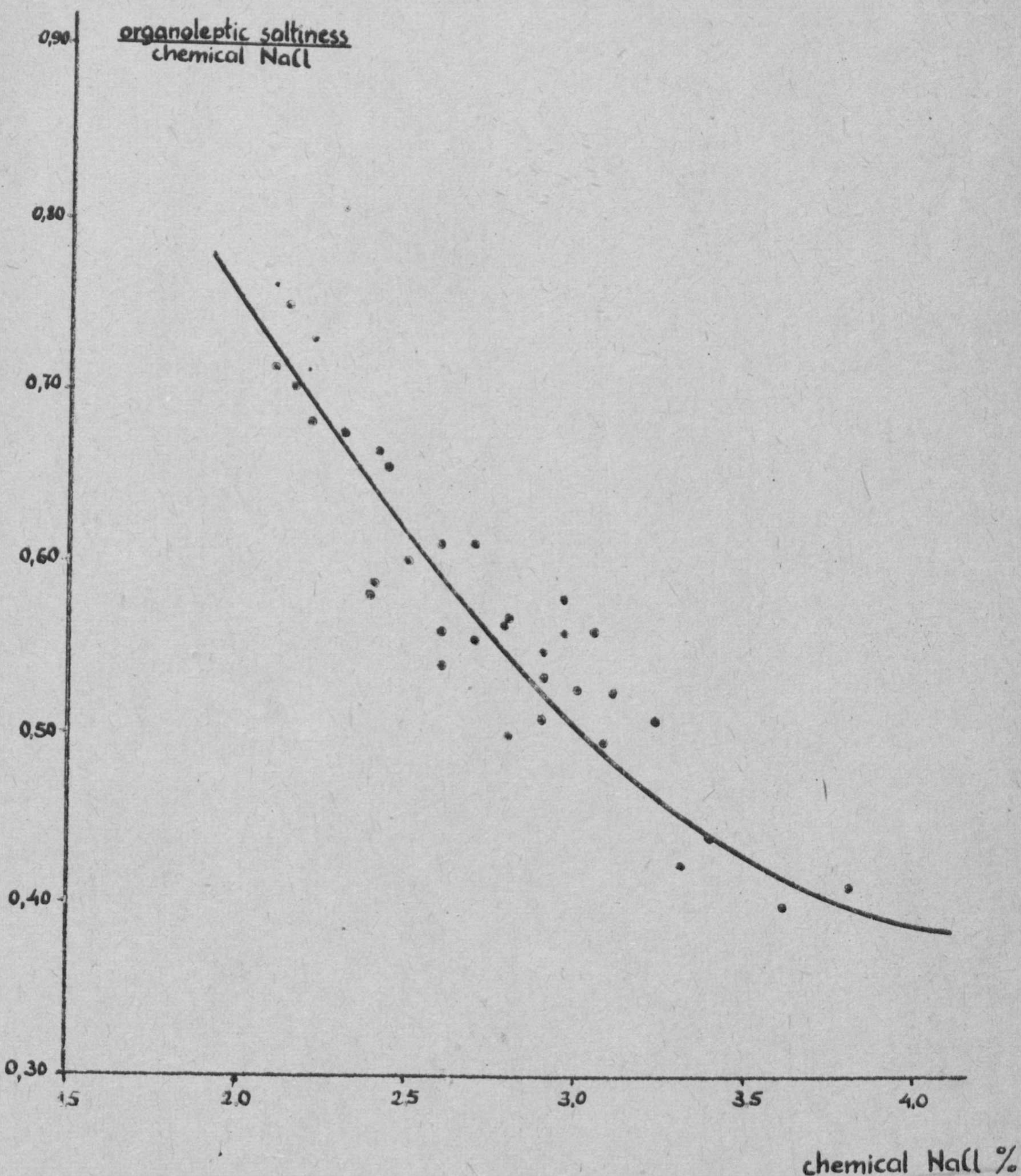

organoleptic saltiness
chemical NaCl
0,90
0,80
0,70
0,60
0,50
0,40
0,30
1.5
2.0
2.5
3.0
3.5
4.0
chemical NaCl %

Fig.3.