RELATIVE TASTE POTENCY AND THE COMPETITIVE OR COMPENSATORY ACTION OF SOME BASIC FOOD CONSTITUENTS

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THESIS

Relative Taste Potency and the Competitive or Compensatory Action of Some Basic Food Constituents

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Introduction

Parker (1922), who has made the most recent thorough investigations into the field of taste reaction, believes that in "ordinary food the flavor is a mixture of true tastes and odors accompanied by the multitude of other buccal sensitivities due to the variety of substances in the mouth and accepted in a rather unanalyzed form by the central apparatus. Yet in all this complexity the elements remain essentially distinct. Competition rather than compensation seems to be the rule".

Nevertheless, Parker is forced to concede that there are instances where gustatory compensation seems probable from experimental evidence offered but still maintains the doubt that they are true compensation.

It is not the purpose of this paper to prove that cases cited are true or false compensation but rather to work with a variety of basic food constituents to show their relative taste potency and the effect they possess upon one another, regardless of whether the compensation is true or false.

The underlying purpose of the work is to show experimentally how individual food constituents affect our taste reactions, either singularily or in combination with a contrasting flavor.

Literature Review

Anatomy of Taste

The organs of taste, the so-called taste buds, were independently discovered by Leven and Schwalbe in 1876.

Tuckerman (1890) found the distribution of the taste buds to vary with the individual and age. In young individuals taste-buds were found to be more widely distributed than in the adult. Later Stahr (1902) pointed out that the center of taste shifted with age from a position near the tip of the tongue in the young to the area of the vallate papillae in adults.

Tuckerman (1889) and others have conclusively shown that taste-buds when found, other than on the tongue, were embeded in the epithelium of the mucous membrane. On the tongue, however, they were invariable associated with a certain type of papillae which have been designated by their structure as conical, filiform, fungiform and vallate. Of these, only the fungiform, foliate, and the vallate carry taste-buds.

It has been shown experimentally by Tuckerman (1889) that the lower surface of the tongue, the inner surfact of the cheeks, the hard palate, and the uvula are insensitive to taste. No taste-buds have been found in these regions. The mucous membranes at the beginning of the gullet, the region of the arytenoid cartilages within the larynx, the epiglottis, the soft palate and the tongue are associated with taste sensations and in all these regions taste-buds have been identified.

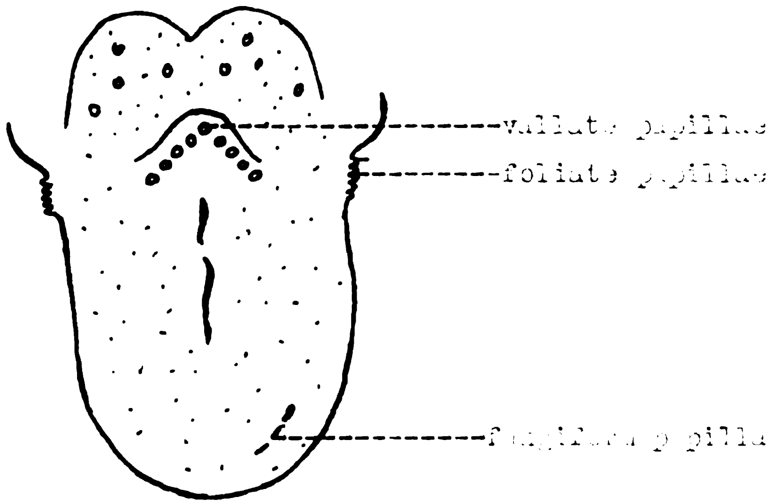


Fig. 1 Dorsal view of the human tongue showing the position of the papillae. (Parker, 1922)

Fig. 2 Vertical section of a fungiform papillae showing two taste buds. (Parker, 1922)

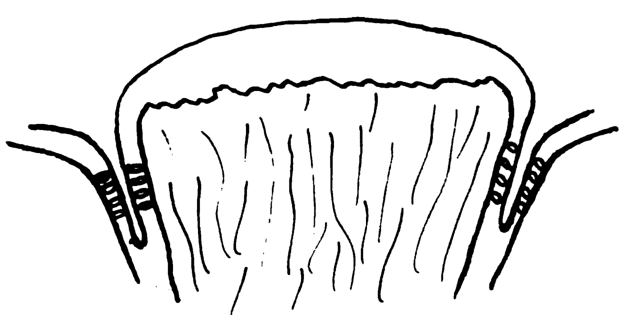


Fig. 3 Vertical section of a vallate papillae showing taste buds. (Parker, 1922)

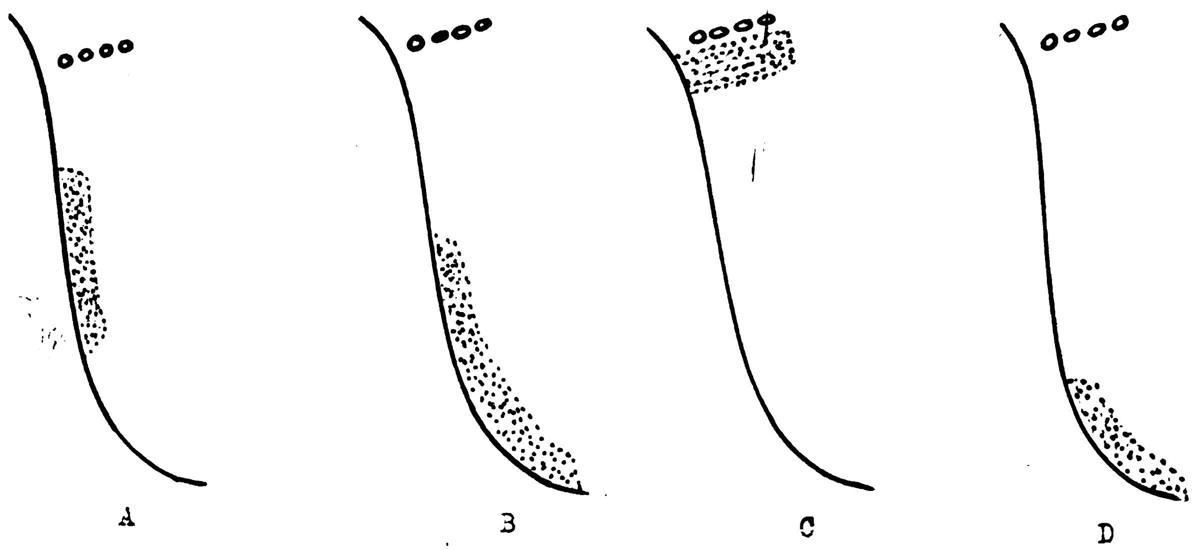
The tongue of man is his chief organ of taste and here there is considerable difference between children and adults. Tuckerman (1890) has shown that in children the entire upper surface of the tongue was associated with taste, while in the adult taste was confined to the tip, the lateral margins and the dorsal surface of the root of the tongue.

According to Schiff (1867) and most other workers in the field, taste falls into four well defined groups, namely: saline, sweet, sour, and bitter. These men claimed that the great variety of tastes associated with foods were a mixture of these four tastes. However, there was not absolute accord on this since some classified metallic and alkaline tastes among the four basic tastes given (Kahlenberg (1898), and others).

Oehrwall (1891) showed that distilled water is one of the very few substances that excited no taste reactions. He attributed its tastelessness to the absence of air, especially carbon dioxide, since its insipidity disappeared upon aeration or even the addition of carbon dioxide to the water.

According to Hanig (1901), the four basic taste reactions have individual distributions on the tongue. (See Fig. 4) The sour sensation is best shown on the lateral edges of the tongue and is accordingly associated with the folliate papillae and to some extent with the fungiform papillae. The bitter taste is largely located at the base of the tongue and is a function of the vallate papillae. The saline taste is most pronounced at the tip and lateral edges and

Fig. 4. Diagrams of the right half of the human tongue showing the distribution of the four basic tastes. (Modified from Hanig, 1901)



A - the sour taste B - the saline taste

C - the bitter taste D - the sweet taste the sweet taste at the tip and lateral margin of the base of the tongue. It would seem that the fungiform papillae are largely responsible for these taste reactions.

The distribution of the various taste reactions according to Kiesow (1894) are shown in Table 1. His work demonstrated that the reactions to sour, sweet, and saline solutions were exhibited almost wherever taste-buds were found but to varying degrees. Accordingly, the saline taste is most pronounced at the tip, edges, base and inferior portion of the tongue. The sour or acid taste reaction is most pronounced at the edge of the tongue while the sweet taste is strongest at the tip of the tongue, growing weaker along the sides.

There was considerable agreement between Hanig and Kiesow except Hanig apparently restricted the taste reactions to too definite an area.

Table 1. Threshold values for individual papillae in different parts of the taste field (after Kiesow).

	Per cent conc. by weight		
	NaCl	HCl	Cane Sugar
Tip of tongue	0.25	0.0102	0.49
Edge of tongue (rt.).	0.24	0.0072	0.76
Edge of tongue (lt.).	0.25	0.0063	0.72
Base of tongue.	0.28	0.0164	0.79
Soft Palate	0.20	0.0150	1.50
Arch of palate (rt.).	0.60	0.0100	1.50
Arch of palate (lt.).	0.50	0.0130	2.00
Uvula	0.90	0.0200	2.50
Inferior tongue (rt.)	0.30	0.0400	6.00
Inferior tongue (lt.)	0.30	0.0500	5.00

Physiology of Taste

The Sour Taste:

The sour taste is excited by acids, acid salts, and materials that produce acids. All these substances upon solution and subsequent dissociation give rise to hydrogen ions. Richards (1898) pointed out that all such solutions have a sour taste, and since the one component they all have in common is hydrogen ions, it is reasonable to assume that the sour taste is the result of the hydrogen ions. Kahlenberg (1898) working along somewhat different lines arrived at the same conclusion. A 0.0025 molar solution of HCl has a marked sour taste, and a 0.0025 molar solution of NaCl is tasteless. Both are considered completely dissociated and therefore the Chlorine ions in both are equal, so Kahlenberg concluded that the sour taste must be due to the hydrogen ions.

In work with organic acids, it has been shown by several workers that sourness of acids can not be solely attributed to the hydrogen ion concentration. Richards (1898) working with tartaric, citric, and acetic acids found them to be more sour than would be expected from their hydrogen ion concentration of their solutions. For example, with hydrogen concentrations equal, acetic acid was approximately five times as sour as hydrochloric acid. Kahlenberg (1898) estimated that acetic acid was four times as sour as would be expected from its hydrogen ion concentration. Paul (1922) offered the following data (Table 2) in proof that the hydrogen ion was not solely responsible for the sour taste.

Table 2. Sourness of acids. (Paul, 1922)

Acids	Concentration of acids and hydrogen ions to produce equal sourness.	
Acetic	M. = 7×10^{-4}	(H) = 3×10^{-4}
Lactic	23×10^{-4}	5×10^{-4}
Malic	8×10^{-4}	4×10^{-4}
Tartaric	4×10^{-4}	3×10^{-4}

Richards (1898) suggested that the sourness of organic acids was due to the undissociated ions acting as a reserve, producing additional hydrogen ions as those present were used.

It is generally assumed that to excite a taste, in particular a sour taste, the acid must penetrate somewhat into the interior of the taste cell. Crozier (1916, 1918a and b) reasoned that if this was the case, then the sour taste was due to the hydrogen ion, but the intensity of that taste was dependent upon the speed with which the acid penetrated the taste cell. In work with the penetration of acids, he gave the order of penetration to pH 5.6 in the tissue of Chromodoris as lactic acid, tartaric acid, citric acid, and last acetic acid.

Taylor (1927) in work with acid penetration into tissues found that:

"1. Polar groups such as OH, Cl and Br have a marked effect in reducing the ability of acids to penetrate living tissue.

2. Optical activity of the acids is important.

3. Penetration velocity influences taste threshold." The following charts and graphs prepared by Taylor confirm Crozier's explanation of the action of acids on the sense of taste. Table 3 shows that the external hydrogen ion concentration can not be the only significant variable. Figure 5 given the relative penetration of various acids.

Table 3. Threshold concentrations for the sour taste. (Taylor, 1927)

Acid	Conc. (Normality)	(H)
Formic	0.0018	0.00055
Acetic	0.0028	0.00028
Lactic	0.0028	0.00177
Tartaric	0.0022	0.00070
Oxalic	0.0020	0.00116
Succinic	0.0032	0.00034
Butyric	0.0035	0.00027
Valeric	0.0037	0.00015

R. M. Beatty and L. H. Cragg (1935) found that equi-sour acids when titrated against a sodium dihydrogen phosphate, di sodium hydrogen phosphate buffer system to a pH 4.45 used equal amounts of buffer. Using a 0.0025M hydrochloric acid solution, by tasting, they determined the molarity of acetic, malic, tartaric and chloroacetic acids that were equally sour. These were titrated against a buffer at pH 6.9 and the curves for each

Fig. 5 Relation between dilution and time of penetration.
(Taylor, 1927)

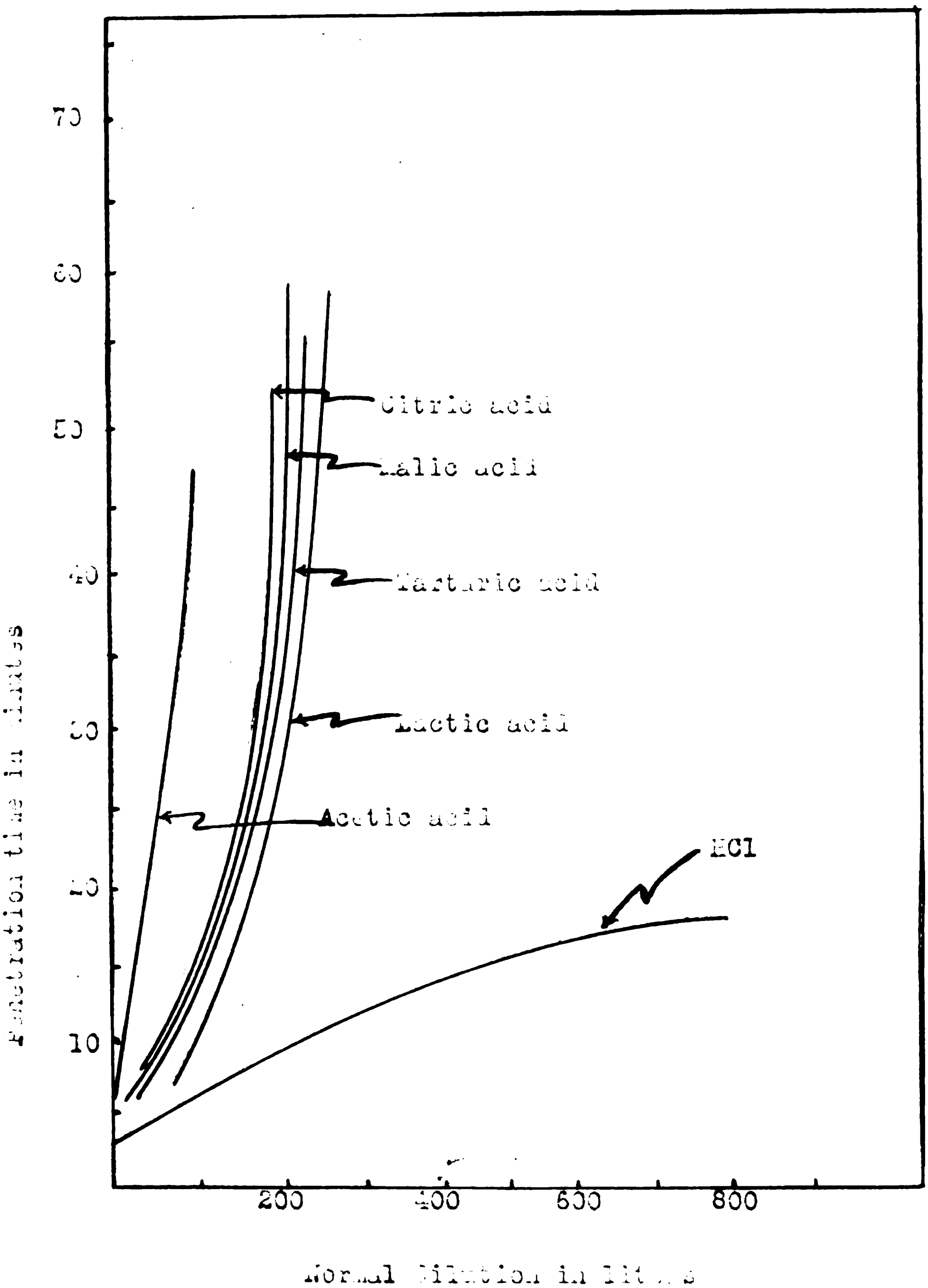


Fig. 6 Buffer curves for acids. (Beatty and Cragg, 1935)

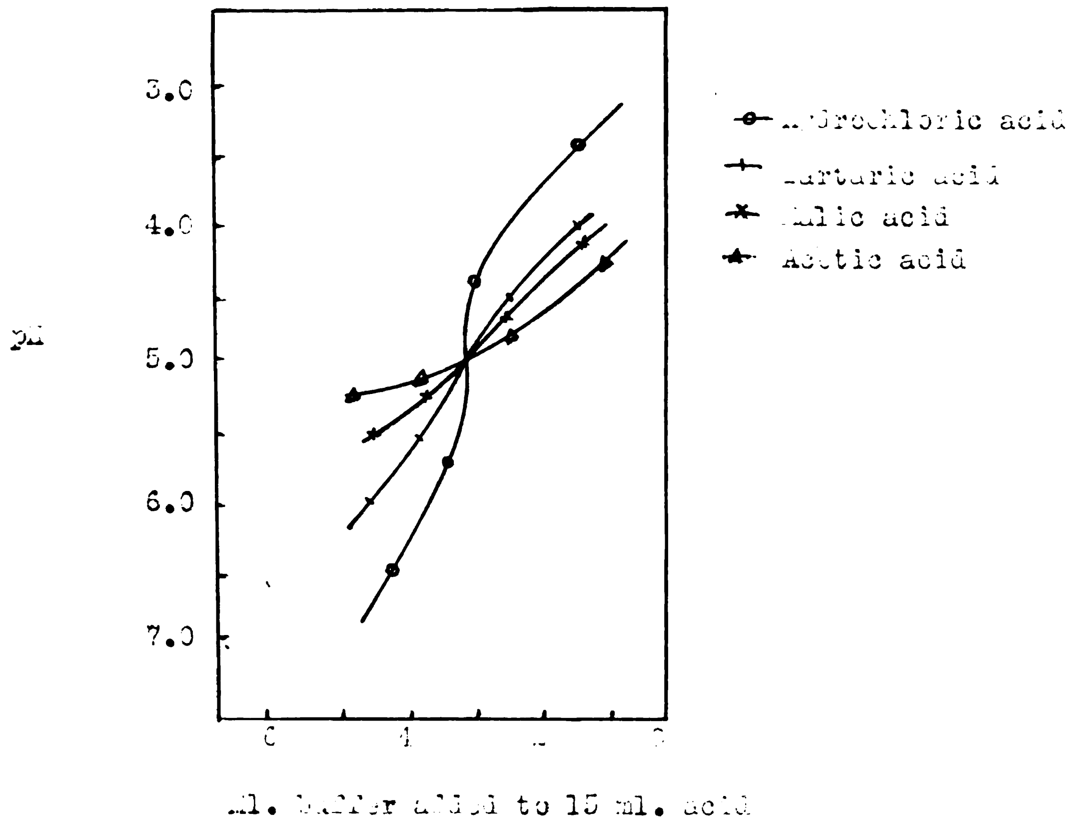
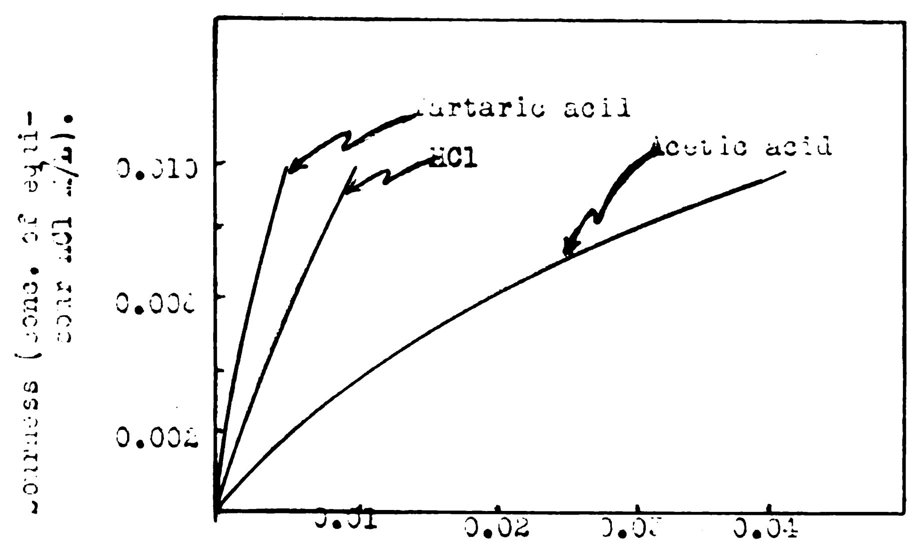


Fig. 7 Relative sourness of acids. (Beatty and Cragg, 1935)



acid shown in Figure 6.

This was repeated varying the pH of the buffer and the molarity of the acids and wherever the curves crossed, they found that the acids were equally sour. The curves consistently crossed at a pH 4.45.

They found that acids more sour than 0.001 M HCl can not be compared by taste and titration measurements so their results only cover the range up to a sourness equal to that of 0.01 M HCl.

From their work over a variety of molarities, they were able to graph relative sourness of acids. (Fig. 7)

They used the phosphate buffer as given above at pH 6.9 and titrated various strength acids to a pH 4.45. The titrations were then expressed as sourness and graphed against molar concentration.

Cragg (1937) noted that variations in the observed sourness of acids could be attributed to variations in the pH of the saliva. He found that the more acid the saliva, the greater is the apparent sourness of acetic acid and that there is some mechanism in addition to buffering for resisting changes in the acidity of the saliva.

The Saline Taste:

The saline taste is typified by sodium chloride but this is not the only compound capable of exciting a saline taste. The chlorides, bromides, and iodides of potassium and lithium as well as their sulfates and nitrates are more or less saline in taste.

Aqueous solutions of these salts are highly dissociated and the results of work by Kahlenberg (1898) and Hober and Kiesow (1898) showed the ions to be the stimulation agent, and in the case of sodium chloride, the anion was largely responsible for the saline taste reaction.

Kahlenberg (1898) found that solutions of sodium chloride so dilute as to be just perceptibly saline were more dilute than a solution of sodium acetate equally saline in taste and hence concluded that the saline taste must be due to the chlorine anion. He showed that equally dilute solutions of potassium chloride and lithium chloride were equally saline in taste as sodium chloride, thereby confirming that the intensity of the saline taste in these solutions was due to the chloride ion. He also demonstrated by similar tests that the order of effectiveness in exciting a saline taste reaction was chlorine, bromine, and iodine.

Crozier's (1934) observations on the taste of salt solutions showed colloids to be quite inactive in this respect. His work showed that the saline taste sensation was predominately an effect of crystalloids in true solutions.

The Bitter Taste:

That the bitter taste was characteristic of almost all the alkaloids, and certain other substances as the glucosides, picric acid, ether, and magnesium sulfate was demonstrated by Parker in 1922. Magnesium sulfate, in contrast to the sulfates of sodium, potassium, and lithium which are saline, is bitter, and this bitterness is attributed to the magnesium ion. Ammonia and calcium ions are also bitter in taste.

As shown by Parker and Stabler (1913), the most effective substances in exciting a bitter taste were the alkaloids as morphine, cocaine, quinine, nicotine, and strychnine. These substances could be detected in great dilution. Strychnine monochloride, for example, could be detected in a solution containing 0.0006 grams per liter of water.

Henry (1895) pointed out that bitter compounds often contain the NO_2-C-CH_2OH group. Other groups that might be classed as saprophores were the amines, hydroxly, and more than one NO_2 group in a compound.

Bitter taste was shown by Herlitzka (1909) to be associated with the cation with the exception of picric acid, where it was the anion.

The Sweet Taste:

According to Parker and Stabler (1913) the sweet, more so than the bitter taste, was caused by organic compounds and centered about the alcohols and the sugars, the majority of which were the aliphatic alcohols. Certain other carbohydrates and a few organic salts excited a sweet taste. Among the inorganic salts, lead acetate was most commonly considered sweet.

The question of what causes the sweet taste is far from settled. The common hexose sugars found in nature differ considerably in their degree of sweetness and yet they are isomers

of each other. Cohn (1914) concluded from his work that sweet-tasting substances contained certain structural groups that determined their taste, as with alcohols, one hydroxy group was associated with a sweet taste and four or five hydroxy groups were accompanied with a considerably stronger sweetness in taste. Oertly and Meyers (1919) proposed quite an elaborate determination for the constitution of the sweet taste, assuming that at least two groups were present in each sweet molecule, a glucophore and an auxogluc.

They defined a glucophore as "a group which has the power of forming sweet compounds by uniting with a number of otherwise tasteless atoms or radicals" and an auxogluc as "an atom or radical which combined with any of the glucophores yields a sweet compound". They listed six glucophores and nine auxoglucs. The glucophores and an example of a sweet compound formed is given in Table 4. The auxoglucs are given in Table 5.

Druce (1929) has made some interesting observations on the chemical constitution of taste and in particular on the sweet taste. He found that extremely dilute sodium and potassium hydroxide solutions tasted sweet. He stated that glycols and sugars were sweet but that the sweetness did not increase with the number of hydroxyl groups. This is contrary to the work of Cohn.

Druce in his work with sweet and bitter substances observed that in homologous series of organic compounds, bitterness in-

creases and sweetness decreases with rising molecular weight. He also found that in many compounds the meta form is sweet, but the ortho and para compounds are bitter. This has been confirmed by others.

Table 4. The glucophores. (Oertly and Meyers, 1919)

	Glucophore	Example of a sweet compound formed
1.	$CH_2OH-CHOL$	glycol
2.	$-CO-CHOH$	glycolaldehyde
3.	$COOH-CHNH_2-$	alanine
4.	CH_2ONO_2	ethyl nitrate
5.*	$C^{H_{3-x}}_{Hlx} - C^{H_{3-x}}_{Hlx}$	$CH_2Br-CHBr-$
6.*	$C^{H_{3-x}}_{Hlx}$	$-CH_2Cl$

* Hl - halogens
x - number of halogens

Table 5. The auxoglucs. (Oertly and Meyers, 1919)

1. H-	5. $(CH_3)_2-CH$
2. CH_3-CH_2-	6. CH_2OH
3. CH_3-	7. CH_3-CHOH
4. $CH_3-CH_2-CH_2-$	8. $CH_2-OH-CH_2-$

9. Radical $C_n\ H_2n\ 1\ O_n$ of normal polyhydric alcohols.

Finzi, C. and Colonna, M. (1938) in their work on the chemical constitution of sweet taste found the theory of Oertly and Meyers an inadequate explanation. They cited numerous examples of substances that do not follow the plan of Oertly and Meyers.

Sense of Smell

The sense of smell in man is the result of nasal stimulation. According to Parker (1922) this stimulation falls into two classes of substances, irritants and true odors. The irritants effect the trigeminal terminals which are a part of the common chemical sense referred to later in this paper, whereas, the true odors stimulate the olfactory nerve endings. Parker contends that they are not entirely separate since certain substances act to stimulate both types of nerves.

Woodrow and Karpman (1917) found that the time needed for an olfactory sensation to disappear was directly proportional to the surface tension of the odorous material. This and other observations lead to the conclusion that olfactory stimulation was the result of material particles.

In testing olfactory acuity the majority of workers have used the method of evaporating a known weight of substance in a known volume of air. Using this method, Fischer and Penzoldt (1886) working with chlorophenol and mercaptan, derived some outstanding results. For example, 1/230,000,000 milligram of chlorophenol per cubic centimeter of air was found to be sufficient concentration to give an olfactory sensation. Mercaptan, a substance giving a garlic odor, caused olfactory stimulation in a concentration of 1/23,000,000,000 milligram per cubic centimeter.

Passy (1892) has made similar minimum determinations for a number of substances, some of which are given in Table 6. It

may be noted that there is some disagreement among various sets of data in minimum determinations for the sense of smell, but they all emphasize the acuteness of man's olfactory sense.

Table 6. Minimum concentration for olfaction in thousandths of a milligram of substance per liter of air. (Passy, 1892)

Substance	Thousandths of a milligram
Ethyl ether	1.0
Citral	0.50 to 0.10
Cumarin	0.50 to 0.01
Vanillin	0.005 to 0.0005
Methyl alcohol	10.0
Ethyl alcohol	2.5

Veress (1903) found that upon introduction of a solution of an odorous substance into the nasal cavity, an olfactory stimulation resulted, but the sensation was not that of the original substance. It has been established by Blackman (1917) and others that vapors of odorous substances, before they can cause an olfactory stimulation, must go into solution with the watery mucous and in this state come in contact with the olfactory hairs. Blackman has further shown that before the substance can gain entrance into the hairs it must also be soluble in the oily coating of the hairs.

It is well known that olfactory organs are quickly fatigued by continuous exposure to an odorous material. Persons working among disagreeable odors soon become insensitive to these odors. Aronsohn (1884) attempted to determine the time necessary for

olfactory fatigue. Oil of lemon and oil or orange were smelled by nine persons until they could no longer distinguish these odors. He found that it took from 2.5 to 11 minutes with an average of 3 minutes for obliteration of these odors. Recovery was found to be equally rapid, being from 1 to 3 minutes.

Anosmia, a condition in which persons are absolutely devoid of true olfaction, was shown by Glaser (1918) to exist. There can also be partial temporary anosmia.

Henning (1916), in working with the quality of odors, has produced the olfactory prism. (Fig. 8) With it he has tried to show the relationship between his six basic odors which are as follows:

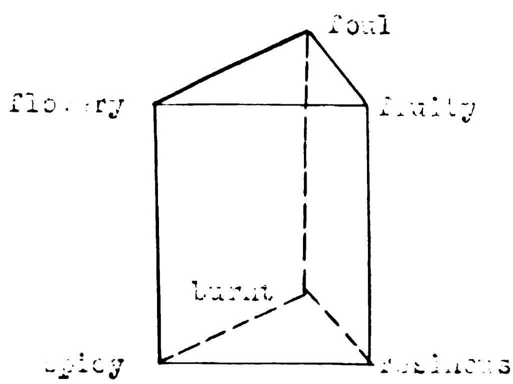
1. Spicey odor, as those of fennel and cloves.
2. Flowery odors, such as those of cumarin.
3. Fruity odors, as those of orange.
4. Resinous odors from turpentine.
5. Burnt odors, such as those from pyridine.
6. Foul odors like hydrogen sulfide.

Between these basic odors, all intermediate odors may be imagined to fall somewhere on an edge or on the surface of the prism. This was the relationship Henning believes to exist between various odors, whether basic or intermediate.

It is readily admitted that olfaction is essentially a chemical process and little progress has been made to show the relation between chemical structure and olfaction. Passy (1892)

set up the following table (Table 7) to show the relationship between various alcohols and their relative olfactory potency.

Fig. 8. Henning's olfactory prism.



(Henning, 1916)

Table 7. Showing olfactory potency of alcohols. (Passy, 1892)

Alcohol	Relative Potency
Methyl	1.0
Ethyl	4
Propyl	100
Butyl	1000
Amyl	10000

Henning has done a great deal of work with aromatic compounds and smell and has concluded that various smells were not a result of the osmophoric groups (hydroxyl, aldehyde, ketone, ester, nitro, and nitril groups), but rather the result of the position they occupied on the benzene ring. Thus in the flowery odors the osmophoric groups were in the meta or ortho positions; in the fruity odors the groups were forked; in the resinous odors the groups were within the ring; in the burnt odors the ring was smooth; and in the foul odors the ring was fragmentary. Intermediate odors were due to the combinations of the groupings.

Aronsohn (1886), in working with combinations of odors, arrived at a number of interesting conclusions. Two odors well balanced will appear as a single odor different from either of the original odors. If the odor is not well balanced, the stronger will dominate.

The Common Chemical Sense

It has long been known that in the nasal cavity of man there are two types of nerve terminations: the olfactory nerves for our true sense of smell, and free nerve terminations which are stimulated by irritants and whose system is part of the common chemical sense.

Coghill (1914) has produced evidence that indicates that these receptors were in reality a part of our tactile sense. However, as Parker (1922) pointed out, this is not definitely established since there is also evidence that indicates our common chemical sense is a separate system of nerves.

The common chemical sense has little to do with either the sense of taste or the sense of smell. Parker and Stabler (1913) have shown that the minimum concentration of ethyl alcohol necessary to stimulate man's irritant receptors is five to ten molar which is considerably stronger than will stimulate man's gustatory organs (about three molar) or olfactory organs (about 0.0001 molar).

Measuring Taste Reactions

Methods:

The methods of measuring taste reactions are naturally varied, depending upon the purpose and the investigator. Here we shall only be concerned with the studies on taste thresholds, placements, and compensation. For sake of clarity, the processes for measuring taste reactions are reviewed by taking certain variables independently and comparing the investigators' methods.

Richter and MacLean (1939) in their studies into salt taste thresholds attempted to evaluate four methods. In the first method tried, they placed three drops of solution on the subject's tongue. They found this method poor due to the difficulty in placing exactly three drops on the tongue and the great dilution of the small quanity of stimulus by the saliva of the mouth. In the next two methods the subjects were given 10 ml. of solution in glass containers, but in the first of these two methods there was no distilled water given between samples, while in the other, a distilled water wash was given the subjects between each sample. In the fourth method used the subjects were given two containers, one with the solution being tested, the other with distilled water. The subjects were allowed to sample both until satisfied with the taste.

The second method was found inadequate because the subjects were given no distilled water between samples for a comparison and as a result it was difficult to state when a change occurred in the increasing salt concentration.

The next method, with distilled water between each sample, was chosen by the investigators as the most adequate. The difficulty here was that the subjects did not have sufficient opportunity to compare taste of the two liquids.

To off-set the difficulty in the previous method, the fourth method was used and found adequate for some work. The difficulty here was psychological and as would be expected, the threshold values were lowest by this method.

Trout and Sharp (1937) used a method very similar to the fourth method of Richter and MacLean. Approximately 75 ml. of solution in 100 ml. beakers was used for placement work. The judges were allowed to taste as large a sample as desired and were also allowed as many retastings as they thought necessary. By volume measurements and the number of trials, the authors determined the average volume per tasting. Two judges, making 190 tastings, averaged 6.13 ml. per tasting.

A. Beister, M. Weigley and C. S. Wahlin (1925) made a study of the relative sweetness of pure sugars. Their method consisted of a 15 ml. distilled water rinse, removing the moisture from the tip of the tongue with a cotton swab and then placing one drop of the solution on the judge's tongue. Results were recorded as sweet or not sweet.

Toulouse and Vaschide (1900), in their work on measuring taste reactions, used 1 ml. of solution placed upon the protruded tongue. Camerer (1869) used 10 ml. of stimulus in an ordinary drinking glass. In some of his studies, Camerer used as much as 30 ml. of solution per tasting. Kahlenberg (1898) gave his judges 4 ml. of solution from a porcelain spoon. Richards (1898), in working with acid solutions alone, allowed the judges to take small mouthfulls of solution from an ordinary drinking glass. Shore (1892), in determining compensation in tasting, used two drops of solution placed on the tongue. King (1937) found 5 ml. portions given in small beakers adequate.

Temperature Coefficient:

The effect of temperature on the taste of sapid solutions is another variable in methods for determining taste reactions. Hollingworth and Poffenberger (1917) were of the opinion that thermal stimuli had a considerable influence upon the effect of taste stimuli. They also stated that the optimum temperature varies from 55° F. to 120° F. At the optimum temperature the least amount of sapid material is necessary to arouse a taste reaction. Any deviation in either direction will cause an increase in the quanity of sapid material necessary to arouse an equally intensive reaction.

Kiesow (1894), on the other hand, believes that the temperature of sapid material has no effect on the taste reaction, but does maintain that the temperature of the mouth previous to tasting has a marked effect on the taste reaction. For example, he holds that tasting is equally acute at 32° F. and 100° F. When the temperature rises or falls beyond a certain point, the temperature reaction becomes so strong that the taste reaction drops out of consciousness. In his experiments, Kiesow used temperatures of 10° C. to 20° C.

Parker (1922) points out that the stimulation of the taste receptors is probably a chemical process and as such there should be considerable temperature coefficient. He goes further to state that as far as he is aware no studies have been carried out with this point in view.

Komuro (1921) found a great temperature coefficient between 10° C. and 20° C., having the sensitiveness of reaction increase 100 per cent in this increase in temperature. He also found the reverse to exist between 30° C. and 40° C. From this, the optimum temperature for taste sensitivity is between 20° C. and 30° C.

Camerer (1869) studied salt solutions at 5°, 10°, 20°, 30°, 40°, 50°, and 60° C. and found the optimum range between 20° and 30° C.

Marchand (1903) believed that optimum temperature range is between 30° and 40° C. and cited experiments which showed that in order to get the same intensity of reaction from sapid material at 0° C. as at 30° C. from four to thirty times as much sapid substance must be used. Marchand offered the following experimental data. (Table 8)

Table 8. Effect of temperature upon threshold values. (Marchand, 1903)

Substance	Threshold values given in parts per 100 at 30° to 40° C.	at 0° C.
Sugar	0.10	0.40
Salt	0.05	0.25
Citric Acid	0.0025	0.0030
Quinine	0.0001	0.0030

G. Trout and P. Sharp (1937) concluded that maximum discriminatory ability for respective solutions was as follows: sodium chloride, 21° C.; sucrose, 35° C.; lactose, 35° C.; lactic acid, 21° C.; quinine sulfate, 21° C.

Richter and Campbell (1939) found no correlation between temperature of solutions of sugar and threshold values when 10 ml. portions were taken into the mouth.

Time Interval Between Tasting:

Brown (1914) believed that tasting in rapid succession had no effect on sensory acuity, but did effect subsequent judgments. For example, in studies with salt solutions, if the solution that was being tasted was weaker than the preceding, there was a tendency to call it salt, whereas, if the solution being tasted was stronger than the preceding one there was an equal tendency to call it water. Brown allowed an average of 25 seconds for each solution.

Camerer (1885) permitted a pause ranging from two to five minuted between samples, while King (1937) specified a pause of

two minutes between samples. The time the solution remained in the mouth was not specified.

Trout and Sharp (1937), and Richter and MacLean (1939), in their studies, made no time specifications, allowing the subjects to proceed as rapidly as desired.

Reaction Time to Stimuli:

The reaction time or latent period for taste excitation is the time interval between application of the solution and appearance of the sensation. (Crozier, 1934)

Kiesow (1903) determined the reaction time for four different solutions, and showed that this time was greatest for bitter, next smaller for acids, next for sugars and least for salt solutions. He gave the reaction times as follows:

Salt	0.308 seconds
Sugar	0.446 "
Acid	0.536 "
Quinine	1.082 "

Hollingworth and Poffinberger (1917) studied the effect of temperature upon the reaction time. Lowering the temperature of the solution below that of the mouth did not affect the reaction time for salt, but lengthened the time for other basic tastes. Raising the temperature above that of the mouth decreased the reaction time to sweet, but increased the reaction time to bitter and sour.

Taste of Water:

Parker (1922) stated that insipidity, such as was characteristic of distilled water, was probably real tastelessness. King (1937) pointed out that the judges noted tastes for distilled water and agreed with Crocker and Henderson (1932) that it took several days of tasting before the judges became accustomed to the tastelessness of water. Gradually a reaction was built up where water really appeared tasteless.

The most common reaction to water, as found by Titchner (1901) and Brown (1914), was that of bitter, described as a smooth bitter.

Kahlenberg (1898) commented on the tastelessness of water. He pointed out that since taste was probably a chemical reaction and that distilled water was composed of undissociated molecules, then distilled water was really tasteless since no chemical reaction was possible.

Other Variables:

There are a few other variables that enter into methods of measuring taste reactions. King (1937) found no relationship to exist between acuity of taste and age or smokers. Blakeslee and Solmon (1931) concluded that females were somewhat more acute tasters than males. Boclike and Routh (1932) found that nonsmokers could taste weaker concentrations of common acids.

Richter and Campbell (1939) concluded that the following conditions were not found to affect taste sensitivity for sucrose:

chronic alcoholism, excessive smoking, badly infected gums, marked decay of teeth, mild head cold, and hay fever or allergy.

Taste Thresholds

A great number of studies have been made to determine the taste threshold of a variety of substances, but they are of little comparative value since there is no uniformity of method. This lack of uniformity in method is largely due to a lack of standard definition of the threshold of taste. Tichner (1905) regarded the threshold, or limen value as that magnitude of stimulus which just brings a sensation to consciousness. Brown (1941) believed it to be at some point on a scale mid-way between the intensity which is just barely strong enough to produce a sensation and the intensity which always produces a sensation.

Richter and Campbell (1939) used possibly the most definite method. They believed that the gustatory threshold should be divided into two individual thresholds, a difference threshold, and a taste threshold. The difference threshold represented the point where the subjects could differentiate between a sapid solution and distilled water, while the taste threshold was the minimum concentration which the subject could recognize.

King (1937) set up score cards whereby she could determine the so-called "difference threshold" and the "taste threshold", but recorded her data only as thresholds and offered no explanation as to the means used to arrive at this threshold.

Parker (1922) in his extensive study into the sense of taste selected the following as being representative threshold values:

	Per cent
Sucrose..................	0.685
Hydrochloric acid........	0.009
Sodium chloride..........	0.234
Quinine hydrochloride....	0.0016

Numerous workers in the field of taste reactions have attempted to determine the threshold values for various substances. Table 9 gives many of these figures for the four basic taste reactions. All the figures have been converted to percentage. The great variation in results may be attributed to variations in methods and to the individual definition of threshold of taste.

In working with sugars, many have concerned themselves only with relative taste although in many cases these were determined by the relationship of threshold values. Table 10 gives the relative values of the sweetness of the more common sugars as found by their respective authors. Here again there is considerable variation, especially for the values assigned to invert sugar, and this may largely be attributed to the variations in methods.

Table 9. Frequently quoted threshold values representing the four basic taste reactions.

Substance	Author	Threshold in percentage
Sodium Chloride		
	Blakeslee and Solomon (1931)	0.34
	Crocker and Henderson (1932)	0.17
	King (1937)	0.11
	Venables (1887)	0.10
	Bailey and Nichols (1888)	0.05
	Zuntz (1891)	0.10
	Kiesow (1894)	0.25
	Hanig (1901)	0.34
	Barley and Doan (1936)	0.19
Sucrose		
	Crecker and Henderson (1932)	0.72
	King (1937)	0.57
	Venables (1887)	0.30
	Bailey and Nichols (1888)	0.50
	Hanig (1901)	0.35
	Blakeslee and Solmon (1935)	1.28
	Richter and Campbell (1939)	0.55
Hydrochloric acid		
	Venables (1887)	0.010
	Beatty and Cragg (1935)	0.036
	Henning (1916)	0.019
	Blakeslee and Solmon (1931)	0.044
	Kiesow (1894)	0.010
Quinine		
	Bailey and Nichols (1889)	0.0003
	Blakeslee and Solmon (1931)	0.0032

Table 10. Literature review on the relative sweetness of sugars.

Author	Sucrose	Dextrose	Fructose	Lactose	Maltose	Invert sugar
Beister, A. et al. (1925)	100	74.3	173.3	16.0	32.5	130.0
Deerr, N. (1922)	100	60.0	120.0			95.0
Rikhter, A. A. (1927)	100	68.2	151.5			
Sale, J. W. and Skinner, W. W. (1922)	100	50.0	150.0		60.0	
Inter. Crit. Tables *	100	55.0	127.5	27.5	60.0	85.5
Tracy, P. H. (1936) *	100	67.5				
Paul, T. (1921)	100	52.0	103.0	28.0		
Humphries, E. (1940)	100					100.0
Spengler, O. and Traegal, A. (1927)	100					103.0

* Averages of values given.

From this and other work there arises a very interesting correlation between acuity of taste and reaction time to the four basic taste reaction substances. This correlation holds generally for other substances classed in the four basic taste groups. Bitter tasting substances as a rule show taste reactions in the greatest dilution and also have the longest reaction time. Acid solutions are next in acuity and their reaction time is second longest. Sugar solutions follow next in this order and salt last with the highest threshold values and the shortest reaction time. This is odd indeed since it would logically seem the reverse of this order.

Trout and Sharp (1937) found the sense of taste capable of discrimination changes as low as one per cent sodium chloride solutions ranging in concentration from 0.13 to 0.20 per cent. With sucrose, lactose and lactic acid solutions, ten per cent changes in concentration were readily detected. They also found that amount of substance required to produce a noticeable change in sensation was only a fraction of the usually stated threshold value.

Blending of Flavors

Parker (1922) believes that in all complexity of taste mixtures the elements remain essentially distinct, concluding that competition rather than compensation is the rule.

Kiesow (1894) studied sucrose and sodium chloride mixtures and showed the effect of small amounts of salt in neutralizing

the sweet taste of sucrose. At a concentration of one per cent the ratio of sugar and salt to bring about neutrality was found to be 0.5 to 0.25 respectively; while at a concentration of ten per cent, the ratio for neutralizing the sugar was about 0.5 to 0.03 respectively.

Komm and Lammer (1940) have shown that acetic, tartaric and citric acids when added to sucrose solutions show a decrease in acid taste. They concluded that the degree of acidity is dependent upon the concentration of the sugar solution.

Titchener (1901) also points out the contrast of sweet and sour and adds that bitter does not contrast with any other taste and so can not be eliminated by compensation.

Zuntz (1892) found that a one per cent solution of sodium chloride increased the sweetness of sugar solutions. Nagel (1896) showed that a mouth wash of potassium chloride made distilled water taste sweet, and Aduco and Mosso (1886) found that after the tongue was held in dilute sulfuric acid for a few minutes, distilled water and even quinine were capable of exciting a sweet taste.

Cragg (1937b) using the method of Beatty and Cragg (1937) attempted to determine the effect of salt and sugar upon sourness. His results indicate that the addition of three per cent sugar decreased the sourness of hydrochloric acid 15 per cent by taste and 40 per cent by titration against a buffer. He also found that the addition of sodium chloride does not affect the sourness of acids.

Experimental Procedure

Thresholds of Sensation

Fifteen judges were availagle throughout this part of the work. The experiments started with 25 judges but ten were eliminated for various reasons, such as, carelessness in tasting, inconsistency, and very limited availability. All the judges were students with very limited or no previous tasting experience.

The tasting was done from 100 ml. beakers, each containing five millileters of solution pipetted for the judges by the author. With each substance, a judge was given a direction-data sheet (No. 1). The author remained with the judges while tasting to insure uniform procedure.

The judges were allowed only one tasting of each solution. Each judge tasted each such substance twice, at different sittings so that each threshold value represents at least 30 judgings.

The tasting work was done on basic food constituents. However, calcium chloride, aluminum chloride, and stannic chloride were used to determine the effect of the anion in salts upon taste by varying the cation; using mono, di, tri, and tetravalent cations. Table 11 gives the substances used and their respective concentrations.

In making solutions of these substances certain precautions were observed. All glassware was thoroughly cleaned with cleaning

Direction-Data Sheet No. 1

RESEARCH ON FLAVOR

Name of Judge ____________________ Substance ________ Date ________ Time ________

Procedure: Rinse the mouth thoroughly with distilled water, discarding the water. Pour 5 c.c. of Solution No. 1 in a beaker, and then put it in your mouth. Swish the solution around so that it reaches the back part of the tongue. Discard. Record the taste. Rinse the mouth with distilled water again. Wait two minutes then taste Solution No. 2. Use a clean beaker for each solution. Continue through the series with the same procedure.

Insert number designating the intensity of taste of the numbered solutions, using following key:

0—No taste
1—Very faint
2—Faint
3—Easily noticeable
4—Strong
5—Very strong

Solution No..................	1	2	3	4	5	6	7	8	9	10
Intensity....................										

What was the taste? ________________________________

Number of solution at which taste was first identified ________________

How long since smoking before taking the test? ________________

How long since eating before taking the test? ________________

solution (H_2SO_4+$K_2Cr_2O_7$), well rinsed with tap water and finally rinsed with distilled water.

Table 11. Molar concentration of substances used in determining the thresholds of sensation.

	Substance		Molar concentration				
Salts:							
	Sodium chloride		0.005	0.010	0.025	0.050	0.070
	Calcium chloride		0.005	0.0075	0.01	0.025	0.050
	Aluminum chloride		0.00025	0.005	0.00075	0.001	0.0025
	Stannic chloride		0.000075	0.0001	0.00025	0.0005	0.00075
Sugars:							
	Sucrose		0.0075	0.010	0.025	0.050	0.075
	Dextrose		0.025	0.050	0.075	0.10	0.125
	Fructose		0.010	0.025	0.050	0.075	0.100
	Lactose	0.050	0.075	0.10	0.125	0.150	0.175
	Maltose		0.010	0.025	0.050	0.100	0.100
Acids:							
	Acetic acid		0.0005	0.00075	0.0001	0.0025	0.0050
	Hydrochloric acid		0.0001	0.00025	0.0005	0.00075	0.0010
	Citric acid		0.0001	0.00025	0.0005	0.00075	0.0010
	Malic acid		0.0001	0.00025	0.0005	0.0075	0.0010
	Lactic acid		0.0001	0.00025	0.0005	0.00075	0.0010
	Tartaric acid		0.0001	0.00025	0.0005	0.00075	0.0010

For each substance listed in Table 11, a standard was accurately made and in the case of the salts and acids checked by titration against known standards. It was from these standards that solutions

tasted were made by dilution using Exax pipettes and volumetric flasks. For the sugars, no checks were made but samples were accurately made by weight and dilution. All solutions were made with fresh distilled water from a Barnstead still.

All substances used were C.P. chemicals from established chemical supply houses. They were made just prior to use and allowed to stand for no longer than a few days. The tasting work on one set was completed by all tasters from the same solutions.

In recording the data, the first solution in the series of increasing concentration that differed from the distilled water in taste was the sensitivity threshold whereas the first solution in which the taste could be described was the taste threshold.

Correlation between Buffer and Sourness

Following the pattern of the work of Beatty and Cragg (1935) attempts were made to correlate sourness with titrations against a phosphate buffer.

A buffer was made as follows:

3.24 gms. $NaH_2PO_4 \cdot H_2O$

0.48 gms. $Na_2HPO_4 \cdot 12H_2O$

20 cc. of approximately 1N NaOH

made up to one liter - final pH 7.05

A variety of solutions of each acid was made in the same manner as previously described. Using 10 ml. of the buffer solution diluted one to five, acid was added until the pH on the Beckman meter reached 4.45. At this point, according to Beatty and Cragg, acids using equal amounts are equally sour. The amount of acid necessary to bring the pH to this point was recorded.

Ten molar solutions of each acid were thus titrated and the milliliters of each titration plotted (Figs. 10 and 11) to determine relative sourness. This was done in two sets of solutions so that appropriate dilutions of the buffer could be used.

Competitive or Compensatory Action

To determine if one substance acted in a competitive way with a contrasting substance or in a compensatory say, two methods were used.

The first method consisted of tasting a series of five solutions and comparing them to a control (Tables 19 to 22). For this work, a series of six solutions was made of equal concentration of a substance, all above the taste threshold. The first was designated as the control and to the remaining five was added a contrasting substance in increasing concentration ranging between the sensitivity and the taste threshold.

This method was used on a series of four combinations of acid, salt and sugar and because of rather inconsistant results, it was discarded in favor of the second method. The direction-data sheet (No. 2) for this work is found on page 41. However, some information was derived from this method and it lead to the use of the second method. Eight judges were used for this work.

The second method consisted in matching molar solutions

Direction-Data Sheet No. 2

Research on Flavor

Name of Judge ______________________ Series No. _____ Date _______ Time _____

Procedure: Rinse the mouth thoroughly with distilled water, discarding the water. Place solution No. 1 in your mouth, swish about so that it reaches the back part of your tongue. Discard. Record the taste. Again rinse the mouth thoroughly with distilled water, discard and after waiting about one minute taste solution No. 2. Continue in the same manner throughout the entire series. RECORD TASTE AFTER EACH SOLUTION!

Use solution No. 1 as a guide and record solution No. 2 as stronger or weaker according to the key below. Also record the taste; i.e. salty, bitter, sweet, etc. Solution No. 1 should be tasted before each of the other solutions.

-3	-2	-1	0	+1	+2	+3
much weaker	noticeably weaker	slightly weaker	Same	slightly stronger	noticeably stronger	much stronger

Solution No.	Change in taste	Taste
1	Control	
2		
3		
4		
5		
6		

where the solution to be matched contained a greater than the taste threshold concentration of a substance and in addition a sub-taste threshold concentration but greater than sensitivity threshold concentration of a contrasting substance. This solution was matched to a series of five solutions of increasing concentration of the greater than taste threshold substance. The series of solutions was made with sufficient difference in concentration so that the judges could easily notice the increase in taste and the concentrations usually varied above and below that of the solution to be matched. For example, a moderately strong tasting solution of sucrose to which had been added a sub-taste threshold amount of sodium chloride was matched to a series of solutions containing only sucrose whose concentration varied above and below that of the control solution. The same method was followed with the other sugars and acids (Table 23).

Competition or compensation was determined by the judges' choice of solution. If the substance added showed a compensatory action, it was indicated by the judges' choice of a solution other than the one of equal concentration of the substance tasted. If, on the other hand, the choice of the judges was a solution of equal concentration of the substance tasted, competition was indicated since the sub-taste threshold substance did not add or detract from the taste of the solution.

This method proved very satisfactory in determining the effect of sub-taste threshold concentrations of one substance upon mildly strong tasting concentrations of a contrasting substance.

Using this method, experiments were made to determine the effect of sodium chloride on all the acids and sugars listed in Table 11. The effect of each individual acid on dextrose, sucrose, fructose and sodium chloride as well as the effect of all the sugars on all the acids was determined. This made a total of 64 such determinations to cover this work. (Tables 23 to 35)

Similar precautions were followed in these determinations as in the determinations of the threshold of sensation in relation to the making of the solutions.

For the tasting work 100 ml. beakers were used and the judges were given as much solution as needed. There was no control on the amount of solution tasted, the time for tasting, or the number of retastings. The judges were allowed as much solution as desired and as many retastings as they found necessary to satisfactorily choose a matched solution.

It was found adviseable to have the judges compare solutions one, three and five with the unknown to determine the relationship and then attempt to match the unknown with a single solution by elimination. They were told that the series was in order of increasing concentration.

Each set of solutions was tasted by ten judges although there were fifteen available for the work. This was done because some judges were either very sensitive to sugars or acids even though these were added in sub-taste threshold concentration, they so

altered the taste for some of the judges that matching was impossible. It was always found that the ten chosen could make what they felt were honest matchings. Between each set of matchings, the judges were required to wait about two minutes. Part of this time was spent in thoroughly rinsing the mouth free of the preceding solution.

As a rule, sour solutions were left for the last. It was found that when they were tasted first they so sensitized the mouth that if the following series contained acids in sub-taste threshold concentrations, the acids were tasted and in some cases to such an extent that the taste of the greater-than-taste-threshold-substance was almost completely obliterated.

It was also found that the judges could not do more than one series of acids at one time. Beyond this, they could not distinguish between the solutions of increasing concentration sufficiently to do satisfactory matchings. In making the sour solutions, care had to be exercised to insure that the solutions were sufficiently strong so that they could easily be tasted by all but not so strong as to be irritating to the delicate membranes of the mouth. Judges were able to taste with accuracy an average of three sets of solutions at one time with the usual two minute rest between sets of solutions.

Correlation between Buffer Titration and Compensation

In the case of acids, an attempt was made to measure the change in sourness of acids, upon the addition of NaCl and sugars, by titrating with the phosphate buffer. This was done to determine if a relationship existed between changes in taste and buffer titration. For this purpose, the buffer was made up in the same manner as before and then diluted 1:25. To 20 ml. of the acid, buffer was added until the solution reached a pH 4.45. The amount of buffer necessary for this was recorded. This was repeated with acids to which had been added sugars or sodium chloride in the same concentration as for the previous determination. The pH of all these solutions was also taken to determine the changes, if any, in pH upon the addition of sodium chloride and sugars.

For each acid a series of seven solutions was made, the first containing only the acid and the remaining six the same concentration of acid plus the concentration of other substances (NaCl and sugars). The results of this set of determinations are recorded in Table 35.

Results

Thresholds of Sensation

The frequency distribution of sensitivity and taste threshold values of the substances listed in Table 11 are given in Tables 12, 13, and 14.

The second set, Tables 15, 16, and 17, is given as the geometric means of the frequency distributions. It was found that in this way the results could be most accurately expressed. The molar concentrations are the geometric means of the frequency distribution of the respective substances. The per cent concentration was determined from the molar concentration. For the determination of the relative weight, the first substance listed was arbitrarily taken as the unit and the remaining substances determined by simple proportions. "Percentage" gives the relative effectiveness in terms of the first substance listed.

Table 12. Frequency distribution of sensitivity and taste threshold values for salt solutions.

	Salts			
Molar conc.	NaCl	$CaCl_2$	$AlCl_3$	$SnCl_4$
0.000075				14-1
0.0001				10-7
0.00025			4-0	8-14
0.00050			16-3	0-8
0.00075			11-17	0-2
0.0010			0-8	
0.0025			0-4	
0.0050	10*-1**	6-1		
0.0070		15-4		
0.010	15-8	10-17		
0.025	13-20	0-8		
0.050	0-8	0-1		
0.075	0-1			
Total	38-38	31-31	31-31	32-32

* Sensitivity threshold is first figure given in each case

** Taste threshold is the second figure given in each case

Table 13. Frequency distribution of sensitivity and taste threshold values for acid solutions.

Acids	Molar concentration							Total samplings
	0.00010	0.00025	0.00050	0.00075	0.0010	0.0025	0.0050	
Hydrochloric acid	1*-0**	6-0	14-4	9-16	0-10			30-30
Lactic acid	0-0	2-0	21-0	7-14	7-15			30-30
Malic acid	0-0	2-0	19-6	3-17	0-7			30-30
Tartaric acid	0-0	9-0	19-8	2-18	0-4			30-30
Acetic acid			4-0	14-0	12-0	0-17	0-4	30-30
Citric acid	0-0	9-0	18-8	3-17	0-5			

* Sensitivity threshold is the first figure given in each case

** Taste threshold is the first figure given in each case

Table 14. Frequency distribution of sensitivity and taste threshold values for sugar solutions.

Sugars	Molar concentration									Total samplings
	0.0075	0.010	0.025	0.050	0.075	0.100	0.125	0.150	0.175	
Sucrose	1*-0**	14-1	13-12	2-13	0-4					30-30
Dextrose			9-0	14-3	7-9	0-14	0-4			30-30
Fructose		10-0	17-3	3-19	0-8	0-0				30-30
Maltose		1-0	11-0	16-2	2-18	0-10				30-30
Lactose				7-0	17-1	6-9	0-11	0-6	0-4	30-30

* Sensitivity threshold is the first figure given in each case

** Taste threshold is the first figure given in each case

Table 15. Relative taste potency of salts.

	Molar conc.		Per cent conc.		Relative Weight		Percentage	
Salt	Sensitivity threshold	Taste threshold	Sensitivity threshold	Taste threshold	Sensitivity	Taste	Sensitivity	Taste
$NaCl$	0.011	0.039	0.064	0.228	100.00	100.00	1.00	1.00
$CaCl_2$	0.0076	0.0126	0.084	0.140	131.03	61.40	.76	1.63
$AlCl_3$	0.00053	0.00072	0.007	0.010	10.94	4.39	9.14	22.77
$SnCl_4$	0.00011	0.00025	0.003	0.007	4.69	3.07	21.32	32.57

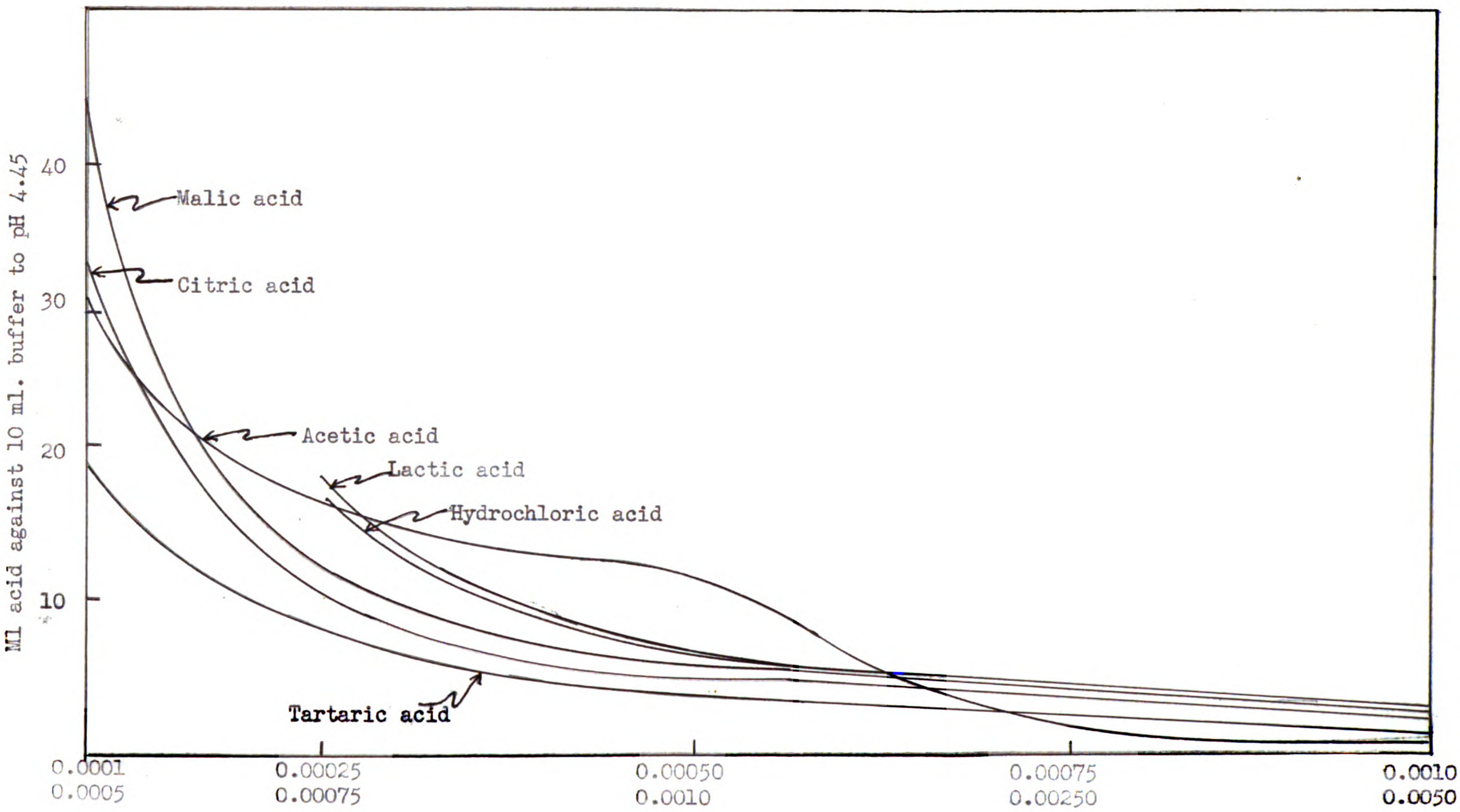
Table 16. Relative taste potency of acids.

Acids	Molar concentration		Per cent concentration		Relative weight		Percentage	
	Sensitivity threshold	Taste threshold	Sensitivity threshold	Taste threshold	Sensitivity	Taste	Sensitivity	Taste
Hydro-chloric	0.00050	0.00078	0.002	0.003	1.00	1.00	100.00	100.00
Lactic	0.00052	0.00085	0.005	0.008	2.50	2.67	40.00	37.45
Malic	0.00043	0.00075	0.006	0.010	3.00	3.33	33.00	30.03
Tartaric	0.00041	0.00070	0.006	0.011	3.00	3.67	33.00	27.25
Acetic	0.00080	0.00210	0.005	0.012	2.50	4.00	40.00	25.00
Citric	0.00042	0.00070	0.008	0.013	4.00	4.33	25.00	23.09

Table 17. Relative taste potency of sugars.

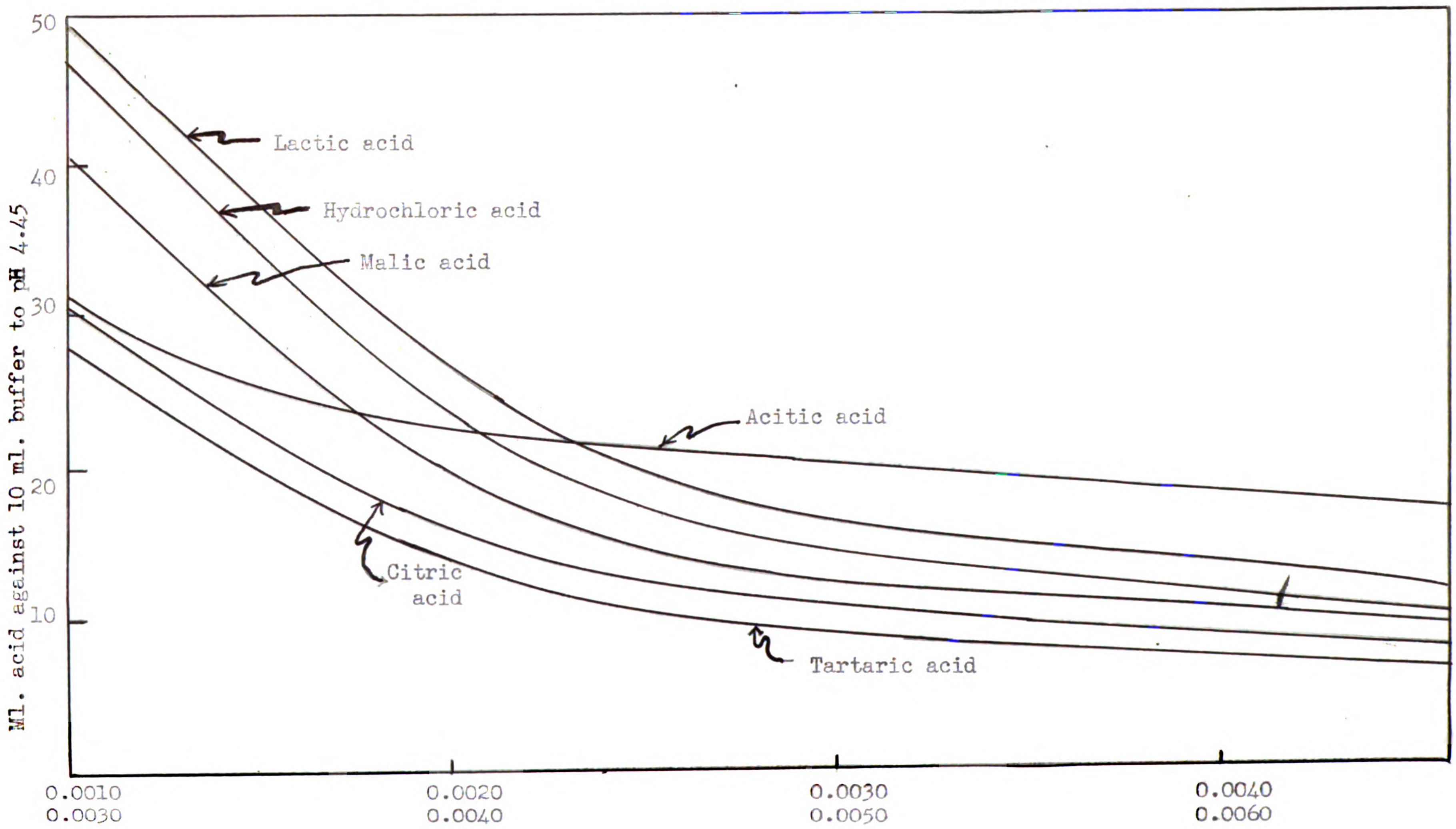
Sugars	Molar concentration		Per cent concentration		Relative weight		Percentage	
	Sensitivity threshold	Taste threshold	Sensitivity threshold	Taste threshold	Sensitivity	Taste	Sensitivity	Taste
Sucrose	0.016	0.037	0.56	1.30	1.00	1.00	100.00	100.00
Dextrose	0.045	0.090	0.80	1.63	1.43	1.25	69.93	80.00
Fructose	0.020	0.052	0.35	0.94	0.63	0.72	158.73	135.14
Maltose	0.038	0.080	1.36	2.89	2.43	2.22	41.15	45.05
Lactose	0.072	0.116	2.60	4.19	4.64	3.22	21.15	31.06

Fig. 10 Relative sourness of acids as determined by titration against a phosphate buffer.



(Lower figures are for Acetic acid)

F.g. 11 Relative sourness of acids as determined by titration against a phosphate buffer.



(Lower figures are for Acetic acid.)

Discussion

There is little that need be written regarding the frequency distribution of the substances. In most cases, they follow a normal distribution curve. It was intended that few or none of the judges should note any difference between the first solution and distilled water and usually this was the case. However, little weight was given to the exceptions since doubtless imagination and other psychological factors were of considerable importance.

Saline taste:

It is evident from table 15 that intensity of taste of salts is dependant upon both, the anion and the cation. It would be expected that stannic chloride would be stronger in taste than sodium chloride by virtue of having four chlorine ions per molecule as compared to one for sodium chloride but this seems insufficient reason to account for stannic chloride being 32 times as strong as sodium chloride. Should we assume that the anion is responsible for the intensity of taste of salts, then how is it possible to account for the relative intensity of calcium chloride and stannic chloride?

It seems only reasonable to conclude that intensity of taste of salts rests with the particular combination of anion and cation. However, it should be noted that the chlorides did not all possess the same taste. Sodium chloride was always described as salty. Calcium chloride was most frequently described as salty but in some cases it was described as a bitter salt, and unknown taste. Aluminum chloride received the following descriptions, in order of frequency:

sour taste, alum taste and bitter taste. The order of frequency for description of stannic chloride is sour taste, bitter taste, and salty taste.

Sour taste:

According to the results (Table 16), Crozier's (1916 &1918a & b) explanation of sour taste seems to be somewhat inadequate. Taylor (1927) found the order of penetration of acids into the tissue to be HCl lactic tartaric malic citric acetic. From this work, the order of intensity of taste was HCl lactic malic tartaric acetic citric. However, where there are differences in the order, upon closer examination of Table 16 and Figure 5, the difference is small and possibly may be attributed to experimental error. Consequently, Crozier's explanation may be of some value.

Table 16 otherwise is self explanatory. There is a relationship between the intensity of the taste of the acids and the amount of acid necessary to bring 10 ml. of phosphate buffer solution to pH 4.45 but this is referred to later in this paper.

Sugars:

There is little that need be written about the relative taste potency of sugars; Table 17 is self explanatory. The value for dextrose is somewhat higher than other workers have found (Table 9) while the fructose value is lower. Lactose is about at the average figure while maltose tends to be somewhat lower. Generally, the results on the sugars correspond with the range of values found in the literature.

This work on salt and sugars is not new, the field having been well covered by other workers but each was taken individually, that is, one worker studied sugars, or acids alone. In this work all three substances were studied individually and then in combination with each other using the same methods and the same judges.

Buffer titrations:

Figures 10 and 11 show the curves of the various acids titrated against the phosphate buffer. The sourness of each acid can be compared by following any line on the vertical axis. Referring back to table 16 and using hydrochloric acid as the reference acid the accuracy of these titrations can be checked.

The results of the titrations check fairly well with taste except in the case of tartaric acid. The differences, with the exception of tartaric acid, are sufficiently small so as to be attributed to experimental error since these differences could not be readily detected by judges. However, tartaric acid shows such a great difference that it makes the entire method somewhat questionable.

Table 18. Accuracy of titration against a phosphate buffer.

Acid	Equi sour by taste	Equi sour by titration
HCl	.0078	.0078
Lactic	.00085	.00078
Malic	.00075	.00065
Tartaric	.00070	.00048
Acetic	.00210	.00230
Citric	.00070	.00062

Competition or Compensation

There are 16 tables giving the results of the experiments to determine the effect upon taste of one substance upon another. The first series of four tables (Tables 19-22) comprises the results of the first method as previously described and Tables 23-34 give the results of the second method for these determinations.

For aid in interpreting Tables 19-22, the reader is referred to direction data sheet No 2 (p.41). These figures represent the results of the taste of the combined solutions given in the tables compared to the taste of the control (solution one).

In the second set of tables (Tables 23-34), the first column in each table indicates the substance that was tasted and the influence upon that substance of sub-taste threshold concentrations of sodium chloride, the various acids and sugars. This was done by matching experiments as previously described. The second and third columns describe the composition of the solution referred to as the unknown. Columns four and five indicate the molar concentrations of the solutions to which this unknown was matched. The last two columns, six and seven, give the results of these matchings. For example, table 23 shows the influence of sodium chloride upon the various acids and sugars. In this table, column one shows acetic acid as the substance being tasted. Columns two and three show that 0.01 M NaCl was added to 0.005 M acetic acid. This solution was called the unknown since the judges had no knowledge of its composition. Columns four and five indicate the molar concentration and the interval of range of the acetic acid, e.g., 0.0045, 0.0050, 0.0055 and 0.0060 respectively, to which the unknown solution (columns two and three) were matched. The results as given in the last two columns show that of ten judges, eight matched the unknown solution to 0.0045M acetic acid, one matched it to 0.0040M acetic acid, and one matched it to 0.0050 acetic acid. Consequently, at these concentrations, sodium chloride reduced the sourness of acetic acid.

Table 19. Effect of molar sub-taste threshold concentrations of acetic acid upon the taste of molar concentrations of sodium chloride.

Solution number	Sodium chloride conc.	Acetic acid conc.	Most frequent effect
1	0.050	0	control
2	0.050	0.0001	-1
3	0.050	0.00025	-1
4	0.050	0.0005	0
5	0.050	0.00075	+ 1
6	0.050	0.0010	+ 2

Table 20. Effect of molar sub-taste concentrations of sodium chloride upon the taste of molar concentrations of acetic acid.

Solution number	Acetic acid conc.	Sodium chloride conc.	Most frequent effect
1	0.0050	0	control
2	0.0050	0.0025	0
3	0.0050	0.0050	0
4	0.0050	0.0075	-1
5	0.0050	0.0100	-2
6	0.0050	0.0250	-3

Table 21. Effect of molar sub-taste threshold concentrations of dextrose upon the taste of molar concentrations of sodium chloride.

Solution number	Sodium chloride conc.	Dextrose conc.	Most frequent effect
1	0.050	0	0
2	0.050	0.010	0
3	0.050	0.025	+1
4	0.050	0.050	-1
5	0.050	0.075	-2
6	0.050	0.100	-3

Table 22. Effect of molar sub-taste threshold concentrations of dextrose upon the taste of molar concentrations of acetic acid.

Solution number	Acetic acid conc	Dextrose conc.	Most frequent effect
1	0.0050	0	control
2	0.0050	0.010	0
3	0.0050	0.025	+1
4	0.0050	0.050	0
5	0.0050	0.075	-1
6	0.0050	0.100	-2

Table 23. **Effect of molar sub-taste threshold concentrations of sodium chloride upon the taste of molar concentrations of different acids and sugars.**

Substance	NaCl Conc.	Sugar or acid conc.	Range in concentration	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Choice	No.	Choice
Acetic acid	0.0100	0.0050	0.0040-0.0060	0.0005	8	0.0045	1 1	0.0040 0.0050
Hydrochloric	0.0250	0.0015	0.0010-0.0020	0.00025	7	0.000125	3	0.0015
Lactic acid	0.0200	0.0030	0.0010-0.0020	0.00025	6	0.00175	3	0.0020
Citric acid	0.0250	0.0015	0.0010-0.0020	0.00025	7	0.00125	2	0.0010
Malic acid	0.0250	0.0030	0.00075-0.00175	0.00025	7	0.00150	2	0.00125
Tartaric acid	0.0250	0.0030	0.00075-0.00175	0.00025	5	0.00150	3	0.00175
Dextrose	0.0250	0.150	0.1000-0.2000	0.0250	10	0.175	0	
Sucrose	0.0250	0.100	0.0500-0.1500	0.0260	6	0.125	3	0.100
Maltose	0.0250	0.125	0.1000-0.2000	0.0250	9	0.150	1	0.175
Fructose	0.0250	0.100	0.0750-0.1750	0.0250	5	0.125	4	0.150
Lactose	0.0250	0.250	0.2250-0.3250	0.0250	7	0.275	2	0.3000

Table 24. Effect of molar sub-taste threshold concentrations of hydrochloric acid upon the taste of molar concentrations of sodium chloride and different sugars.

Substance	HCl conc.	NaCl or sugar conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.0006	0.100	0.050-0.150	0.025	7	0.100	3	0.075
Dextrose	0.0006	0.175	0.100-0.200	0.025	7	0.105	3	0.175
Sucrose	0.0006	0.100	0.070-0.130	0.015	6	0.100	2	0.085
Fructose	0.0006	0.100	0.020-0.100	0.020	7	0.100	3	0.080

Table 25. Effect of molar sub-taste threshold concentrations of lactic acid upon the taste of molar concentrations of sodium chloride and some different sugars.

Substance	Lactic acid conc.	NaCl or sugar conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.0005	0.100	0.060-0.140	0.020	7	0.120	3	0.100
Dextrose	0.0005	0.175	0.100-0.200	0.025	7	0.175	2	0.150
Sucrose	0.0005	0.115	0.070-0.130	0.015	8	0.130	2	0.115
Fructose	0.0005	0.100	0.020-0.100	0.020	6	0.080	4	0.100

Table 26. Effect of molar sub-taste threshold concentrations of malic acid upon the taste of molar concentrations of sodium chloride and different sugars.

Substance	Malic acid conc.	NaCl or sugar conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.0005	0.100	0.060-0.140	0.020	9	0.120	1	0.100
Dextrose	0.0005	0.175	0.100-0.200	0.025	8	0.175	1 1	0.150 0.200
Sucrose	0.0005	0.100	0.070-0.130	0.015	8	0.115	1 1	0.100 0.130
Fructose	0.0005	0.100	0.020-0.010	0.020	7	0.080	3	0.100

Table 27. Effect of molar sub-taste threshold concentrations of tartaric acid upon the taste of molar concentrations of sodium chloride and different sugars.

Substance	Tartaric acid conc.	NaCl or sugar conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.0005	0.100	0.060-0.140	0.020	7	0.120	2	0.100
Dextrose	0.0005	0.175	0.100-0.200	0.025	8	0.175	1 1	0.150 0.200
Sucrose	0.0005	0.100	0.070-0.130	0.015	6	0.115	2 2	0.100 0.130
Fructose	0.0005	0.100	0.020-0.100	0.020	6	0.080	4	0.100

Table 28. Effect of molar sub-taste threshold concentrations of acetic acid upon the taste of molar concentrations of sodium chloride and different sugars.

Substance	Acetic acid conc.	NaCl or sugar conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.0020	0.100	0.050-0.150	0.025	6	0.125	3	0.100
Dextrose	0.0020	0.175	0.100-0.200	0.025	6	0.150	3	0.175
Sucrose	0.0020	0.100	0.070-0.130	0.015	8	0.100	2	0.085
Fructose	0.0020	0.100	0.020-0.100	0.020	7	0.080	3	0.100

Table 29. **Effect of molar sub-taste threshold concentrations of citric acid upon the taste of molar concentrations of sodium chloride and different sugars.**

Substance	Citric acid conc.	NaCl or sugar conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.0005	0.100	0.060-0.140	0.020	7	0.120	3	0.100
Dextrose	0.0005	0.175	0.100-0.200	0.025	8	0.175	1 1	0.150 0.200
Sucrose	0.0005	0.100	0.070-0.130	0.015	5	0.115	3	0.100
Fructose	0.0005	0.100	0.020-0.100	0.020	7	0.100	3	0.080

Table 30. Effect of molar sub-taste threshold concentrations of sucrose upon the taste of molar concentrations of sodium chloride and different acids.

Substance	Sucrose conc.	NaCl or acid conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.030	0.100	0.050-0.150	0.025	8	0.075	2	0.100
Acetic acid	0.015	0.0050	0.0035-0.0055	0.0005	9	0.0045	1	0.0050
Hydrochloric acid	0.015	0.0010	0.0004-0.0012	0.0002	6	0.0008	2 2	0.0006 0.0010
Lactic acid	0.015	0.0030	0.0018-0.0030	0.0003	8	0.0027	2	0.0024
Citric acid	0.015	0.0010	0.0004-0.0010	0.0002	8	0.0008	2	0.0010
Malic acid	0.015	0.0030	0.0018-0.0030	0.0003	7	0.0024	3	0.0027
Tartaric acid	0.015	0.0030	0.0018-0.0030	0.0003	8	0.0024	2	0.0027

Table 31. Effect of molar sub-taste threshold concentrations of dextrose upon the taste of molar concentrations of sodium chloride and different acids.

Substance	Dextrose conc.	NaCl or acid conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.100	0.100	0.050-0.150	0.025	8	0.075	2	0.100
Acetic acid	0.075	0.0050	0.0035-0.0065	0.0005	7	0.0045	3	0.0050
Hydrochloric acid	0.075	0.0010	0.0004-0.0012	0.0002	6	0.0008	4	0.0010
Lactic acid	0.075	0.0030	0.0018-0.0030	0.0003	8	0.0027	2	0.0024
Citric acid	0.075	0.0010	0.0004-0.0012	0.0002	8	0.0008	2	0.0010
Malic acid	0.075	0.0030	0.0018-0.0030	0.0003	8	0.0027	2	0.0024
Tartaric acid	0.075	0.0030	0.0018-0.0030	0.0003	7	0.0027	3	0.0024

Table 32. Effect of molar sub-taste threshold concentrations of fructose upon the taste of molar concentrations of sodium chloride and different acids.

Substance	Fructose conc.	NaCl or acid conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.04	0.1000	0.0600-0.1400	0.0200	8	0.0800	2	0.1000
Acetic acid	0.04	0.0050	0.0035-0.0055	0.0005	6	0.0040	2 2	0.0045 0.0050
Hydrochloric acid	0.04	0.0010	0.0004-0.0012	0.0002	7	0.0008	2	0.0010
Lactic acid	0.04	0.0030	0.0018-0.0030	0.0003	9	0.0027	1	0.0024
Citric acid	0.04	0.0010	0.0004-0.0012	0.0002	8	0.0008	2	0.0010
Tartaric acid	0.04	0.0030	0.0018-0.0030	0.0003	8	0.0027	2	0.0024
Malic acid	0.04	0.0030	0.0018-0.0030	0.0003	8	0.0027	2	0.0024

Table 33. Effect of molar sub-taste threshold concentrations of maltose upon the taste of molar concentrations of sodium chloride and different acids.

Substance	Lactose conc.	NaCl or acid conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.10	0.100	0.060-0.140	0.02	6	0.080	4	0.100
Acetic acid	0.10	0.0050	0.0035-0.0055	0.0005	6	0.00045	2	0.0040
Hydrochloric acid	0.10	0.0010	0.0004-0.0012	0.0002	7	0.0008	3	0.0010
Lactic acid	0.10	0.0030	0.0018-0.0030	0.0003	7	0.0027	3	0.0024
Citric acid	0.10	0.0010	0.0004-0.0002	0.0002	6	0.0008	4	0.0010
Malic acid	0.10	0.0030	0.0018-0.0030	0.0003	6	0.0027	4	0.0024
Tartaric acid	0.10	0.0030	0.0018-0.0030	0.0003	6	0.0024	4	0.0027

Table 34. Effect of molar sub-taste threshold concentrations of maltose upon the taste of molar concentrations of sodium chloride and different acids.

Substance	Maltose conc.	NaCl or acid conc.	Range in conc.	Intervals of range	Most frequent choice		Second most frequent choice	
					No.	Conc.	No.	Conc.
NaCl	0.06	0.1000	0.060-0.140	0.0200	7	0.080	3	0.100
Acetic acid	0.06	0.0050	0.0035-0.0055	0.0005	7	0.0045	2	0.0050
Hydrochloric acid	0.06	0.0010	0.0004-0.0012	0.0002	7	0.0008	3	0.0010
Lactic acid	0.06	0.0030	0.0018-0.0030	0.0003	8	0.0027	1	0.0024
Citric acid	0.06	0.0010	0.0004-0.0012	0.0002	6	0.0008	4	0.0010
Malic acid	0.06	0.0030	0.0018-0.0030	0.0003	7	0.0027	3	0.0024
Tartaric acid	0.06	0.0030	0.0018-0.0030	0.0003	8	0.0027	2	0.0024

Table 35. The effect of the addition of sodium chloride and sugars upon buffer titration and pH of acids.

Molar conc. of acid	Molar conc. of substance added	Ml. acid necessary buffer pH 4.45	pH before buffer added
0.0010 HCl		21.0	3.00
	0.025 NaCl	20.5	3.03
	0.075 Dextrose	20.7	3.03
	0.015 Sucrose	20.6	3.05
	0.100 Lactose	21.3	3.02
	0.040 Fructose	21.0	3.06
	0.060 Maltose	21.0	3.01
0.005 Acetic acid		30.8	3.56
	0.025 NaCl	31.2	3.57
	0.075 Dextrose	30.4	3.59
	0.015 Sucrose	31.1	3.55
	0.100 Lactose	30.3	3.60
	0.040 Fructose	30.5	3.59
	0.060 Maltose	30.7	3.55
0.001 Citric acid		25.2	3.27
	0.025 NaCl	25.5	3.30
	0.075 Dextrose	25.0	3.25
	0.015 Sucrose	24.8	3.28
	0.100 Lactose	25.0	3.26
	0.040 Fructose	25.1	3.28
	0.060 Maltose	25.3	3.30
0.003 Malic acid		73.5	3.10
	0.025 NaCl	72.0	3.05
	0.075 Dextrose	73.0	3.09
	0.015 Sucrose	74.0	3.10
	0.100 Lactose	74.2	3.07
	0.040 Fructose	73.9	3.08
	0.060 Maltose	72.5	3.12
0.03 Tartaric acid		92.0	2.93
	0.025 NaCl	93.2	2.97
	0.075 Dextrose	92.8	2.95
	0.015 Sucrose	91.5	2.91
	0.100 Lactose	92.7	2.94
	0.040 Fructose	93.1	2.98
	0.060 Maltose	92.2	2.96
0.003 Lactic acid		60.3	3.22
	0.025 NaCl	59.5	3.20
	0.075 Dextrose	61.0	3.18
	0.015 Sucrose	61.2	3.26
	0.100 Lactose	60.8	3.22
	0.040 Fructose	59.7	3.21
	0.060 Maltose	60.9	3.24

Discussion

Table 19 shows that when the concentration of acetic acid approaches the sensitivity threshold its effect in increasing the saltiness of sodium chloride was discernible to the judges. Above the threshold the increase in taste became greater.

Table 20 shows that in the range where the judges were sensitive to sodium chloride, it acted to reduce the sourness of acetic acid and this action was increased with increasing concentrations of sodium chloride.

In tables 21 and 22 the taste of both sodium chloride and acetic acid was reduced by the action of sub-taste threshold concentrations of dextrose. It would seem the effect of dextrose was greatest on sodium chloride. The effect was likewise noticeable only when the concentration was beyond the sensitivity threshold.

Sodium chloride in sub-taste threshold concentrations consistantly reduced the sourness of all the acids tested but to varying degrees. (Table 23) It reduced the sourness of acetic, hydrochloric and citric acids only moderately but sufficiently for a noticeable taste difference. While with malic, lactic and tartaric acids, sodium chloride exhibited a marked effect in reducing sourness, very much greater than with the other acids.

The effect of sodium chloride upon the taste of sugars (Table 23) was just the opposite since an increase in sweetness was noted by the judges for all the sugars. On the basis of molarity, the relative increase in sweetness of the sugars was fructose lactose and maltose dextrose sucrose. On the basis of concentration by weight, the relative effect of sodium chloride is maltose and lactose fructose dextrose sucrose.

Table 24 shows the effect of hydrochloric acid upon the taste of sodium chloride and sugars. Hydrochloric acid showed no effect on the taste of sodium chloride, reduced the sweetness of dextrose and left sucrose and fructose unchanged but with a tendency toward a decrease in sweetness.

It is interesting to note that hydrochloric acid has no effect upon the taste of sodium chloride. If the intensity of taste of sodium chloride was a result of the chlorine ions, then hydrochloric acid should, if anything, increase the taste of salt by the addition of chlorine ions. Seven of ten judges could notice no change in taste and three judges noted a reduction in taste. If the tendency is for a reduction in taste, it would seem that the sodium ion has considerable to do with the intensity of taste of salt since the sodium ions are reduced by the action of a common ion. This is also indicated in the subsequent tables where the effect of other acids upon the taste of sodium chloride is an increase in saltiness.

Table 25 shows that lactic acid in sub-taste threshold concentrations increases the saltiness of sodium chloride and reduces the sweetness of fructose. Dextrose remained unaffected while the sweetness of sucrose was increased.

Tartaric and malic acids in sub-taste threshold concentrations have the same effect as lactic acid on the taste of sodium chloride, fructose, dextrose and sucrose as shown in Tables 26 and 28. These three acids acted very much alike throughout the entire experiments.

Table 29 shows the action of sub-taste threshold concentrations of citric acid on sodium chloride, dextrose, sucrose and fructose. The saltiness of sodium chloride was increased, the sweetness of dextrose and fructose unchanged and sucrose increased.

Certain generalities can be drawn from the results of the effect of sub-taste threshold concentrations of acids. The organic acids increase the saltiness of sodium chloride. With the exception of acetic and hydrochloric acids, the sweetness of dextrose remained unchanged, while the sweetness of sucrose was increased. All the acids but hydrochloric acid reduced the sweetness of fructose.

Tables 30 through 34 show the effect of sugars in sub-taste threshold concentrations upon sodium chloride and the different acids. All the sugars reduced the saltiness of sodium chloride about equally well. The sourness of acetic acid was reduced by all the sugars with fructose showing the greatest effectiveness. The action of the sugars upon the sourness of hydrochloric acid and citric acid was an approximately equal reduction in sourness. Lactic acid, malic acid and tartaric acids showed the greatest reductions in sourness upon the addition of sugars. Sucrose was the most effective of the sugars in reducing sourness of malic and tartaric acids in the concentrations used. However, the same concentration of all sugars did not have the same effect.

Both acetic and hydrochloric acids have little if any effect upon the sweetness of sucrose as shown in tables 24 and 28. Lactic, malic, tartaric and citric acids affect the taste of sucrose by increasing the sweetness (Tables 24, 25, 26, and 28). This was checked by use of a polariscope to determine if inversion of the sucrose took place at their respective concentrations and no inversion of sucrose could be noted.

Table 35 shows that the decrease in sourness upon the addition of sodium chloride and sugars to acids can not be measured by changes in buffer titrations of pH.

Summary

1. The order of effectiveness of taste for salts was stannic chloride > aluminum chloride > calcium chloride > sodium chloride. However, the differences were such that it is likely that intensity of taste rests with both the cation and anion.

2. The results indicate that ability to penetrate tissues, pH, and effectiveness against phosphate buffers were all factors involved in the sourness of acids and that no single factor can be used to measure sourness.

3. The order of effectiveness of taste for acids was hydrochloric acid > lactic acid > malic acid > tartaric acid > acetic acid > citric acid. Specific values for each are given.

4. The order of effectiveness of taste for sugars was fructose > sucrose > dextrose > maltose > lactose. Here also specific values for each are given.

5. The effect of sodium chloride, as indicated in the results, was to reduce the sourness of acids and to increase the sweetness of sugars. The reduction of sourness of acids was particularily noticeable for lactic, malic and tartaric acids.

6. With the exceptions of hydrochloric and acetic acids, where a reduction in sweetness was noted, acids showed no effect upon dextrose.

7. Generally, acids tend to increase the saltiness of sodium chloride. However, hydrochloric acid was the exception and showed no effect upon salt.

8. Hydrochloric and acetic acids had no effect upon the taste of sucrose while the remaining acids increased its sweetness. It was found that at the concentrations used, the acids caused no inversion of the sucrose as measured by the polariscope.

9. The sweetness of fructose was reduced by all the acids except hydrochloric and citric acids where no change in sweetness could be noted.

10. All the sugars acted to reduce the saltiness of sodium chloride.

11. All the sugars reduced the sourness of the acids but to varying degrees. Lactic, malic and tartaric acids were outstanding in this respect.

12. The effect of sodium chloride and sugars upon the sourness of acids could not be correlated with changes in phosphate buffer titrations nor with changes in hydrogen ion concentration.

BIBLIOGRAPHY

Aducco, V. et Mosso, U. (1886) Richerchi sopra fistiologia del gusto. Gior. Accad. Med. 34:34-42. Cited from Parker (1922).

Aronsohn, E. (1884) Beitage sur Physiologie des Geruchs. Arch. Anat. Physiol., physiol. Abt., pp. 163-167. Cited from Parker (1922).

Bailey, E. and Nichols (1888) The delicacy of the sense of taste. Nature 37:557-558.

Beatty, R. M. and Cragg, L. H. (1935) The sourness of acids. Amer. Chem. Soc. Jour. 57:2347-2351.

Biester, A., Weigely, M. and Wahlin, C. S. (1925) The relative sweetness of sugars. Amer. Jour. Physiol. 73:387-390.

Blackman, E. L. (1917) Ueber die Verstaubungselektricitat. Arch. ges. Physiol. 168:351-371. Cited from Parker (1922).

Boclike, R. A. and Routh, J. E. (1932) Effect of smoking upon taste. Master's Thesis. Catholic Univ. of Amer., Wash., D. C. Cited from King (1937).

Brown, W. (1914) The judgment of very weak sensory stimuli with special reference to absolute threshold of sensation for common salt. Univ. Cal. Pub., Psychol., 1:199-286.

Camerer, H. (1869) Die Grenzen dur Schmeckbarkeit von Chlornatrium in wasseriger Losung. Arch. gesam Physiol. Mensch. u. Thier 2:322-329. Cited from Trout and Sharp (1937).

__________ (1885) Die Methode der richtigen und falschen Falle angewendt auf den Geschmackssinn. Ztschr. Biol. 21:570-602. Cited from Trout and Sharp (1937).

Coghill, G. E. (1914) Correlated anatomical and physiological studies of the growth of the nervous system. Jour. Comp. Neurol. 24:161-233. Cited from Parker (1922).

Cohn, G. (1914) Die organischen Geshmacksstoffe. Berlin, 936 pp. Cited from Parker (1922).

Cragg, L. H. (1937a) Relation between sourness and pH of the saliva. Trans. Roy. Soc. Canada 31:7-13. Cited from Chem. Abstr. 32:2965:1938.

Cragg, L. H. (1937b) Sour taste. Trans. Roy. Soc. Canada 31:131-140. Cited from Chem. Abstr. 32:2965:1938.

Crocker, W. J. and Henderson, L. (1932) The glutamic taste. Amer. Perfumer and Ess. Oils Rev. Cited from Trout and Sharp (1937).

Crozier, W. J. (1916) The taste of acids. Jour. Comp. Neurol. 26:453-456.

__________ (1918a) Sensory activation by acids. Amer. Jour. Physiol. 45:323-341.

__________ (1918b) Cell penetration by acids. Jour. Bio. Chem. 33:463-470.

__________ (1934) Chemoreception. Chapter 19, A Handbook of Gen. Exp. Psych. Editor, C. Murchison, Clark Univ. Press.

Darley, W. and Doan, C. (1936) Amer. J. Med. Sci. 191:633-634.

Deerr, N. (1922) Relative sweetness of sucrose, levulose and and dextrose. Intern. Sugar J. 24:481. Cited from Chem. Abstr. 16:4085:1922.

Druce, J. G. (1929) Taste and chemical constitution. Chemist and Druggist 111:775. Cited from Chem. Abstr. 24:2482:1930.

Finzi, C. and Colonna, M. (1937) Chemical constitution and sweet taste. Lincei, Classe sci. fis., mat. nat. 26:19-24. Cited from Chem. Abstr. 32:3761:1938.

Fisher, E. and Penzoldt, F. (1886) Ueber die Empfindlickeit des Geruchssinnes. Sitzb. phys-med. Soc. Erlangen. 18:7-10. Cited from Parker (1922).

Glaser, O. (1918) Hereditary deficiencies in the sense of smell. Science 48:647-648.

Hanig, D. P. (1901) Zur Psychophysik des Geschmackssinnes. Phisosoph. Studien. 17:576-623. Cited from Trout and Sharp (1937).

Henning, H. (1924) Der Geruch. (2nd Edition) Leipzig, 434 pp. Cited from Crozier (1934).

Henry, L. (1895) Formation synthetique d'alcohils nitrates. Comp. rend. Acad. Sec. 121:210-213.

Herlitzka, A. (1909) Contributo all'analise fisicochimica del sapore dei Sali. Arch. Fisiol. 7:557-558. Cited from Parker (1922).

Hober, R. and Kiesow, F. (1898) Ueber den Geshmack von Salzen und Laugen. Zeitchr. phys. Chemie. 27:601-606.

Hollingworth, H. and Poffinberger, A. (1917) The sense of taste. New York: Moffat, Yard. 200 pp.

Internationas Critical Tables 1:357.

Kahlenberg, L. (1898) The action of solutions on the sense of taste. Bull. Univ. Wis. sci. ser. 2:1031.

Kiesow, G. (1894) Ueber die Wirkung des Cocain und des Gymemasaure auf die Schleimhaut der Zunge und des Mundraums. Philosoph. Studien. 9:510-527.

__________ (1903) Ein Beitrag zur Frogenach den Realtionszeiten der Gerschmacksempfindungen. Zeitschr. Psychol. Physiol. Sinnesorgane. 33:453-461. Cited from Parker (1922).

King, F. B. (1937) Obtaining a panel for judging flavors in foods. Food Research 2:207.

Komm, E. and Lammer, H. (1940) Uber die Starke des sauren Geschmacks von in der Subwarenindustrie gebrauchbehen organischen Sauren. Zeitschr. f. Untersuchung der Lebensmittel 79:541-561.

Komuro, K. (1921) Has the sense of taste a temperature coefficient. Arch. Neerland. physiol. 5:572-579. Cited from Chem. Abstr. (16:3906:1922)

Marchand, L. (1903) Le gout. pp. 1-330. Cited from Trout and Sharp (1937).

Nagel, W. A. (1896) Ueber die Wirkung des chlorsauren Kali auf den Geshmackssinn. Zeitschr, Physiol. physiol, Sinnesorg. 10:235-239. Cited from Parker (1922).

Oertly, E. and Meyers, R. (1919) A new theory relating constitution to taste. Jour. Amer. Chem. Soc. 41:855-867.

Oehrwall, H. (1891) Untersuchvngen ueber den Geschmackssin. Akandenavisches Arch. Physiol. 2:1-69. Cited from Parker (1922).

Parker, G. H. (1922) Smell, taste and allied senses in the vertebrates. Lippencott & Co. pp. 1-192.

_____________ and Stabler, E. M. (1913) On certain distinctions between taste and smell. Amer. J. Physiol. 32:230-240.

Passy, J. (1892) Les proprietes odorants des alcohils de la series grasse. Comp. rend. Acad. Sci. 114:1140-1145.

Paul, T. (1921) Sweetness of various sugars. Chem. Ztg. 45:705-706.

_____________(1922) Investigations of acid tastes. Zsch. Electrochem. 28:435-446.

Richards, T. W. (1898) The relation of the taste of acids to their degree dissociation. Jour. Amer. Chem. Soc. 20:121-127.

Richter, C. and MacLean, A. (1939) A salt taste threshold of humans. Amer. J. Physiol. 126:1-6.

__________ and Campbell, K. H. (1939) Sucrose taste thresholds of rats and humans. Amer. J. Physiol. 128:291-298.

Rikhter, A. A. (1927) Judging sugar by taste. J. Exp. Landw. Sudost. Eur. Russlands 3, No. 2, 101-106. Cited from Exp. Sta. Rec. 58:611.

Sale, J. W. and Skinner, W. W. (1922) Relative sweetness of invert sugar. Ind. and Eng. Chem. J. 14:522-525.

Schiff, M. (1892) Lecons sur la Physiologie de la Digestion. Florence & Turin 1:414. Cited from Parker (1922).

Schore, L. E. (1892) A contribution to our knowledge of taste sensation. Jour. Physiol. 13:191-217.

Spengler, O. and Traegal, A. (1927) Degrees of sweetness of fructose as compared with that of sucrose. Z. Ver. deut. Zuckerind 77:1-12.

Stahr, H. (1902) Ueber die Papillae fungiformes der Kinderzunge und ihre Bedeutung als Geschmacksorgane. Zeitschr. Morph. Anthrop. 4:199-260. Cited from Parker (1922).

Taylor, A. (1927) Acid penetration into living tissues. J. Gen. Physiol. 11:207-221.

Titchner, E. B. (1905) Experimental Psychology. 2:i-xli:1-208.

Toulouse, E. and Vaschide, N. (1900) Methode pour L'examen et la mesure du gout. Acad. rend. Acad. Sci. 130:803-805.

Tracy, R. H. (1936) Using corn sugar as an ingredient in the manufacture of ice cream. Ice Cream Trade 32:30.

Trout, G. M. and Sharp, P. F. (1937) The reliability of flavor judgments with special reference to the oxidized flavor in milk. Cornell University, Memoir 204.

Tuckerman, (1890) On the gustatory organs of the mammilia. Proced. Boston. Soc. Nat. Hist. 24:470-482.

__________ (1889) On the development of the taste organs of man. Jour. Anat. Physiol. 23:559-582.

Venables, F. P. (1887) Sensativeness of taste. Chem. News 56:221.

Veress, E. (1903) Ueber die Reizung des Riechorgans durth directe Einwirkung riechende Flussigkeitin. Arch. ges. Physiol. 95:368-408. Cited from Parker (1922).

Woodrow, H. and Karpman, B. (1917) A new olfactometric technique and some results. Jour. Exp. Psych. 2:431-447.

Zuntz, N. (1892) Bertrag zur Physiologie des Geschmacks. Arch. Anat. Physiol., physiol. Abt. pp. 556. Cited from Parker (1922).

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