PRESIDENT'S ADDRESS

THE SCIENCE OF TASTE

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The subject is an ancient one; there are a number of references to it in the Bible. One from Matthew goes, "Ye are the salt of the earth; but if the salt have lost its savor, wherewith shall it be salted? It is henceforth good for nothing, but to be cast out and trodden under foot of men." This presumably refers to natural salt deposits that have lost their saltiness by leaching. But in spite of mankind's long interest in taste, Alexander Graham Bell could remark that the science of smell and taste was still in the Dark Ages. Even today it is certain there is no field in which it is more essential to take every literature statement "with a grain of salt."

The fact is that the chemical senses—smell, taste, and general irritability to chemicals—are more difficult to study than the physical senses—sight, hearing, and touch. Taste, smell, and the sensation caused by tear gases arise from the effect of chemicals on nerve endings, taste usually requiring a higher concentration of the stimulating agent than the other two. The sensations are distinct, though often confused because human anatomy places the several detectors so close together.

But why is knowledge of the chemical senses so imperfect and even unscientific? Not for lack of effort: psychologists and physiologists have studied the nature of sensation; philosophers have philosophised on the connection between nature and mind; chemists have prepared synthetic flavors; and nutritionists and pharmacists have worked to make foods and drugs palatable. The great lack is a measuring instrument. Light we turn into dial readings with a photoelectric cell or a spectrometer, temperature with a thermometer, sound with other meters; but for taste we have to depend on somebody's tongue. And no two tongues are alike; even the same tongue does not taste things alike on different days. As a result the literature is full of contradictions and questionable data.

It is only in the higher animals that the senses of taste and smell are differentiated. In simple ones like Hydra or a starfish there is only a generalized chemical sense to indicate the presence of food or of irritants, such as acid or salt. Differentiation is observed in many insects; ants, bees, and moths use odors as the main basis of communication, and bees can distinguish sugar solutions from glycerin or saccharin solutions, although they all taste sweet alike to us. In insects, and in some fishes, notably catfish and carp, some of the taste receptors are scattered over the outside of the body—much as if we could taste with our elbows or our knees! Reptiles, amphibians, and birds show little sensitivity to taste; among mammals, whales are least sensitive, but then their feeding habits are highly indiscriminating.

In general we can say that dogs and insects excel in sensitivity to odor, birds in sight, and man in taste, although one type of monarch butterflies (Danaus archippus) has been shown to recognize a sugar solution at 1200 times the dilution perceptible to man. Whether children have higher taste sensitivity than adults is still disputed; certainly they hate bad-tasting medicines more.
In man, the taste buds, where the taste nerves end, are scattered over the top of the tongue, mostly in the papillae. There is great variation in their sensitivity to different basic tastes, but it is certain that bitterness is tasted mostly at the back of the tongue. The confusion of odor and taste can be reduced or prevented by stopping the nose; it is a common-place observation that foods lack flavor when one has a bad cold. Chloroform is often said to have a sweet odor, but it really has a sweet taste and an ethereal odor—whatever that is.

Classification of odors remains an unsettled problem, but for tastes it is well agreed that there are four fundamental ones: sweet, sour, salty, and bitter. Every other true taste is then a blend of these. Of course the tongue can also notice pressure, pain, warmth, cold, and chemical irritants. So-called metallic tastes, as of silver nitrate or alum, involve some true taste and much astringency, which is a touch sensation. Perhaps the indescribable taste of alkales belongs in this category. Peppery tastes, as of mustard, onions, and carbonated water, represent chemical irritants, which stimulate the mucous membranes of the nose and eyes also.

The effect of temperature on taste sensitivity was studied about a hundred years ago by Weber. The optimum is body temperature, and much higher or lower temperatures partly anesthetize the tongue. Thus if soup is hot enough, one cannot tell whether it is salted; and lemonade and ice-cream manufacturers know that it takes more sugar to sweeten these delicacies than it would if they were served warm.

The technique of taste tests has been developed by professional tasters of products such as tea and wine. Using solutions whenever possible, the taster rinses the mouth with a fixed portion of the sample at about 37° C and then spits it out. After a few minutes the process is repeated with a standard. It is simplest to use distilled water as the standard and to determine the minimum concentration of solution just distinguishable from the water, the threshold concentration. We must note that there is a difference between sensation value—the ability to distinguish the unknown from water—and quality value—the ability to recognize the taste as, say, sweet. For sodium chloride the most reliable values (Moncrieff 1946) are 0.016 percent sensation value and 0.067 percent quality value.

Instead of comparing substances on the basis of threshold concentrations, we may find for each the concentration at which the tastes are of equal intensity (most-exact method), or make up solutions of all substances at the same concentration, and rank them in order of intensity (least exact). The psychologist here would remark that Weber's law holds for taste as for other sensations; the least noticeable difference is a constant fraction of the stimulus. For example, a change of one candela power in light is easily noticeable in a dim light, but not in a bright one; and a little more salt is not easily noticed in a solution already very salty.

Sweet taste has been most studied, in keeping with the fact that in the history of human culture sweetening agents play a noteworthy role. They have always been sought and refined as something costly and pleasant, while salts and sour substances were regarded as mere necessities, and bitter ones as downright hateful. To quote H. G. Wells (Wells, Huxley, and Wells 1934:1150) on this point:

"The sense organs which life does possess are narrowly conditioned by the facts of the lifeless environment. Sugar is abundant in nature, and sugar-containing substances are nutritious. Hence we not only possess sense-organs capable of detecting a sweet taste, but we find sweet things agreeable. Had the nutritious sugars been rare in nature, and saccharin, which is useless for food purposes, been abundant, the sensation of sweet-
ness would doubtless not have been pleasant; while if lead acetate or sugar of lead, which is sweet but poisonous, had been the common sweet substance, sweetness would of necessity have been disagreeable to the higher animals, for only those with natures that found sweetness nasty could have escaped being poisoned."

It is familiar that some herbivorous animals develop a craving for salt, which is not abundant in plants. Since the taste buds respond to substances in the blood stream as well as to those in saliva, it appears that a deficiency in the blood stream increases their sensitivity to the external stimulus (Hartridge 1945). It is a temptation to associate unpleasant, bitter taste with poisonous nature in foods, for we know that many animals are warned away from toxic plants by taste or odor. In support of this, the alkaloids, such as strychnine, nicotine, and morphine, are the bitterest known substances. But they are not poisonous in the same order that they are bitter; and moreover we actually like some bitter tastes in combinations, as in grapefruit, tea, coffee, and beer.

It was formerly believed that it takes longer to taste bitterness than other tastes, because a mixture of sweet and bitter substances usually tastes first sweet, then bitter. Actually this probably demonstrates only the much lower threshold for the bitter, which makes it persist after the sweet is too dilute to be perceptible. Since a weak electric current between electrodes on the tongue induces taste sensation, a current interrupted with sufficient rapidity just to give a continuous sensation can be used to measure duration of taste (Allen and Weinberg 1925). By this means taste was found to have a shorter duration than touch, hearing, or sight; no one has yet conceived a method for similarly studying odor. Of the four tastes, bitter has the shortest duration, but values for all of them are of the order of 0.002 second.

As we have noted, one of the worst obstacles to taste research is variation in sensitivity of individuals; thus for one bitter substance, phenylthiourea (phenylthiocarbamide, "PTC"), the threshold concentration in aqueous solution ranges from 1/312 to 1/280,000, and for quinine 1/5000 to 1/320,000. Moreover a taster may be relatively insensitive to phenylthiourea and still taste quinine well. This fortunately is not typical; the ratio of threshold bitterness of various substances is fairly constant from individual to individual, except for phenylthiourea and relatives (Wasicky, Barbieri, and Weber 1942-43). The same constancy is assumed for sweet taste. However, Blakeslee (1939) obtained a "vote" of 3121 persons on the taste of mannose, a rare sugar, at a meeting of the American Association for the Advancement of Science. The compound was sweet to 1120, tasteless to 885, bitter to 352, sour to 93, salty to 38, bitter then sweet to 90, sweet then bitter to 286, and bitter-sweet to 46, and reported in still other combinations. All this evidence calls for tolerance in the matter of food preferences; don't expect others to like olives, spinach, and liver just because you do!

The extreme range of sensitivity to the taste of phenylthiourea has led to designation of low ability or total inability to taste it as "tasteblindness" or better "taste deficiency." Among white people 70 percent can taste it, among Chinese and American Indians 90 percent. The geneticists report that the ability to taste phenylthiourea is a dominant characteristic, whereas the taste deficiency is a recessive one. Phenylthiourea is suitable for use in accelerating the vulcanization of rubber, and was so used in the rubber of ice-cube trays in refrigerators until the manufacturers began to get complaints! It is also the nearest chemical neighbor to the important new rat poison, alpha-naphthylthiourea, which rats evidently do not taste.

Taste impressions, like others derived from the senses, are subject to the phenomena of mixture (combinations, neutralizations), adaptation (fatigue),
and contrast. The idea of combinations is too familiar to need any dis-

cussion; we really do not sweeten lemonade much, but merely add another
taste to it. It is rare to find any true cancellation of tastes. The phar-

macists have always looked for something to cancel bitter tastes of drugs,
but the best they can do is to mask them with sweet sirups, or else par-
tially anesthetize the taste buds with one of several plant extracts.

The sweetness of a 15-percent-sugar solution is increased by the add-
tion of a trace of sodium chloride or quinine sulfate. It is common
knowledge that a taste is intensified by contrast with a previous different
one. Fruits seem much sourer after candy or other sweets, and water it-
self appears sweet after one has been tasting something salty, bitter, or
sour. Fatigue of taste is as easy as that of other senses; a 1 percent solu-
tion of sucrose soon cannot be tasted at all. To add one more complication:
solutions being tested often do not obey the dilution law, i.e., that twice
the concentration will give twice the effect. Whether because of ioniza-
tion, association, dissociation, or some other factor, sweetness relative
to sucrose usually does not change as expected upon dilution.

The basic question in the science of taste is: What factors determine
the quality and the intensity of taste of a compound? The chemist in par-
ticular has always hoped and tried to find a connection between taste and
structure of the molecule. In Tables I, II, and III are assembled quanti-
tative data on compounds with sour, bitter, and sweet tastes; since sodium
chloride is the only purely salty-tasting compound, nearly all other salts
having bitter components, no scale of saltiness has been established.

The sour taste is produced by acids and nothing else. As one would
guess, the sourness depends mainly upon pH of the solution, but it is modi-
fied by diffusibility of the anions and unionized molecules, which contribute
to the taste. Beatty and Cragg (1936) have shown that sourness, defined
as the normality of an equally sour hydrochloric-acid solution, can be
measured by a nombiological method. This is done by titrating the unbuffered
unknown to a pH of 4.4 with a phosphate buffer solution; the sourness is
directly proportional to the volume of buffer used. The results agree very
well with taste tests, and demonstrate that relative sourness of equimolar
solutions is independent of concentration, unlike relative sweetness.

The data on relative bitterness are largely very old and in need of
confirmation, preferably by the more accurate procedure of determining
at what concentration each compound is as bitter as a standard, instead
of the threshold method. But bitterness is of no great commercial im-
portance, and it is not easy to assemble a group of tasters willing to
work on it.

Research on sweetness and sweeteners is stimulated by wars; Napoleon
in 1810 offered a prize of a million francs for a practicable process of ob-
taining sugar from sugar beets, and Table III shows a preponderance of
literature reports dated soon after World War I or II. The newest sweet-
ening agents—synthetic aromatic compounds which also have local anesthetic
action—were studied in the Netherlands during German occupation and
now give promise of displacing saccharin, which they far surpass in sweet-
ening power.

A survey of Table III shows that all the compounds of sweetening
power more than 2.5 times that of sucrose (excepting chloroform) are
nitrogen compounds, either substituted amines, amides, imides, nitriles, or
oximes. Those below this value are either sugars, sugar-like alcohols, or
amino acids. One easy check on the purity of synthetic glycine is to find
whether it is pleasantly sweet. In addition to the quantitative data, it
must be noted that soluble beryllium and lead salts, most halogenated
hydrocarbons, and many mononitro hydrocarbons are sweet.
It is common practice in the food-manufacturing industries to invert sucrose before or during its use; whether or not this process increases the total sweetness has been much argued (Willaman, Wahlin, and Biester 1925; Sale and Skinner 1922; Tuffel 1926; Anon. 1946; and others). We can see from Table III that the confusion has been due to different methods of assay. A molecule of sucrose gives one of glucose and one of fructose; of these glucose is definitely about 0.7 times as sweet as sucrose. Where, as by the threshold method, fructose is found to be 1.7 in sweetness, invert sugar, the average, is sweeter than sucrose. If substantial sweetening power is tested instead, fructose has the value of 1.1 to 1.2 and invert sugar is if anything a little less sweet than sucrose. Since the latter is the condition in practical use, inversion should not be expected to increase the sweetening power of ordinary sugar.

Now what can we say in conclusion about the reasons for the taste of a compound? There is clearly some relation with structure, and yet the most widely differing chemicals have the same taste, and apparently insignificant changes in molecular architecture radically alter the taste. This is the organic-chemist's standard research procedure, but saccharin and dulcin, for example, become tasteless or bitter with nearly every change; the results hardly make sense. It must be that some particular combination of physical and chemical properties is required; not surface tension alone, nor lipid solubility, nor chemical behavior determines taste, but all these together, and more. Clearly this is the place for some of the cooperative, interdisciplinary research advocated by Dr. H. E. Carter at our meeting a year ago.

This is the same attack that must be used in explaining other physiological activity of chemicals—the toxicity of DDT for insects, the local anesthetic action of p-aminobenzoic esters, the antibiotic potency of penicillin and streptomycin. At present we really have no very satisfactory explanation of these things. Perhaps some day we can do better.

**TABLE I**

<table>
<thead>
<tr>
<th>Acid</th>
<th>Sourness</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formic</td>
<td>1.1</td>
<td>Beatty and Cragg 1935</td>
</tr>
<tr>
<td>Hydrochloric</td>
<td>1.0</td>
<td>(the standard)</td>
</tr>
<tr>
<td>Chloroacetic</td>
<td>0.9</td>
<td>Beatty and Cragg 1935</td>
</tr>
<tr>
<td>Lactic</td>
<td>0.92</td>
<td>Fabian and Blum 1943</td>
</tr>
<tr>
<td>Acetyllactic</td>
<td>0.78</td>
<td>Paul 1922</td>
</tr>
<tr>
<td>Tartaric</td>
<td>0.85</td>
<td>Paul 1922</td>
</tr>
<tr>
<td>Acetic</td>
<td>0.8</td>
<td>Beatty and Cragg 1935</td>
</tr>
<tr>
<td></td>
<td>0.64✈</td>
<td>Komm and Lämmer 1940</td>
</tr>
<tr>
<td></td>
<td>0.63</td>
<td>Paul 1922</td>
</tr>
<tr>
<td></td>
<td>0.56</td>
<td>Fabian and Blum 1943</td>
</tr>
<tr>
<td>Malic</td>
<td>0.69</td>
<td>Paul 1922</td>
</tr>
<tr>
<td></td>
<td>0.35-0.38</td>
<td>Beatty and Cragg 1935</td>
</tr>
<tr>
<td></td>
<td>0.37</td>
<td>Fabian and Blum 1943</td>
</tr>
<tr>
<td>Potassium H tartrate</td>
<td>0.58</td>
<td>Paul 1922</td>
</tr>
<tr>
<td>Citric</td>
<td>0.55</td>
<td>Komm and Lämmer 1940</td>
</tr>
<tr>
<td></td>
<td>0.37</td>
<td>Fabian and Blum 1943</td>
</tr>
<tr>
<td>Carbonic</td>
<td>0.09</td>
<td>Paul 1922</td>
</tr>
<tr>
<td></td>
<td>0.02</td>
<td>Beatty and Cragg 1935</td>
</tr>
</tbody>
</table>

*Calculated from sourness as defined by Paul (1922) and Beatty and Cragg (1935) by dividing by normality of the acid tested.

*By comparison with lactic but calculated relative to hydrochloric by using the mean value lactic = 0.85.
**TABLE II**

Bitterness of various substances

<table>
<thead>
<tr>
<th>Substances</th>
<th>Relative bitterness</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brucine</td>
<td>100-125</td>
<td>Threshold</td>
<td>Scholl and Munch 1937</td>
</tr>
<tr>
<td>Chlorostrychnine</td>
<td>50</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>Strychnine</td>
<td>30-33</td>
<td>Threshold</td>
<td>Scholl and Munch 1937</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>Nicotine</td>
<td>13</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>Quinine</td>
<td>10.0 (standard)</td>
<td>Threshold</td>
<td>Cohn 1914, Scholl and Munch 1937</td>
</tr>
<tr>
<td>Ethystrychnine</td>
<td>10</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>Colchicine</td>
<td>9</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>Phenylthiourea</td>
<td>9 maximum</td>
<td>Threshold</td>
<td>Blakeslee 1935</td>
</tr>
<tr>
<td>Sucrose octaacetate</td>
<td>6.7</td>
<td>Threshold</td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>Threshold</td>
<td>Scholl and Munch 1937</td>
</tr>
<tr>
<td>Caffeine</td>
<td>4</td>
<td>Threshold</td>
<td>Crocker 1945</td>
</tr>
<tr>
<td>Alcolin</td>
<td>3.3</td>
<td>Threshold</td>
<td>Gertz 1923</td>
</tr>
<tr>
<td>Cinchonine</td>
<td>2.5</td>
<td>Threshold</td>
<td>Scholl and Munch 1937</td>
</tr>
<tr>
<td>Veratrine</td>
<td>2</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>Picocarpine</td>
<td>1.6</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>Atropine</td>
<td>1.3</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>2,3,5,6-tetraacetyl-β-phenol glucoside</td>
<td>0.97</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>Aconitine</td>
<td>0.9</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>3,5,6-tribenzoyl-glucose carbon tetrachloride</td>
<td>0.53</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>Theobromine</td>
<td>0.5</td>
<td>Threshold</td>
<td>Gertz 1923, Scholl and Munch 1937</td>
</tr>
<tr>
<td>Maltose octaacetate</td>
<td>0.5</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>3-benzoylestatone-glucose</td>
<td>0.40</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>β-phenol glucoside</td>
<td>0.25</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>2,3,5,6-tetraacetyl-β-methylglucoside</td>
<td>0.23</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>2,3,5,6-tetraacetyl-α-phenol glucoside</td>
<td>0.23</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>β-glucose pentaacetate</td>
<td>0.22</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>Cocaine</td>
<td>0.2</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>Morphine</td>
<td>0.2</td>
<td>Threshold</td>
<td>Cohn 1914</td>
</tr>
<tr>
<td>2,3,5,6-tetraacetyl-glucose</td>
<td>0.11</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>3-acetyldiacetone-glucose</td>
<td>0.097</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>α-glucose pentaacetate</td>
<td>0.088</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>6(?)-benzoyl-monooacetoneglucose</td>
<td>0.088</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
<tr>
<td>2,3,5,6-tetraacetyl-α-methylglucoside</td>
<td>0.038</td>
<td></td>
<td>Brigl and Sheyer 1926</td>
</tr>
</tbody>
</table>
**Relative bitterness Method**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Relative bitterness</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dicetoneglucose</td>
<td>0.032</td>
<td>*</td>
</tr>
<tr>
<td>α-phenol glucoside</td>
<td>0.031</td>
<td>*</td>
</tr>
<tr>
<td>3(?)-acetylmonoacetone glucose</td>
<td>0.019</td>
<td>*</td>
</tr>
</tbody>
</table>

*By comparison with 0.02 M α-glucose pentasaccharate; rated in terms of quinine by the intermediacy of sucrose octasaccharate, and calculated from weight (not molar).

### TABLE III

**Relative sweetness of various substances**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Relative sweetness</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-propoxy-2-amino-4-nitrobenzene</td>
<td>5000</td>
<td>1% sucrose</td>
<td>Blankama 1946</td>
</tr>
<tr>
<td></td>
<td>4100</td>
<td>1% sucrose</td>
<td>Verkade, van Dijk, and Meerburg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1946; cf. Verkade, van Dijk</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and Meerburg 1942</td>
</tr>
<tr>
<td></td>
<td>3300</td>
<td>1% sucrose</td>
<td>Blankama and von der Weyden</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1940</td>
</tr>
<tr>
<td>1-allyloxy-2-amino-4-nitrobenzene</td>
<td>2000</td>
<td>1% sucrose</td>
<td>Verkade, van Dijk, and Meerburg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1946</td>
</tr>
<tr>
<td>α-anti-perillaldoxime</td>
<td>2006</td>
<td></td>
<td>Furuikawa 1921</td>
</tr>
<tr>
<td>1-ethoxy-2-amino-4-nitrobenzene</td>
<td>1400</td>
<td>1% sucrose</td>
<td>Blankama and von der Weyden</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>1% sucrose</td>
<td>1940</td>
</tr>
<tr>
<td></td>
<td>950</td>
<td>1% sucrose</td>
<td>Blankama 1946</td>
</tr>
<tr>
<td>6-bromo-3-nitroaniline</td>
<td>1250</td>
<td>1% sucrose</td>
<td>Blankama, van den Broek, and Hoegen</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1946</td>
</tr>
<tr>
<td>1-n-butoxy-2-amino-4-nitrobenzene</td>
<td>1000</td>
<td>1% sucrose</td>
<td>Verkade, van Dijk, and Meerburg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1946</td>
</tr>
<tr>
<td>6-bromo-3-nitroaniline</td>
<td>800</td>
<td>1% sucrose</td>
<td>Blankama, van den Broek, and Hoegen</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1946</td>
</tr>
<tr>
<td><strong>syn-5-benzyl-2-furfuraldoxime</strong></td>
<td>690</td>
<td>2% sucrose</td>
<td>Gilman and Dickey 1930</td>
</tr>
<tr>
<td>Saccharin, as sodium salt</td>
<td>675</td>
<td>2% sucrose</td>
<td>Gilman and Hewlett 1929</td>
</tr>
<tr>
<td></td>
<td>200-700</td>
<td>Varied sucrose</td>
<td>Paul 1922</td>
</tr>
<tr>
<td></td>
<td>190-675</td>
<td>Varied sucrose</td>
<td>Magidson and Gorbachov 1923</td>
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<td>1-isopropoxy-2-amino-4-nitrobenzene</td>
<td>600</td>
<td>1% sucrose</td>
<td>Verkade, van Dijk, Meerburg 1946</td>
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<td>α-amylichloromalonalamide</td>
<td>400</td>
<td>2% sucrose</td>
<td>Dox and Jones 1928</td>
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<td>6-chloro-3-nitroaniline</td>
<td>400</td>
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<td>Blankama 1946</td>
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<td>6-chlorosaccharin</td>
<td>ca. 340</td>
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<td>Davies 1921</td>
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<td>4-nitro-2-aminotoluene</td>
<td>330</td>
<td>1% sucrose</td>
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<td>1-methoxy-2-amino-4-nitrobenzene</td>
<td>330</td>
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<td></td>
<td>220</td>
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<td>Method</td>
<td>Reference</td>
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<td>1-propanoyl-2-amino-4-nitro-6-methylbenzene</td>
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<td>310</td>
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<td>N-methyl-N-p-ethoxyphenylurea</td>
<td>ca. 265</td>
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<td>Bergmann, Camacho, and Dreyer 1922</td>
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<td>265</td>
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<td>170</td>
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<td>anti-5-benzyl-2-furfuraldoxime</td>
<td>ca. 100</td>
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<td>Furumonitrile</td>
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<td>Cohn 1914</td>
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<td>sym-phenylacetaldoxime</td>
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<td>17</td>
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<td>Audrieth and Sveda 1944</td>
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<td>Furfuraldehyde</td>
<td>2.5</td>
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<td>dl-erythritol</td>
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<td>1.03</td>
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<td>Spengler and Traegel 1927</td>
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<td>1.3</td>
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<td>0.49</td>
<td>3% sucrose</td>
<td>Paul 1922</td>
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<tr>
<td>dl-alanine</td>
<td>0.63-1.70</td>
<td>Varied sucrose</td>
<td>Heiduschka, Komm, and Simeons 1925</td>
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<td>0.92</td>
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<td>Cameron 1944</td>
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<td>0.48</td>
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<td>Glycine</td>
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<td>Dahlberg and Penczek 1941</td>
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<td>Glucose</td>
<td>0.53-0.88</td>
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<td>Renner 1939</td>
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<td>3% sucrose</td>
<td>Paul 1922; cf. Deerr 1922 and Sale and Skinner 1922</td>
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<td>Threshold</td>
<td>Belsey, Wood, and Wahlin 1925</td>
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<td>Threshold</td>
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<td>d-alanine</td>
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<td>Paul 1923</td>
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<td>0.27–0.28</td>
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<td>Raffinose</td>
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LITERATURE CITED


