TRANSLATION

New Seasonings

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The relationship between our senses and chemistry is a most interesting issue from several points of view. Among the senses, olfaction and taste are regarded as the chemical senses proper. It is clear, therefore, that there must be a close relationship between the chemical structure of a substance and its smell and taste. However, I regret to say, little scientific evidence has been obtained for this relationship. (. . .)

In the past it was said that there are five taste qualities: sour, sweet, salty, bitter and hot. A hot sensation is just a skin mechanical sensation, therefore today's scientists do not regard this sensation as a taste. Furthermore, such qualities as metallic, alkaline and astringent are not considered to be tastes (at least not pure tastes), because they cannot be separated from the sensation accompanied by tissue damage. Therefore, physiologists and psychologists recognize only the four tastes sour, sweet, salty and bitter. Other tastes are considered to be a mixture of these tastes. However, I believe that there is at least one other additional taste which is quite distinct from the four tastes. It is the peculiar taste which we feel as 'UMAI [meaning brothy, meaty, or savory]', arising from fish, meat and so forth. The taste is most characteristic of broth prepared from dried bonito and seaweed [*Laminaria japonica*]. While it is based on a subjective sensation, many people who are asked always agree to this conjecture either immediately or after brief consideration. Consequently, there can be little doubt that another taste exists in addition to the four tastes. I propose to call this taste 'UMAMI' for convenience.

The next problem is to identify the chemical substance which produces 'UMAMI'. It is difficult to prove the existence of a small quantity of unknown taste substance, extracted from a variety of animals and plants. To challenge the difficulty, I first selected dried seaweed as a material for our study, because the protein in this dried material is coagulated and its aqueous extract may have a relatively simple composition. Previously published analytical results concerning the composition of the seaweed demonstrated that it contains a large amount of mannitol and specific amounts of salts. However, the taste substances in the aqueous extract are unknown.

The taste substances of seaweed, of course, are to be found in the extract. When the extract is evaporated at the crystalization point and is cooled, a large quantity of crystaline mannitol is obtained. I have isolated ~200 g of crude mannitol from 1 kg of high-quality seaweed by one-time crystallization. Thus, seaweed may be the best raw material for mannitol in Japan. In the future, mannitol may be inexpensively extracted from seaweed for industrial use. Re-evaporation of the mother liquor from which mannitol crystals have been removed yields salt [NaCl] crystals. Decanting and cooling the solution yields mannitol crystals once more. Repeating the process of boiling down and crystalizing removes most mannitol, salt [NaCl], potassium chloride, etc. The final mother liquor does not crystalize when dried in a vacuum dryer. Adding anhydrous alcohol to the mother liquor produced two liquid phases without precipitation. This suggests that the substances in the mother liquor are quite soluble in water. Although all taste components of seaweed were expected to be concentrated in the mother liquor, no taste, of the kind which I expected, has so far been found at least in the crystaline precipitations and its purified crystal.

The mother liquor was neutral. After it was dried and heated, and the residue dissolved in water, the solution reacted strongly alkalic. This indicated that the taste substance is a salt of an organic acid. Many attempts were made to precipitate the acid with different methods. Chlorine, iodine and sulfuric acids mixed in the mother liquor precipitated, but the acid being sought was not deposited. Finally, on adding a saturated solution of lead nitrate, a precipitate was obtained. It was slightly soluble in water, so a large amount of lead nitrate was required. Lead (II) acetate trihydrate and lead acetate were also used for precipitation, but without good results. This may be attributed to the relatively weak dissociation when these lead salts form complexes. A resinous precipitate obtained using lead nitrate contained large amounts of chlorides and sulfates, as well as some lead nitrate. The precipitation was

partially dissolved in boiling water. This yielded a resin-like matter which was cooled to yield very brittle lumps. The substance was easily crushed into powder.

The powder, together with calcium carbonate, was placed in water and then put in a flow of hydrogen sulfide, converting all of the organic acids to calcium salts. The solution was filtered to remove lead sulfate and excess calcium carbonate, and then evaporated and dried to yield powder. The powder was dissolved in 98% ethanol and exuded with a Soxhlet's extractor for a long time. However, the results showed that nothing was extracted except for a small amount of a bitter substance. The purpose of this operation was to dissolve the calcium chloride and calcium nitrate, but these were not dissolved in the hot ethanol at all. This is probably due to the formation of complexes with the salt of the taste substance. This point should be clarified in the future.

Subsequently the powder was treated with silver sulfate to remove chlorine and iodine, then with barium oxide to remove the sulfuric acid and finally with oxalic acid to remove calcium. A solution of a mixture of unknown acid(s) and a small amount of nitric acid were obtained. This solution might also contain a relatively small quantity of other substances. The volume of the resulting solution was quite large due to the use of silver sulfate, which is only slightly water-soluble. The solution was concentrated through reduced pressure evaporation and then kept in a dryer with sulfuric acid.

In a few days a crystaline substance started to develop, but its growth was very slow. It took a week to obtain a crystal the size of a rice corn. The substance was slightly unclear and semi-crystaline. Its hardness was relatively strong for an organic substance not soluble in water. The solution was acidic. The substance's melting point was at first at 192°C and, following repeated re-crystalization, almost reached 200°C. The crystals appeared similar to sand when I bit them and displayed a peculiar taste of seaweed's broth with little sour taste. This 'UMAMI' was perceived clearly after the sour taste had faded. The crystal was neutralized with alkali to yield a salt that was strongly 'UMAMI'.

These results clarified that the taste component of seaweed is the salt of an organic acid which can be extracted in pure form. Therefore, the procedure described above was used again with a larger amount of raw material. Only one difference was introduced, in that barium carbonate was used instead of calcium carbonate. The crystaline acid obtained was analyzed. Its molecular weight was evaluated from the boiling point of the aqueous solution and the acid was neutralized with alkali of known concentration for the determination of its equivalent. The molecular formula was determined to be $C_5H_9NO_4$. Since its other properties agreed with those of glutamic acid, the substance was finally determined to be glutamic acid.

This study has discovered two facts: one is that the broth of seaweed contains glutamate and the other that glutamate causes the taste sensation 'UMAMI'.

E. Fischer says that glutamic acid has a specific 'not palatable' (fader) taste and a weak sour taste (*Untersuchungen über Aminosäuren, Polypeptide und Proteïne*, p. 69). Unfortunately, the tastes of glutamates have not been reported as yet. This is because the salts of glutamic acid have not been studied sufficiently, so their properties are yet to be revealed. For example, the monovalent sodium salt of glutamic acid was described as a deliquescent substance, but actually crystalized easily and had a solubility similar to salt [NaCl] at ambient temperature. It did not deliquesce when exposed to air in the rainy season. The barium salt was described as an enameled substance, but really it is a silk-thread-like crystal. The calcium salt can be obtained as an unclear crystal. The potassium salt, however, has not been crystalized as yet. The aqueous solutions of all these salts have an intense and pure 'UMAMI' taste. In addition, monovalent glutamates of ammonium, magnesium, zinc, cadmium, aluminum, copper, and iron [ferrous] solutions, produced by double decomposition of their metal sulfates and barium glutamate, also are 'UMAMI', with a particular metallic taste added. Thus, the 'UMAMI' definitely comes from the ionic form of monovalent glutamic acid. This is similar to the bitter taste of neutral sulfates, which is attributed to bivalent ionic sulfuric acid.

The taste intensity of glutamate is quite strong. The threshold value of sodium glutamate is ~1/3000, i.e. its taste can be perceived when 1 g of sodium glutamate or more is dissolved in 3 l of water. Less than 1 g cannot be detected. Its intensity is inferior when compared to substances with an extremely strong taste such as alkaloids and saccharin, but it is stronger than salt or sugar which are used as a common seasoning. Threshold values for several taste substances are:

Sucrose	1/200
Salt [NaCl]	1/400
Sodium glutamate	1/3000
Hydrochloric acid	1/10 000

When these values are converted to the degree of (molar) dilution, one obtains

Sucrose	70 l
Salt [NaCl]	23 l
Sodium glutamate	500 l
Hydrochloric acid	370 l
(. . .)	

The taste intensity of 'UMAMI' becomes stronger when increasing the concentration of glutamic acid. However, we found it not to be proportional. To be more specific, changes in the taste intensity may be smaller relative to the extent of increase in the ion concentration. (. . .) In fact, the taste of salt [NaCl] stands out more than the taste of the ionic

glutamic acid when a mixture of NaCl and glutamate is present and both concentrations are high. As the concentrations are decreased by the addition of water, the 'UMAMI' of ionic glutamic acid gradually becomes stronger. When the mixture is heavily diluted with water, the taste of ionic glutamic acid can still be perceived even after the taste of NaCl has disappeared. Evaluation of soy sauce actually uses this relationship.

There is an interesting observation concerning mixtures. Addition of acids like vinegar to a glutamate solution substantially reduces the taste of ionic glutamic acid. This may not be due to the interaction between opposite tastes. Glutamic acid is a weak acid, so that, when hydrogen ions are added to a glutamate solution, the ionic glutamic acids combine with the hydrogen ions to yield non-dissociated hydrogen glutamate. The decrease in glutamic acid anions leads to the reduction of its taste. This demonstrates that the 'UMAMI' is attributed to the properties of the ionic glutamic acid. (. . .)

Many people may recognize that the palatability of ionic glutamic acid increases remarkably when a sufficient amount of salt [NaCl] is present. This is because meals usually contain salt [NaCl]. People thus have the habit of tasting 'UMAMI' and a salty taste at the same time. A weak salty taste, however, does not enhance the 'UMAMI' intensity. (. . .) The fact that the salty taste is especially related to 'UMAMI' is an interesting issue for taste research.

Regarding the relationship between sweetness and 'UMAMI', sweetness of sugars is rarely affected by the taste of ionic glutamic acid, whereas strong sweetness weakens the taste of ionic glutamic acid and makes 'UMAMI' indistinguishable. There is also a certain similarity between the taste of ionic glutamic acid and sweetness. When the concentration of ionic glutamic acid is close to its threshold value, some people taste it sweet by mistake. However, the taste intensity of ionic glutamic acid, as mentioned previously, does not increase in proportion with an increase in concentration of the ion. On the other hand, the sugar's sweetness increases with an increase of sugar concentration. Thus, the two are completely different types of tastes. If these substances can be likened to color, 'UMAMI' would be yellow and sweetness red.

(. . . extensive verbal quotations from E. Fischer, *Untersuchungen über Aminosäuren, Polypeptide und Proteine*, p. 683, footnote . . .)

Our results, together with those of Fischer, clearly indicate that the 'UMAMI' of the ionic glutamic acid is related first to the characteristics of an amino acid and second to the fact that its amino group occupies the *alpha* position for one carboxyl group and the *gamma* position for the other carboxyl group. It is noteworthy that ionic aspartic acid does not produce 'UMAMI', which suggests that the location of every residue is relevant for the taste. It is also apparent that stereochemical structure is associated with taste. One could conjecture that ions with a structure similar to glutamic acid, having a similar 'UMAMI', exist in the hydrolysis products of proteins. Furthermore, such compounds can be artificially synthesized.

To explain the relationship between a certain structure and a type of taste scientifically is extremely difficult. On the other hand, it is easy to see why people have a preference for the sweetness of sugar and the 'UMAMI' of ionic glutamic acid, considering the nutritional value.

Taste preferences have gradually developed as a result of the evolution of living organisms. Thus instinctive actions serving the preservation of life and the breeding were selected for. It appears that taste preference in foods was developed to select the more nutritive foods. The most remarkable taste component of good plant foods is the sweetness of sugars. A food component with no taste, like starch, produces some sweetness after it is chewed. It is thus natural for humans consuming plant foods to prefer sweetness. A preference for 'UMAMI' can be explained by a similar argument. A certain amount of hydrolysis products of proteins is always present in various parts of animal bodies as a result of the metabolism. Actually, a certain amount of glutamic acid, along with other amino acids, is found in meat extracts prepared by evaporation of meat juice. The taste of glutamate is the most remarkable among these and can be perceived even in trace amounts. Therefore, the taste of glutamate is closely associated with animal food. It is quite reasonable that a preference for 'UMAMI' must naturally have developed with the intake of such nutritive foods.

A rational method of production satisfying this natural preference must be developed. The best method is to produce glutamates by hydrolyzing proteins, and especially plant proteins, using strong acids and thus to prepare seasonings containing glutamates. I obtained a patent on the production method last summer. The most convenient glutamate for seasoning is sodium glutamate. To produce purified sodium glutamate is costly. Therefore, the use of glutamate contaminated with other components [impurities] as a seasoning seems more practical. A mixture like this may even be more nutritious. The seasoning mentioned above has been produced and marketed by Mr Saburosuke Suzuki, a well-known iodine vendor. The taste of soy sauce may also in part be attributed to the 'UMAMI' of the ionic glutamic acid. I believe that the time has come to revolutionize the production method of this important seasoning. Although scientific studies on hydrolysis products of proteins have actively been conducted, their industrial applications seem to be rare. I hope that the production of seasonings will become a starting point for the development of a chemical industry in this field.

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