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Psychometric Studies on the Taste of Monosodium Glutamate

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Monosodium glutamate (MSG) is generally used as a flavor enhancer. There are several scientific papers on the flavor effect of MSG added to food, but they seem to focus on its practical use (3a,4,5,6,17a,19,25). We conducted a two-part study to define the flavor effect of MSG. In the first part, the aspect of the flavor profile change of food when MSG was added to food was investigated psychometrically. In the second part, the fundamental flavor properties of MSG and other flavor substances were examined.

STUDY ON THE FLAVOR EFFECT OF MSG ON FOODS

Psychometric Approach

The addition of MSG, broth, salt, or sugar to a variety of different foods was investigated to learn how a general population, not specialists in food science, describe the flavor change of food. The flavor profile evaluation for a mass panel used the Semantic Differential Method (20) and the results were analyzed statistically.

Collection of Evaluation Terms

One hundred and fifty adults in our research laboratories and 30 female students studying food science were presented with eight different foods, with or without added MSG (0.1 to 2%) or containing different concentrations of broth, salt, or sugar. Comparing the samples, the subjects expressed freely their impression of the flavor profile of the food using their own expressions. They were not informed of the sample ingredients nor the purpose of the test.

Out of approximately 500 expressions obtained, 32 pairs of the expressions, which appeared most frequently and expressed the differentiated characteristics concretely, were selected. The expression of MSG-like taste or MSG taste appeared frequently. But these terms were consciously eliminated because the purpose of the study was to make a clear flavor profile of MSG itself. The 32 paired terms were

listed on the evaluation sheet (Fig. 1) for the following set of experiments described below.

Methods in the Flavor Evaluation Test

The panel comprised 300 people, and the panel size of each experiment was 25 to 50 persons. Panel members received oral instructions from the experimenter. They

FLAVOR PROFILE OF [FOOD NAME]

Date _____

Name _____

DIRECTIONS : mark each line in the place that best expresses your feelings of SAMPLE B compared with SAMPLE A.

			certainly	slightly	almost same	slightly	certainly	
			−2	−1	0	1	2	
1	Whole aroma	/ weak						strong
2	Meaty aroma	/ weak						strong
3	Aroma derived from (·····)	/ weak						strong
4	Whole aroma	/ bad						good
5	Meaty flavor	/ weak						strong
6	Flavor derived from (·····)	/ weak						strong
7	Flavor of spice	/ weak						strong
8	Whole taste	/ weak						strong
9	Salty taste	/ weak						strong
10	Salty taste	/ rough						smooth
11	Sweet taste	/ weak						strong
12	Sour taste	/ weak						strong
13	Bitter taste	/ weak						strong
14	Meaty taste	/ weak						strong
15	Taste derived from (·····)	/ weak						strong
16	Oily or Fatty	/ weak						strong
17	Foreign flavor	/ weak						strong
18	Continuity	/ short						long
19	Simple							Complex
20	Watery							Concentrated
21	Mouthfulness	/ weak						strong
22	Development	/ narrow						broad
23	Flat							Body
24	Light							Heavy
25	Poor							Rich
26	Thin							Thick
27	Harsh							Mild
28	Crude							Aged
29	Balance	/ bad						good
30	Punch	/ weak						strong
31	Unfavorable							Tasty
32	Palatability	/ bad						good

FIG 1. Evaluation sheet for the food flavor profile.

were to use the five-point rating scale for evaluating the 32 paired terms. The meanings of the terms were not defined for the panel members.

The foods were prepared (2,13,26,27,35) just before the test, and their appearance and temperature were controlled to preserve their best condition at serving (Table 1). Beef or chicken broth was prepared according to Berolzheimer's *Encyclopedic Cook Book* (2). Test samples were standardized at 100 g.

TABLE 1. *Foods presented for flavor profile test*

Item	Main raw material	Test additive
Soup		
beef consommé	Lean beef, vegetables	MSG, beef broth
chicken consommé	Chicken, vegetables	MSG
cream of chicken soup	Chicken, milk	MSG
chicken noodle soup	Chicken, noodle	MSG
cream of vegetable soup	Potato, onion, milk	MSG, chicken broth
vichyssoise	Potato, milk, chicken broth	MSG
onion soup	Onion, butter	MSG
cream of tomato soup	Tomato, milk	MSG, chicken broth
Japanese miso soup	Soybean paste	MSG
Meat		
hamburger	Ground beef, onion	MSG, salt
Poultry and eggs		
seasoned egg custard	Eggs, chicken, mushroom	MSG, bonito broth
Sea food		
coquilles of scallops	Scallops	MSG
Vegetable		
cooked vegetables	Carrot, corn, peas	MSG, chicken broth, beef broth
cooked broccoli	Broccoli	MSG
Dessert		
Bavarian cream	Gelatine, egg, cream	Sugar
caramel custard	Eggs, milk	Sugar

Results of the Flavor Evaluation Test

Classification of Evaluation Terms

The average scores obtained by the test on the evaluation scales were analyzed by principal-component analysis and by cluster analysis. The paired terms were classified into five major groups according to flavor functions, and some paired terms were united by their high coefficient of correlation (Table 2).

This classification was used to arrange the results of the evaluation sheets. The average score given by the subjects on each scale was drawn in a bar diagram to show the flavor profile change induced by the addition of MSG or other flavor

TABLE 2. *Classification of evaluation terms*

Aroma
Whole aroma
Aroma derived from material (meaty, vegetable-like, etc.)
Basic taste
Whole taste
Salty
Sweet
Sour
Bitter
Flavor character
Continuity
Mouthfulness (complex, development, body, rich)
Impact (concentrated, heavy, punch)
Mild (aged)
Thick
Other flavor
Spicy
Oily
Flavor derived from material (meaty, vegetablelike, etc.)
Whole preference
Preference (palatability, tasty, balance)

substance to the food (Figs. 2–7). Each bar diagram includes a line indicating the 95% confidence level.

Flavor Profile

The addition of MSG to beef consommé had no effect on aroma, but increased the overall taste intensity. Saltiness, sweetness, sourness, and bitterness were not significantly increased (Fig. 2). The addition of MSG increased the characteristics of the flavor (Fig. 2), i.e., continuity, mouthfulness, impact, mildness, and thickness of beef consommé. It also increased the meaty flavor and the overall preference for the beef consommé.

The same pattern was observed with hamburger, chicken consommé, chicken noodle soup, and cream of chicken soup (Figs. 3 and 4), as well as with scallop coquilles, cooked vegetables, and seasoned egg custard.

Doubling the concentration of beef consommé gave the same pattern of change in the flavor profile of beef consommé as did the addition of MSG, but additionally increased the intensity of aroma and the four basic tastes (Fig. 2).

Cream of tomato soup was found to be an exception. The addition of MSG did not change the flavor profile of this food very much. Adding chicken broth to the tomato soup changed only the sourness and continuity of the flavor (Fig. 5).

The beef consommé mentioned above contained 0.8% NaCl. Increasing NaCl levels to 1.2% changed only the saltiness ratings of the food and decreased its palatability (Fig. 6). But an increase in NaCl from 0.2% to 0.8% enhanced

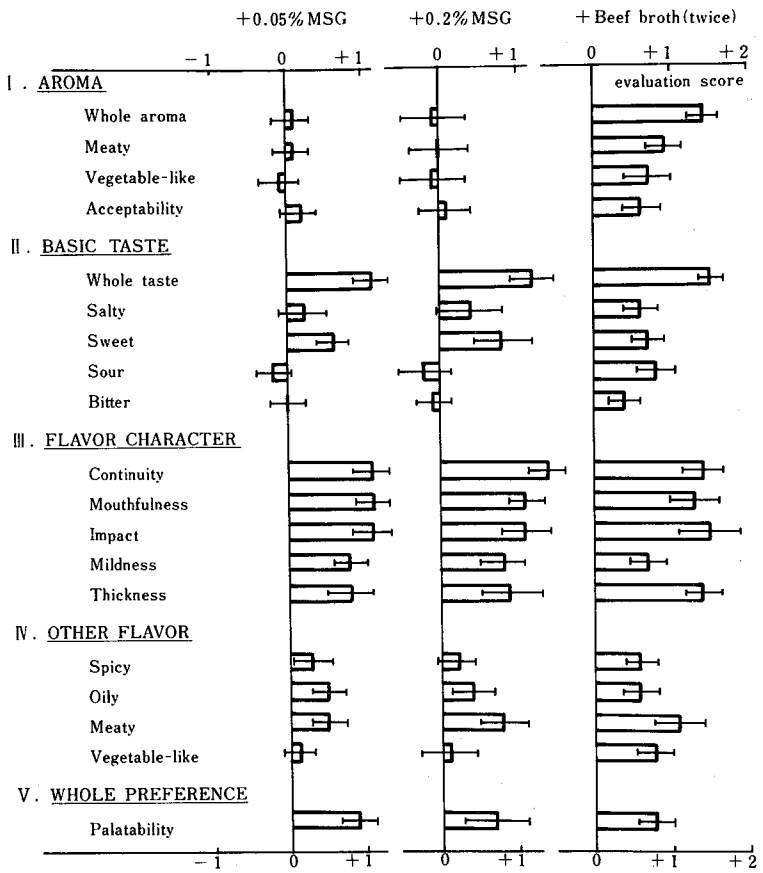


FIG. 2. Effect of MSG and beef broth on the flavor profile of beef consommé.

palatability and increased the flavor characteristics of continuity, mouthfulness, impact, mildness, and thickness (Fig. 6).

When comparing the different sugar contents of Bavarian cream between 10 and 20%, the latter was given larger evaluation scores of continuity, mouthfulness, impact, mildness, and thickness, as well as increased sweetness (Fig. 7).

Thus, in the case of some foods, both salt and sugar not only increased their intrinsic tastes, but also enhanced the flavor characteristics of the flavor character.

Flavor Effects of MSG

In summary, our experiments demonstrated the following pattern of effects of MSG on foods:

1. MSG has no effect on aroma of food.

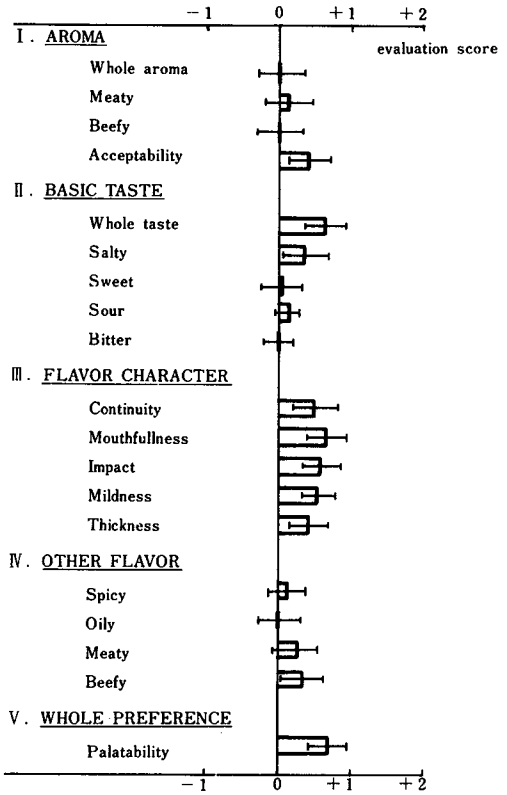


FIG. 3. Effect of MSG (+1%) on the flavor profile of hamburger.

2. MSG increases the total taste intensity of food. The quality of the taste brought about by MSG is different from the four basic tastes.

3. MSG enhances certain flavor characteristics of food: continuity, mouthfulness, impact, mildness, and thickness.

4. MSG enhances the specific flavor of meat and poultry foods.

5. MSG has a flavor effect similar to broth (beef stock), although MSG has no effect on aroma.

6. MSG increases the whole preference or palatability of food.

Discussion

The pattern of flavor effects of MSG on food was obtained by the flavor profile test. The role of MSG in food can be summarized by saying that MSG increases the taste other than the four basic tastes and improves certain flavor characteristics of food.

MSG has two flavor functions. One is that MSG imparts an intrinsic taste

different than the four basic tastes. This intrinsic taste corresponds to the Japanese expression *umami,* meaning tastiness.

Another function of MSG is that it intensifies the flavor characteristics of food: continuity, mouthfulness, impact, mildness, and thickness; MSG also increases the whole preference of food. The same effect is brought about by the increase of broth concentration. Both salt and sugar, in some cases, not only increase the intrinsic tastes of foods, but also enhance the flavor characteristics mentioned above. These facts suggest that MSG, as well as salt and sugar, may generally be called a flavor enhancer.

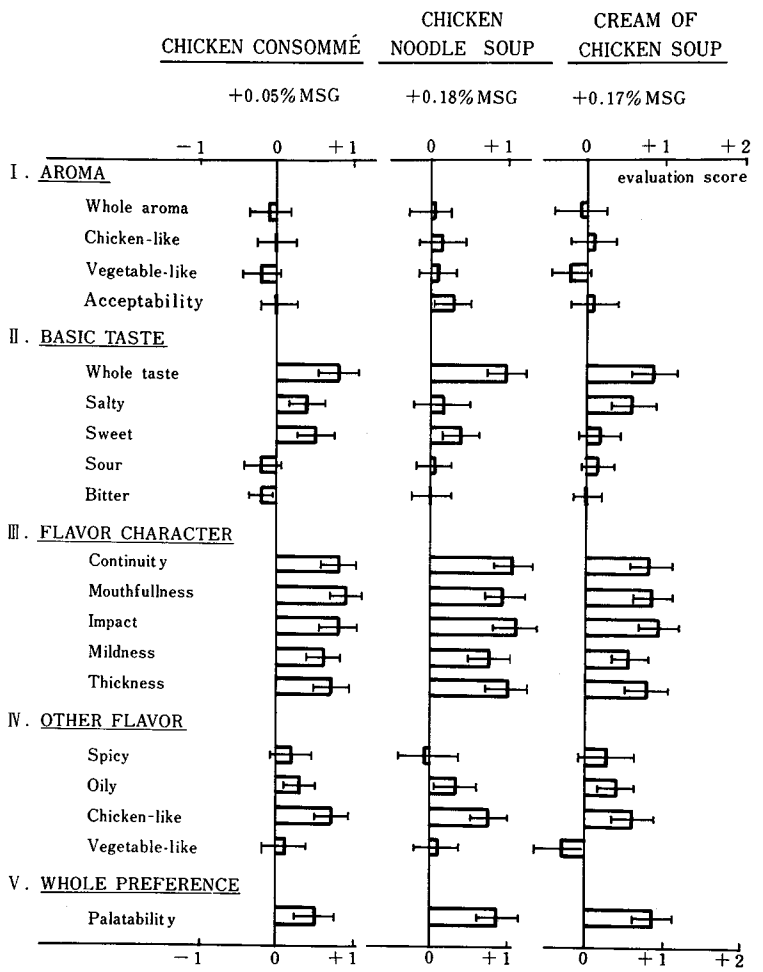


FIG. 4. Effect of MSG on flavor profile of chicken soups.

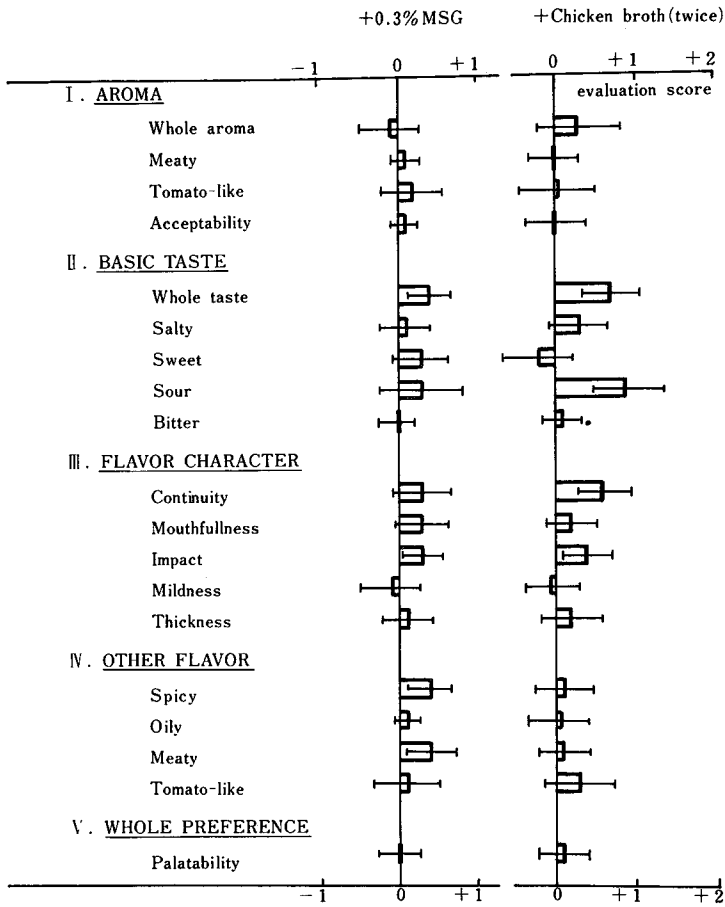


FIG. 5. Effect of MSG and chicken broth on the flavor profile of cream of tomato soup.

STUDY ON THE FUNDAMENTAL FLAVOR PROPERTIES OF MSG

Taste Threshold for MSG

The taste threshold for MSG is reported in a wide range of values from 4×10^{-5} to 4×10^{-3} M (7,12,14,17,18,23,24,36). The value varies depending on the methods of measurement or on the composition of the panel.

The absolute threshold for MSG was measured as follows: The triangle test was administered to a panel composed of 30 persons from our laboratories. The three samples, two pure water and one MSG solution, were presented to the panelist in each trial. For the series of trials, the samples of MSG solution were presented in order of decreasing concentration until subjects reported no difference between the MSG solution and pure water.

The absolute threshold for MSG was found to be 6.25×10^{-4} M. The thresholds for the four basic taste substances were determined in the same way by the same panel (Table 3). The threshold for MSG was higher than for quinine sulfate or tartaric acid, lower than for sucrose, and about the same as for sodium chloride.

Taste Intensity of MSG

The relationship between concentration and the perceived taste intensity of MSG and the four basic tastes were studied. The panel was the same group used for establishing the taste thresholds. The panelists were first trained to rate taste intensity by using a 100-point scale: zero was pure water and 100 was a 3.2×10^{-4} M quinine sulfate. The panelists evaluated 30 samples (5 taste com-

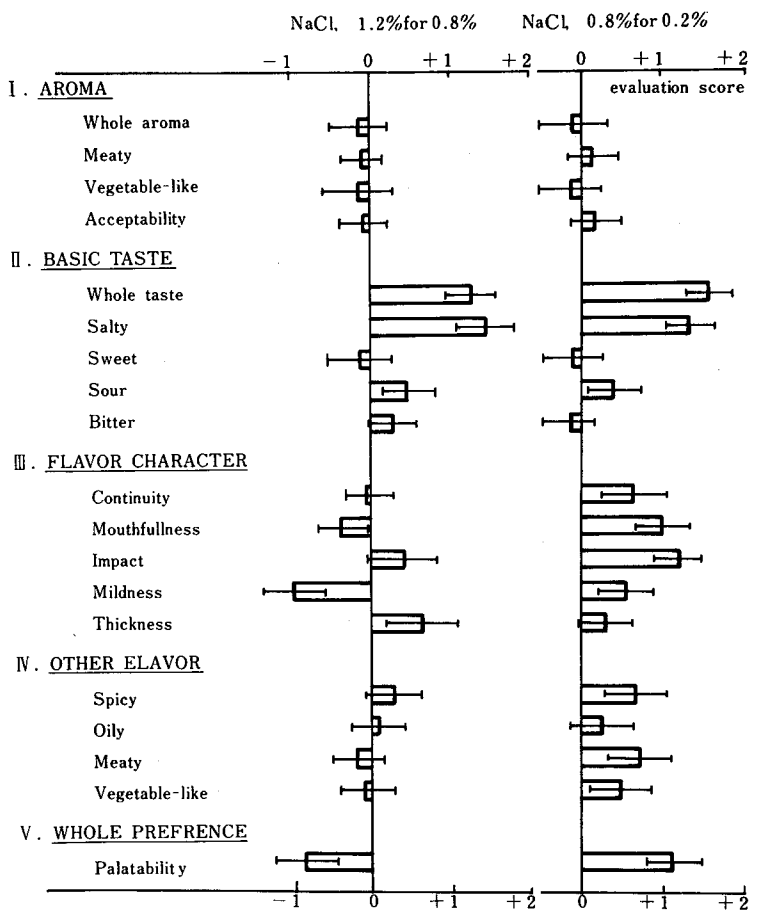


FIG. 6. Effect of NaCl on the flavor profile of beef consommé.

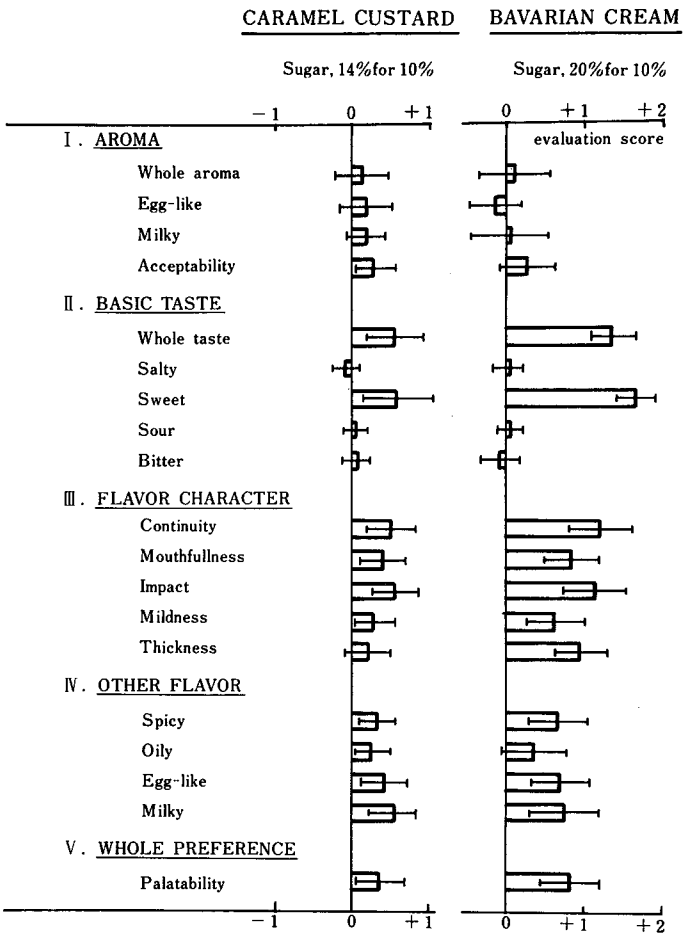


FIG. 7. Effect of sugar on the flavor profile of caramel custard and Bavarian cream.

TABLE 3. *Taste thresholds for selected compounds*

Solvent	Absolute threshold[a]				
	Sucrose	Sodium chloride	Tartaric acid	Quinine sulfate	MSG
Pure water	1.25×10^{-3} M (4.3×10^{-2}%)	6.25×10^{-4} M (3.7×10^{-3}%)	6.25×10^{-5} M (9.4×10^{-4}%)	6.25×10^{-7} M (4.9×10^{-5}%)	6.25×10^{-4} M (1.2×10^{-2}%)
5×10^{-3} M MSG	1.25×10^{-3} M	6.25×10^{-4} M	1.25×10^{-4} M (1.9×10^{-3}%)	6.25×10^{-7} M	—
5×10^{-3} M IMP	1.25×10^{-3} M	6.25×10^{-4} M	2.0×10^{-3} M (3.0×10^{-2}%)	2.5×10^{-6} M (2.0×10^{-4}%)	—

[a] Significant at 5% level.

pounds times 6 concentrations); the order of sample presentation was randomized. All 30 samples were evaluated twice by the same panelist. The panelist was instructed to do the following: (a) hold 10 ml of the sample in the mouth for 10 sec, (b) evaluate and score the taste strength, (c) rinse with tap water, and (d) take 1-min interval before the next tasting. The panelist recorded the subjective rating score of the taste intensity of each sample in the range between 0 and 100 points.

The results showed that Weber-Fechner's law was applicable to the relationship between concentration and the taste intensity of MSG, as well as to the relationship of the other four basic tastes (Fig. 8) (1,8).

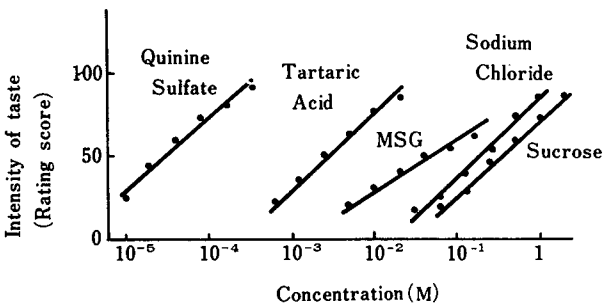


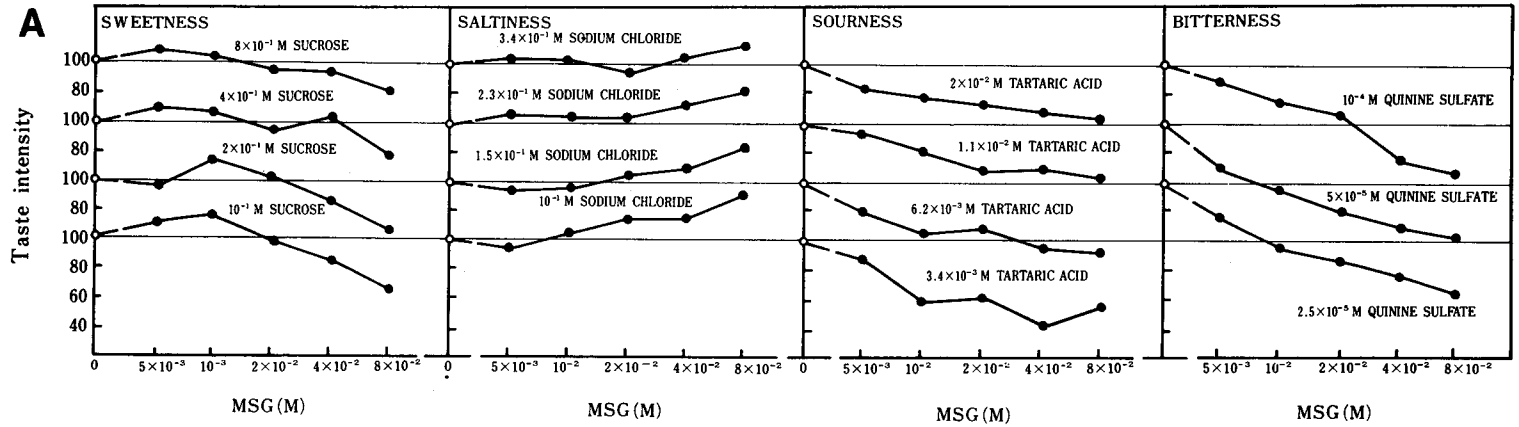
FIG. 8. Relationship between concentration and taste intensity.

Interaction Between MSG and the Four Basic Tastes

The influences of both MSG and inosinate (IMP) on the absolute thresholds of four basic tastes were tested with the same panel (Table 3). The results showed that the threshold for the four basic tastes in 5×10^{-3} M MSG or IMP solution was the same as in pure water. A slightly higher threshold for sourness in the MSG or IMP solution may have been caused by the change of the pH value.

The same panel was used to determine the interactions between MSG and the four basic tastes at suprathreshold levels. Magnitude estimation was used to measure the influence of MSG on the four other basic tastes. For example, the strength of sweetness was reported after the addition of MSG (the sweetness was set as 100 with no addition). The same method was used to measure the influence of the four basic tastes on MSG.

MSG did not increase the intensity of the four basic tastes. Conversely, the four basic taste substances did not increase the intensity of the taste of MSG (Fig. 9). A masking effect was observed more or less between MSG and the four basic tastes; this effect has been reported among the four basic tastes (9,21,22). The taste of MSG seems not to be one of the traditional four basic tastes nor to be composed of them. Multidimensional scaling has shown that the taste of MSG comprises a dimension independent from those of the four basic tastes (37). A number of psychologists who have studied MSG taste call it "distinctive" or "unique" (3).


A
SWEETNESS
SALTINESS
SOURNESS
BITTERNESS
Taste intensity
8×10⁻¹ M SUCROSE
4×10⁻¹ M SUCROSE
2×10⁻¹ M SUCROSE
10⁻¹ M SUCROSE
3.4×10⁻¹ M SODIUM CHLORIDE
2.3×10⁻¹ M SODIUM CHLORIDE
1.5×10⁻¹ M SODIUM CHLORIDE
10⁻¹ M SODIUM CHLORIDE
2×10⁻² M TARTARIC ACID
1.1×10⁻² M TARTARIC ACID
6.2×10⁻³ M TARTARIC ACID
3.4×10⁻³ M TARTARIC ACID
10⁻⁴ M QUININE SULFATE
5×10⁻⁵ M QUININE SULFATE
2.5×10⁻⁵ M QUININE SULFATE
100
80
60
40
0
5×10⁻³
10⁻²
2×10⁻²
4×10⁻²
8×10⁻²
MSG (M)

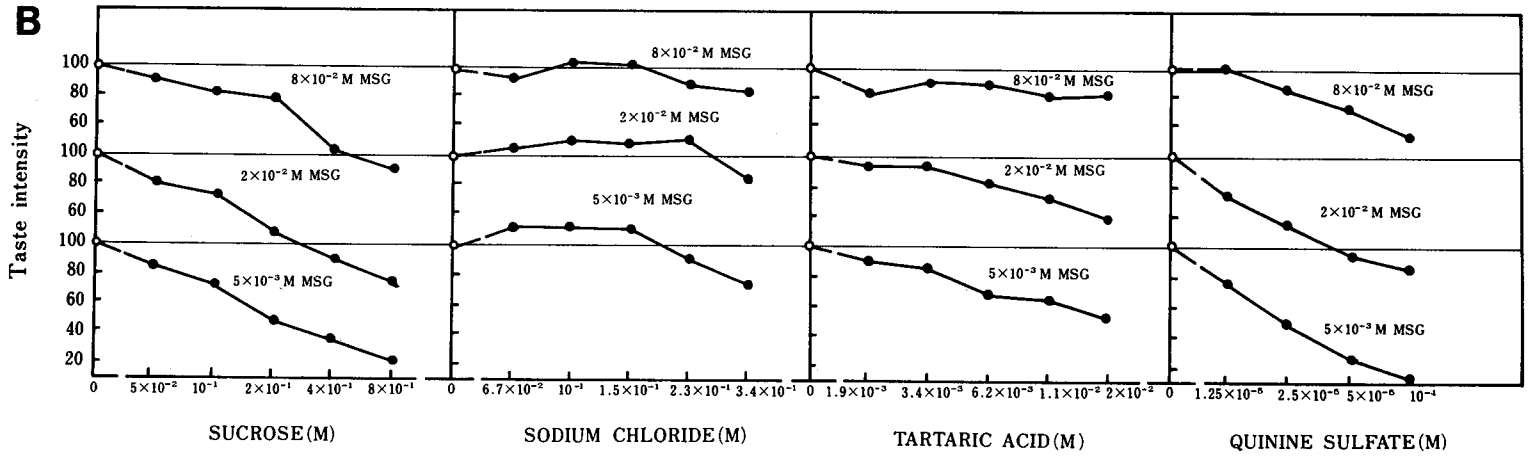


FIG. 9. Interactions between MSG and the four basic tastes by the Magnitude Estimation Method. **A:** Effect of MSG on the four basic tastes. **B:** Effect of the four basic tastes on MSG.

TABLE 4. *Taste substances similar to MSG*

Substance	Relative taste intensity	
	(g/g)	(mole/mole)
Monosodium L-glutamate·H_2O	1	1
Monosodium DL-threo-β-hydroxy glutamate·H_2O	0.86 ± 0.06	0.92
Monosodium DL-homocystate·H_2O	0.77 ± 0.04	0.92
Monosodium L-aspartate·H_2O	0.077 ± 0.007	0.071
Monosodium L-α-amino adipate·H_2O	0.098 ± 0.008	0.10
L-Tricholomic acid (erythro form)[a]	5–30	4.3–26
L-Ibotenic acid[a]	5–30	4.2–25

Table from Yamaguchi et al., ref. 34.
[a] From Terasaki et al., refs. 28 and 29.

Taste Compounds Similar to MSG

Several compounds have a similar taste to MSG: monosodium DL-threo-β-hydroxy glutamate, monosodium DL-homocystate, monosodium L-aspartate, monosodium L-α-amino adipate (10,11) L-tricholomic acid, and L-ibotenic acid (28,29). The taste intensity of these compounds was measured (29,34), and the results are shown in Table 4.

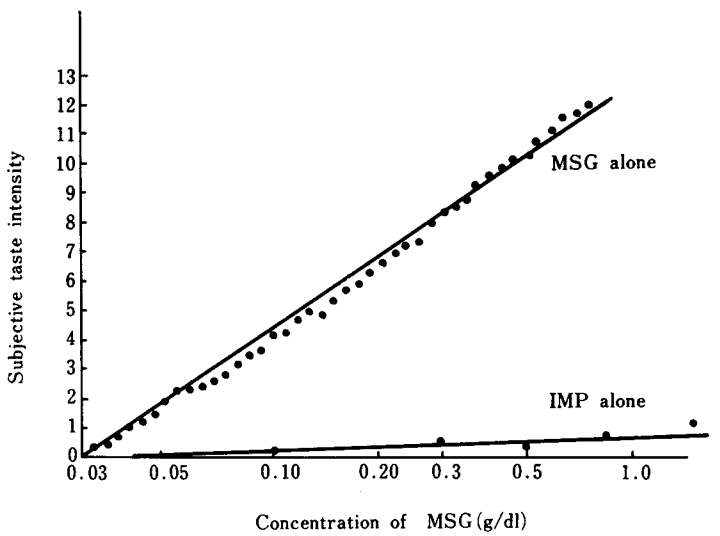


FIG. 10. Relationship between the concentration of MSG or IMP alone and taste intensity. (From Yamaguchi, ref. 31.)

Synergistic Effect of Nucleotides on the Taste of MSG

Inosinate (IMP) (15) alone has only a very weak taste (34) (Fig. 10). It is, however, known that IMP increases the intensity of the taste of MSG synergistically (16,30). The quantitative relationship of IMP to the taste intensity of MSG has been reported in detail (31,32,33).

The main points of those investigations are itemized as follows:

1. When the total concentration of MSG and IMP is constant, the taste intensity of the mixture increases remarkably following an increase of IMP. When the ratio of IMP reaches 50%, the intensity starts decreasing. The relationship between the portion of IMP and the taste intensity of the mixture is shown as a bisymmetric curve in Fig. 11.
2. According to the concentration of the mixture of both MSG and IMP, the taste intensity of the mixture increases acceleratingly, compared with MSG alone (Fig. 12).
3. The relationship between the taste intensity of the mixture and the concentration of the components is expressed as follows:

$$y = u + 1{,}200\,uv$$

where y is the concentration (% or g/100 ml) of MSG alone, giving the equivalent taste intensity to the mixture;
u is the concentration (% or g/100 ml) of MSG in the mixture; and
v is the concentration (% or g/100 ml) of IMP in the mixture.

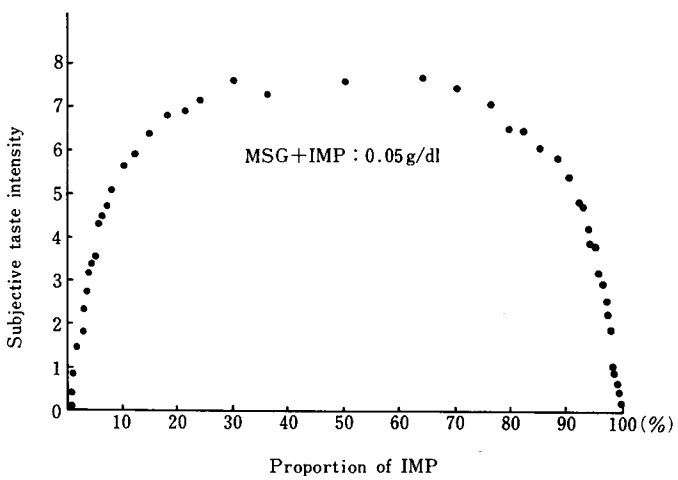


FIG. 11. Relationship between the mixing ratio of MSG and IMP and taste intensity. (From Yamaguchi, ref. 31.)

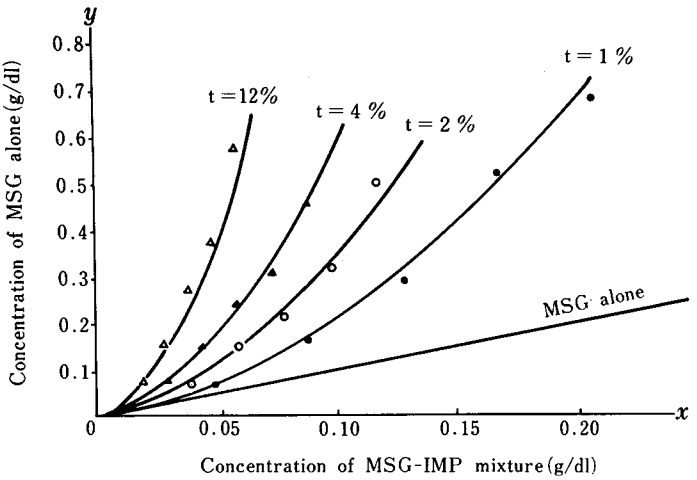


FIG. 12. Relationship of the taste intensity between MSG and mixtures of MSG and IMP (*t* being the proportion of IMP in the mixture). (From Yamaguchi, ref. 31.)

TABLE 5. *Nucleotides having synergistic effect on MSG*

Substance (disodium salt)	Relative intensity of taste activity	
	(g/g)	(mole/mole)
5′-Inosinate·7.5 H_2O	1	1
5′-Guanylate·7 H_2O	2.3 ± 0.07	2.3
5′-Xanthylate·3 H_2O	0.61 ± 0.04	0.53
5′-Adenylate	0.18 ± 0.03	0.13
Deoxy 5′-guanylate·3 H_2O	0.62 ± 0.07	0.52
2-Methyl-5′-inosinate·6 H_2O	2.3 ± 0.16	2.2
2-Ethyl-5′-inosinate·1.5 H_2O	2.3 ± 0.14	2.0
2-Methylthio-5′-inosinate·6 H_2O	8.0 ± 0.97	8.2
2-Ethylthio-5′-inosinate·2 H_2O	7.5 ± 0.75	6.9
2-Methoxy-5′-inosinate·H_2O	4.2 ± 0.33	3.5
2-Chloro-5′-inosinate·1.5 H_2O	3.1 ± 0.25	2.7
2-N-Methyl-5′-guanylate·5.5 H_2O	2.3 ± 0.15	2.3
2-N-Dimethyl-5′-guanylateY2.5 H_2O	2.4 ± 0.13	2.2
N^1-Methyl-5′-inosinate·H_2O	0.74 ± 0.09	0.59
N^1-Methyl-5′-guanylate·H_2O	1.3 ± 0.13	1.1
N^1-Methyl-2-methylthio-5′-inosinate	8.4 ± 0.75	7.4
6-Chloropurine riboside 5′-phosphate·H_2O	2.0 ± 0.20	1.6
6-Mercaptopurine riboside 5′-phosphate·6 H_2O	3.4 ± 0.35	3.3
2-Methyl-6-mercaptopurine riboside 5′-phosphate·H_2O	8.0 ± 0.83	6.7
2-Methylthio-6-mercaptopurine riboside 5′-phosphate·2.5 H_2O	7.9 ± 0.69	7.5
2′, 3′-O-Isopropylidene 5′-inosinate	0.21 ± 0.06	0.16
2′, 3′-O-Isopropylidene 5′-guanylate	0.35 ± 0.06	0.28

From Yamaguchi et al., ref. 34.

In case of guanylate (GMP), instead of IMP, the constant number is 2,800, which is 2.3 times larger than the 1,200 of IMP.

4. MSG has this synergistic effect with many other kinds of 5′-ribonucleotides (Table 5) (32).

Relationship Between Flavor Preference of Food and MSG

In order to show the relationship between the flavor preference of food and its MSG content, the y value, mentioned above, was calculated by substituting both u and v with the analytical values obtained for glutamate, inosinate, and guanylate in each food presented in the flavor evaluation test of Table 6.

The y value of beef consommé with no added MSG was 0.15; however, the value became 0.59 by increasing beef broth concentration, and the whole preference score was 0.80. The addition of MSG (0.05%) to beef consommé gave 0.91 of the y value by the effect of both IMP and GMP, which were contained naturally in the food itself, and gave 0.85 of the whole preference score. The addition of very little MSG gave a larger y value to this food, as did the increase of beef broth concentration, and increased the whole preference score. One observes the close relationship between the whole palatability of food and the total concentration (the y value) of MSG and nucleotides, whether they are added intentionally to food or contained naturally in food.

Discussion

The above-mentioned experiments suggest that MSG has an intrinsic taste independent of the four basic tastes: saltiness, sweetness, sourness, and bitterness. The taste intensity of MSG is shown to be increased synergistically by 5′-ribonucleotides, which alone have a very weak taste intensity. The effect of 5′-ribonucleotides on MSG is confirmed by the phenomena that the addition of a small amount of MSG (0.05%) greatly increases the palatability of food like beef consommé, which contains large amounts of 5′-ribonucleotide.

CONCLUSION

Psychometric methods were used to clarify the flavor function of MSG added to food. The flavor profile changes of foods produced by the addition of MSG and the taste properties of MSG itself were evaluated by panels of subjects.

MSG not only imparts an intrinsic taste of its own, but also enhances several specific flavor characteristics such as continuity, mouthfulness, impact, mildness, and thickness of the food. Furthermore, it improves the overall preference for a food. A similar change of the flavor characteristics is observed with beef consommé by increasing the concentration of the consommé stock.

These studies have provided the experimental basis for understanding the use of MSG as a flavor enhancer and for the reported improvement MSG adds to the flavor

TABLE 6. *Relationship between* y *value and palatability of food*

Item	Sample A				Sample B			Difference of B to A
	Analysis (%)			*y*	Additive		*y*	Evaluation score of the whole preference
	MSG	IMP	GMP		Name	Quantity (%)		
Beef consommé	0.010	0.0113	0.0002	0.15	Beef broth	—	0.59	0.80
Beef consommé				0.15	MSG	0.05	0.91	0.85
Beef consommé				0.15	MSG	0.1	1.67	0.62
Beef consommé				0.15	MSG	0.2	3.19	0.67
Beef consommé				0.15	MSG	0.4	6.08	0.03
Chicken consomme	0.023	0.0097	0.0005	0.31	MSG	0.05	1.01	0.54
Cream of chicken soup	0.010	0.0023	0.0006	0.05	MSG	0.17	0.83	0.85
Chicken noodle soup	0.008	0.0014	0.0001	0.02	MSG	0.18	0.63	0.87
Cream of vegetable soup	0.026	0.0005	0.0002	0.06	MSG	0.05	0.16	0.49
Cream of vegetable soup				0.06	Chicken broth	—	0.21	0.71
Vichyssoise	0.011	n.d.	0.0003	0.02	MSG	0.18	0.30	0.58
Onion soup	0.012	n.d.	n.d.	0.01	MSG	0.50	0.51	0.85
Cream of tomato soup	0.122	n.d.	0.0006	0.32	MSG	0.30	1.11	0.17
Cream of tomato soup				0.32	Chicken broth	—	0.92	0.08
Japanese miso soup	0.074	n.d.	n.d.	0.07	MSG	0.3	0.37	0.56
Hamburger	0.009	0.0579	0.0011	0.68	MSG	1.0	74.2	0.68
Seasoned egg custard	0.029	0.0005	0.0002	0.06	MSG	0.3	0.68	0.75
Seasoned egg custard				0.06	Bonito broth	—	0.37	0.42
Cooked mixed vegetables	0.069	n.d.	0.0005	0.17	MSG	0.5	1.39	0.40
Cooked broccoli	0.061	n.d.	0.0004	0.13	MSG	0.25	0.65	−0.20

of food. The addition of salt or sugar to certain foods increases the flavor characteristics mentioned above. Therefore, in this context, salt and sugar may also be called flavor enhancers.

The results of the studies lend support to the notion that MSG has an intrinsic taste—*umami* or tastiness—independent of the other four basic tastes, and these studies demonstrate that MSG improves the flavor of food.

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