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— **Current Topics** —

Taste and Health: New Frontiers in Oral Physiology and Rehabilitation

Taste-active Components in Foods, with Concentration on Umami Compounds

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A century ago, an amino acid, L-glutamate (Glu), was found to be the important substance for umami (savory) taste of a Japanese soup stock cooked with sea tangle. Since that time, umami seasoning has been used to make foods palatable all over the world. Chemical analysis proved that Glu had been used for savory seasonings around the world, though its taste had been hidden behind the flavors of fat or herbs. Recently, research has shown that Glu affects the chemical senses not only in the oral cavity but also in the gastrointestinal tract, and it modulates the ingestion, digestion and metabolism of proteins. Umami taste, one of the five basic tastes along with sweet, salty, sour and bitter tastes, derived from Japanese cuisine, might be applicable for the nutritional care of elderly people, who are at risk for protein malnutrition even in developed countries.

Key words —— taste, umami taste, eldery people, L-glutamate, 5′-purine mononucleotide

INTRODUCTION

Gustatory sensation is a chemical sense elicited by molecules/ions acting on taste receptors/channels in taste cells in the mouth. Gustatory sensation consists of five basic tastes: sweet, salty, sour, bitter and umami tastes. Amongst these basic tastes, umami taste (savory taste) was discovered by a Japanese scientist, Kikunae Ikeda, in 1908. He found that umami compound of a Japanese typical soup stock of dried sea tangle, *kombu*, was a neutralized salt of the amino acid L-glutamate (Glu).[1)] Ikeda then developed a manufacturing process for umami seasoning using hydrolysis of wheat protein by HCl.[2)] After that, discoveries of other umami compounds such as 5′-purinemononucleotides were also made by Japanese scientists.[3, 4)] These umami compounds are abundant in traditional soup stocks and fermented seasonings. In this paper, we review the research on taste compounds, focusing on umami taste discovered in Japanese cuisine.

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STRUCTURE OF TASTE SUBSTANCES

Taste substances are generally hydrophilic and consist of small molecules/ions, extracted from foods into the saliva, that then interact with taste receptors/channels for each basic taste in the taste cells in the mouth. Substances similar in structure elicit a similar taste (Table 1). Each basic taste has a distinct physiological meaning, and animals use taste as a signal to accept or reject foods. As the representative umami substance Glu is one of the protein amino acids, it is likely that umami taste is a signal for protein nutrition. The concentration of Glu in human milk exceeds the threshold concentration for umami taste.[5)] In a neonate experiment, the willingness to ingest vegetable soup, to which neonates were slightly aversive, was induced by adding umami compound, potassium glutamate.[6)]

Though large molecules such as polysaccharides or proteins do not elicit taste in general, there are several sweet proteins, most of which, includ-

Table 1. Oral Chemical Sense

Modality	Receptors/Channels	Stimulanting substances	Physiological meanings
Gustatory sensation			
Sweetness	GPCRs (T1R2+T1R3)	sugars (mono-, di-saccharides), sweet glycosides, sweet proteins/peptides	energy sources
Saltiness	? (channels)	NaCl, LiCl	minerals
Sourness	TRP channels (PKD1L3+PKD2L1)	proton (acids)	spoiled foods underripe fruits
Bitterness	GPCRs (T2Rs)(*ca.*30 types)	alkaroids, terpenoids, flavans, bitter peptides, thiocarbamides, inorganic salts	poisons
Umami taste	GPCRs (T1R1+T1R3, mGluRs)	acidic L-amino acids, 5′-purinemononucleotides	proteins
Olfactory sensation	GPCRs (ORs)(~350 types)	(low-molecular compounds)	
Somatic sensation			
Thermal sense	TRP channels (TRPA1, M8, V4, V3, V1, V2)	capsaicin (TRPV1, hot/acid), menthol (TRPM4, cold)	

ing monellin,[7] thaumatin[8] and brazzein,[9] were purified from tropical fruits. Miracurin[10] and curcurin,[11] which change sour taste into sweet taste, were also purified from tropical fruits. Using these fruits might be the way to make sour underripe fruits sweeter and more palatable.

Human have traditionally had to taste substances to know their taste characteristics. Recently, however, because genes for taste receptors/channels have been identified, *in vitro* assays for structure-taste relationships can be performed.

TASTE-ACTIVE COMPONENT OF FOODS

Because Japan is surrounded by oceans, marine products make up a large portion of Japanese cuisine. Research on the components of seafoods other than the materials for soup stock, which were the origin of umami discovery, has been performed vigorously in Japan. In these studies, artificial extract was prepared by mixing components according to the analysis of the extract. Then, the screening test for taste-active components was done by omission of some components. The components whose absence caused a significant change in the taste of the artificial extract when omitted were then labeled as taste-active components. That is, in these studies, the interaction between taste compounds was analyzed by the combination of quantitative analysis and sensory evaluation. Representative data are summarized in Table 2.[12] Amino acids play crucial roles in the taste of most seafoods. The taste quality of L-amino acids, which are the building blocks of proteins, depends on the structure of the side chains (*e.g.*, acidic: umami, hydrophobic: bitter). On the other hand, most of the D-amino acids are dominantly sweet, and their taste qualities hardly depend on the side-chain structure.[13,14] Many L-amino acids have umami taste, while none of the D-amino acids has umami taste.[15]

Amino acids analysis of fermented seasonings/foods of the world showed that Glu is the most abundant amino acid and the most important taste-active component in them (Table 3). Studies on the taste function of small amounts of novel compounds in foods have also been performed by purification, structure analysis, synthesis and verification of the function using sensory evaluation. Several taste-active substances produced by Maillard reaction during cooking processes have been reported.[18,19]

PROPERTIES OF UMAMI TASTE

Ikeda theorized that umami taste is one of the basic tastes, along with sweet, salty, sour and bitter tastes. Umami taste was later proved to be a basic

Table 2. Taste-active Component of Seafoods

	Sea urchin	Snow crab	Scallop	Short-necked clam	Dried skipjack
Glutamate	Umami *Sweetness*	Umami Sweetness Character	Umami Sweetness Palatability	Umami Sweetness Platability	Umami Sweetness
AMP	—	Umami	Umami Sweetness Palatability	Umami Sweetness Palatability	—
IMP	Umami Aftertaste	—	—	—	Umami Sweetness Palatability
Gly	Sweetness Character *Bitterness*	Umami Sweetness	Sweetness Palatability	Sweetness	—
Ala	Sweetness *Bitterness*	Sweetness	Sweetness	—	—
Arg	Umami *Sweetness*	Character Palatability	Character	Character	—
Na^+		Sweetness Umami Character	Umami Character Palatability	Sweetness Umami Sourness	Sourness Character Palatability
Cl^-		Palatability	Sweetness Umami Palatability	Sweetness Umami Palatability	Sourness Character Palatability
Others	Met: Character			Succinate: Character	His: Charater

Taste-active components and their roles for the taste in each seafood extract are summarized. Effects in normal font mean reduced by omission. Effects in small italic font mean enhanced by omission. Modified from the reference 12.

taste independent from the other four basic tastes by physiological and psychological research.[20,21] Characteristics of umami taste are a potential synergistic enhancement of umami taste when its components are mixed and a flavor-enhancing effect.

The magnitude of umami taste is synergistically enhanced when umami amino acids such as acidic L-amino acids (*e.g.*, Glu, aspartate) and umami nucleotides such as 5′-purinemononucleotides (*e.g.*, 5′-inosinate, 5′-guanylate) are mixed (Fig. 1).[22–24] This phenomenon has been used not only in Japanese cuisine for the preparation of soup stock with sea tangle and dried bonito (*katsuo-bushi*) but also in traditional cuisines all over the world. That is, foodstuffs rich in umami amino acids and umami nucleotides have been combined in cooking and observed empirically in many countries, and G-protein coupled receptors for the synergism have been identified.[25,26]

Another prominent characteristic of umami taste is its flavor-enhancing effect. This is a phenomenon in which the flavor, which is an integrated sensation of taste and smell, is strengthened

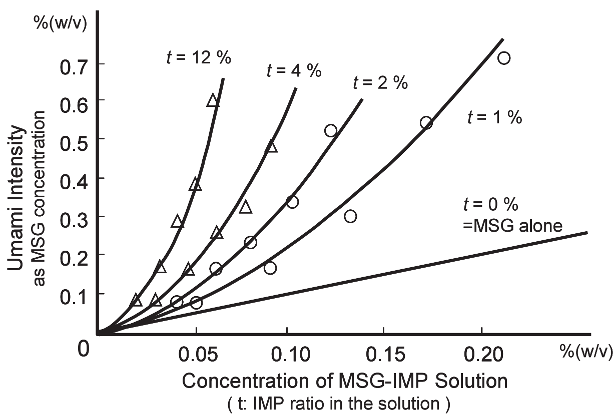

Fig. 1. Synergistic Enhancement of Umami when MSG and IMP are Mixed

MSG: monosodium L-glutamate (FW187); IMP: disodium 5′-inosinate (FW527). Subjects tasted MSG-IMP mixed solution and evaluated its umami intensity as MSG concentration.

when the umami compound is added to plain food (Fig. 2).[27] We can use the phenomenon for the reduction of salt intake by substitution of NaCl by umami seasoning such as monosodium L-glutamate (MSG).[28,29]

Table 3. Amino Acid Contents in Fermented Seasonings/Foods (mg/100 g)

Seasonongs/ Foods	Bean paste[a] (Haccho-miso)	Bean paste[a] (Sendai-miso)	Soy sauce[16]	Fish sauce[16]	Cured ham[17]	Cured ham[a]	Cheese[17] (Emmental)	Cheese[17] (Parmigiano reggiano)
Materials	soybean	soybean	soybean	fish	pork meat	prok meat	milk	milk
Form	paste	paste	liquid	liquid	solid	solid	solid	solid
Country	Japan	Japan	Japan	Japan	Spain	China	France	Italia
Glycine	149	92	184	536	107	105	30	297
Alanine	303	177	348	908	209	262	49	253
Serine	286	179	344	585	115	138	43	561
Threonine	211	113	235	609	109	125	74	212
Cystine	0	0	12	0	0	0		
Methionine	69	34	92	261	73	83	43	212
Valine	323	158	336	745	132	190	131	671
Leucine	438	267	450	538	219	267	210	695
Isoleucine	283	147	300	433	148	149	59	535
Phenylalanine	248	169	234	395	119	145	103	435
Tyrosine	193	139	91	196	152	79	48	242
Tryptophan	28	0		127	96	29	9	
Aspartic acid	387	366	495	1060	68	148	10	414
Glutamic acid	625	432	782	1383	337	362	308	1680
Asparagine	139	12	19	0	9	14		
Glutamine	0	63			147	0		
Lysine	249	220	213	1158	226	353	203	1130
Arginine	192	293	253	338	84	74	0	2
Histidine	79	37	104	532	19	83	30	236
Prorine	327	158	291	424	117	138	160	884

a): analyzed in our laboratories.

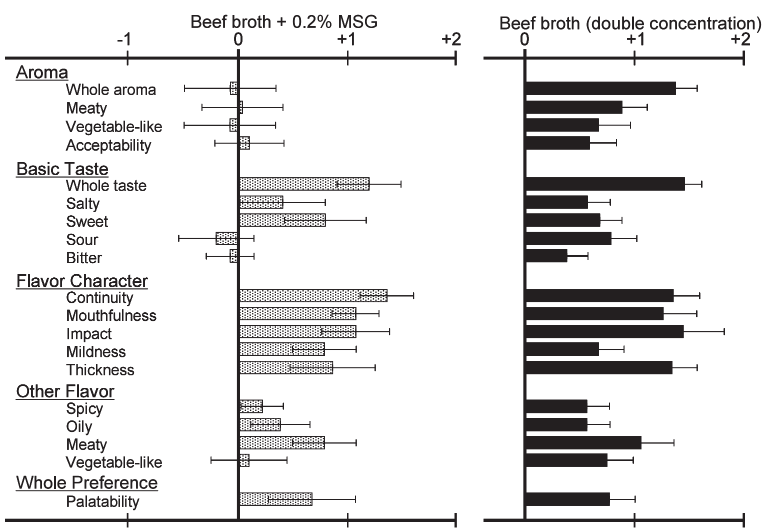

Fig. 2. Changes in Flavor Profile of Beef Broth by MSG

Subjects tasted and evaluated each attribute of beef broth with 0.2%-MSG and double concentration. Sensory scores were rated by comparing to the control broth, which was beef broth without MSG. +/−2: stronger/weaker than the control; +/−1: slightly stronger/weaker than the control; 0: same as the control.

UMAMI FOODS FOR JAPANESE ELDERLY

Sensitivity to taste stimuli is often reduced in the elderly due to natural senescence, medication, hyposalivation resulting in poor oral hygiene, and other natural effects of aging. Reduction in the sensitivity to umami taste among the elderly has been reported.[30, 31] A significant reduction in umami taste sensitivity following radiotherapy for head and neck cancer was also reported. In the report, it was shown that the loss of taste was accompanied by the loss of appetite.[32] Therefore, to enjoy a meal and to maintain quality of life, it might be important to sense umami taste of soup stock, which is the basis of the taste of many meals. One question is whether these findings have been taken into account in the seasoning of meals at institutions for the elderly. We measured the concentrations of both Glu and Na of miso soup served at hospitals for the elderly in Japan. Miso soup is a very popular savory soup, and its taste-active compounds are Glu and Na. We found that the deviation in the concentration of Glu was large (156.3 ± 101.3 mg/100 g, Range: 15.7–697). In contrast, that of Na was small [835.5 ± 178.3 mg/100 g, Range: 363–1516 (as NaCl)] (Fig. 3). This result might mean that Glu concentration of foods was not considered by dietitians who planned menus, but Na concentration was taken into account in attempts to reduce sodium intake.

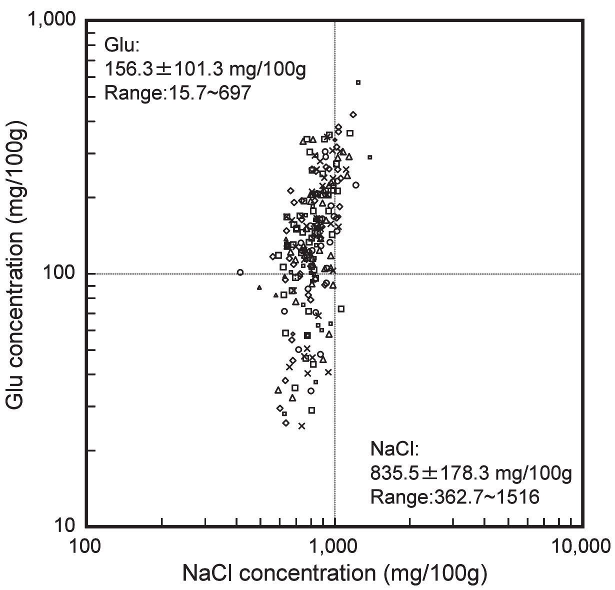

Fig. 3. Glu-NaCl Concentration of Miso Soups Collected from 220 Hospitals for the Elderly in Japan

Each symbol represents the mean value of three miso soups served at each hospital. NaCl concentration was derived from the analytical value for Na concentration. Supernatant of each miso soup was analyzed by an amino acid analyzer and inductively-coupled plasma atomic emission spectrometry.

PERSPECTIVE—APPLICATION OF TASTE MOLECULES IN FOODS FOR THE ELDERLY

Recently, it has been reported that taste receptors found in the mouth also exist in the gut, and function in nutrient sensing. T1R1, which is a receptor subunit for sweet and umami tastes, is expressed on cells of the duodenum and functions as a glucose sensor.[33, 34] Regarding umami taste, only Glu among the protein amino acids was found to activate the gastric branch of vagus afferent nerve.[35] One study showed that supplementation of Glu to meals affected the velocity of gastric emptying.[36] Furthermore, supporting the idea that umami taste is a signal for protein nutrition, gustatory stimulation by umami taste induced the secretion of digestive fluids such as saliva[37] and pancreatic juice.[38]

Even with the heightened awareness and lifestyle improvements made in recent years, elderly people can easily fall into a state of protein-energy malnutrition. It is possible that the supplementation of meals with umami substances would help the elderly who have poor taste sensitivity and low food intake to enjoy and digest small amount of foods well.

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