Academy of Nutrition and Dietetics

Umami

The Science and Lore of Healthy Eating

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Although the complexity of umami taste makes it difficult to both describe and recognize, we are unconsciously exposed to umami in everyday meals. What exactly is umami? What is the connection between umami and deliciousness? What are the interactions of umami with our eating behaviors? The information here will help you understand the unique characteristics of umami and its potential benefits on taste and food consumption.

Umami Overview

Understanding taste and components of deliciousness is an important aspect in our food choices. The palatability or pleasantness of food is a key criterion for satisfaction and consequent food choices. We know eating a balanced diet with plenty of fruits and vegetables is good for our health. But, what if you don't like the taste of those foods, even though they are very nutritious?

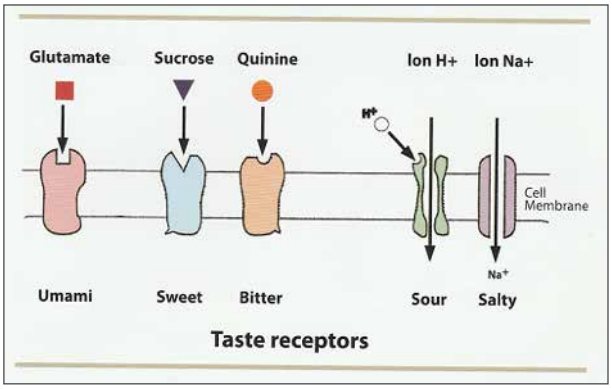
Umami is the 5th basic taste, along with sweet, sour, salty, and bitter. It has been scientifically associated to the amino acid glutamate since the early 20th century by the Japanese scientist, Kikunae Ikeda. Umami fills a unique position towards deliciousness and food acceptability because it blends well with other basic tastes, and layers and rounds out the flavors. Umami is even known to elicit the original flavor of food itself. Although it is often mistakenly recognized as a taste unique to Japanese cuisine, in fact, umami has been appreciated in many cuisines for thousands of years. Examples include the fish sauce (garum) in ancient Rome, the stocks and broths in western cooking, the sauces used in French cooking, and the Chinese broth. With the discovery of the umami taste receptor in 2000—a unique receptor for glutamate—it has firmly established its position as the fifth basic taste. Now, umami research has expanded to its role in human health and nutrition-related behaviors. It not only helps us to boost the flavor of dishes, but also provides an alternative to salty foods, and has the potential to influence our eating behaviors.

This paper reviews the current scientific evidence on umami, its role in human body, the connection between umami and deliciousness, safety concerns of umami ingredients, and potential health benefits of adding umami compounds during food preparation.

Contents:

1. What Exactly is Umami?

Glutamate is the key



For those who are just starting to understand umami, it is important to see the unique characteristics of umami in view of five basic tastes. When we eat foods, our taste perception begins on the tongue. The tongue is such a small organ but has an ability to pick up the tastes of sweet, salty, sour, bitter, and umami through specific receptors. This information is then sent to the brain through nerves to help us recognize the taste of the food we eat. As with all of the basic tastes, the amino acid glutamate is one of the predominant ingredients that triggers umami taste receptors. Other umami substances include **5'-ribonucleotides such as inosinate and guanylate**. This means that umami is the taste imparted by glutamate and specific ribonucleotides. It is not easy to describe umami. These substances themselves do not have an outstanding taste. Let's imagine you are making a vegetable soup without the use of chicken broth or bouillon. Your soup may taste bland or boring even if the right amount of salt and pepper are added. You may feel something is missing, so you add a cube of bouillon into the soup. You will see how the taste is changed. Rather than offering its own taste, umami substances add complexity in overall flavor and contribute as a harmonizer and a flavor enhancer by interacting with food ingredients.

Umami signals the presence of protein

You may crave sweets when you feel tired, or salty foods after exercising or sweating on a hot day. This is a sign that your body needs more calories for fuel or electrolytes to refill the lost minerals. It is interesting to note that each taste has a physiological meaning that sends specific signs to our body. A sweet taste signals foods with sources of energy; saltiness suggests foods with vital electrolytes and minerals; strong sourness indicates whether a fruit or vegetable is ripe or a food is spoiled; and bitter provides a warning sign of potentially harmful substances in foods. Finally, the **taste of umami suggests the presence of amino acids and proteins in foods**. Once our brain catches the sensation of umami, our body increases salivary flow and becomes ready to secrete gastric and pancreatic juices for digestion. Physiologically, umami's key function is to promote the digestion of foods, particularly proteins.

Did You Know…?

- Typically, Americans aged 20 years old and older consume 70–100 g of dietary protein each day, which corresponds to about 7–10 g of glutamic acid bound to proteins and about 1–2 g of free glutamate, the portion of glutamate that is not bound to proteins. (Data source: What We Eat in America, NHANES 2013–2014, or go to www.ars.usda.gov/nea/bhnrc/fsrg)

- Our body produces about 50 g of free glutamate each day.

Bottom Line

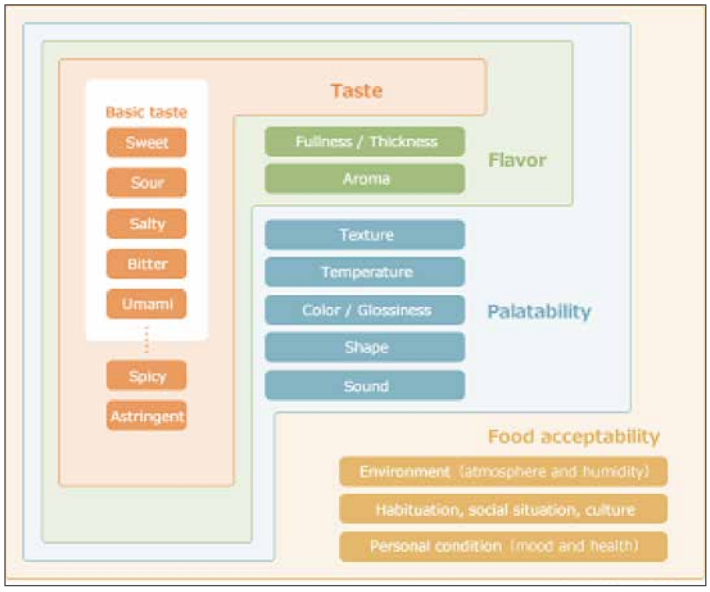
1. Umami, the fifth basic taste, is the taste of glutamate and specific 5′-ribonucleotides.

2. Glutamate—a main umami-eliciting substance—is a multifunctional amino acid involved in taste perception, with nutritional and physiological roles including gastrointestinal system, cellular metabolism, and neurotransmission.

3. The taste properties of umami suggest presence of amino acids and proteins in foods.

2. What is the Connection Between Umami and Deliciousness?

In Western societies, the word umami is often confused with deliciousness, possibly because the definition of umami also refers to the degree of food deliciousness from a sensory perspective in Japanese culture. From a scientific perspective, umami is a taste, not deliciousness by itself. Umami does not have a simple English translation. Savory, mouth fullness, or meatiness is close. It is important to clarify the relationship between umami and deliciousness from a scientific perspective to better understand what umami is.



As shown in the figure above, many components make food delicious besides the five basic tastes. These include spiciness, astringency, aroma, color, texture, and even food presentations. Environmental factors such as mealtime atmosphere, weather, who you eat with, and interpersonal factors such as your mood and health condition also may influence the deliciousness of food, making umami just one element in a whole scheme of how we experience the sensation of deliciousness.

3. Where Can I Find Umami Taste?

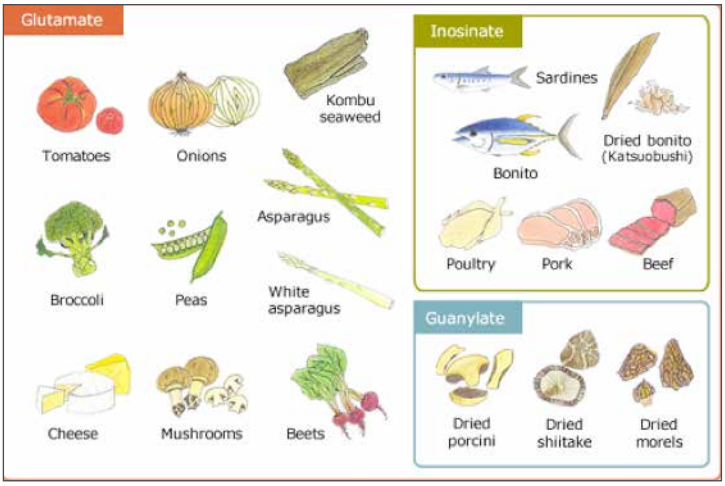
We experience umami taste sensation by the presence of umami-eliciting substances such as glutamate and 5'-ribonucleotides (inosinate and guanylate), or a combination of both in foods. The following foods are high in glutamate and/or 5'-ribonucleotids, and may elicit distinct umami sensation by interacting with food ingredients or pairing with other umami-rich foods.

Umami Sources From Food Ingredients

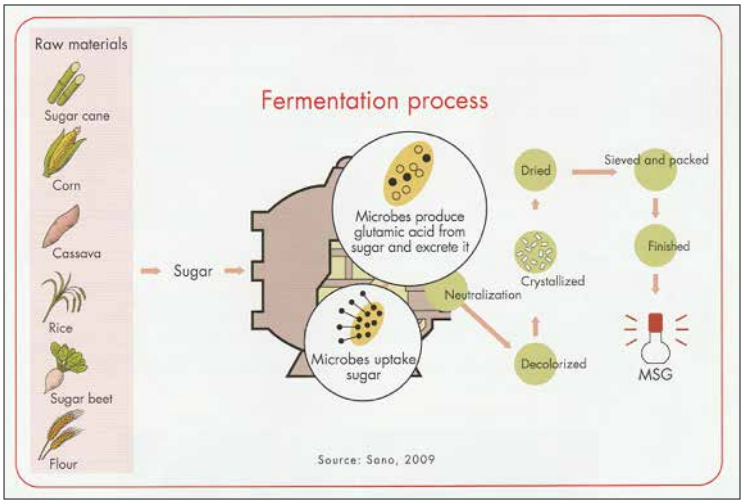
Glutamate, one of the 20 amino acids, presents abundantly in many type of foods. Inosinate can be found in animal-based foods such as meat and fish, and guanylate is mainly detected in a variety of dried mushrooms such as dried shiitake or porcini mushrooms. Found in almost every living thing, we see that umami substances are fundamental to our biological system.

Umami Sources from Seasonings:

- Tomato ketchup
- Soy sauce
- Miso paste (fermented soybean paste)
- Fish sauce
- Chicken/beef bouillon
- Monosodium glutamate (sodium salt of glutamic acid)
- Hydrolyzed vegetable protein
- Yeast extract



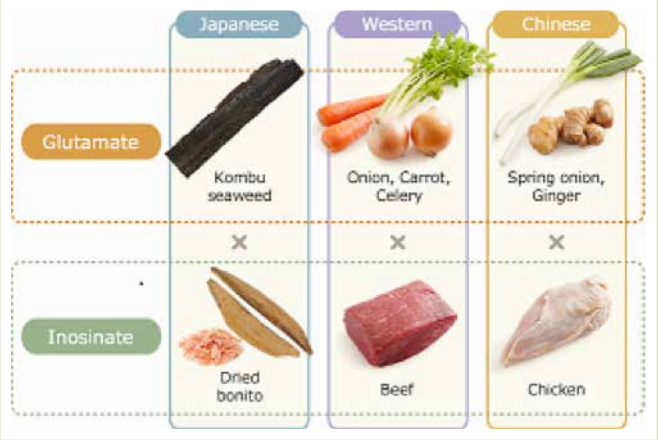
Not all but most of these commonly known seasonings/condiments listed above are made through a natural process called fermentation (ie, a metabolic process in yeast and bacteria), the same method normally seen in making vinegar, yogurt, cheese, beer, etc. For instance, the fermentation of soy beans produces condiments such as soy sauce and miso paste, fermented fish is an important ingredient for fish sauce, and monosodium glutamate is made through the fermentation of carbohydrates from raw materials such as sugarcane and cassava.

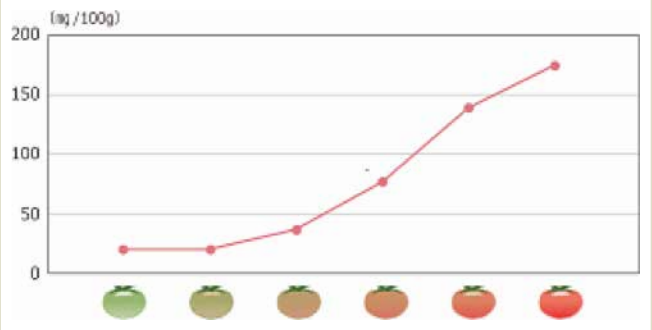


Umami in Mother's Breast Milk

You may be surprised to learn that umami is one of the first tastes a newborn infant encounters, together with the aromas of the mother's diet. Glutamate is the most abundant amino acid in breast milk, more than 50% of the total amino acids. This is more than in a cow's milk. It has been said that glutamate in breast milk supports gut function for a newborn. Also, glutamate concentration in breast milk is 6 to 10 times higher than that in our blood. Thus, glutamate also is an essential substance for babies.

Did You Know…?





- **Umami synergism** is the scientific phenomenon observed when you combine ingredients rich in glutamate with those rich in inosinate or guanylate; the sensation of umami taste is dramatically magnified. This synergistic effect is applied in many cuisines. For example, making soups with vegetables (rich in glutamate) and meat (rich in inosinate), along with a stock made with dried kombu seaweed (rich in glutamate) and dried bonito flakes (rich in inosinate) will boost umami sensation with more sustained and longer-lasting flavors.
- **Aging and ripening** increases the amount of glutamate in foods. For example, when tomatoes are fully ripened to a rich red color, the level of glutamate has reached its peak. The intensity level of umami is optimal to enjoy the best flavor. Glutamate also becomes prominent during the process of aging in cheeses and meats such as parmesan cheese or cured ham.
- **Fermentation** increases the amount of glutamate in foods. Other food preparation techniques such as moist heat preparation (stewing and simmering) using stocks or broths also can enhance umami taste by extraction.

Bottom Line

1. Umami substances such as glutamate and 5′-ribonucleotides can be found in most of living things, including our body, foods such as vegetables, most protein-rich foods, fermented foods, fermented seasonings, and breast milk.
2. The combination of glutamate-rich foods and 5′-ribonucleotides-rich foods can significantly boost umami taste sensation 7 to 8 times (synergistic effect).
3. Some food processing techniques such as fermenting, aging, ripening, curing, and drying liberate free glutamate, resulting in higher umami levels.

Source: Umami Information Center

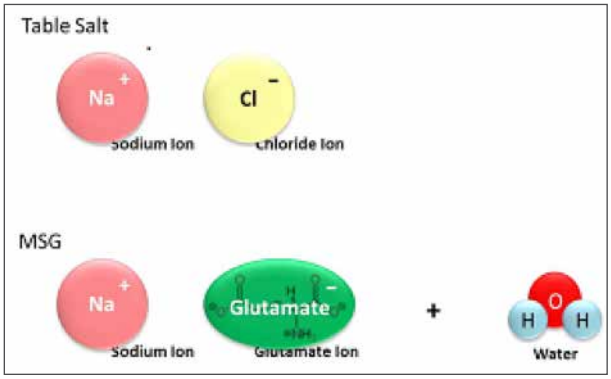
Agostoni C, Carratù B, Boniglia C, Lammardo AM, Riva E, Sanzini E. Free glutamine and glutamic acid increase in human milk through a three-month lactation period. J Pediatric Gastroenterol Nutr. 2000;31(5):508-512.

Sarwar G, Botting HG, Davis TA, Darling P, Pencharz PB. Free amino acids in milk of human subjects, other primates and non-primates. Br J Nutr. 1998;79(2):129-131.

4. Umami and Monosodium Glutamate (MSG)

Due to the current trend among consumers to ask for label-free products, use of monosodium glutamate (MSG) in foods as an additive has become a health concern among some consumers. This section clarifies the facts about MSG and presents the information found from our evidence-analysis library's (EAL) umami project.

What is MSG?



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Again, glutamate—widely present in foods and our body—is the key to trigger the umami taste sensation. Glutamate exists in two forms: protein-bound and free glutamate, which is not bound to proteins. Within foods in liquid form, free glutamate often binds together with ions such as sodium, calcium, and magnesium. These derivatives include sodium glutamate, potassium glutamate, ammonium glutamate, calcium diglutamate, and magnesium diglutamate. Just like table salt, sodium chloride, which is made up of one molecule of sodium ion plus one molecule of chloride ion, MSG is monosodium glutamate, which also consists of one molecule of sodium ion plus one molecule of glutamate along with one molecule of water. Among the glutamate salts, MSG is stable at room temperature, easily dissolved in water, and capable of adding a strong umami taste sensation. It is sometimes added to foods during food preparation as a seasoning or a flavor enhancer. MSG contains 78% glutamate, 12% sodium, and 10% water, and is the purest and simplest umami seasoning with no aroma.

Is MSG safe to eat? Are there any adverse effects?

Because of its interest for many people in the US, MSG and its safety has become one of the areas with the most extensive studies. The MSG myth began in 1960s when a Chinese American doctor wrote a letter to the editor of a scientific journal describing an anecdotal, possible association between consuming MSG, among other food ingredients, and symptoms such as headache, nausea, flushing, weakness, and heart palpitations (ie, the so-called Chinese Restaurant Syndrome). But many of the early subsequent studies confirming that association had essential flaws in study design, subjects, or conditions of intervention, which unfortunately resulted in false positive responses. Along with recent intensive studies, the FDA has repeatedly confirmed the safety of MSG at levels normally consumed by the general population. Consistent with the FDA's report, our evidence-based analysis from 1995 onwards also showed no clear evidence linking MSG consumption to any serious, potential adverse reactions. However, inconsistent findings reported in some studies still pointed out methodological issues once observed in early studies.

Thus, the results cannot be fully generalized to the whole population. Keep in mind that the results would be greatly influenced by the followings:

- The MSG dosage ranged from 1.25 g to over 10 g of MSG consumption upon challenge in studies. Such large doses may lead to false positive response. Note that the average daily intake of MSG is estimated to be 0.3–2.4 g across the countries. In the US, the average intake of MSG is around 0.55 g per day.

- A mode and a condition of MSG challenge included whether or not MSG is ingested in a form of a capsule, dissolved in liquid, or is in meals or on an empty stomach (fasting condition), with or without food. Note that MSG is used as a seasoning or a flavor enhancer added to food in real life.

- Target population: Some studies only targeted self-identified possible MSG responders and individuals with chronic urticaria or asthma.

The difficulty of studying adverse effects attributed to MSG is that symptoms are subjective and there is a possibility of a placebo effect. Nonetheless, the possible adverse responses reported in some studies were inconsistent and were not reproducible when evaluated in carefully controlled tests. Moreover, ingestion of MSG did not worsen symptoms of chronic urticaria or asthma.

Did You Know…?

- The safety of MSG has been repeatedly endorsed by worldwide organizations with hundreds of scientific studies. In the US, MSG is considered a common food ingredient such as salt, baking powder, and pepper. FDA designates MSG as Generally Recognized as Safe (GRAS). Go to **http://www.fda.gov/Food/IngredientsPackagingLabeling/FoodAdditivesIngredients/ucm328728.htm** for additional information about FDA's position on MSG.
- To read more about governmental and third-party, worldwide endorsements for MSG safety, go to International Glutamate Information Service.
- In 2014, the American Chemical Society (ACS) launched a professional custom video on their site for raising awareness of MSG's safety. Click **here** to watch the video.
- Glutamate contained in commercially made MSG (made by fermentation process) is the same substance as the glutamate found in common umami-rich foods such as cheeses, ripe tomatoes, and anchovies.

What is the meaning of No added MSG?

- The claim of "No MSG" or "No added MSG" on the food packages has raised much confusion over the safety of MSG. As it was described earlier, a variety of food ingredients originally contain a wide range of glutamate. Foods with those ingredients cannot claim No MSG or No added MSG in countries like the US or Canada. Nonetheless, the food manufacturers often use these terms to indicate that glutamate as a form of MSG was not added during food preparation. It is important to remember that there is no chemical difference between free glutamate naturally present in foods and MSG as an additive; therefore, they are treated exactly the same by our body. No added MSG on their packaging is a voluntary labeling by food industries that has often been used for marketing purpose because of the concern regarding what is in the food we eat.

Bottom Line

On the basis of the available evidence, no clear association was reported regarding adverse reactions following MSG consumption.

Source:

Federation of American Societies for Experimental Biology. Analysis of Adverse Reactions to Monosodium Glutamate (MSG), Report. Bethesda, MD: Life Sciences Research Office, Federation of American Societies for Experimental Biology; 1995.

Geha RS, Beiser A, Ren C, et al. Multicenter, double-blind, placebo-controlled, multiple-challenge evaluation of reported reactions to monosodium glutamate. *J Allergy Clin Immunol.* 2000;106(5):973-980.

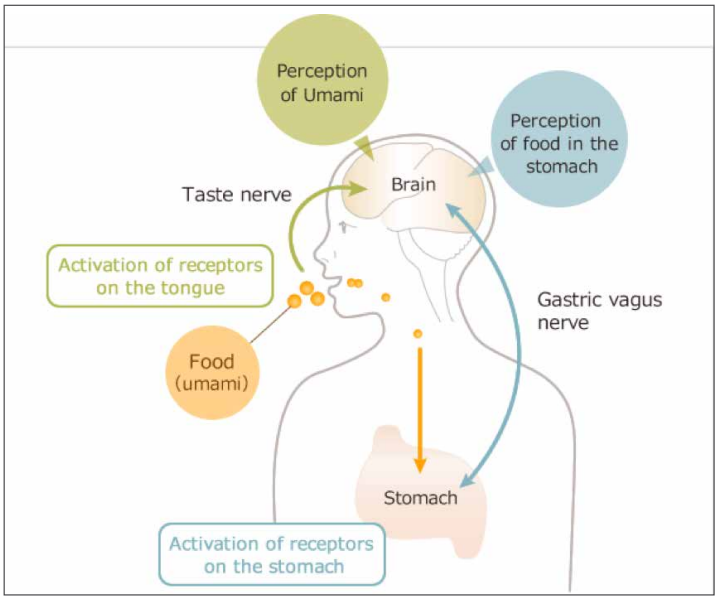
Mouritsen OG. Umami flavour as a means of regulating food intake and improving nutrition and health. *Nutr Health*. 2012;21(1):56. Found at: http://nah.sagepub.com/content/21/1/56. Accessed April 5, 2017.

Walker R, Lupien JR. The safety evaluation of monosodium glutamate. *J. Nutr.* 2000;130(4S Suppl):1049S-1052S.

5. Umami and the Relationship with Healthy Eating

i. Umami and digestion

Depending on what we eat, the taste of foods including umami helps the stomach and intestine communicate with the brain. How does it occur? Studies show that glutamate plays an important role in sending signals to our brain to command the organs (gut-brain axis). In response to the signals, the organs secrete more gastric and pancreatic juices to promote digestion, especially for the digestion of proteins.



Did You Know…?

- Glutamate (umami) receptors exist not only in our tongue but also in our gastrointestinal tract (stomach and intestine). There is a novel hypothesis that the dietary glutamate may be sensed at the gastrointestinal wall in addition to the oral cavity (based on animal studies).
- Recent studies demonstrated that glutamate helps promote salivation in elderly. Adding another umami substance such as inosinate further enhances the salivation. This will provide the potential for umami substances to aid in chewing and swallowing of food.

Bottom Line

1. Glutamate is sensed by our tongue, stomach, and intestine to help secrete digestive juices in our body.
2. Glutamate helps increase saliva flow, which raises the potential to promote chewing and swallowing of food in elderly population.

Source:

Sasano T, Satoh-Kuriwada S, Shoji N, Sekine-Hayakawa Y, Kawai M, Uneyama H. Application of umamitaste stimulation to remedy hypogeusia based on reflex salivation Biol Pharm Bull. 2010;33(11):1791-1795.

ii. Does umami allow for less salt?

We do know that cutting down on salt intake is good for our health, yet maintaining a low-sodium diet is challenging because food prepared with reduced salt is less tasty in general.

Current research consistently demonstrates that use of umami-containing seasonings such as MSG and soy sauce allows for less salt without compromising the palatability of food.

Research

- **Use of umami-rich stock or MSG:** Studies reported approximately **15% to 22% salt reduction*** when test soup was prepared with Japanese traditional umami-rich stock [Recipe: adding 10 g of dried bonito flakes into 500 mL of heated water OR the combination of 2.64 g of dried kelp and 5.28 g of dried bonito flakes to make 300 mL of stock]. The same research group also demonstrated that adding a small amount of MSG (0.0094% to 0.12%) showed similar salt reduction effect (15% to 16% salt reduction*) in the soup. The comparison was made with the soup prepared with no umami-containing stock.

- **Use of calcium diglutamate (CDG):** The effect of salt reduction was greater when glutamate was added in the form of CDG because CDG does not provide sodium. The addition CDG resulted in **43% to 67% salt reduction*** in soup.

- **Use of soy sauce:** A study evaluated the effect of soy sauce, which naturally contains MSG, in various test foods. Results suggested a full replacement of table salt with soy sauce contributed to salt reduction of approximately 50% for salad dressing, 17% for soup, and 29% for stir-fried pork, without change in taste qualities.

*The salt reduction percentages were based on the calculations using the information provided in each article.

Yet, the resulting salt reduction may vary because it is influenced by:

- Type of umami seasonings; whether the form of umami source is MSG, CDG, soy sauce, or stocks prepared with umami-rich ingredients

- Amount of umami seasonings or concentration of umami-rich stocks

- Type of food to which umami is added; ie, whether food is liquid or solid, temperature of food to be served, etc.

Did You Know…?

- MSG contains 3 times lower sodium (12%) compared to table salt (about 40%).

- Soy sauce contains a large quantity of glutamate and has 87% less sodium per teaspoon than salt (Na content of 291 mg/teaspoon in regular soy sauce versus 2,325 mg/teaspoon in table salt, according the USDA National Nutrient Database for Standard Reference; go to http://ndb.nal.usda.gov/).

Bottom Line

Small quantities of umami-rich seasonings used in combination with a reduced amount of table salt during cooking allow for less salt while maintaining palatability of the food.

iii. Does adding umami to foods affect our appetite?

In fact, umami has the potential to influence food intake, sensations of hunger and fullness, and the liking and acceptability of food. Although our taste preferences affect food selection, if umami substances are deemed pleasing in taste or increasing the acceptability of food, appetite may be influenced either by improvements in food intake or early satiety. This would be particularly beneficial among older adults or individuals potentially in need of appetite regulation.

Research

There are multiple ways to assess appetite, but the following effects on eating behaviors were evaluated in our evidence-based analysis.

- Satiation effect (ie, feeling of fullness during the course of a meal, usually assessed by food intake): 6 evaluated studies provided inconsistent changes in food intake or no effect in adults and older adults (over 65 years old).
- Satiety effect (ie, feeling of fullness after consumption of food, usually assessed by feeling of hunger, fullness, desire to eat, and subsequent food intake): 6 evaluated studies reported mixed results regarding appetite-related sensation of hunger and fullness upon MSG supplementation in adults. One study suggested a biphase effect of umami substances on appetite, meaning that it may help increase both early satiety and after-meal satiety.
- Appetizer effect (ie, whether or not appetite is increased following ingestion of food with umami): limited evidence suggests liking and acceptability of foods with umami substances does not influence appetite in adults and older adults.

Thus, the evidence provided inconsistent findings, which leads us to conclude that there is no clear association between consumption of foods with umami substances and change in food intake, appetite-related sensation of hunger, and fullness in adults. Even with older adults, addition of umami substances resulted in either inconsistent change in food intake or no effect, possibly due to altered sensory functions and individual variation in familiarity with umami taste or underlying health conditions. Also, the influence of MSG on intake of those foods may vary among types of food to which MSG is added.

More research is needed to develop evidence-based conclusions for use of umami substances in clinical settings. Specifically, additional research may be needed in older adults with or without decreased smell/taste perception, or with age-related anorexia.

Bottom Line

Current evidence suggests addition of umami substances such as MSG to foods contributes little to no influence on the regulation of appetite, which is assessed by food intake and perception of hunger and fullness.

iv. Does adding umami to foods help improve nutritional status?

Given the possibilities for umami substances to enhance palatability, reduce sodium intake, and potentially influence overall food intake, addition of umami substances to foods may impact nutritional status as evidenced by anthropometric measures and dietary intake of macro- and micronutrients.

Research

In EAL, 8 studies examining the effects of umami on the nutritional status in human have been evaluated:

- In older adults (>65 years of age), only 2 studies evaluated body weight and ratio of reduced-form albumin to total albumin as the parameters of nutrition status. This resulted in inconsistent findings in improved body weight status associated with MSG consumption.
- In adults (18–65 years of age), 1 study reported a significant increase in calcium and magnesium levels when MSG was present in soups and vegetables.
- In adults, nutritional profiles (percentage of energy from protein, carbohydrate, or fat) associated with MSG consumption in foods were unchanged in 3 out of 6 studies. However, the rest reported opposing conclusions; for example, 1 study suggested a positive but the other reported an inverse association with energy from fat intake. One study even reported mixed effects within the same study, ie, increased fat intake as well as decreased carbohydrate intake in relation with MSG consumption.

Bottom Line

The evidence reviewed did not clearly indicate the association between consumption of umami substances and change in nutrition status and dietary intake of micro- and macronutrients.

v. Does adding umami to foods influence energy intake?

Obviously, regulation of energy intake is determined by various factors. However, given a premise that adding umami improves palatability and thus liking of the food, the presence of umami substances in food may influence that decision. If that occurs, is energy intake potentially suppressed by early satiety or promoted by a mediation of appetizer effect?

Research

Nine studies reviewed in EAL successfully answered to this question. For example:

- Six out of 9 studies concluded there was no significant difference in total energy intake from foods with umami additives.
- Two studies reported an increase in immediate energy intake following the consumption of either soup and vegetables or a high-protein meal, respectively, with umami additives because of flavor enhancement (liking).
- One study showed a marginal decrease in total energy intake from snack foods following a preload of MSG consumed in broth compared to the control broth.

These studies vary in many aspects, including type of intervention, number of subjects, type of food to which umami was added, and amount of umami used. Nonetheless, from current studies there are strong evidence-based reasons in these study results to determine that adding umami to foods is not likely to impact overall energy intake.

Bottom Line

Evidence suggests that consumption of food with umami may have a varied yet minimal influence on total energy intake.

6. Putting It Into Practice

For now, the evidence is not available to fully determine if adding umami to foods can impact our eating behaviors, including the potential to influence appetite regulation, food choices, or nutritional status. Emerging evidence suggests that adding umami is less likely to impact overall energy intake regardless of change in palatability. What is clear, however, is that umami—with glutamate as a key element—is vital to our body, as evidenced by its roles in taste perception as well as nutritional and physiological functions including cellular metabolism, protein digestion/absorption, and neurotransmission. The safety of umami used as a seasoning is secure using more complete body of evidence. In addition, umami does indeed have a role to play in sodium-reducing effects and increasing the liking of low-sodium foods.

For culinary application of umami-rich ingredients/seasonings into everyday meals, Registered Dietitians and Nutritionists can deliver the following suggestions:

- Use fruits and vegetables in season. The umami concentration reaches its peak with in-season food.
- In order to boost umami flavor, prepare your dish with a broth or bouillon and/or use umami-rich ingredients/seasonings prepared by fermenting, aging, ripening, curing, and drying.
- In order to improve the taste/acceptability of low-sodium foods, prepare your food with a hint of umami-rich seasonings including broth or bouillon, soy sauce, or MSG. In other words, you can reduce the sodium content of your dish with small quantities of umami-rich seasonings used in combination with less table salt.
- Do not use an excess amount of umami-rich seasonings to further improve the taste. In the case of MSG, use just a sprinkle (optimal concentration = 0.3% wt to 0.8% wt). The use of excess umami-rich seasonings or MSG does not make the food taste better, but actually worsens the taste. Just like any other condiments, use the right amount of umami-rich seasonings to boost flavors.

7. Resource Guide

In order to access the White Paper on umami background, go to
http://www.andeal.org/vault/2440/web/Umami%20in%20Foods%20White%20Paper.pdf

For additional information about FDA's position towards MSG, go to
http://www.fda.gov/Food/IngredientsPackagingLabeling/FoodAdditivesIngredients/ucm328728.htm

To learn more about governmental and third-party worldwide endorsements for MSG safety, go to
http://www.glutamate.org/safety/scientific_evaluations.html

The following organizations provide additional information:

- Umami Information Center: http://www.umamiinfo.com
- International Glutamate Information Service: http://www.glutamate.org
- The Glutamate Association: http://www.msgfacts.com
- The American Chemical Society (ACS): https://www.acs.org/content/acs/en/pressroom/newsreleases/2014/august/is-msg-bad-for-you-debunking-a-long-running-food-myth-video.html

Research Articles

The following is a list of the research articles used in the Umami in Foods and Umami and Healthy Eating Evidence Analysis Projects:

1. Essed NH, Kleikers S, van Staveren WA, Kok FJ, de Graaf C. No effect on intake and liking of soup enhanced with mono-sodium glutamate and celery powder among elderly people with olfactory and/or gustatory loss. *Int J Food Sci Nutr.* 2009;60(Suppl 5):143-154.
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3. Essed NH, van Staveren WA, Kok FJ, de Graaf C. No effect of 16 weeks flavor enhancement on dietary intake and nutritional status of nursing home elderly. *Appetite.* 2007;48(1):29-36.
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15. Ehlers I, Niggemann B, Binder C, Zuberbier T. Role of nonallergic hypersensitivity reactions in children with chronic urticaria. *Allergy.* 1998;53(11):1074-1077.
16. Geha RS, Beiser A, Ren C, et al. Multicenter, double-blind, placebo-controlled, multiple-challenge evaluation of reported reactions to monosodium glutamate. *J Allergy Clin Immunol.* 2000 Nov;106(5):973-980.
17. Prawirohardjono W, Dwiprahasto I, Astuti I, et al. The administration to Indonesians of monosodium L-glutamate in Indonesian foods: an assessment of adverse reactions in a randomized double-blind, crossover, placebo-controlled study. *J Nutr.* 2000;130(4S Suppl):1074S-1076S.
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