Glutamate in meat processing – origin, function and novel application

Glutamat u preradi mesa – podrijetlo, funkcija i novija primjena

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ABSTRACT

Glutamate is one of the most abundant amino acids in nature, accounting for up to 8-10% of most dietary proteins and peptides and most tissues. Only the free form of glutamate has taste-enhancing properties as a unique umami taste, and when glutamate is bound to proteins, it is tasteless with no umami taste. Fermentation, ageing, ripening and heat cooking are typical natural processes of protein hydrolysis during which free glutamate is released. The food industry most commonly uses it in the form of monosodium glutamate (MSG) in amounts between 0.1 and 0.8% as a flavour enhancer. Since the beginning of the 21st century, its use as a flavour enhancer in meat and meat products with reduced salt content has become more widespread. The sodium content of MSG (12.28 g/100 g) is one-third that of salt (39.34 g/100 g), making MSG a promising salt alternative in sodium reduction strategies. There is no one-sided and conclusive scientific information reporting adverse human health effects of MSG in the general population, and it is still considered safe. However, in the wake of "clean label" initiatives, many consumers would prefer not to have additives or flavour enhancers such as glutamates in their food. This can be overcome by the known synergistic effect of natural 5'-ribonucleotides and glutamates found in seaweed, cheese, fish sauce, yeast extract, soy sauce, fermented soybeans and tomatoes, as they enhance the overall perception of umami flavour.

Keywords: monosodium glutamate, sodium reduction, flavour enhancers, sensory properties, meat products

SAŽETAK

Glutamat je jedna od najzastupljenijih aminokiselina u prirodi, koja čini 8-10% većine prehrambenih proteina i peptida te većine tkiva. Samo slobodni oblik glutamata ima svojstva poboljšanja okusa hrane poznat kao jedinstveni umami okus, a kada je glutamat vezan na proteine, bezukusan je i nema umami doprinos. Fermentacija, odležavanje, zrenje i toplinska obrada tipični su prirodni procesi hidrolize proteina tijekom kojih se oslobađa slobodni glutamat. Prehrambena industrija ga najčešće koristi u obliku mononatrijevog glutamata (MSG) u količinama između 0,1 i 0,8% kao pojačivač okusa. Od početka 21. stoljeća sve je raširenija njegova primjena kao pojačivača okusa mesa i mesnih proizvoda sa smanjenim udjelom soli. Sadržaj natrija u MSG-u (12,28 g/100 g) iznosi jednu trećinu sadržaja soli (39,34 g/100 g), što čini MSG obećavajućom alternativom soli u strategijama smanjenja natrija. Ne postoje jednostrane i uvjerljive znanstvene informacije o štetnim učincima MSG-a na ljudsko zdravlje u općoj populaciji, a još uvijek se smatra sigurnim. Međutim, u svjetlu inicijative "clean label", mnogi potrošači radije ne bi konzumirali aditive ili pojačivače okusa kao što su glutamati. To se može prevladati poznatim sinergističkim učinkom prirodnih 5'-ribonukleotida i glutamata koji se nalaze u morskim algama, siru, ribljem umaku, ekstraktu kvasca, sojinom umaku, fermentiranoj soji i rajčicama, jer oni pojačavaju ukupnu percepciju umami okusa.

Ključne riječi: mononatrijev glutamat, redukcija natrija, pojačivači okusa, senzorska svojstva, mesni proizvodi

INTRODUCTION

Naturally occurring glutamate was first discovered in 1866 by German scientist Karl Ritthausen, who isolated it from the acid hydrolysate of wheat gluten (Vickery and Schmidt, 1931). Almost half a century later, the first applicable function of glutamate as a salt of glutamic acid was introduced in 1908 by Japanese scientist Kikunae Ikeda, who identified the unique fifth taste (independent of the four basic tastes of sweet, sour, salty and bitter) imparted by glutamic acid and named it "umami", a Japanese word meaning "pleasant savory taste" or "essence of deliciousness". The scientist Ikeda also extracted and identified glutamic acid from a soup broth prepared from konbu seaweed (Ikeda, 2002). Glutamic acid and its derivatives act as flavour enhancers in various foods, either as a hydrolysed protein or as a pure monosodium salt declared as E621. In addition, it was noted by Mortensen et al. (2017) that glutamate can also be labelled as a food preservative due to its antioxidant properties.

Nowadays, the addition of glutamate is associated with one of the many strategies to reduce sodium in meat products. Certain health problems caused by the consumption of too much salt in the diet are the main reason for launching various initiatives to reduce the addition of salt in meat production. According to the recommendations of the World Health Organisation (WHO), a daily intake of 5 g NaCl (less than 2 g sodium) is considered safe for adults (WHO, 2007). This is related to consumer concerns about high sodium chloride (NaCl) intake and the associated risk of cardiovascular disease (Rossitto and Delles, 2022). As a result, many strategies have been developed in the meat industry to reduce and/or reconsider the use of sodium in food. However, the addition of NaCl to meat products improves their quality, including water-holding capacity, juiciness, improved texture, extended shelf life and preservation, and the salty taste to which consumers have become accustomed (Noort et al., 2010; Ahn et al., 2013; Chun et al., 2014). Therefore, it is difficult to completely remove salt from meat products, but it is possible to reduce the salt content by using, for example, other food additives such as flavour enhancers (Kim et al., 2021). According to the EU Regulation on Food Additives (European Commission, 2008), food additives are "substances which are not normally consumed as food itself but are added to food for a technological purpose". This EU regulation also states that flavour enhancers are "substances which enhance the existing taste and/or odour of a foodstuff". Although the meat industry faces various challenges in reducing the concentration of NaCl in its products, there are two main methods of reducing salts. The first requires partial or total replacement of NaCl with other ingredients, while the second method suggests reducing the amount of NaCl used by adding flavour enhancers such as monosodium glutamate (MSG) (Gou et al., 1996; Gelabert et al., 2003; Chun et al., 2014).

Many studies have suggested the potential use of umami substances as a healthy and natural solution to reduce salt intake in various foods (Wang et al., 2019; Buechler and Lee, 2020; Kongstad and Giacalone, 2020). Previous methods of replacing NaCl with other salts such as potassium, calcium and magnesium have been partially accepted as they tend to produce an undesirable taste in the final product (Gou et al., 1996; Gelabert et al., 2003; Chun et al., 2014; Jůzl et al., 2019; Kos et al., 2021). Compared to NaCl, MSG has a much lower Na content (12.28% in MSG compared to 39.34% in NaCl) and can therefore be used as a substitute for NaCl in certain proportions. However, too much MSG can cause undesirable food flavours (Jinap and Hajeb, 2010). Therefore, the recommended amount of MSG as a food additive is 0.1% - 0.8% of the total product weight. This amount corresponds to the amount of free L-glutamate found in tomatoes and Parmesan cheese (Beyreuther et al., 2007).

ORIGIN AND FORMS OF GLUTAMATE

Glutamic acid (glutamate) is one of the most abundant amino acids found in nature. It is the main component of many proteins and peptides (Bera et al., 2017).

Free glutamic acid is present in large quantities in the organs and tissues of the living body (Ninomiya, 1998). Glutamate, as a salt of glutamic acid, is produced naturally in the body and is very important for human metabolism (Bera et al., 2017) and is largely synthesised and metabolised in the brain. The daily turnover of glutamate in the human body is estimated to be around 4,800 mg. Some of the significant metabolic processes in which glutamate is involved are protein production (in which it serves as a substrate), biosynthesis of all amino acids as a transamination partner with α-ketoglutarate, biosynthesis of glutamine (which is important for amino acid metabolism and free ammonia conversion), rapid synaptic transmissions (in which it functions as an important neurotransmitter), and it is also an energy-providing substrate (Wijayasekara and Wansapala, 2017).

Monosodium glutamate (IUPAC name: sodium 2-aminopentanedioate) is the sodium salt of glutamic acid. Industrially, MSG is mostly produced by fermentation processes using microorganisms such as bacteria of the genera *Corynebacterium* and *Brevibacterium*. Molasses and starch hydrolysate are usually used as carbon sources and ammonium salts and urea as nitrogen sources for the industrial production of MSG. After glutamic acid production, the pH of the fermentation broth is adjusted to 3.2 to obtain L-glutamic acid crystals, which are then converted to MSG with purity greater than 99% by neutralisation and purification (Wijayasekara and Wansapala, 2017).

Glutamate and its salts come in many forms: monosodium glutamate, monopotassium glutamate, calcium diglutamate, mono ammonium glutamate and magnesium diglutamate. The flavouring function of glutamate added to food is similar to that of naturally occurring free glutamate (Löliger, 2000). It should be emphasized that only the free form of glutamic acid or glutamates has a flavour-enhancing effect. When bound to other amino acids in a protein, glutamate is not active (Kurihara, 2015).

BEHIND UMAMI TASTE

The substances that make umami taste possible are divided into two main groups. One is the amino acid group, represented by MSG. The other is the group of 5'-nucleotides represented by inosine 5'-monophosphate (IMP) and guanosine monophosphate (GMP) and their derivatives (Kurihara, 2009). MSG imparts a unique taste due to its taste-active chemical properties. The distinctive taste of MSG is the result of its stereochemical structure (D- and L-stereoisomers). Fermented products have a higher content of D-glutamate (5% or more) compared to non-fermented products (Ganong, 1999). Excessive use of MSG is self-limiting, as adding more glutamate contributes little, if anything, and may even result in poorer taste. According to Food Standards Australia New Zealand (2003), the maximum palatable dose of MSG is about 60 mg/kg body weight.

The umami effect only occurs with the fully dissociated form of L-glutamic acid and the optimal umami effect is present at a pH of 6 to 8 because the ionic forms of glutamic acid are pH dependent. The ionic forms of glutamic acid are shown in Figure 1. MSG decomposes only under acidic conditions (such as pH 2.2-2.4) and at high temperatures. Under these conditions, MSG is partially dehydrated and converted to 5-pyrrolidone-2-carboxylate (Wijayasekara and Wansapala, 2017). At very high temperatures and under alkaline conditions, glutamate tends to racemise to DL- glutamate. MSG in combination with L-phenylalanine and L-tyrosine has the ability to undergo Maillard-type reactions, resulting in flavour enhancement (Lioe et al., 2005). The combination of the Maillard reaction product glutathione xylose and MSG has been found to have a positive synergistic effect on the sensory properties of beef (Hong et al., 2012).

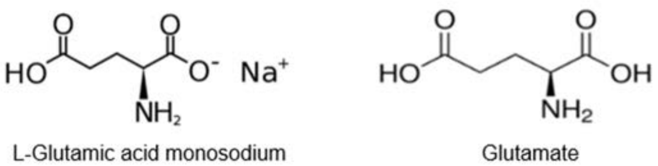

Figure 1. Ionic forms of glutamic acid (Wijayasekara and Wansapala, 2017)

Umami can be considered one of the five basic tastes (along with sweetness, sourness, bitterness and saltiness) and has a light but lingering aftertaste. It stimulates the flow of saliva and stimulates the throat, palate and back of the mouth. Most taste buds on the tongue and in the mouth can perceive the umami taste, regardless of where it is located (Yamaguchi, 1998; Wijayasekara and Wansapala, 2017).

NATURAL OCCURRENCE OF GLUTAMATE IN FOOD

Glutamate occurs naturally in foods in free and protein-bound forms (Table 1). The content of free glutamate in foods varies but is generally low. Glutamate is released during protein hydrolysis during fermentation, ageing, ripening and heat cooking processes (Löliger, 2000). A very small proportion, less than 5-10%, of total glutamate intake comes from natural sources and is relatively high in tomatoes and Parmesan cheese (Brosnan et al., 2014). Glutamate concentrations after hydrolysis of glutamic acid can be as high as 50,000 mg/kg in certain oilseeds and 25,000 mg/kg in animal products (Tennant, 2018).

Seaweed, cheese, fish sauce, soy sauce, fermented soybeans and tomatoes have high levels of free glutamic acid (Jinap and Hajeb, 2010). The level of free glutamate varies greatly due to the degree of ageing and ripening (Tennant, 2018). In fact, glutamic acid is the most abundant free amino acid in some cheeses that undergo a long ripening period (Ninomiya, 1998). Cheese ripening is a complex process involving many physio-chemical changes that lead to an accumulation of lactic acid, fatty acids and free amino acids. These processes lead to a change in colour, texture and taste. In the end, grated Parmigiano Reggiano is often used as a seasoning in Italian cuisine due to its high free glutamic acid content, which can vary between 1,200-1,600 mg/100 g of cheese (Ninomiya, 1998).

Glutamate is an important component of the ripening process that leads to a fullness of flavour. However, some flavour components are lost during the industrial processing of food (broths, slow-cooked meat and vegetables), so MSG is used to compensate for this loss (Giacometti et al., 1979). In this context, kombu seaweed is traditionally used in Japanese cuisine. Research has shown that about 60% of the free amino acids in kombu consist of glutamic acid, while another seaweed, wakame, is rich in glycine and alanine (Ninomiya, 1998).

Table 1. Natural glutamate content of fresh food (mg/100 g food)

Types of foods	Bound glutamate	Free glutamate
Milk/Milk products		
Cow	819	2
Human	229	22
Parmesan cheese	9,847	1,200
Poultry products		
Eggs	1,583	23
Chicken	3,309	44
Duck	3,636	69
Meat		
Beef	2,846	33
Pork	2,325	23
Fish		
Cod	2,101	9
Mackerel	2,382	36
Salmon	2,216	20
Vegetables		
Peas	5,583	200
Corn	1,765	130
Beets	256	30
Carrots	218	33
Tomatoes	238	140

Source: Bera et al. (2017)

Tomato is used in many dishes to enhance savoury taste (Oruna-Concha et al. 2007). Oruna-Concha et al. (2007) conducted a study of 14 tomato varieties. The analysis showed that the most important amino acids in the tomatoes were glutamic acid, aspartic acid, glutamine and asparagine. The pulp with the seeds contained much higher concentration of glutamic acid (4.56 g/kg) than the tomato flesh (1.26 g/kg) in all samples. Processed tomatoes such as canned, puree, paste, ketchup and chilli sauce add a rich flavour to many dishes. Glutamic acid is the predominant free amino acid in tomatoes and its amount progressively increases with ripeness. Immature green tomato contains only about 20 mg/100 g of glutamic acid and the content of glutamate in fully ripe red tomatoes is more than eight times higher than in green tomatoes (Inaba et al., 1980).

Unlike tomatoes, glutamate is generally not the dominant amino acid in fruits (Ninomiya, 1998). In addition, storage of raw or cooked vegetables leads to a decrease in glutamate content, so that fresh products taste better. Also, in maize, for example, the starch content increases and the MSG content decreases with maturity (Hac et al. 1949, cit. Maga and Yamaguchi, 1983).

It is well known that the preparation of food has a great influence on taste. The meat juices of cooked beef have a higher MSG content than the meat portion, so the loss of the juices or poor utilisation of the juices due to inadequate preparation techniques will result in a significant loss of flavour (Maga and Yamaguchi, 1983).

CONSUMPTION OF MSG AND IMPACT ON HUMAN HEALTH

Global glutamate consumption has increased dramatically in recent decades (He et al., 2008). Flavour enhancers such as MSG are now used in pure form as seasonings to enhance the flavour of savoury-based processed foods and to replace flavours that normally develop during the slow cooking of vegetables and meats (Löliger, 2000). Tennant (2018) distinguished data on natural free glutamate, protein-derived glutamate and glutamate from additives E620-E625, and then estimated the total intake of glutamic acid by combining the data. His analysis showed that the average intake of glutamate varied from 88 mg/kg body weight/day in elderly people in the UK to 474 mg/kg body weight/day in young children in Finland. The main sources of high intake were found to be cow's milk, meat and some cereal products.

According to the U.S. Department of Health and Human Services (USDHHS, 1958), MSG is safe to use due to its low toxicity. Using LD_{50} values, a 22 kg child would have to consume 1 pound (453.59 g) of MSG to reach an equivalent LD_{50} amount, which is highly unlikely (Maga and Yamaguchi, 1983). Nevertheless, there is an ongoing debate about whether MSG causes any diseases (Geha et al., 2000). The consequences of long-term consumption of added MSG have been the subject of numerous studies (Maga and Yamaguchi, 1983; Niaz et al., 2018). According to acute toxicity studies in rodents, MSG was reported to be less toxic than NaCl, while long-term toxicity studies showed no signs of carcinogenicity. Furthermore, multigenerational studies in which MSG was administered in the diet for up to three generations showed no adverse effects on the mother or offspring (Filer and Stegink, 1994).

MSG is blamed for many diseases, and one of them is Chinese restaurant syndrome, a complex of symptoms allegedly triggered by MSG after eating Chinese food. It was first described in 1968 (Geha et al., 2000). The symptom complex consists of numbness in the neck and arms, weakness and palpitations. MSG is said to cause numerous diseases, including asthma, urticaria, atopic dermatitis, ventricular arrhythmia, neuropathy and abdominal discomfort. For example, consumption of high doses or amounts of MSG over a prolonged period of time can cause a decrease in red blood cell count and packed cell volume, leading to anaemia (Nusaiba et al., 2018). However, according to Geha et al. (2000), who conducted a study to analyse the response of individuals who reported symptoms after taking MSG, there is no evidence to support these claims. The results suggest that high doses of MSG, administered without food, may cause more symptoms than a placebo in people who believe they are reacting negatively to MSG. However, the frequency of reactions was low and the reported reactions were inconsistent and not reproducible. No reactions were observed when MSG was administered with food.

In contrast, Baad-Hansen et al. (2010) conducted a study on the effects of MSG on the occurrence of headaches and pericranial muscle sensitivity. They were able to demonstrate that subjects who consumed higher amounts of MSG in their diet suffered from severe headaches as well as increased systolic blood pressure and had higher pericranial muscle sensitivity. These could be limiting facts for the use of MSG in food production.

Because glutamate is the primary excitatory neurotransmitter in the brain, it has been hypothesised that it can become an excitotoxin in excessive amounts. MSG has been linked to migraines, seizures, autism, Alzheimer's disease, multiple sclerosis, Parkinson's disease and other conditions (Bera et al., 2017). Many toxic effects on the central nervous system have been mentioned in animal studies. There are problems in transferring the results of animal studies to the effects of MSG in the human diet due to the different doses administered to the animals and those that a people consume in food as a flavour enhancer. Thus, the above results are very contradictory and it is necessary to further investigate the effect of MSG on the human central nervous system (Husarova and Ostatnikova, 2013).

There is concern that the taste enhancement provided by umami flavours leads to overeating and thus more obesity (Bera et al., 2017) but according to Al Hayder et al. (2019) MSG has no effect on the body weight. The results of their study showed no significant differences between the weight gain of adult male rats treated with MSG (20 mg/kg) and the control group after thirty experimental days. Vu et al. (2013) and Shi et al. (2010) also found no connection between MSG consumption and obesity. On the other hand, He et al. (2011) found positive relationship between MSG intake and overweight in Chinese participants.

Accordingly, there is no scientific information on negative effects of glutamate on human health in the general population and it is still considered safe (Jinap and Hajeb, 2010). However, in the wake of "clean label" initiatives, many consumers would prefer not to have additives or flavour enhancers such as glutamates in their food. In response, some manufacturers have taken the opportunity to introduce labels such as "No MSG" and "No MSG Added" even though their products contain glutamate (Jinap and Hajeb, 2010).

GLUTAMATE USE IN MEAT PROCESSING

In the modern meat processing industry, the raw material consists of skeletal muscle, certain organ groups such as the heart and liver, and some fatty tissue. Non-meat ingredients such as water, salts, sugars, phosphates, spices, antioxidants, nitrites and ascorbates are commonly added to meat products and especially sausages (Lonergan et al., 2019), while some products also contain some amount of MSG, which is mainly used as a flavour enhancer. On the other hand, the link between high dietary NaCl intake and human health deterioration has led to adjustments in the meat industry, which needs to solve the problem of reducing NaCl concentration in recipes. This reduction in NaCl can be achieved by using other salts such as KCl, $MgCl_2$, and $CaCl_2$ (Fulladosa et al., 2009), with KCl being the most commonly used salt (Kos et al., 2021). Considering the increasing consumption of processed meat products and the consequent increased intake of NaCl, dos Santos et al. (2014) conducted a study based on the use of a mixture of KCl and other ingredients such as MSG, disodium guanylate, lysine and taurine to reduce NaCl concentration in sausages. The main objective of their research was to evaluate the influence of such a mixture on the sensory and physiochemical properties of fermented cooked sausages. The final physiochemical properties of sausages with reduced NaCl content showed that water activity did not change significantly, confirming a possible use of KCl and other mentioned ingredients as a substitute for NaCl without affecting the drying process. On the other hand, the water activity in dry-cured loins in the experimental treatments with the substitution of NaCl by KCl was at the limit of what is acceptable and may pose a risk to microbiological safety, with negative financial implications for producers (Kos et al., 2021). The rapid decrease in pH (pH = < 5.2) of the tested samples after 24 hours of fermentation indicates a positive effect of KCl, MSG, disodium guanylate, lysine and taurine on the inhibition of a large number of pathogenic microorganisms and microorganisms causing spoilage (Leroy et al., 2006; Urso et al., 2006; dos Santos et al., 2014). Lücke (1998) claims that the texture of sausage changes when the NaCl content is reduced, as NaCl is responsible for stabilising the miofibrillar proteins that contribute to the formation of a firm gel structure. Therefore, sausage makers need to be careful when lowering NaCl content with MSG and other salts, even though MSG itself has little to no effect on texture.

MSG directly affects certain sensory properties of foods and its effect is largely dependent on the presence of sodium chloride (NaCl). Therefore, different strategies have been tested to prevent the deterioration of meat products while reducing NaCl concentration. This led to the development of different production protocols without compromising the sensory quality and safety of meat products. For example, the addition of MSG in combination with lysine, taurine, disodium inosinate and disodium guanylate to reformulated sausages masked the undesirable sensory characteristics associated with the replacement of 50% and 75% NaCl with KCl and enabled the production of fermented cooked sausages with good sensory acceptability and a sodium reduction of about 68% (dos Santos et al., 2014).

Ruusunen et al. (2001) demonstrated an intensification of taste when MSG, disodium inosinate (IMP) and guanylate (GMP) nucleotides were added to Bologna sausage recipes. The authors also demonstrated that even MSG alone improved the sensory quality of the products. The salty taste sensation was improved in sausages with MSG, suggesting that the NaCl content can be reduced while maintaining the expected salty taste. Another supporting study was conducted by Chun et al. (2014) on pork patties to test the sensory properties and quality characteristics of samples with different NaCl/MSG complexes. The results showed that only the complete replacement of NaCl with MSG resulted in significantly higher cooking loss during heat treatment, but there was no significant difference in cooking loss for pork patties prepared with different MSG concentrations. The water-binding properties as well as the texture of the tested samples were not significantly affected by MSG. When NaCl is completely replaced by MSG, a lower salt content in meat products is to be expected, since MSG as a stand-alone ingredient does not promote the salt taste, but acts as a flavour enhancer. Therefore, it can only replace part of the amount of NaCl in meat products without affecting their sensory properties.

The use of MSG also has its disadvantages. Using too much MSG as a direct substitute for NaCl can lead to undesirable taste changes, such as reduced salinity, which can be seen in the research findings described earlier (Chun et al., 2014). Originally, MSG was considered a food additive with negative effects on human health, which is why people were very cautious about purchasing foods containing MSG. In recent years, the Food and Drug Administration (FDA) has tested both the physiological and toxicological effects of MSG and has since declared it safe (WHO, 2012), but a certain percentage of customers are still careful of taking MSG, especially when it is declared as E621. For this reason, natural sources of glutamate are or can be used instead of MSG in meat products, such as yeast extracts, mushrooms like shiitake, kombu seaweed, tomato extracts, hydrolysed vegetable protein, fermented soy products and many more. A study by Dermiki et al. (2013) showed that the use of natural ingredients rich in umami flavours can successfully increase the total content of umami compounds in cooked minced meat.

The same study showed that there was a significant synergistic effect of glutamic acid and 5'-ribonucleotides in natural ingredients, resulting in an increased overall perception of umami flavour. Besides MSG, there are four other forms of glutamate such as potassium glutamate, ammonium glutamate, calcium glutamate and magnesium glutamate (Chun et al., 2014). All other glutamate forms are responsible for creating the umami taste and, because of the other minerals, have a certain metallic taste that can be repulsive to some people, which is why their use is limited.

CONCLUSION

The modern lifestyle of most people today, characterised by busyness and lack of time to prepare daily meals has led to the increasing popularity of processed meat products. Such products are characterised by the presence of preservatives, flavour enhancers and other additives that give them a rich taste. Monosodium glutamate (MSG) is one of the most commonly used flavour enhancers in the food market, and its increasing consumption is at the same time raising concerns about possible harmful effects. MSG is the sodium salt of glutamic acid and a common ingredient in foods, especially those that are a good source of protein. Glutamic acid is in fact one of the most abundant amino acids in nature and a very important link in many metabolic processes as well as a primary excitatory neurotransmitter. Today, the addition of glutamate is associated with one of many strategies to reduce the sodium content in meat products to address consumer concerns about high sodium chloride (NaCl) intake and its association with cardiovascular disease. It has been found that it is possible to reduce salt content and still maintain flavour when glutamates are added. This has been confirmed in many studies on the partial reduction of salt in meat products, and MSG has been shown to be a beneficial addition to the reduced amount of NaCl. If the recommended amount of glutamate added to food is respected, it will ultimately have no harmful effects on human health or the sensory properties of the final products.

REFERENCES

Ahn, S., Park, S., Kim, J. M., Han, S. N., Jeong, S. B., Kim, H. K. (2013) Salt content of school meals and comparison of perception related to sodium intake in elementary, middle, and high schools. Nutrition Research and Practice, 7, 59-65. DOI: https://doi.org/10.4162/nrp.2013.7.1.59

Al Hayder, M. N., Al Zobidy, A. M., Al Masoddy, E. (2019) The effect of monosodium glutamate alone or with lycopene on some physiological and biochemical parameters in adult male rats. Al-Qadisiyah Journal of Veterinary Medicine Sciences, 18 (1), 81-88.

Baad-Hansen, L., Cairns, B., Ernberg, M., Svensson, P. (2010) Effect of systemic monosodium glutamate (MSG) on headache and pericranial muscle sensitivity. Cephalalgia, 30 (1), 68-76. DOI: https://doi.org/10.1111/j.1468-2982.2009.01881.x

Bera, T. K., Kar, S. K., Yadav, P. K., Mukherjee, P., Yadav, S., Joshi, B. (2017) Effects of monosodium glutamate on human health: A systematic review. World Journal of Pharmaceutical Sciences, 5 (4), 139-144.

Beyreuther, K., Biesalski, H. K., Fernstrom, J. D., Grimm, P., Hammes, W. P., Heinemann, U., Kempski, O., Stehle, P., Steinhart, H., Walker, R. (2007) Consensus meeting: monosodium glutamate - an update. European Journal of Clinical Nutrition, 61 (3), 304-313. DOI: https://doi.org/10.1038/sj.ejcn.1602526

Brosnan, J. T., Drewnowski, A., Friedman, M. I. (2014) Is there a relationship between dietary MSG obesity in animals or humans? Amino acids, 46 (9), 2075-2087. DOI: https://doi.org/10.1007/s00726-014-1771-6

Buechler, A. E., Lee, S. Y. (2020) Drivers of liking for reduced sodium potato chips and puffed rice. Journal of Food Science, 85, 173-81. DOI: https://doi.org/10.1111/1750-3841.14972

Chun, J. Y., Kim, B. S., Lee, J. G., Cho, H. Y., Min, S. G., Choi, M. J. (2014) Effect of NaCl/monosodium glutamate (MSG) mixture on the sensorial properties and quality characteristics of model meat products. Korean Journal for Food Science of Animal Resources, 34 (5), 576-581. DOI: https://doi.org/10.5851/kosfa.2014.34.5.576

Dermiki, M., Mounayar, R., Suwankanit, C., Scott, J., Kennedy, O.B., Mottram, D.S., Gosney, M., Blumenthal, H., Methven, L. (2013). Maximising umami taste in meat using natural ingredients: effects on chemistry, sensory perception and hedonic liking in young and old consumers. Journal of the science of food and agriculture, 93 (13), 3312-3321. DOI: https://doi.org/10.1002/jsfa.6177

dos Santos, B. A., Bastianello Campagnol, P. C., Morgano, M. A., Rodrigues Pollonio, M. A. (2014) Monosodium glutamate, disodium inosinate, disodium guanylate, lysine and taurine improve the sensory quality of fermented cooked sausages with 50% and 75% replacement of NaCl with KCl. Meat Science, 96 (1), 509-513. DOI: https://doi.org/10.1016/j.meatsci.2013.08.024

European Commission (2008) Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives. Official Journal of the European Union, 354, 16-33.

Filer, Jr L. J., Stegink, L. D. (1994) A report of the proceedings of an MSG workshop held August 1991. Critical Reviews in Food Science and Nutrition, 34 (2), 159-174. DOI: https://doi.org/10.1080/10408399409527655

Food standards Australia New Zealand (2003) Monosodium glutamate. A safety assessment. Technical report series no. 20. Available at: https://www.foodstandards.gov.au/publications/documents/msg%20Technical%20Report.pdf Accessed March 31 2023

Fulladosa, E., Serra, X., Gou, P., Arnau, J. (2009) Effects of potassium lactate and high pressure on transglutaminase restructured dry-cured hams with reduced salt content. Meat Science, 82 (2), 213-218. DOI: https://doi.org/10.1016/j.meatsci.2009.01.013

Ganong, W.F. (1999) Review of Medical Physiology. Stamford: Appleton and Lange.

Geha, R. S., Beiser, A., Ren, C., Patterson, R., Greenberger, P. A., Grammer L. C., Ditto, A. M., Harris, K. E., Shaughnessy, M. A., Yarnold, P. R., Corren, J., Saxon, A. (2000) Review of alleged reaction to monosodium glutamate and outcome of a multicenter double-blind placebo-controlled study. The Journal of Nutrition, 130 (4), 1058S-1062S. DOI: https://doi.org/10.1093/jn/130.4.1058S

Gelabert, J., Gou, P., Guerrero, L., Arnau, J. (2003) Effect of sodium chloride replacement on some characteristics of fermented sausages. Meat Science, 65, 833-839. DOI: https://doi.org/10.1016/S0309-1740(02)00288-7

Giacometti, T., Filer, L. J., Garattini, S., Kare, M. R. (1979) Free and bound glutamate in natural products. Glutamic acid: advances in biochemistry and physiology, Raven Press, New York, 25-34.

Gou, P., Guerrero, L., Gelabert, J., Arnau, J. (1996) Potassium chloride, potassium lactate and glycine as sodium substitutes in fermented sausages and in dry-cured pork loins. Meat Science, 42, 37-48. DOI: https://doi.org/10.1016/0309-1740(95)00017-8

He, K., Du, S., Xun, P., Sharma, S., Wang, H., Zhai, F., Popkin, B. (2011) Consumption of monosodium glutamate in relation to incidence of overweight in Chinese adults: China Health and Nutrition Survey (CHNS). The American Journal of Clinical Nutrition, 93 (6), 1328-1336. DOI: https://doi.org/10.3945/ajcn.110.008870

He, K., Zhao, L., Daviglus, M. L., Dyer, A. R., Van Horn, L., Garside, D., Zhu, L., Guo, D., Wu, Y., Zhou, B., Stamler, J. (2008) Association of monosodium glutamate intake with overweight in Chinese adults: the INTERMAP Study. Obesity (Silver Spring), 16 (8), 1875-1880. DOI: https://doi.org/10.1038/oby.2008.274

Hong, J. H., Kwon, K. Y., Kim, K. O. (2012) Sensory characteristics and consumer acceptability of beef stock containing the glutathione-xylose Maillard reaction product and/or monosodium glutamate. Journal of Food Science, 77 (6), S233-9. DOI: https://doi.org/10.1111/j.1750-3841.2012.02724.x

Husarova V., Ostatnikova D. (2013) Monosodium glutamate toxic effects and their implications for human intake: a review. JMED Research, 2013, 1-12. DOI: https://doi.org/10.5171/2013.608765

Ikeda, K. (2002) New seasonings. Chemical senses, 27, 847-849.

Inaba, A., Yamamoto, T., Ito, T., Nakamura, R. (1980). Changes in the concentrations of free amino acids and soluble nucleotides in attached and detached tomato fruits during ripening. Journal of the Japanese Society for Horticultural Science, 49 (3), 435-441.

Jinap, S., Hajeb, P. (2010) Glutamate. Its applications in food and contribution to health. Appetite, 55 (1), 1-10. DOI: https://doi.org/10.1016/j.appet.2010.05.002

Jůzl, M., Piechowiczová, M., Řehůřková, K. (2019) Comparison of quality parameters of the cooked salami „Gothajský“ in dependence on used salt content and additives. Potravinárstvo Slovak Journal of Food Sciences, 13 (1), 390–395. DOI: https://doi.org/10.5219/1117

Kim, T. K., Yong, H. I., Jung, S., Kim, H. W., Choi, Y. S. (2021) Technologies for the production of meat products with a low sodium chloride content and improved quality characteristics - a review. Foods, 10, 957. DOI: https://doi.org/10.3390/foods10050957

Kongstad, S., Giacalone, D. (2020) Consumer perception of salt-reduced potato chips: Sensory strategies, effect of labeling and individual health orientation. Food Quality and Preference, 81, 103856. DOI: https://doi.org/10.1016/j.foodqual.2019.103856

Kos, I., Bendelja Ljoljić, D., Kiš, G., Bedeković, D., Janječić, Z., Vnučec, I., Škrlec, A. (2021). Effect of partial replacement of NaCl with KCl on physical and sensory traits of dry-cured loin. MESO: Prvi hrvatski časopis o mesu, 23 (5), 389-399. DOI: https://doi.org/10.31727/m.23.5.2

Kurihara, K. (2015) Umami the fifth basic taste: history of studies on receptor mechanisms and role as a food flavor. BioMed Research International, 189402. DOI: https://doi.org/10.1155/2015/189402

Kurihara, K. (2009) Glutamate: from discovery as a food flavor to role as a basic taste (umami). The American Journal of Clinical Nutrition, 90, 719S–722S. DOI: https://doi.org/10.3945/ajcn.2009.27462D

Leroy, F., Verluyten, J., Vuys, L. D. (2006) Functional meat starter cultures for improved sausage fermentation. International Journal of Food Microbiology, 106, 270-285. DOI: https://doi.org/10.1016/j.ijfoodmicro.2005.06.027

Lioe, H. N, Apriyantono, A., Takara, K., Wada, K., Yasuda, M. (2005) Umami taste enhancement of MSG/NaCl mixtures by subthreshold L-α-aromatic amino acids. Journal of Food Science, 70 (7), s401-s405. DOI: https://doi.org/10.1111/j.1365-2621.2005.tb11483.x

Löliger, J. (2000) Function and importance of glutamate for savory foods. The Journal of Nutrition, 130 (4), 915S-920S. DOI: https://doi.org/10.1093/jn/130.4.915S

Lonergan, S. M., Topel, D. G., Marple, D. N. (2019) Chapter 14 - Sausage processing and production. In: Steven M. Lonergan, S.M., Topel, D.G., Marple, D.N., eds. The Science of Animal Growth and Meat Technology (Second Edition). Academic Press, 229-253. DOI: https://doi.org/10.1016/B978-0-12- 815277-5.00014-7

Lücke, F. K. (1998) Fermented sausages. In: B. J. B. Wood, B.J.B., ed. Microbiology of fermented foods. London: Blackie Academic and Professional, pp. 441-483.

Maga, J. A., Yamaguchi, S. (1983) Flavor potentiators. C R C Critical Reviews in Food Science and Nutrition, 18 (3), 231-312. DOI: https://doi.org/10.1080/10408398309527364

Mortensen, A., Aguilar, F., Crebelli, R., Di Domenico, A., Dusemund, B., Frutos, M. J., Galtier, P., Gott, D., Gundert-Remy, U., Leblanc, J., Lindtner, O., Moldeus, P., Mosesso, P., Parent-Massin, D., Oskarsson, A., Stankovic, I., Waalkens-Berendsen, I., Woutersen, R. A., Wright, M., Younes, M., Boon, P., Chrysafidis, D., Gürtler, R., Tobback, P., Altieri, A., Rincon, A. M., Lambr´e, C. (2017) Re-evaluation of glutamic acid (E620), sodium glutamate (E 621), potassium glutamate (E622), calcium glutamate E 623), ammonium glutamate (E 624) and magnesium glutamate E 625) as food additives. EFSA Journal, 15 (7), 4910. DOI: https://doi.org/10.2903/j.efsa.2017.4910

Niaz, K., Zaplatic, E., Spoor, J. (2018) Extensive use of monosodium glutamate: A threat to public health? EXCLI Journal, 17, 273-278. DOI: https://doi.org/10.17179/excli2018-1092

Ninomiya, K. (1998) Natural occurrence. Food Reviews International, 14 (2-3), 177-211. DOI: https://doi.org/10.1080/87559129809541157

Noort, M. W. J., Bult, J. H. F., Stieger, M., Hamer, R. J. (2010) Saltiness enhancement in bread by inhomogeneous spatial distribution of sodium chloride. Journal of Cereal Science, 52, 378-386. DOI: https://doi.org/10.1016/j.jcs.2010.06.018

Nusaiba, S., Fatima, S. A., Hussaini, G., Mikail, H. G. (2018) Anaemogenic, obesogenic and thermogenic potentials of graded doses of monosodium glutamate sub-acutely fed to experimental Wistar rats. Current Clinical Pharmacology, 13 (4), 273-278. DOI: https://doi.org/10.2174/1574884713666181002120657

Oruna-Concha, M. J., Methven, L., Blumenthal, H., Young, C., Mottram, D. S. (2007) Differences in glutamic acid and 5 '-ribonucleotide contents between flesh and pulp of tomatoes and the relationship with umami taste. Journal of Agricultural and Food Chemistry, 55 (14), 5776-5780. DOI: https://doi.org/10.1021/jf070791p

Rossitto, G., Delles, C. (2022) Mechanisms of sodium-mediated injury in cardiovascular disease: old play, new scripts. The FEBS Journal, 289, 7260-7273. DOI: https://doi.org/10.1111/febs.16155

Ruusunen, M., Simolin, M., Puolanne, E. (2001) The effect of fat content and flavor enhancers on the perceived saltiness of cooked 'Bologna-type' sausages. Journal of Muscle Foods, 12, 107-120. DOI: https://doi.org/10.1111/j.1745-4573.2001.tb00303.x

Shi, Z., Luscombe-Marsh, N. D., Wittert, G. A., Yuan, B., Dai, Y., Pan, X., Taylor, A. W. (2010) Monosodium glutamate is not associated with obesity or a greater prevalence of weight gain over 5 years: findings from the Jiangsu Nutrition Study of Chinese adults. British Journal of Nutrition, 104, 457-463. DOI: https://doi.org/10.1017/S0007114510000760

Tennant, D. R. (2018) Review of glutamate intake from both food additive and non-additive sources in the European Union. Annals of Nutrition and Metabolism, 73 (5), 21-28. DOI: https://doi.org/10.1159/000494778

Urso, R., Comi, G., Cocolin, L. (2006) Ecology of lactic acid bacteria in Italian fermented sausages: Isolation, identification and molecular characterization. Systematic and Applied Microbiology, 29, 671–680. DOI: https://doi.org/10.1016/j.syapm.2006.01.012

USDHHS. (1958) U.S. Department of Health and Human Services. Subpart A- General Provisions: substances that are generally recognized as safe. Code of Federal Regulations: Food and Drugs 21, No. 182.1(a)

Vickery, H. B., Schmidt, C. L. A. (1931) The History of the Discovery of the Amino Acids. Chemical Reviews, 9 (2), 169-318. DOI: https://doi.org/10.1021/cr60033a001

Vu, T. T. H., Nguyen, T. H., Nguyen, C. K., Wakita, A., Yamamoto, S. (2013) Monosodium glutamate is not associated with overweight in Vietnamese adults. Public Health Nutrition, 16, 922-927. DOI: https://doi.org/10.1017/S1368980012003552

Wang, S., Tonnis B. D., Wang, M. L, Zhang S., Adhikari, K. (2019) Investigation of monosodium glutamate alternatives for content of umami substances and their enhancement effects in chicken soup compared to monosodium glutamate. Journal of Food Science, 84, 3275–83. DOI: https://doi.org/10.1111/1750-3841.14834

WHO (2012) Guideline: Sodium intake for adults and children. W.H.O. (WHO) (Ed.).

WHO (2007) Reducing salt intake in populations: Report of a WHO Forum and Technical Meeting, 5-7 October Paris, France. Geneva, Switzerland: WHO Document Production Services. Available from: https://apps.who.int/iris/bitstream/handle/10665/43653/9789241595377_eng.pdf

Wijayasekara, K., Wansapala, J. (2017) Uses, effects and properties of monosodium glutamate (MSG) on food & nutrition. International Journal of Food Science and Nutrition, 2 (3), 132-143.

Yamaguchi, S. (1998) Basic properties of umami and its effects on food flavor. Food Reviews International, 14 (2-3), 139-176. DOI: https://doi.org/10.1080/87559129809541156