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The umami taste: from discovery to clinical use

Katarzyna Stańska, Antoni Krzeski

Department of Otorhinolaryngology, Medical University of Warsaw, 19/25 Stepinska Street, 00-739 Warsaw, Poland

Article history: **Received:** 18.04.2016 **Accepted:** 21.04.2016 **Published:** 10.07.2016

ABSTRACT: In the diversity of the flavor world only five basic tastes have been described. The newest one, umami, has been identified about one hundred years ago by Kikunae Ikeda but widely accepted just in the second half of the twentieth century by international scientific world. There are three umami substances: monosodium glutamate (MSG), inosine-5'-monophosphate (IMP), guanylo-5'-monophosphate (GMP). A real breakthrough in umami history concerned the finding about independent receptors for umami: T1R1 and T1R3 (taste receptors type 1 member 1 and member 3). The palatable, delicious taste of umami and its mechanism determined a lot of research studies on this highlight. Umami substances elicit salivary secretion, enhance appetite and increase food palatability. They are desirable to improve the quality of diet. Moreover, the association between umami substances and the suppression of obesity has been found. Studies suggest that umami is engaged in metabolism but also increases satiety and reduces the post-ingestive recovery of hunger.

KEYWORDS: umami taste, monosodium glutamate, taste, nutrition, diet, food

INTRODUCTION

Taste is one of the human senses. It provides essential sensory information to the brain regulating ingestive behavior. Distinct epithelial taste receptor cells on the tongue, palate, throat and in some points near the epiglottis and the upper esophagus are activated by chemical substances [1-3]. The stimulation of the receptors determines whether a particular food or beverage is finally ingested.

There are infinity of sensory impressions of nourishment but only five distinguishable sensations of taste [3]:

- bitterness is often considered as a general signal of poison in food,
- sourness indicates acid or spoiled food,
- sweetness signifies the presence of carbohydrates,
- saltiness signals minerals,
- umami refers to the presence of proteins and nucleotides [3].

Despite the diversity of the flavor world, not every taste is classified as basic [4]. According to the definition, 'basic taste' should be [5, 6] :

- a characteristic taste that is different from any other tastants,
- not reproduced by any combination of other basic taste stimuli,
- a universal taste induced by components of many food,
- proved electrophysiologically to be independent from other basic tastes.

HISTORY

Professor Kikunae Ikeda worked at the Imperial University of Tokyo, being interested in the relationship between the chemical structure of substance and its smell and taste. At that time, four basic tastes had been accepted: sweet, salty, sour and bitter. At the beginning of the twentieth century, professor Ikeda identified a unique taste describing it as tasty, savory and named it *umami* – a delicious taste.

Professor Ikeda worked on a project identifying the chemical structure of the umami substance. He used a dried konbu (a Japanese seaweed) and extracted an organic acid which had a salt form in a water and elicited a strong umami taste [7]. Ikeda recognized the molecular formula $C_5H_9NO_4$ as a glutamic acid which was already identified by Ritthausen [8] and described by Fischer as a peculiar insipid taste (Fig. 1).

 DOI: 10.5604/00306657.1199991

The first detected umami substance was monosodium glutamate (MSG) [6, 7, 9]. The other umami substance had been identified in 1913. Shintaro Kodama- Ikeda's student detected in a dried bonito fish, inosine-5'-monophosphate (IMP). A few decades later, another scientist, Kuninaka, noticed that a guanylo-5'- monophosphate (GMP) had also umami taste (1957). He extracted GMP from a shiitake mushroom (Fig. 2) [6, 9].

For a long time only four basic tastes had been described. The fifth taste - umami, had not been accepted in the scientific world in Europe and the United States for a few decades after detection [9]. Scientists observed that umami fulfilled the 1st, 2nd, and 3rd criterion of the basic taste. In the second half of the twentieth century studies noticed that umami substances activate independent receptors. It was a real breakthrough which helped the umami taste to be accepted as the fifth taste [5, 6].

SYNERGISTIC EFFECT OF UMAMI

Professor Kunianka explored aspects of synergism between umami substances. He described that IMP has a weak and MSG has a strong umami taste. Surprisingly, when he mixed both substances, a much stronger umami taste was identified. Yamaguchi also observed that the taste of MSG or IMP alone is rather weak. An increase of the ratio of IMP in GMP solution or inversely elicits a very strong umami taste [6, 10].

MECHANISM OF UMAMI TASTE

There are between 5000 and 10000 taste buds in the human oral cavity, situated on the tongue surface, palate and epiglottis. Taste stimulation is detected by the sensory cells in the taste buds of specialized papillae [1, 2].

Taste buds are aggregates of up to 100 cells. According to the morphological features, the protein expression and the signaling taste cells have been categorized into three established types [1, 2]. Cells express specialized receptors that bind compounds, giving rise to taste perception. For the umami taste the following receptors are responsible: T1R1 (taste receptor type 1 member 1), T1R3 (taste receptor type 1 member 3) [11, 12] and taste-specific isoforms of metabotropic glutamate receptors (mGluR), especially mGluR4 [13] and mGluR1 [14] but also mGluR2 and mGluR3 (Tab. 1). Moreover, inotropic glutamate receptors for NMDA and kainate receptors have detected umami substances [3, 12, 15, 16]. Several studies have noticed the elimination of the response to oral glutamate after knocking out T1R1 or T1R3. The scientific results

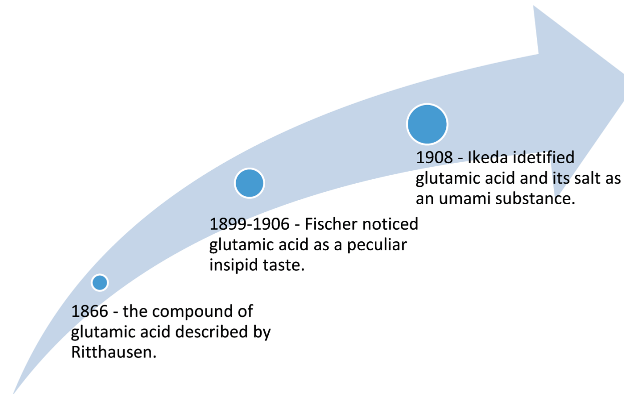

Fig. 1. Discovery of the umami

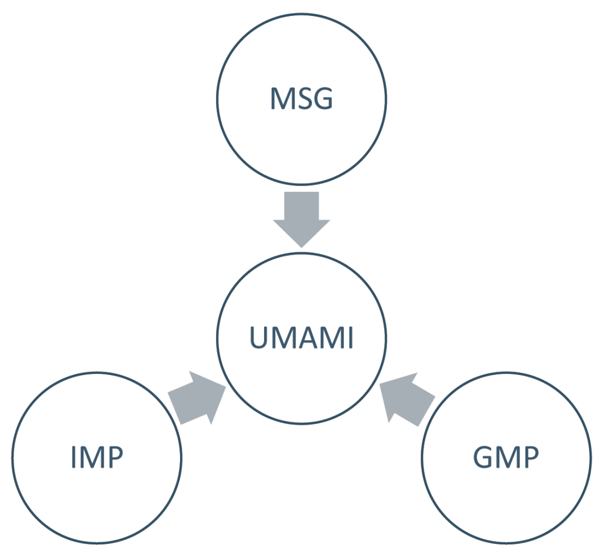

Fig. 2. Umami substances

Tab. I. Receptors for umami substances [11-16]

METABOTROPIC	IONOTROPIC
T1R1/T1R3	NMDA receptor
mGluR	kainate receptor

Tab. II. The essential role of saliva [28]

TEETH	FOOD	MICROORGANISM
Lubrication	Taste	Anti-bacterial
Remineralization	Digestion	Anti-viral
Protection against demineralization	Bolus formation	Anti-fugal
Buffer		

suggest that the heterodimer T1R1/T1R3 is exactly the umami receptor [12, 16].

Signal from taste receptors in the oral cavity is transported by sensory fibers in the cranial nerves to the central nervous system. Taste cells and their receptors in the front of the tongue transduce taste signals by the chorda tympani (a branch of the facial nerve), and sensory fibers from the glossopharyngeal nerve conduct impulses from the posterior one-thirds of the tongue. Sensations from the soft palate are transmitted by the greater superficial petrosal nerve (a branch of the facial nerve). Fibers from the superior laryngeal nerve (a branch of the vagus nerve) transport taste arousal from the epiglottis [4].

Taste cells with high expression of umami receptors are localized in the posterior part of the tongue. Moreover, studies noticed that a higher amount of umami sensitive fibers is present in the glossopharyngeal nerve rather than in other cranial nerves. Results suggest, according to a defined taste topography, that the best umami sensation is elicited when the umami substances reach the rear of the tongue [17, 18].

In the central nervous system the switch station for the taste sensation are sensory ganglia - from there the information goes to the nucleus of the solitary tract, then to the ventral posterior medial nucleus of the thalamus, and finally to the primary taste cortex located in the insular and opercular region, secondary – orbitofrontal cortex and the anterior cingulate cortex [19]. De Araujo et. al noticed that the umami taste activates similar brain regions as other basic tastes [20]. These results show that umami works like other tastants and thus can be considered as the “fifth taste” [20, 21]. The umami stimulation promotes the activation in some regions in the human brain and may elicit not only the taste identification but also different sensations: pleasure, satisfaction, contentment [20, 21]. It is the effect of the anterior cingulate cortex stimulation which is engaged in behaviors, emotions and control of our mood. The studies suggest that umami may have impact on human sensations and emotional reactions and behavior [20, 22, 23].

ESSENTIAL ROLE OF THE UMAMI SUBSTANCES

The umami taste is engaged in many processes of the human body. The umami substances stimulate pancreatic exocrine secretion, gastric juice, gastric acid and insulin release [24]. These effects improve digestion and reduce dissatisfaction with meal [25]. Moreover, MSG promotes gastric emptying [26] and distal colon peristalsis [27]; it regulates bicarbonate release and gastric mucous secretion [25].

Tab. III. Content of glutamate in foodstuff [35].

Food	Free glutamate
Vegetables:	
Tomato	246
Green peas	106
Onion	51
Cabbage	50
Spinach	48
Potato	10
Fruits:	
Avocado	18
Kiwi	5
Apple	4
Meat and poultry:	
Chicken	22
Beef	10
Pork	9
Fish :	
Salmon	20
Mackerel	36
Seafood:	
Scallop	140
Alaska crab	72
Blue crab	43
White shrimp	20
Cheese:	
Parmesan	1300
Emmenthaler	308
Cheddar	182
Milk:	
Cow	1
Goat	4
Human	19
Soy sauce:	
Japan	782
China	926
Korea	1264

The umami taste elicits salivary secretion. Surprisingly, the total amount of long-lasting salivary secretion inducted by umami substances is larger than stimulation by a sour meal. Through salivation umami may improve the functions of saliva (Tab. 2) [28-30] whose role is essential for the taste. All substances are first dissolved by saliva to induce afterwards the taste receptor. Moreover, saliva protects them from mechanical and chemical stress and pathological infections. Studies noticed that taste disorders are associated with hyposalivation [17, 29, 31]. In one research the sensitivity test of the umami taste was used for taste disorder examination. The MSG-moistened paper discs were placed on the tongue surface. The concentration of MSG was from 1 to 200 mM. Patients with taste disorders felt umami taste for higher MSG concentration than a healthy group. Moreover, the sense of umami taste progression was achieved after treatment [17]. These results suggest that umami substances might be involved in the therapy of the dry mouth and taste disorder. [4, 29, 31-33].

Umami substances enhance appetite and improve food palatability increasing food intake. The addition of umami substances can decrease the desire for saltiness. In this regard, the umami stimulation improves the quality of diet and is significant for nutrition [34-36]. Decreased taste sensitivity may induce malnutrition and weight loss deteriorating the overall quality of health and life [31, 33]. Table third shows the amount of free glutamate in food and beverage. A soy sauce, a dried fish bonito and seaweeds also a meat and a cheese are reach in umami substances. (tab. 3).

Umami substances are engaged in metabolism through oxidative substrate mediation [37]. Furthermore, an association between umami substances and suppression of obesity has been found in rats. These animals were taking the MSG solution or water alone in the experiment. A significantly smaller weight gain, lower plasma leptin levels and reduced abdominal fat mass were noticed for animals ingesting MSG in comparison with the second group without MSG [38]. The mechanism of this phenomenon is not completely explained. Several studies noticed that MSG increases satiety and reduces the postingestive recovery of hunger [39]. Other studies described the role of glutamate in infant nutrition. The consumption of the formula higher in free glutamate was smaller than the consumption of the formula lower in free glutamate. Results showed greater levels of satiety and equivalent levels of satiation after glutamate intake. Infants presented a positive facial expression such as facial relaxation, smacking, followed by mouth gaping during feeding with a high-glutamate formula [40].

DISCUSSION

The umami taste has a characteristic taste which is different from any other tastants. Ikeda noticed that it is delicious and savory, suggesting the introduction of a new fifth taste. It was proved that no combination of the basic taste mixture can elicit the umami taste. What is more, umami substances are components of many foodstuffs [7, 35]. Despite these observations, umami was not accepted by the international scientific world for a long time. In the second half of the twentieth century after the identification of specific receptors which left no doubts, the umami taste could be classified as the fifth taste [5, 6, 9].

The role of the umami taste is essential not only for the diverse diet but also for the overall health and quality of life. Umami stimulates salivary secretion, enhances taste of food, increases appetite, positively influences the reduction of fat mass and increases satiety [28, 29, 31, 34, 35, 39, 40]. A lot of mechanisms which are engaged in the umami function are not well understood. Future studies may shed light on the problem and expand the role of umami substances.

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Word count: 1900 Tables: 3 Figures: 2 References: 40

Access the article online: DOI: 10.5604/00306657.1199991 Full-text PDF: www.otolaryngologypl.com/fulltxt.php?ICID=1199991

Corresponding author: Katarzyna Stańska; Klinika Otorynolaryngologii, Wydział Lekarsko-Dentystyczny Warszawski Uniwersytet Medyczny. Szpital Czerniakowski, ul. Stępińska 19/25, 00-739 Warszawa; e-mail: katarzyna.stanska@gmail.com

Competing interests: The authors declare that they have no competing interests.

Cite this article as: Stańska K., Krzeski A.: The umami taste: from discovery to clinical use; Otolaryngol Pol 2016; 70 (4): 10-15