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Trends in Natural Flavor Enhancer: A Review on Umami Compounds

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Abstract. Flavor enhancers are pivotal in numerous food products in the commercial markets. Among these enhancers, umami flavor compounds stand out for their ability to elicit a pleasurable taste response and elevate the overall sensory characteristics of food. This short review offers insights into incorporating natural ingredients as sources of umami, a cornerstone in enhancing savory flavors while shedding light on emerging trends within the food industry concerning the utilization of these natural ingredients. Furthermore, this review delves into the intricacies of umami taste, encompassing its constituent elements and characteristic profile. In addition to exploring the essence of umami, the study also delves into various technologies instrumental in their creation and processing. These technologies encompass a range of methods, including fermentation, enzyme hydrolysis, acid hydrolysis, the Maillard reaction, water-based extraction, and drying techniques.

1 Introduction

The heightened attention towards natural food additives among consumers and manufacturers can be primarily attributed to heightened health awareness and the inclination towards foods that incorporate natural additives instead of chemical alternatives [1]. Research findings indicate that individuals prefer food products that contain natural additives instead of chemical options, driven mainly by health-related considerations [2]. Moreover, including natural additives has garnered attention due to their various health advantages and synergistic effects. Furthermore, the heightened interest can be attributed to apprehensions regarding chemical additives and previous incidents that have sparked concerns. Consequently, this has facilitated the growing appeal of natural additives among consumers [3,4]. In contemporary times, there exists a prevailing inclination among consumers to favor natural additives in food products as opposed to synthetic alternatives. Nevertheless, despite the potential benefits of using natural additives, the industry encounters several obstacles and constraints alongside contradictory data [5]. Furthermore, evaluating

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the efficacy of natural additives holds significant importance, as shown by [2].

Umami compounds contribute to the taste and flavor of food by providing a distinctive savory flavor and enhancing the overall palatability of the food [6,7]. Umami compounds can function as flavor enhancers, increasing the intensity of other flavors in food. Culinary dishes often incorporate umami-related compounds, regardless of variations in ethnicity, region, and historical context [8]. The umami content of natural ingredients as well as the processing process, dramatically affects the concentration of umami substances produced [9–11]. Flavoring ingredients from natural ingredients can also provide several benefits, in addition to giving umami flavor, they also provide health effects due to the content of secondary metabolites and antioxidant effects that are good for the body [12–14]. This article contains information on natural ingredients as an alternative to synthetic flavoring and the effect of processing on the umami content of natural ingredients. This article also highlights the need for further research on umami substances in local commodities that provide added value to a region.

2 Intricacies of umami taste

The term "glutamate" comes from a compound known as wheat gluten. This came about when Karl Heinrich Ritthausen, a German scientist, researched combining this substance with sulfuric acid. As a result of these investigations, L-glutamic acid, a naturally occurring form of glutamate, was first discovered and identified in 1866. The most prominent elucidation of the characteristics of glutamic acid and its salts was done by Japanese scientist Kikunae Ikeda before 1908. This investigation stemmed from observations relating to the flavor profile of dashi, the base broth in Japanese cuisine. Ikeda stated that the flavor profile of dashi is characterized by a subtle yet distinguishable taste of four primary flavors. This astringent flavor was designated as umami, a term derived from a Japanese adjective, which translates to "delicious". [15] also reported the physical properties of L-Glutamate or MSG in crystalline form (table 1). After Ikeda's initial discovery, subsequent research identified additional umami flavor compounds, including inosinate and guanylate. In 1909, commercial production of monosodium glutamate began under the Ajinomoto brand, known as the premiere umami seasoning worldwide. Today, the brand has significantly expanded its global reach in 35 countries and regions worldwide. Consequently, this has resulted in the wide availability of this additive in households worldwide [16].

Table 1. Some physical and chemical characteristics of Monosodium Glutamate (MSG).

Characteristics	Evaluation
Molecular weight	187,13 g/mol
Color & Odor	White & Odorless
Form	Crystalline powder
Melting point	232°C
Appearance	Solid (Room temperature)
Solubility in water	~740 g/L (25 °C)
pH	slightly acid to neutral (5-8)
Palatability concentration	0,2–0,8%
Dose	60mg/kg body weight

Source : [15,17]

3 Natural ingredients as umami sources

3.1 Amino Acid

Amino acids that contribute to umami flavor include L-glutamic acid (L-Glu), L-aspartic acid (L-Asp), and their sodium [18]. [19] stated that glutamate is essential to plant and animal proteins that provide umami flavor. Free glutamic acid and free aspartic acid impart an umami or savory taste to food [20]. Monosodium glutamate (MSG) is one of the most common forms of free glutamic acid used as a flavoring in foods. Small amounts of glutamate combined with reduced amounts of table salt during food preparation allow less salt to be used during and after cooking. Research results show that adding umami substances can reduce sodium intake by about 30% without reducing the palatability of the food or the level of satisfaction from the meal [21].

The umami compounds of the glutamate type exhibit a standard underlying skeletal structure characterized by -O-(Cn)-O- moiety, where n ranges from 3 to 9. It is essential to acknowledge that the umami flavor is quite pronounced when the value of n falls within the range of 4-6, as Ardö [22] stated. The umami amino acid flavor is perceived as a result of the electrostatic interaction between the NH3+ and COO- groups, creating a five-membered ring structure. The detection of this structure can be facilitated by umami receptors [22].

Numerous commonly consumed food items possess a considerable capacity to generate an umami taste sensation, contingent upon the successful extraction of glutamic acid. The presence of umami compounds in natural components has been observed to consist of amino acids, specifically glutamic and aspartic acids [23]. The data about the concentrations of free glutamic acid in different natural ingredients and processed products is presented in Table 2.

Table 2. Free glutamic acid content of natural ingredients and products.

Ingredients	Free Glutamic Acid (mg/100g)	Ingredients	Free Glutamic Acid (mg/100g)
Meat and poultry :		**Vegetables :**	
Cured ham	337	Tomato (dried)	648
Beef	33	Tomato (fresh)	200
Duck	69	Potato (raw)	102
Chicken	44	Potato (cooked)	180
Egg	23	Broccoli	176
Fish and shellfish:		Corn	130
Sardine	280	Carrot	20
Mackerel	36	Green peas	106
Marinated anchovies	1200	Soy bean	66
Blue mussel	105	**Fruits and nuts Walnut :**	
Oyster	130	Strawberry	45
Algae (seaweeds) :		Grapefruit juice	19
Konbu	1400-3200	Orange juice	21
Laver, nori (Porphyra yezoensis)	1378	Walnut	658
Wakame	9	**Fermented Product :**	
Leave :		Fish sauce	828–1383
Bekkai lan leaves	48	Soy sauce	782–1264
Chaya leaves (powder)	12	Miso	500–1000

Source : [6,24–29]

3.2 Nucleotides

Nucleotides are widely employed in the food and pharmaceutical sectors and are frequently incorporated to augment the taste of food items. Nevertheless, it is essential to acknowledge that the umami flavor is not present in all 5′nucleotides and their derivatives. According to [11], umami flavor can be derived from steroid nucleotides; however, pyrimidine nucleotides do not contribute to the umami taste sensation. The nucleotides that elicit the umami sensation consist of di-sodium adenosine-5´-monophosphate (adenylate, AMP), di-sodium guanosine-5´-monophosphate (guanylate, GMP), and di-sodium inosine-5´-monophosphate (inosinate, IMP) [23]. The data about nucleotides present in different natural ingredients and processed products is shown in Table 3.

A synergistic relationship has been seen between monosodium glutamate (MSG) and inosine monophosphate (IMP) or guanosine monophosphate (GMP). For instance, GMP in isolation has no flavor impact, but when combined with MSG, it yields a pronounced umami taste [30]. Inosinolates, or IMP, are predominantly found in animal-derived dietary sources such as dried sardines, bonito flakes, horse meat, mackerel, tuna, cattle, and chicken. Guanylate (GMP) can only be found in plant food sources, including mushrooms and tomatoes, which are rich sources of this compound [31]. The perception of umami flavor is contingent upon the pH level. Monosodium glutamate (MSG), guanosine monophosphate (GMP), and inosine monophosphate (IMP) are instances of umami chemicals that can be encountered in their salt forms under conditions of neutral pH. The employment of glutamate as a flavor enhancer within a pH range of 5 to 8, encompassing slightly acidic to neutral circumstances, has been substantiated by the findings of [32]. Furthermore, it has been noted that the ionic milieu around the cells of taste buds influences the interplay between the chemicals responsible for producing flavors and the receptor cells.

Table 3. Free nucleutide content of natural materials.

Ingredients	5’IMP (mg/100 g)	5’GMP (mg/100 g)	5’AMP (mg/100 g)
Meat and poultry :			
Beef	70	4	8
Chicken	201	5	13
Fish and shellfish :			
Sardine	193	ND	6
Mackerel	215	ND	6
Marinated anchovies	300	5	ND
Tuna	286	ND	6
Salmon	154	ND	6
Cod	44	ND	23
Vegetables :			
Tomato (sun-dried)	ND	10	ND
Tomato (fresh)	ND	ND	21
Potato (boiled)	ND	2	4
Fungi :			
Shiitake (dried)	ND	150	ND
Craterellus comucopioides	3,97	2,88	0,35

Ingredients	5'IMP (mg/100 g)	5'GMP (mg/100 g)	5'AMP (mg/100 g)
Flammulina velutipes (Enoki)	0,28	0,45	1,48
Seaweed :			
Nori (Porphyra yezoensis)	9	5	52
Leaves :			
Bekkai lan leaves (powder)	1	ND	ND

ND : Not Detected
Source : [25–28,33]

3.3 Organic Acids

Numerous investigations have been undertaken to extract, produce, and analyze umami chemicals. The flavors of succinic acid and theanine have been found to exhibit similarities to umami despite their distinct flavor profiles in comparison to MSG, GMP, AMP, or IMP. Yamaguchi and Ninomiya [16], have found succinic acid and theanine as flavorful constituents in shellfish and tea. Numerous botanical species inherently possess organic acids. This study investigates the impact of succinic acid and malic acid on the umami taste perception in food, specifically focusing on morel mushrooms. The umami flavor of morel mushrooms is mostly derived from several critical flavoring compounds, including glutamic acid, aspartic acid, succinic acid, and (S)-maltic acid 1-O-D-glucopyranoside, as identified by Rotzoll *et al.* [34]. Similarly, in the case of camembert cheese and swiss cheese, the umami flavor is attributed to succinic acid and propionic acid [35]. Organic acid compounds are present in diverse varieties of leaves. Quince (*Cydonia oblonga Miller*) leaves were discovered to contain succinic acid, malic acid, oxalic acid, shikimic acid, and fumaric acid, as reported by [36].

3.4 Umami Peptides

Several peptides have also been confirmed to possess a taste profile reminiscent of monosodium glutamate (MSG). Peptides present in food significantly influence the perception of umami taste, alongside the presence of glutamic acid, aspartic acid, and ribonucleotides. Peptides are oligomers composed of various amino acids, typically ranging from 2 to 50, and are interconnected by peptide bonds [37] (Table 5). Temussi [38] reported that peptides exhibiting an umami taste sensation contain glutamic acid, arranged in the sequence H-Lys-Gly-Asp-Glu-Glu-Ser-Leu-Ala-OH.

Natural-based flavoring has emerged as a prevailing practice in promoting locally sourced commodities that offer a nutritious and umami-rich option. One noteworthy category for examination is the Kalimantan endemic plants, which have played a significant role as a natural flavoring source [39]. The Menispermaceae family encompasses a variety of plant species, such as *Pycnarrhena tumefacta Miers, Albertisia papuana Becc*, and *Pycnarrhena cauliflora* (Miers) Diels [12,32,40]. The findings indicated that plants belonging to the Menispermaceae family possess secondary metabolites, specifically flavonoids, alkaloids, steroids, saponins, and phenolics [12,13,41]. Furthermore, a study by Purwayanti *et al.* [28] demonstrated that the aqueous extract of bekkai lan leaves yielded an umami flavor due to aspartic acid, GMP, and AMP. According to Purwayantie *et al.* [28,42], several compounds, including alanine, oxalic acid, malic acid, gallic acid, sucrose, fructose, glucuronic acid, as well as the elements sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), and phosphorus (P) have been identified as supportive agents for umami flavor components.

Chaya leaves (*Cnidoscolus chayamansa*) also can serve as alternative sources of umami in plant-based applications. These substances include quinic acid, trigonelline, alanyl-tyrosine, leucyl-glycyl-proline, and leucyl-aspartyl-glutamine. Furthermore, Hutasingh *et al.* [43] asserted that this research confirmed three umami chemicals, namely l-glutamic acid, pyroglutamic acid, and 5'-adenosine monophosphate, which were previously identified in chaya leaves. The experiment revealed that the combination of leucyl-glycyl-proline and monosodium glutamate had a synergistic effect, leading to an augmentation of umami taste perception. Apart from umami compounds, chaya leaves are also rich in secondary metabolites, including flavonoids, polyphenols, anthocyanins, tannins, alkylresorcinols, phytosinols, and banzols [29]. Therefore, it is imperative to investigate further the prospective application of indigenous raw materials in harnessing natural components as a viable source of umami compounds, abundant in secondary metabolites and possessing antioxidant properties that promote well-being.

4 Progresses on processing methods of umami substances

In recent years, there has been a significant increase in interest in umami compounds. It is essential to ascertain and investigate efficacious umami processing methodologies to meet the increasingly pressing needs of the food sector. To produce umami, most unprocessed organic foodstuffs must be processed to separate proteins into free amino acids and nucleic acids into free nucleotides. Several methods have been developed to process umami substances. It is essential to recognize that umami flavor is affected by various elements, including pH, temperature, and interactions among different umami ingredients. Therefore, it is critical to effectively manage these influencing parameters during processing using one of the mentioned methods outlined below [11].

4.1 Fermentation

Fermentation is one method that has been developed to process umami substances. This method involves using microorganisms to convert raw materials into desired substances. In the context of umami, fermentation can be used to break down proteins in raw materials into free amino acids and peptides, which contribute to the umami flavor [44–46].

4.2 Enzymatic hydrolysis

To obtain umami components, suitable enzymes such as protease or cellulase can be selected to decompose raw materials' cell walls so that the cell wall's main features can be destroyed, dissolved, and extracted. In addition to cell wall components, some macromolecular proteins are also broken down by enzymes into oligopeptides and free amino acids [47]. The hydrolysis process must be effectively regulated and controlled. If the hydrolysis rate is low, an undesirable bitter taste may result. If hydrolysis is too long, microorganisms may grow and multiply, causing product contamination [48].

4.3 Maillard reaction

The Maillard reaction can contribute to the formation of umami flavor by producing compounds with flavor-enhancing properties [49]. During the Maillard reaction, temperature is considered the main factor affecting the flavor properties of the product. Some studies suggest that 110°C may be a critical temperature that will reduce the bitter characteristics of Maillard reaction products due to the decomposition of bitter amino acids and bitter peptides at that temperature [50,51].

4.4 Acid hydrolysis

This process usually involves heating raw materials in an acidic solution, which breaks down proteins into free amino acids and peptides, contributing to the umami flavor. However, acid hydrolysis has some limitations. For example, this process can produce a bitter taste if the hydrolysis conditions are poorly controlled. In addition, acid hydrolysis can also produce unwanted by-products, such as hydrolyzed sugars and organic acids, which can affect the taste and aroma of the final product. Therefore, it is essential to control the hydrolysis conditions, such as acid concentration, temperature, and time, to ensure optimal results [52,53].

4.5 Water-based extraction

Since umami substances such as umami amino acids and peptides are generally soluble in water, water can be easily used as a solvent to extract umami ingredients from umami raw materials. Previous studies have reported water-based extraction and quantification of umami amino acids and nucleotides from Jinhua and Parma hams, mushrooms, and doenjang [54]. However, these methods require long extraction times and involve multi-step operations; high energy consumption is another drawback of these extraction methods [55].

4.6 Synthesis methods

Synthesis methods, particularly synthesis based on genetic engineering techniques, have been proposed as an alternative to producing umami substances. Although genetic engineering approaches can make safe and hygienic products and work with various raw materials while producing high-quality natural peptides, they have technical limitations, including separation-related difficulties, low yield, high cost, and difficulty in scaling up [56,57]. Therefore, further research is needed for the industrial application of this approach.

4.7 High-temperature and high-pressure processing

High temperature and pressure processing are commonly used in the food industry to extract flavor substances and nutrients from animal bones. This process can promote the breaking of secondary and partial peptide bonds of collagen triple helix, melting collagen molecules, and converting insoluble collagen into soluble proteins, peptides, and amino acids [58]. However, it is essential to control the process conditions, such as extraction temperature, extraction time, material-to-liquid ratio, and extraction pressure. Temperature is the most influential factor [59].

In response to the growing demand for high-quality umami compounds, there is a need for innovative processing methods to fulfill this need effectively. Each approach has different advantages when processing umami compounds derived from various base materials. The selection of a suitable processing method should be based on the characteristics of the raw materials, processing conditions, and product type to achieve optimal processing results. However, research has shown that integrating various processing mechanisms, known as composite processing, can provide superior results in processing umami compounds. According to [11], considering the integrated application of the diverse technologies examined is essential for processing umami compounds. Technologies could result in substantial improvements in production efficiency and overall economic performance of the entire production process.

5 Conclusions

Through continued research on umami knowledge, local food-based natural ingredients with umami properties are expected to be identified. Umami substances, including amino acids (glutamate and aspartate), nucleotides (IMP, GMP, and AMP), umami peptides, and organic acids (succinic acid) contained in natural ingredients are strongly influenced by the concentration of umami substances present in the ingredients as well as the processing method. Simultaneously, efforts will be made to introduce and evaluate new umami processing methodologies. Based on the current state of research, it is anticipated that future advances in umami processing techniques will focus on developing composite processing technologies from existing methods such as fermentation, enzymatic hydrolysis, Maillard reaction, acid hydrolysis, extraction and drying, high temperature and pressure processing, and microwave-based methods.

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