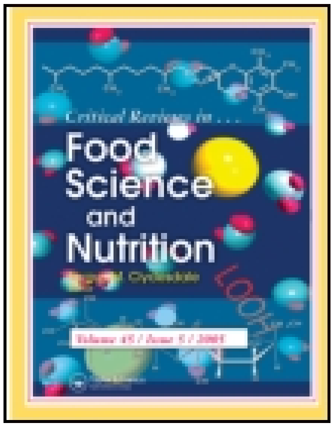

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Umami Taste Components and Their Sources in Asian Foods

P. Hajeb[a] & S. Jinap[ab]

[a] Food Safety Research Centre (FOSREC), Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

[b] Institute of Tropical Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

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Umami Taste Components and Their Sources in Asian Foods

P. HAJEB[1] and S. JINAP[1,2]

[1]Food Safety Research Centre (FOSREC), Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
[2]Institute of Tropical Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

Umami, the fifth basic taste, is the inimitable taste of Asian foods. Several traditional and locally prepared foods and condiments of Asia are rich in umami. In this part of world, umami is found in fermented animal-based products such as fermented and dried seafood, and plant-based products from beans and grains, dry and fresh mushrooms, and tea. In Southeast Asia, the most preferred seasonings containing umami are fish and seafood sauces, and also soybean sauces. In the East Asian region, soybean sauces are the main source of umami substance in the routine cooking. In Japan, the material used to obtain umami in dashi, the stock added to almost every Japanese soups and boiled dishes, is konbu or dried bonito. This review introduces foods and seasonings containing naturally high amount of umami substances of both animal and plant sources from different countries in Asia.

Keywords Asian foods, umami, taste active compounds, glutamate, 5′-nucleotides

WHAT IS UMAMI?

Taste qualities are classified in different ways all over the world. The classification of the four basic tastes, salty, sour, sweet, and bitter was established worldwide in 19th century. The theories proposed earlier were based on the observation rather than on scientific evidence. Umami, the fifth taste, was first identified in 1908 by Dr. Ikeda who isolated glutamate as the source of this taste in a Japanese broth prepared from *kombu* seaweed which is naturally high with glutamate. Umami taste was scientifically introduced as one of the basic tastes in the first international symposium on umami in Hawaii in 1985 (Ninomiya, 2002).

There are three umami substances in nature; monosodium glutamate (MSG), disodium gluanylate (GMP), and disodium inosinate (IMP). The umami substances are originally acids and they exist in the salt form at neutral pH, which usually contains the sodium ion, i.e., MSG, GMP, and IMP (Kurihara and Kashiwayanagi, 1998). There is a synergism between MSG and IMP or GMP; for instance, GMP alone elicits practically no taste, but by mixture of them can obtain a strong umami taste (Kuninaka, 1967). The mixing of glutamate and inosinate deeply boosts the taste of umami. For instance, *konbu dashi* alone does not elicit a strong umami taste, but the sharp umami taste can be achieved by adding bonito flakes or dried sardines containing inosinate (Kurihara, 2009). By cooking beef or chicken, which contains inosinate with vegetables containing free glutamate, the strong umami taste is achieved. Glutamate alone as a taste stimulus is not highly pleasant and does not act synergistically with other basic tastes. When glutamate is given in combination with a consonant, savory odor of vegetables, the resulting flavor which is formed by a convergence of the taste and olfactory pathways in the orbitofrontal cortex is more satisfying (Rolls, 2000). Umami synergy characterizes the interaction among MSG, IMP, and GMP. It amplifies and sustains taste sensations more than any single ingredient. The degree of the multiplication of the umami taste can reach up to eight times the taste of the total of the separate ingredients (Marcus, 2005).

Umami substances have been extracted, synthesized, and evaluated by various studies. Beside the typical umami substances (L-a-amino acids represented by MSG and 5′-ribonucleotides represented by IMP and GMP), other amino acids have also been considered. It has also been claimed that the tastes of succinic acid and theanine belong to umami, although their taste qualities are considerably different from that of the MSG, GMP, or IMP. Succinic acid and theanine were known as taste components of shellfish and tea, accordingly (Yamaguchi and Ninomiya, 1998). Several peptides have also been reported

Address correspondence to S. Jinap, Food Safety Research Centre (FOSREC), Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia. Tel: +603-8946 8393; Fax: +603-8942 3552. E-mail: jinap@food.upm.edu.my; sjinap@gmail.com

to have tastes similar to that of MSG. Acidic oligopeptides rich in hydrophilic amino acid residues, such as Glu-Asp-Glu, Glu-Gly-Ser, Glu-Gln-Glu, and Ser-Glu-Glu have MSG-like taste (Noguchi et al., 1975). A peptide with the primary structure of H-Lys-Gly-Asp-Glu-Glu-Ser-Leu-Ala-OH called beefy meaty peptide with a delicious flavor was isolated from beef meat gravy (Yamasaki and Maekawa, 1980). This peptide was similar to MSG in its ability to enhance the flavor of beef gravy. Inosinate is found only in animal food products such as dried sardines, bonito flakes, horse, mackerel, tuna, pork, beef, and chicken (Yamaguchi and Ninomiya, 2000). Guanylate occurs only in foods of plant origin, especially mushrooms and tomato (Yamaguchi, 1967).

Foods containing umami have been used for centuries. The pizza and bouillon in Europe, the *dashi* and tan broths in Japan and China, and the fish and soy sauces in Southeast Asia are well-known examples of foods with umami sources. Several foods are rich in the umami substances, including vegetables (potato, tomato, mushroom, cabbage, soybean, carrot, and green tea), seafood (fish, prawn, crab, oyster, seaweed, sea urchin, clam, and scallop), meats (beef, chicken, and pork), and cheeses (Ninomiya, 2000). Umami contributes deeply to the characteristic tastes of these foods; when the umami substances are eliminated, the unique taste of the food disappears (Konosu et al., 1987).

In this review, we introduce and discuss foods and seasonings naturally high in umami from different countries around Asia. The materials of this article are collected from the published studies on foods and condiments rich in umami taste or containing umami taste active compounds.

SOURCES OF UMAMI IN THE ASIAN FOODS

Asia is known for its cultural diversity with several ethnic groups and their individual specific cultures. Asian cuisine styles can be broken down into several regional styles which have roots in their cultures. They are divided to East Asian (Japan, China, and Korea), Southeast Asian (Thailand, Malaysia, Indonesia, the Philippines, Singapore, Viet Nam, Brunei, Cambodia, and Laos), South Asian (India, Sri Lanka and Pakistan), Central Asian, and Middle Eastern. Umami is a unique taste to Asian food. There are many traditional and local foods in Asian regions which are rich in umami. In Asia, umami is found in animal and plant-based origin foods; mainly in fermented and dried seafood products, fermented beans and grains, mushrooms and tea. People in any region, however, use different methods to add umami to their foods. For instance, traditional Japanese cooking promote the use of fish and seafood, *konbu* seaweed, *shitake* mushroom, vegetables and soybean products as well as Japanese tea, all of which enhance the umami taste (Tada et al., 2011). Umami taste in China, known as *xian-wei*, is an important part of the spectrum of taste and flavor to generate delicate harmony. There are several types of cuisine in China which are rich in umami such as dried foods, fermented products, seasonings, and soup stocks. The cuisines are very unique as they use a wide variety of ingredients and contain dried ingredients (such as mushrooms), which have a richer concentration of umami than their fresh equivalents. In Korea, the most popilar condiment with umami taste is s*hiokara*, which is fermented fish with salt used either for a side dish or a seasoning.

In Southeast Asia, the main culinary function of fermented products is to provide a salty and umami taste (Mizutani et al., 1987). Malaysia is a multi-ethnic country; therefore, the culinary culture of each ethnic group contributes to the characteristics of Malaysian cuisines (Hutton, 2005). There are several traditional Malaysian fermented condiments used as food flavoring which have strong umami taste and contain considerable amount of free glutamic acid, such as fermented bean and fish and seafood products. The traditional Malaysian fermented condiments are *taucu* (fermented soybean paste), *budu* (fermented fish sauce), *cencaluk* (fermented shrimp), and *belacan* (fermented shrimp paste) (Khairunnisak et al., 2009). Pilipino also uses several traditional fermented food and seasonings made from both animal and plant sources with umami taste such as white soft cheese (*kesong puti*), fermented mustard leaves (*burong mustasa*), fermented rice–fish mixture (*burong isda*), fermented rice–shrimp mixture (*balao-balao*), fish paste (*bagoong*), fish sauce (*patis*), fermented rice cake (*puto*), and soy sauce (*toyo*).

ANIMAL-BASED ORIGIN OF UMAMI SOURCES

Fish and Seafood Fermented Products

In Southeast Asia, the most favored seasonings containing umami are fish sauces. This region is considered as the center of origin for fish sauces and other seafood products. There is an increasing trend in the production and export of this product especially in Vietnam and Thailand. In 2000, for instance, the annual production of fish sauce was nearly 200,000 and 40,576 tones in Vietnam and Thailand, respectively (Kok, 2000). Fermented fish sauces, made by pickling fish and shrimp with salt, are major side dishes and condiments in many dishes. Fish sauce is marketed with various names in different countries; *shottsuru ishiru* or *ikanago-shoyu* in Japan, *aek-jeot* in Korea, *nampla* in Thailand, *nouc-mam* in Vietnam, *patis* in the Philippines, *bakasang* in Indonesia, and *budu* in Malaysia (Tables 1 and 2). Every country has different recipes for making fish sauce. The two major ingredients in fish sauce production are fish and salt, where the ratio between this two is very different depending on the country (Lopetchart and Park, 2002). The fermented fish products used as seasoning are classified into two groups; fish sauce and paste (Ohmori et al., 2011). These products develop umami taste by the decomposed products, amino acids, nucleotides, and salt together with a reddish brown color and a characteristic smell (Otsuka, 1998).

In Japan, fish sauces are traditionally make from salmon, octopus, urchin, and scallop. New types of fish sauce have been developed recently in the northern part of Japan using

Table 1 Free glutamic acid (mg/100 g) in fermented fish and fish sauces from Asian countries

Country	Products (Local name)	Free glutamic acid (mg/100 g)	Reference
Japan	Fish sauce (*Ishiru*/sardine)	1383.12	Sado, 1996
	Fish sauce (Flying fish)	399	Taira et al., 2007
	Fish sauce (Dolphin fish)	387	Taira et al., 2007
	Fish sauce (Deep-sea smelt)	514	Taira et al., 2007
	Fermented fish (*narezushi*)	574.6	Itou et al., 2006
	Fish sauce	1088	Park et al., 2001
	Katsuobushi	1771.2	Kaddoumi et al., 2000
Korea	Fermented fish (*Myulchichot*)	1079.44	Mizutani et al., 1987
	Fish sauce	550	Park et al., 2001
China	Fish sauce	828.4	Mizutani et al., 1987
	Fish sauce	1164	Park et al., 2001
	Fermented fish sauce (*Yu-lu*)	582.91	Jiang et al., 2007
Malaysia	Fish sauce (*Budu*)	948.09	Mizutani et al., 1987
	Fish sauce (*Budu*)	1585	Khairunnisak et al., 2009
Indonesia	Fish sauce (*Bakasang*)	727	Ljong and Ohta, 1995
Thailand	Fish sauce (*Nam-pla*)	620.61	Yoshida, 1998
	Fish sauce	1489	Park et al., 2001
Vietnam	Fish sauce (*Nuoc mam*)	1370	Yoshida, 1998
	Fish sauce	1584	Park et al., 2001
Philippine	Fish sauce (*Patis*)	988.1	Mizutani et al., 1987

innovative methods including the addition of exogenous proteases and *koji* for the promotion of proteolysis. In those new types of fish sauce, they effectively use seafood parts that are currently discarded (octopus and skin) and underutilized fish species (Taira et al., 2007; Ohmori et al., 2011). A new type of fish sauce was produced by Nobuhiko et al. (2001) from two kinds of fish and squid using *koji*-mold, lactobacilli, and yeast in soy sauce fermentation. This fish sauce had a mellow taste and savory aroma without unpleasant smell in comparison with the traditional fish sauces. The amounts of free amino acids especially glutamic acid were in the same range with the traditional Japanese fish sauces.

In Japan, several studies have been done to produce fish sauce without unpleasant smell. They have added different ingredients during the fermentation of fish flesh: addition of pineapple juice (Kataoka et al., 1987); application of bacteria isolated from the fish-sauce mash (*moromi*) (Fukami et al., 2004); proteolysis by pure enzymes, e.g., bromelain (Beddows et al., 1976; Fukuda et al., 1986; Nakano et al., 1986), visceral enzymes (Yoshinaka et al., 1983), soy sauce *koji* (Hayakawa et al., 1993; Funatsu et al., 2000; Dohmoto et al., 2001; Yokoyama et al., 2002; Osako et al., 2005; Uchida et al., 2005), *koji*-mold, lactobacilli, and yeast with adoption in soy sauce fermentation (Nobuhiko et al., 2001), wheat gluten as the base material for *koji* (Indoh et al., 2006) have all been studied. It has been shown that fish sauces made by such methods have a better taste and savory aroma without unpleasant smell in comparison with the traditional fish sauces.

The amounts of free amino acids especially glutamic acid were higher or in the same range with the traditional Japanese fish sauces. Taira et al. (2007) produced high-grade fish sauces from underutilized fish species. They used the flying fish, small dolphin fish, and deep-sea smelt, to produce fish sauce using salt and *koji* mold. The smell of the fish sauce products was lower than that of Vietnamese fish sauce (*nuoc mam*). They were high in sweetness and umami and low in saltiness and bitterness as compared with *nuoc mam*. The contents of total amino acid and organic acid were almost the same as those of soy sauce and *nuoc mam*. All the products contain high levels of glutamic acid which were higher than *nuoc mam*.

Chinese consume many types of fish sauce called *yeesu*. Dark color fish sauce is usually preferred over light colored fish sauce

Table 2 Free glutamic acid (mg/100 g) in shrimp pastes, sauces, and fermented shrimp from Asian countries

Country	Products (Local name)	Free glutamic acid (mg/100 g)	Reference
Korea	Fermented shrimp sauce	420	Kim et al., 2002
China	Shrimp sauce	436.76	Mizutani et al., 1987
Malaysia	Shrimp paste (*Balacan*)	1550.00	Yoshida, 1998
	Shrimp paste (*Balacan*)	4207	Jinap et al., 2010
	Fermented shrimp (*Cencaluk*)	864	Khairunnisak et al., 2009
Indonesia	Shrimp paste (*Terasi*)	1508.56	Mizutani et al., 1987
Thailand	Shrimp paste (*Kapi*)	190.2	Sumino et al., 1996
	Shrimp paste (*Kapi*)	1647.28	Mizutani et al., 1987
Philippine	Fermented shrimp (*Bagoong alamang*)	814.15	—
Vietnam	Shrimp sauce (*Nuoc mam*)	740.15	—

(Lopetchart et al., 2001). One of the traditional fermented fish sauces is *yu-lu* which widely consumed as condiment for cooking in the Southern and Eastern parts of China. It is produced by fermenting salted anchovies and other small fishes (Jiang et al., 2007). This sauce has a strong and complicated umami taste and contains all essential amino acid and many vitamins and minerals (Lopetchart et al., 2001). Nowadays, they also use fish and seafood by-products to produce fish sauce. Soybean *koji* is usually used as inocula to accelerate the fermentation of fish sauce and improve the aroma, nutrition, and color. Study by Xu et al. (2008) revealed that glutamic acid was the major amino acid in the soy sauce produced from squid processing by-product in China and the sauce had pleasant umami taste.

In Taiwan as what in other Asian countries, fish sauce is widely used as a condiment to add flavor to the flatness taste of rice. They use small fishes or fish wastes to produce fish sauces. Shih et al. (2003) proposed fish sauce production using bonito processing by-products. The produced sauce exhibited intense umami taste and high content of glutamate (259.2 mg/100 mL of the fish source).

Fish sauces, known as *nam pla*, are popular fermented foods in Thailand. Their major application is as flavoring of rice dishes. *Nam pla* is produced by the fermentation of anchovies for 6–12 months at a room temperature. In Thailand, anchovies and other small fishes are usually used to make fish sauce (Hjalmarsson et al., 2007). Thai fish sauces contain high levels of peptides, amino acids, and nucleic acids and exhibit a strong umami taste (Ohmori et al., 2011). Thailand is considered one of the leading countries in production and exports of fish sauce (Brillantes, 1999). Content of L-Glu was 32.8 ± 2.6 (mM) in Thai fish sauce.

In Vietnam, 80% of the population regularly consumes fish sauce. Fish sauce in Vietnamese cuisines is the equivalent of salt in the Western cuisine (Mannar and Gallego, 2002). Fish sauce, called *nuoc mam*, is one of the traditional seasoning and condiments in Vietnam. The taste-active components of typical Vietnamese fish sauce consisted of glutamic and aspartic acids, threonine, alanine, valine, histidine, proline, tyrosine, cystine, methionine, and pyroglutamic acid. The most effective compound for the characteristic flavor of fish sauce is glutamic acid which contributes to umami taste of this fermented product. Glutamic acid content of fish sauce reaches 575 mg/100 mL after hydrolysis (Park et al., 2002).

Several types of fermented fish and seafood are used in Indonesia. Same as what in other Southeast countries, fish sauce is one of the main traditional condiments used as flavoring in many Indonesian dishes. The saturated sauce with red chillies, tomato, red onion, garlic, and coconut oil is usually eaten with hot porridge mixtures of rice and vegetables called *tinutuan*. *Bakasang*, the fermented fish sauce of Indonesia, is produced by fermenting whole sardines for about 3–6 weeks in 30–60°C (Ljong and Ohta, 1995). During fermentation, both total soluble nitrogen and total free amino nitrogen are increased. Alanine, isoleucine, glutamic acid, and lysine were reported as prominent amino acids in *bakasang*. High glutamic acid is related to umami taste imparted from *bakasang* (Lopetchart et al., 2001).

Fish paste and sauce are the most popular products in the Philippine due to their salty, cheese-like flavor and appetite-stimulating aroma. Fish sauce, called *patis*, is considered as one of the main seasoning in the Philippine with strong umami taste. Glutamic acid was reported as the main free amino acid in *patis* (Peralta et al., 2008). Fish or shrimp paste is made by the fermentation process of whole fish or shrimp in the presence of 20–25% salt under ambient conditions. Fish sauce is a yellow or clear liquid extracted through the complete hydrolysis of fish/salt mixture for 9–12 months (Lopetchart et al., 2001).

Terasi, a fermented shrimp paste, is another traditional condiment used commonly in Indonesia. It has considerable levels of free glutamic acid and umami taste (Table 2). *Petis ikan* is a concentrated extract made from fish. It is used as a flavor enhancer in various Indonesian dishes. *Petis kupan* is a concentrated clam paste flavored with sugar. It is served with boiled clams and vegetables. *Petis udang* or shrimp paste is produced by boiling the heads and shells of shrimp. It is consumed widely as a seasoning in salad dressings and other dishes in Indonesia. Its content of free amino acids, such as glysine, alanine, and glutamic acid is very high (Yoshida, 1998).

Shrimp paste, called *belacan*, is one of the most popular traditional condiments. It is used as flavor enhancer in many local dishes such as chilli *belacan* (*sambal belacan*), spicy noodle soup (*laksa*), fried rice with belacan (*nasi goreng belacan*), stir-fried chilli paste (*sambal tumis*), sour and spicy fish stew with *belacan* (*asam pedas*), as well as stir-fried water convolvulus with belacan (*kangkung goreng belacan*) (Lee, 2001; Hutton, 2003, 2005). *Belacan* is made from fermented tiny shrimp known as *geragau* or *geragok*. It has salty and umami taste with strong shrimp odor (Adnan, 1984). *Belacan* has a major role in enhancing the taste of Malaysian foods and it is well accepted by all races in the country (Leong et al., 2009). It has been introduced as one of the major umami enhancers in Malaysian cuisines (Jinap et al., 2010). Dishes containing *belacan* show meaty flavor which best represent umami taste. To Malaysian people, food without *belacan* is regarded as tasteless. Adding this fermented product will make the food more flavorful and appetizing. Thus, it has become an essential ingredient in curries and dipping sauces for a more appealing taste (Leong et al., 2009). Glu content were reported 19.87 and 15.85 mg/g in *belacan* and *budu*, respectively (Khairunnisak et al., 2009).

Several types of fermented fish products (e.g., *ishiri, shottsuru, heshiko, narezushi*) are found in Japan. These are produced from fermented fish such as sardines, squid viscera, or other small fish which are seasonally available in large quantities. Some of them are made of lacto-fermented fish with rice or other grains. Mackerel *heshiko* and *narezushi* are representatives of fermented fish products in Wakasa Bay and adjacent areas. Mackerel *heshiko* is produced by salting and fermenting with a large amount of rice bran. Mackerel *narezushi* is produced by fermenting salted chub mackerel with boiled rice (Itou et al., 2006).

Sabazushi is a fermented mackerel produced in Wakayama (Chang et al., 1992). *Saba-narezushi* is made from desalted *heshiko* with boiled rice (Kariya et al., 1990). There are different types of mackerel *narezushi* in Japan which produced using different amounts of salt and fermentation times. The umami characteristic of these products is high which is believed to be produced by the high concentration of extractive components, such as free amino acids and organic acids (Table 1). The study on chemical composition of fish from different Asian countries Park et al. (2001) categorized fish products into three distinct groups from their levels of total nitrogen, total amino acids, total nucleosides and bases, and creatinine or the total of creatine and creatinine. According to their research, Japanese fish sauces are grouped in the high content group with strong umami taste.

The core materials used to obtain umami in Japan are called *dashi*, literally meaning boiled extract. It is made from *katsuobushi* (dehydrated bonito), *konbu* (dried kelp), and dried *shiitake* mushroom (Otsuka, 1998). *Dashi* is a stock used to add umami to almost all Japanese boiled dishes and soups. It is typically made from *katsuobushi* (dehydrated bonito), *konbu* (dried kelp), and dried shiitake mushroom (Otsuka, 1998). However, in Japan, any fish or seafood may be used to make fish stock, or *dashi*, except for bitter and unpalatable fish. A special type of *dashi* made from small dried sardines (*niboshi*) which is often used in daily preparation of *miso* soup. Japanese usually learn the perception of umami taste by taking *dashi* from childhood (Kawasaki et al., 2003). Japanese has also developed a special type of vegetarian *dashi* called *shojin-dashi* (*dashi* from vegetable materials) by combining vegetables such as dried *shiitake* and *konbu*, different beans (soybeans and red beans), dried gourd shavings, ground sesame, walnuts, and sea plants. Dried *konbu* is the most favored by the common people in Japan. *Konbu* is Sun dried on the beach after harvest and used as *dashi* and vegetable in Japan (Otsuka, 1998).

Katsuobushi is made from steamed, heat-dried or smoked, and further dehydrated bonito fillets by growing a particular mold on the surface. *Katsuobushi*, literally meaning hard bonito fillet, was invented long time ago and is said to be the hardest food in the world (Otsuka, 1998). It is the traditional material used for Japanese soup stock. It is known for its high contents of MSG, IMP, and GMP and rich umami taste (Kaddoumi et al., 2000).

Irori paste is the concentrated bonito soup made during *katsuobushi* production. It is the concentrate of the brew remained after boiling the bonito. *Irori* paste is rich in the various types of amino acids and nucleotides (Yoshida, 1998). The rich flavor of umami taste is developed by the synergy between the 5′-nucleotides and glutamic acid contained in *irori* (Yoshida, 1998).

Dried bonito is made using various processes such as boiling, smoke-drying, trimming, and inoculation with moulds. *Arabushi*, dried bonito without trimming and mould inoculation, and *karebushi*, mould-covered dried bonito are two kinds of popular dried bonito consumed in Japan (Kohno et al., 2005). These stocks are very rich with umami substances (MSG and IMP) and other taste-active components, including histidine and lactic acid (Fuke and Konosu, 1991). Manabe et al. (2009) suggested that application of dried bonito stock improves the palatability of salt-reduced foods. They suggested that the characteristic aroma and umami taste of dried bonito prevent the loss of palatability of a low-salt diet. They also found that using a combination of dried kelp and *karebushi*, could contribute effectively to the preparation of palatable salt-reduced foods in Japan. Studies on the difference between taste and aroma components of Chinese and Japanese bouillon and bonito-kelp stock (one of the basic Japanese stocks) showed significant differences in the contents of taste components such as glutamic acid. Chinese chicken bouillons contained more glutamic acid, while Japanese chicken bouillons were richer in IMP (Kazuyo et al., 2005).

Dried fish fillets, known as *migaki-nishin* in Japan, is widely used as an ingredient in savory dishes such as noodles. The study by Azad Shah et al. (2009) showed that changes in lipids during drying effect on the characteristic taste and flavor of *migaki-nishin* increases the umami taste. *Akamoku* is the brown algae used as a food in Japan. It is consumed as boiled where boiling increases free glutamic acid and glutamine content and umami taste of this food (Yoko et al., 2005). Fresh, salted-dried (*karasumi*) and salted-fermented fish roe products (*karashi mentaiko*) are very popular in Japan. The fish roe products are usually high with glutamic acid content and rich in umami taste (Ueda et al., 2009).

Fermented seafood is popular in the Korean diet as well. Typical fermented seafood in Korea is divided into three groups: salt-fermented fish (*jeotkal* or *jeot*), fermented fish with cereals (*sikhae*), and fish sauce (*aekjeot*) (Kim, 1999). Salt-fermented fish is produced by fermentation of the meat, viscera, fish, or shellfish using endogenous hydrolyzing enzymes or microorganisms (Park et al., 1995). In Korea, salt-fermented fish products, such as salt-fermented anchovy and its sauce, salt-fermented sand eel sauce, and salt-fermented shrimp are used as a side dish for steamed rice and added to other traditional foods such as *kimchi* as seasoning. However, in Korea, like in other East Asian countries such as China and Japan, fish sauce has been driven out by soy sauce which has a much milder taste and smell (Kim et al., 2004). Kim et al. (2003) produces salt-fermented sauce from by-products from shrimp processing and compared it with the commercial sauces in Korea market. The proposed sauces showed a 35% higher total amino acid content (mainly glutamic acid and aspartic acid) than commercial salt-fermented shrimp sauce.

According to the study by Park et al. (2001), Korean fish sauces contained low glutamate and high proline, glycine, and alanine which are sweet amino acids. The fish sauces have sweet and mild taste which is different from fish sauces of the other countries. Korean fish sauces contained an intermediate amount of nucleosides. In fish sauces' categories by Park et al. (2001) based on creatinine and other compounds, Korean fish sauce is grouped into intermediate class. *Shiokara* (fermented fish with salt) is one of the condiments most widely used as a side dish or a seasoning in Korea. There are more than 80 kinds of *shiokara* with different names (according to the materials used and the seasonings or spices added) used in this country. It contains amino acids produced by the decomposition of fish protein which develops strong umami taste. *Shiokara* is one of the most important ingredients for preparing *kimchi* (Otsuka, 1998).

Chinese mitten crab is another traditional savory food with a unique pleasant aroma and a delicious taste (Chen and Zhang, 2006). The crab meat is popular for its very *tian* (means sweetness) and *xian* (means umami) taste in Chinese cooking (Naiguang, 2004). Chinese mitten crab was considered to be a luxury food in China, previously. However, it turned into a common food today by advances in the fisheries industry in this country (Yuan, 2005). The study by Chen and Zhang (2007) showed that AMP (75.3 mg/100 g), IMP (34.4 mg/100 g), and GMP (2.3 mg/100 g) are the main flavor compounds of crab meat. Arginine, glycine, alanine, and glutamic acid were high, which account for more than 70% of the total free amino acids. These compounds had strong taste impacts on the crab meat flavor.

Other Fermented Animal Products

Cooked duck products are also popular foods in China. These products are regarded as a delicacy in China due to their delicious flavor. Nanjing cooked duck is one of the traditional Chinese meat products, which is famous for its delicate processing, savory, and tender flavor. Liu et al. (2007) studied changes in taste compounds of cooked Chinese Nanjing duck during processing. They observed that the application of certain processes such as brining, prior to boiling, increased amounts of savory taste compounds. The desirable amino acids possess umami tastes (Asp and Glu) in Nanjing cooked duck were higher than in the control, which could be one of the reasons contributing to the popular taste of Nanjing cooked duck.

According to Chen and Zhang (2007), umami flavor is much stronger in crab than in processed duck meat. Succinic acid contributes more to the impact of umami taste in duck than in crab meat. However, Yamaguchi et al. (1971) reported that 5′-nucleotides contribute more to umami taste in duck than the MSG-like amino acids (Asp and Glu). Chinese usually prefer low-temperature cooking for duck meat as high temperatures result in warmed-over flavor and poor texture due to meat juice exudation (Byrne et al., 2003). Dai et al. (2011) claimed that product treatment at low temperature is preferable due to their light and delicate taste, having lower umami and higher sweetness. However, higher temperature treatment by microwave produced higher levels of umami taste compounds (Dai et al., 2011).

Nham, fermented pork sausage, is a very popular food in Thailand. It is made of fresh lean ground pork, mixed thoroughly with salt, garlic, sugar, chili, and sodium nitrite and traditionally wrapped in small banana leaf packets and fermented within 3–4 days at room temperature (Yanasugondha, 1977). The sour taste of *nham* is the result of lactic acid fermentation. The fermentation depends mainly on the indigenous microorganisms present in the ingredients of *nham.* Fermentation increases the free amino acids content in *nham* which produce umasmi taste in this product. Glutaminases from microorganisms (*W. cibaria* and *L. citreum*) also help to increase glutamic acid production during the fermentation process and enhancing the umami taste (Thongsanit et al., 2009).

PLANT-BASED ORIGIN OF UMAMI SOURCES

Fermented Soybean Products

In East Asian countries, soybean sauces are the main source of umami substance in the routine cooking (Table 3). The main soy sauce producer countries are China, Japan, Korea and Hong Kong with a total production of 135,000 tonnes per year. The manufacture of soy sauce in Southeast Asia regions is much lower with about 30,000 tonnes per year in Thailand, Indonesian and Singapore (FAO, 2004). The origin of soybeans is believed to be Siberia and the northeastern district of China, or northern Vietnam and the Javanese island, Indonesia.

Shoyu is fermented soybean sauce traditionally used in Japanese cooking for grilling, frying, boiling, dressing, and also as dipping sauce for *sashimi* and *sushi* (Otsuka, 1998). *Shoyu* is usually produced from the biochemical breakdown of soybean and wheat components in the presence of salt and using microorganisms which are added in the form of *koji* mold. Soybean components contribute to its umami and unique reddish color, and wheat components give the flavor and coloring (Otsuka, 1998). There are different types of *shoyu* that result from differences in the soybean and wheat composition as well as fermentation processes used in their production (Fukushima, 1989). Three typical forms of *shoyu* are *koikuchi*, *tamari*, and *shiro shoyu. Koikuchi shoyu*, with sharp aroma and a deep brown color, is obtained from equal amounts of soybeans and wheat. *Tamari shoyu*, characterized by greater viscosity and less aroma than *koikuchi shoyu* with a darker brown color, is made using soybeans (the main ingredient) with smaller amount of wheat. *Shiro shoyu* is produced using a relatively high ratio of wheat to soybeans with light yellow to tan color. The *koikuchi* makes up nearly 90% of the Japanese soy sauce (Yokotsuka, 1986). The research by Lioe et al. (2007) showed that salty and umami are characteristic tastes of all types of *shoyu*. Nevertheless, the umami taste intensities of *koikuchi* and *tamari shoyu* were found to be higher than that of *shiro shoyu*.

Tofu, solidified soymilk, is cooked in many ways in Japan. One of the most popular *tofu* dishes is *Hiyayakko*. *Hiyayakko* is raw tofu with minced green onions, topped with sliced dried bonito and soy sauce. Another popular *tofu* dish is *Yu-dofu*, which is the boiled tofu in soup stock. Many Japanese eat it with minced green onions and soy sauce during the winter. Also, it is popular to cut tofu into small cubes and put it into *miso* soup (Yasuda, 2010). *Tofuyo* is a low-salt fermented Japanese *tofu* with a unique fermentation with respect to its

Table 3 Free glutamic acid (mg/100 g) in fermented beans and bean sauces from Asian countries

Country	Products (Local name)	Free glutamic acid (mg/100 g)	Reference
Japan	Soy sauce	782	Yoshida (1998)
	Fermented soy (*Natto*)	136	Yoshida (1998)
	Bean paste (*Haccho miso*)	625	Kawai et al., 2009
	Bean paste (*Sendai miso*)	432	Kawai et al., 2009
Korea	Soy sauce	1264	Yoshida (1998)
	Soy sauce	1117	Lee et al. (2006)
	Soy sauce (*meju*)	3863.7	Kang et al., 2011
	Soybean paste (*doenjang*)	300	Kim and Lee (2003)
China	Soy sauce	926	Yoshida (1998)
	Fermented soy (*Douchi*)	476	Yoshida (1998)
	Tufu	102.9	Han et al., 2004
	Sufu	101.2	Han et al., 2004
Malaysia	Fermented soybean paste (*taucu*)	1902	Khairunnisak et al., 2009
	Oyster/mushroom soy sauce	4358	Khairunnisak et al., 2009
	Thick Soy sauce	440	Khairunnisak et al., 2009
	Thin soy sauce—salty	2032	Khairunnisak et al., 2009
	Thin soy sauce—sweet	2069	Khairunnisak et al., 2009
Philippine	Soy sauce	412	Yoshida (1998)

soybean proteins having undergone limited hydrolysis by proteinase in the presence of ethyl alcohol originating from *awamori* (distilled liquor). This is a new type of tofu made from an alkaline serine proteinase with high soybean–milk-coagulating activity isolated from *Bacillus pumilus*. The soybean proteins are digested into peptides and amino acids during maturation. Yasuda (2010) stated that the amount of free glutamic acid and aspartic acid is greatly related to umami taste of this product.

Miso is fermented and salted soybean paste made from steamed, mashed, and mixed raw soybean with an amount of steamed rice or wheat. The mixture is fermented in a warm storage house after *miso* bacteria have been sprayed onto the mash. The matured, fermented soybean paste, then becomes *miso* in paste form. Although it is used primarily as a seasoning, *miso* soup and *miso* flavored pickles are very popular in Japan. *Miso* are classified according to the different ratios of raw material used; soybean *miso* (made from soybean alone), rice *miso* (made from rice and soybean), and barley *miso* (made from barley and soybean). Rice *miso* accounts for 80% of the *miso* consumed by the Japanese (Yamabe et al., 2007).

Nonsalted fermented beans are another type of fermented bean products in Japan called *natto*. The nonsalted fermented bean products are used in a similar way as shrimp paste is used in other Asian countries. *Natto* has been popular in parts of Japan as a flavoring, especially as topping on rice for breakfast. It is usually eaten with rice and noodles and mixed to flavor vegetables, seafood, and meat. Two kinds of *natto* are *itohiki natto* from the bacterium *Bacillus natto* which is more common and *hama natto* which is similar to *miso* but sweeter and fermented with *Aspeigillus oryzae* (Norris, 2007). According to Yoshida (1998), the fermentation time for Japanese nonsalted beans is shorter than for other fermented bean products. However, the glutamic acid content is lower than in other products (Table 3). Japanese pickles are fermented vegetables with different kinds such as bran pickles, salt pickles, and *sakekasu* (Japanese wine lees) pickles. Japanese pickles are also high in umami taste. The umami taste is improved by suitable weight usually applied to the vegetables during fermentation (Kumakura, 2011).

Fermented soybean foods are important component of Korean diet also. *Doenjang* (soybean paste), *kochujang* (hot pepper soybean paste), *cheonggukjang* (fermented soybean paste by Bacillus), *eoyukjang* (mixed soy sauce), *kanjang* (soy sauce), and *meju* (fermented soybean) are the most frequently consumed fermented soybean foods in Korea. These products are very rich in umami taste (Table 3). *Doenjang* is a fermented soybean paste used as soup base and as a dipping sauce for vegetables and meat in Korea (Joo et al., 1992). Study by Kim and Lee (2003) showed that umami taste of this product is directly related to high concentrations of glutamic acid and aspartic acid. Kim et al. (2010) investigated the sensory profiles of *doenjang*, to understand consumers' acceptability of different types of *doenjang* and to identify the sensory characteristics that drive consumer acceptability of this product. The commercially modified *doenjang* was characterized with strong sweet and umami tastes; which were introduced as reasons people liked this Korean soy product. Recently, Rhyu and Kim (2011) reported that the umami taste characteristics of *doenjang* is from the low molecular weight acidic peptides (MWP500<1000) naturally produced during the fermentation of soybeans. They introduced proteolytic peptides, with higher molar ratio of bound-type Glu and Asp, as important contributors to umami taste of this product.

Kochujang is produced by cooking and mashing and fermenting the mixture of soybeans, grains (rice and others), hot pepper flours. Fermentation will produce strong umami taste of this product (Shin et al., 2001). *Cheonggukjang* is a traditional soybean fermented food that is fully fermented within 2–3 days. It represents a particular quality characteristic caused by some microorganisms (e.g., *Bacillus subtilis*) showing palatable umami taste and a unique smell due to the protein generated by protease. Large amounts of free amino acids are generated in its fermentation process which affects the taste of *Cheonggukjang* (Santos et al., 2007). Baek et al. (2010) reported that glutamic acid is one of the major amino acids found in this fermented product, which is highly correlated to its strong umami taste. At the final fermentation stage, the content of glutamic acid was 10 times greater than that at the start of fermentation. *Cheonggukjang* is a sticky viscous material which is similar to Japanese *natto*. Korean *Cheonggukjang* are usually used in stews and mixed with other foods (Kim et al., 1998).

Mixed soy sauce (*eoyukjang*) is one of the Korean traditional fermented soy sauces consumed as condiment for cooking. Mixed soy sauce is different from soy sauces produced in other countries. It is used as condiment to flavor soup and prepared foods (Kim and Lee, 2008). Mixed soy sauce is produced by fermenting meats and fishes preconditioned with high concentrations of salt. By fermentation and hydrolysis of the fishes and meats protein, free amino acid, peptides and ammonia will be produced. High concentrations of salt controls pathogenic microorganism growth and it also results in a desirable taste and aroma. Consequently, mixed soy sauce provides the strong and complicated umami taste which is stronger than that of soy sauce (Chae and Lee, 1990).

Eoyukjang, is a traditionally fermented soybean food, manufactured with fish and meat as well as fermented soybean (*meju*). Yoon et al. (2007) characterized the volatile components in *eoyukjang*; it was 36 components, including aliphatic hydrocarbons, acids, ketones, phenols, alcohols, pyrazines, pyrones, and furanones, miscellaneous components and 20 aroma-active compounds. *Meju* is a block of crushed steamed fermented soybean, which is used to produce other Korean-style fermented soy foods such as *doenjang* and *kanjang*. Fermentation causes accumulation of amino acids known to be related to the unique taste characteristics of Korean fermented soybean (Ardo, 2006). Especially, the content of glutamic acid providing the most representative taste (umami taste) of fermented soy foods, increased 52 times greater than the levels of glutamic acid measured in nonfermented soybean in 60 days of fermentation of *meju* (Kang et al., 2011). *Miso*, a paste-like condiment made by fermenting soybeans with salt and *koji*, taken as the starter in Korea, is believed to be originated in ancient Korea. It is also used extensively as a side dish or as a seasoning in different parts of Korea (Otsuka, 1998).

Soy sauce is also frequently consumed in Vietnam. Like fish sauce, it has been used as an all-purpose seasoning for many years. This fermented product also contain high umami (Fidler et al., 2004). Different types of fermented soy product are used in every-day meals of Malaysians. They are fermented soybean paste (*taucu*), *tufu*, and soy sauces. Two different types of soy sauces are consumed by Malaysians; thick soy sauce and thin salty soy sauce, which both contain high free glutamic acid (Khairunnisak et al., 2009). Glu content reaches 19.02 and 43.58 in fermented soybean paste and soy sauces, respectively.

Soy sauce, called *kecap* in Indonesia, is a Chinese type of soy sauce. However, it is influenced by local Indonesian cooking style (Roling et al., 1994). It is produced using soybeans (black or yellow soybeans) as the only ingredient and a two-step fermentation; the mold fermentation and the brine fermentation at a high concentration of salt (Apriyantono et al., 2004). There are two types of Indonesian soy sauces; *kecap manis* (a thick soy sauce with sweet taste) and *kecap asin* (the common light soy sauce with salty taste) (Roling et al., 1994). Study on the taste active compounds of Indonesian soy sauce showed that the umami taste compounds are in the fraction with a molecular weight of less than 500 Da (Lioe et al., 2004a, 2004b). It has been reported that other than L-a-glutamic acid and sodium salt, L-phenylalanine and L-tyrosine are also present in Indonesian soy sauce; which they are responsible for the intense umami taste of soy sauce as well (Lioe et al., 2004b, 2005).

Chinese usually use a lot of umami condiments in their foods. Several varieties of soups are made by using umami seasoning in China (Nakayama and Kimura, 1998). Soy sauce, known as *chiang-you* in China, is a dark-brown liquid with a salty taste and sharp flavor. The history of soy sauce goes back over 3000 years. The origin of soy sauce is generally considered to be in China and it was brought to East Asian countries by the Chinese immigrants (Xu, 1990). It has been used as a table condiment as well as all purpose seasoning in the preparation of foods in oriental countries from ancient time. To produce *chiang-you,* the *koji* is mixed with brine and then stored for a period of time. The special flavor of soy sauce, which composed of the umami taste and an aromatic odor, is produced by enzymatic degradation and maturation during the mash phase. Several types of soy sauces are produces in China that are different in the salt content and moisture of the mash, temperature, and the period of fermentation (Xu, 1990). In China, there are two main categories of soy sauce based on their processing which are light or fresh soy sauce (*shengchou*), and dark or old soy sauce (*laochou*). *Shengchou* is a kind of thin, opaque, and lighter brown fermented soy sauce. This sauce is mainly used as seasoning. *Laochou* is a kind of darker and slightly thicker soy sauce, which is mostly used for cooking because its flavor develops during heating. The main difference of the processes between light and dark soy sauce is that a further process, including adding caramel color, drying, and condensation under natural conditions, is needed after fermentation for light soy sauce (Yang et al., 2001). However, there is no study on the comparison of these products in terms of umami taste active compounds.

As with other Southeast Asian countries, soy sauce is used as a condiment or seasoning in Thailand. Thai soy sauce is called *see-ieu* (O'Toole, 1997). It has a long history in development of its manufacture and consumption in this country (Valyasevi and Rolle, 2002). Thai soy sauce is a kind of Chinese-type soy sauce which made of less wheat compared to Japanese soy sauce (Wanakhachornkrai and Lertsiri, 2003). *Aspergillus oryzae* is usually used for in the fermentation of soy sauce *koji* production in Thailand (Lotong, 1998). There is a variation in Thai soy sauces based on the production method employed, as well as raw materials and strains of microorganism used. Therefore, variation and complexity of soy sauce flavor characteristic from various origins is obvious (Nunomura and Sasaki, 1993). *Thua nao*, a popular traditional fermented soybean, used as seasoning and flavor enhancer in northern Thailand. *Bacillus subtilis* is the main fermenting bacteria in these products, and, during fermentation, proteolytic degradation occurs as the major activity in liberating free-amino acids to the products (Dajanta et al. 2011). The conventional production method of *thua nao* is soaking, boiling, and fermenting soybean. A sufficiently fermented *thua nao* is covered with a slimy substance, brownish in color with ammonia odor (Chukeatirote et al., 2006). Dajanta et al. (2011) examined the free amino acid content in fermented and unfermented *thua nao*; the fermented products had higher concentrations of free amino acid than the unfermented counterpart. The umami attribute of *thua nao* came from acidic free amino acid.

Sufu or *fu-ru* in Chinese is a fermented soybean food originated in China. It is a soft creamy cheese-type product made from cubes of *tofu* (soybean curd) by the action of a mould (Steinkraus, 1996). It has been widely consumed by Chinese as a salty appetizer. There are different types of *sufu* produced in China (Wang and Du, 1998). The most popular type is the mould-fermented *sufu* (Han et al., 2001). Based on the color, *sufu* are classified into red, white, and gray sufu, which are mainly based on the different ingredients of dressing mixtures in the ripening. Ripening of *sufu* usually takes 3–6 months when hydrolysis of protein occurs. During this stage, protein is hydrolyzed and the flavor and umami taste increased (Han et al., 2003). Study by Han et al. (2004) showed that the content of acidic amino acids (i.e., glutamic acid, aspartic acid) is increased during ripening. Total FAA in red sufu increased from 28 to 88 mg/g (8% salt), 28–63 mg/g (11% salt), and 26–42 mg/g (14% salt) during ripening in 80 days. The levels of free Glu increased from 7.2 to 21.3 (8% salt), 6.5 to 14.4 mg/g (11% salt), and 6.1 6.8–9.3 mg/g (14% salt) during ripening.

Mushrooms

Shiitake, types of mushrooms which grow on hardwood logs, is very much favored in Japan and other East Asian countries (Otsuka, 1998). Dried shiitake mushroom is consumed after rehydrating and give a unique and pleasant flavor and texture to meals, especially soups and sauces. It has become increasingly popular to cultivate them on sawdust substrates on an industrial scale in Japan, China, and Taiwan. However, it is believed that the mushroom grown on sawdust is inferior in the taste to those cultivated on logs. The umami components are higher in the *sawdust-shiitake* as compared with log-shiitake (Tabata et al., 2006).

Edible mushrooms are commonly used as foods and flavoring substances and also traditional Chinese medicines. Dried *shiitake* mushroom is often used for Chinese stocks and dishes. The GMP content of dried *shiitake* is three times more than that of fresh *shiitake* (Fuke and Shimizu, 1993). Button mushroom is also a mushroom commercially available and consumed widely in China. It has high culinary and commercial value because of its flavor properties (Tsai et al., 2007). Glu and 5′-IMP were identified as the major taste-active component in button mushroom (Chen, 1986; Li et al., 2011). The effect of cooking methods on the flavor of mushroom soup made from bottom mushroom was studied by Li et al. (2011). Their study indicated that microwave cooking mushroom soup contained higher levels of free amino acids and 5′-nucleotides, due to short cooking time and different heat penetration as compared with boiling or autoclave. Glu content decreased from 21.24 ± 0.06 in control to 17.12 ± 0.08 (mg/g) in microwave cooked soups. However, the loss of Glu during cooking was more after boiling or autoclave the soup. The contents of 5′-AMP and 5′-AMP increased from 0.173 ± 0.005 to 0.377 ± 0.006 and 0.106 ± 0.002 to 0.767 ± 0.007 (mg/g), accordingly.

Shiitake mushroom is a traditional delicacy in Korea as well (Stamets, 1993). It is commonly used as food in Asian countries and also as a traditional Chinese medicine. The predominant flavor of this mushroom is the umami taste which is related to an overall flavor perception induced by MSG, glutamic acid, and 5′-nucleotides (Bellisle, 1999). Lin et al. (2008) proposed substitution of shiitake for wheat flour to make bread. Examination of bread quality (specific volume, color and sensory evaluation, and taste components including proximate composition, soluble sugars, free amino acids and 5′-nucleotides) in *shiitake* stipe bread were compared with those of white bread. The umami intensities of 100 g of white bread and 5% shiitake stipe bread were equivalent to those given by 0.054 and 3.238 g MSG, respectively. The umami intensity of the 5% shiitake stipe bread was considerably higher than white bread.

Maitake mushroom is a white-rot mushroom found in the wild on dead stumps of broad leaf trees such as oak and chestnut. It has high production and consumption in Japan (Ohashi, 2000). Japanese believe in its medicinal properties (Ohtsuru et al., 1999). Study by Tabata et al. (2004) showed that umami tasting compounds are high in this mushroom especially those cultivated on logs exposed to the Sun. Pine mushroom is another type of mushrooms commonly consumed in Korea. Cho et al. (2010) identified the umami-taste active components of different grades and different parts of pine mushrooms from Korea. The contents of umami-taste active free amino acids, such as aspartic acid and glutamic acid, were high in second-grade mushrooms. Also, the contents of 5′-nucleotides were highest in pine–mushrooms of second grade. The contents of umami-taste active amino acids and 5′-nucleotides were higher in the pileus than in the stipe of pine–mushroom. Equivalent umami concentration values of pine–mushrooms ranged from 13.26 to 204.26 g per 100 g (Cho et al., 2010).

Mushrooms are highly appreciated as a centerpiece of Taiwanese cooking (Yang et al., 2001). Different types of fresh mushrooms are available in the Taiwan market, such as clitocybe, ferulae, and gray tree oyster mushroom. Tsai et al. (2009) reported that three types of mushrooms possess highly intense umami taste with high content of glutamate and 5′-nucleotides. *Phellinus linteus* is a tan-yellow-colored mushroom which grows on mulberry trees. It has been used as food and traditional medicine in Taiwan, China, Korea, Japan, and other Asian countries. The contents of MSG-like components and 5′-nucleotides in *Phellinus linteus* were 1.76–8.89 and 1.89 to 7.59 mg/g, respectively. Liang et al. (2009) determined the umami content of fermented adlay and rice by *P. linteus*. Contents of free amino acids and 5′-nucleotides were high. Phellinus fermented products possessed high level of umami taste. The contents of MSG and total 50-nucleotides were as high as 917.17 g/100 g and 1.74 mg/g in these fermented products. Common mushrooms (button mushrooms), *shiitake*, oyster mushrooms, ear mushrooms, winter mushrooms, and paddy straw mushrooms are also popular in Taiwan (Chang, 1999). They are used as a food or food-flavoring agent due to their unique and delicate flavor. The taste of edible mushrooms is primarily due to the presence of some water-soluble substances, including 5′-nucleotides, free amino acids and soluble sugars and polyols (Mau, 2005). Some of the mushrooms are commercially available in the form of canned mushrooms for consumption. However, the sensory evaluation of canned mushrooms showed that the umami taste of canned mushrooms is relatively weak due to few remaining taste components (Chiang et al., 2006). There are other types of mushrooms commercially available in Taiwan, namely *maitake*, morel, and termite mushroom which also contain high amounts of free amino acid. *Maitake* is also called the king of mushrooms, and the hen of the woods (Stamets, 1993). The MSG-like components and total 5′-nucleotides of these mushrooms are very high and they possess intense umami taste (Tsai et al., 2006). Contents of total 5′-nucleotides and MSG-like components in these mushrooms were as high as 26.19 and 6.51 mg/g, respectively. Several special mushrooms are also commercially available in Taiwan. Mature basket stinkhorn is a mushroom that consists of a conical to bell-shaped cap on a stipe, with a large lace-like veil flaring out from beneath the cap (Stamets, 1993). Lion's mane is another mushroom composed of downward, cascading, nonforking spines (Stamets, 1993). The giant mushroom (called white *matsutake* in Japan) is remarkably large compared to other edible mushrooms. Contents of flavor 5′-nucleotides were high in white *matsutake*, moderate in basket stinkhorn, and low in lion's mane and *maitake* (Mau et al., 2001). Levels of total 5′-nucleotides and MSG-like components were reported as high as 13. 9 and 1.09 mg/g, respectively.

Several types of medicinal mushrooms are also available in Taiwan. They are traditionally valuable as folk medicines and functional foods (Wasser and Weis, 1999). *Ling chih* or *reishi* is one of the commercially available medicinal mushrooms in Taiwan (Stamets, 1993). It has varnished dark red fruit body with a circular or kidney-shaped cap. *Sung shan ling chih* is another medicinal mushroom, which is similar to *ling chih* in appearance. Though, *sung shan ling chih* is thicker than *ling chih*. *Yun chih* is typically in groups, rows, tiers, shelving masses, or overlapping clusters on logs, stumps and fallen branches of dead hardwoods. Mau et al. (2001) reported that owing to the low contents of MSG-like components (Asp and Glu), the umami taste of these mushrooms mainly depends on contents of flavor 5′-nucleotides. The content of total 5′-nucleotides reached as high as 31.9 mg/g.

Kimchi is a representative traditional food in Korea and a type of vegetable product that is the unique complex lactic acid fermentation. It has a unique umami taste which is not included in raw materials, such as red pepper powder, garlic, ginger, salted fish, and Chinese cabbages (Kim and Shin, 2008). The characteristic taste and flavor of *kimchi* is produced by various species of lactic acid bacteria involved during its fermentation (Kim et al., 2005). During the fermentation, various organic acids and amino acids are produced, which they contribute to the sensory properties of *kimchi* (Cho et al., 1998). *Kimchi* has recently become popular in other countries. Kim (2006) compared the taste preference between the Korean and Japanese using a sensory evaluation. He showed that Koreans have preference for the traditional taste of *kimchi*, while Japanese do not. Japanese showed a higher preference for *kimchi* with a mild taste for the powdered hot pepper and garlic.

Tea

Green tea is traditionally preferred as one of the most popular beverages in Japan. The *mat-cha*, literally means powdered tea, is a special type of green tea made from hand-picked, high-grade Japanese tea. It has a typical rich umami-like taste besides fresh vegetable-like and green odor (Kaneko et al., 2006a). By removing the amino acids from infusions of green tea and sensory analysis of the remaining tea extract depleted in amino acids, Nakagawa (1975) showed that approximately 70% of the umami taste intensity of green tea is due to amino acids. Theanine was introduced as the main free amino acid component of tea (more than half) and the major umami component of tea (Suzuki et al. (2002). High-quality Japanese green tea called *Maccha* or *Gyokuro* contains 1.5–2% of theanine per dry weight (Goto et al., 1996). Besides L-glutamate, the theanine (5-*N*-ethylglutamine) was also reported as a key contributor to the umami taste of green tea (Sakato, 1950; Yamada et al., 2009). Adenosine 5′-monophosphate (AMP) was also identified as umami-tasting compounds and proposed to synergistically enhance the taste of monosodium L-glutamate (Kuninaka, 1960; Yamaguchi, 1967).

Narukawa et al. (2008) also reported the synergy between L-theanine and IMP for enhancement of umami taste of Japanese green tea. Kaneko et al. (2006b) identified the compounds contributing to the umami taste of Japanese green tea using molecular and sensory studies. Based on their research, L-theanine, succinic acid, 3,4,5-trihydroxybenzoic acid (gallic acid), and (1R,2R,3R,5S)-5-carboxy-2,3,5-trihydroxycyclohexyl-3,4,5-trihydroxybenzoate (theogallin) are umami-enhancing compounds in the green tea beverage. Using sensory studies, they showed that these compounds are able to raise the umami intensity of sodium L-glutamate proportionally. Study by Kaneko et al. (2006a) revealed that the *matcha* extract contained not only umami-like taste compounds but also umami enhancing compounds; (1R,2R,3R,5S)-5-carboxy-2,3,5- trihydroxycyclohexyl 3,4,5-trihydroxybenzoate (known as theogallin). It enhanced the umami intensity of MSG.

Tea is one of the traditional beverages in China as well. The primary Chinese tea products are categorized into six types, i.e., green tea, white tea, yellow tea, oolong tea, black tea, and dark tea. They are different in their processing procedure, especially the degree of fermentation (Lin et al., 2012). Green tea is the favorite type consumed in China. The harmony of astringency and umami is crucial to tea flavor (Huang et al., 2007). Free amino acids are seen as the main biochemical components influencing tea quality and as the major contributors to the umami of green tea. Theanine, the predominant amino acid in tea infusions, is primarily responsible for umami taste of green tea (Ruan et al., 1998, Kato et al., 2003). Kato et al., (2003) reported 1475 mg theanine in 100 g of green tea leaves.

CONCLUSION

Umami in Asian foods involves long tradition and foods high in umami substances are widely consumed. The umami taste of the foods is produced naturally in the cuisines made both from animal and plant sources. Glutamate in Asian foods is mainly from fermented sauce and paste made from fish, soybeans and vegetables, inosinate is from fish, seafood and meat, whereas guanylate is mainly from mushroom. Unique food recipes which contain ingredients having different types and high amount of umami substances, and preparation that enhance the release of umami substances have made Asian food not only nutritious but also delicious. The umami substances from these ingredients would enable us to expand the recipe into many different and new types of food cuisines in Asian countries and also in other parts of the world.

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