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Non-volatile taste components of canned mushrooms

Pei-Dih Chiang, Chih-Tai Yen, Jeng-Leun Mau *

Department of Food Science, National Chung-Hsing University, 250 Kuokuang Road, Taichung 40227, Taiwan, ROC

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Abstract

Three species of canned mushrooms are available in Taiwan, including *Agaricus bisporus*, *Volvariella volvacea* and *Flammulina velutipes*. The non-volatile taste components of fruit bodies and broth in cans were studied. Mushroom cans of *V. volvacea* and *F. velutipes* had similar weights whereas the cans of *A. bisporus* were lighter. Contents of soluble sugars and polyols were in the range of 22.9–30.9 and 5.62–14.2 mg g^{-1} for fruit bodies and broth, respectively. Contents of total free amino acids were in the descending order of *F. velutipes* (247 and 146 μg g^{-1}) > *A. bisporus* (42.8 and 33.3 μg g^{-1}) > *V. volvacea* (27.2 and 12.4 μg g^{-1}) for fruit bodies and broth, respectively. Three mushrooms were considerably different in their profiles of free amino acids. γ-Aminobutyric acid was found in the canned mushrooms. As compared with other taste components, contents of monosodium glutamate-like components were relatively lower. Contents of flavour 5′-nucleotides were in the range 14.8–36.5 μg g^{-1}. Equivalent umami concentration (EUC) values were in the range of 0.10–13.2 mg MSG/100 g and in the descending order of *F. velutipes* > *A. bisporus* > *V. volvacea*. However, EUC values were low and insignificant in canned mushrooms.

Keywords: Canned mushrooms; Soluble sugars; Free amino acids; 5′-Nucleotides

1. Introduction

Common mushrooms, shiitake, oyster mushrooms, ear mushrooms, winter mushrooms and paddy straw mushrooms are popular in the world (Chang, 1999). Among them, common, winter and paddy straw mushrooms are also available in the form of canned mushrooms for consumption. Common mushrooms [*Agaricus bisporus* (Lange) Imbach], also called button mushrooms, are cultivated throughout the world. Paddy straw mushrooms [*Volvariella volvacea* (Bull. ex Fr.) Sing.], also called Chinese mushrooms, are widely cultivated in China and Southeast Asia (Mau, Chyau, Li, & Tseng, 1997). Winter mushrooms [*Flammulina velutipes* (Curtis: Fries) Sing.], also called enokitake and golden mushrooms, are notable for their abnormal feature of small caps and long stipes (Stamets, 1993).

Mushrooms have long been used as a food or food-flavouring material due to their unique and subtle flavour. The typical flavour of mushrooms consists of non-volatile components (Litchfield, 1967) and volatile compounds (Maga, 1981). The taste of edible mushrooms is primarily due to the presence of several small water soluble substances, including 5′-nucleotides, free amino acids and soluble sugars and polyols (Litchfield, 1967). The taste components of mushrooms, including fruit bodies and mycelia, have been extensively studied and their equivalent umami concentrations were calculated (Mau, 2005). However, the profile of taste components in canned mushrooms was not available. Accordingly, this research was designed to analyze the non-volatile taste components in canned mushrooms of *A. bisporus*, *V. volvacea* and *F. velutipes*.

* Corresponding author. Tel.: +886 4 2285 4313; fax: +886 4 2287 6211.
E-mail address: jlmau@dragon.nchu.edu.tw (J.-L. Mau).

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2. Materials and methods

2.1. Sample preparation

Commercial cans #4 of *A. bisporus*, *V. volvacea* and *F. velutipes* were purchased from Save & Safe Hypermarket, Dali City, Taichung County, Taiwan. For each mushroom, three cans were opened and drained in a stainless steel mesh colander for 2 min. Afterwards, both the separate fruit bodies and broth were weighed. Degrees Brix and pH value of broth were measured using a hand refractometer (N-1α, Atogo Co., Tokyo) and a pH meter (Sp-701, Suntex Instruments Inc., Tapei, Taiwan), respectively. Fruit bodies were blended with an equal amount of deionized water for 45 s. The homogenized mushroom slurry and broth were stored at −4 °C before analyses.

2.2. Soluble sugar or polyol assay

Soluble sugars or polyols were extracted and analyzed as described by Ajlouni, Beelman, Thompson, and Mau (1995). Mushroom slurry or broth (20 g) was extracted with 100 ml of 80% aqueous ethanol (95% pure, Taiwan Tobacco & Wine Monopoly Bureau, Taipei). This suspension was shaken for 45 min at room temperature and filtered through Whatman No. 4 filter paper. The residue was washed five times with additional 25 ml portions of 80% ethanol. The combined filtrate was then rotary-evaporated at 40 °C and redissolved in deionized water to a final volume of 10 ml. The aqueous extract was passed through a Millex-HV filter unit (13 mm, Millipore, Billerica, MA), and filtered using a 0.45-μm PVDF filter (Millipore) prior to injection into a high-performance liquid chromatograph (HPLC).

The HPLC system consisted of, a Shimadzu LC-10AT*VP* pump, a Rheodyne 7725i injector, a 20 μl sample loop, a Shimadzu RID-10A detector, and a Phase Sep-NH_2 column (4.6 × 250 mm, 5 μm, Phase Separation Inc., Norwalk, CT). The mobile phase was acetonitrile (LC grade, Tedia Co., Fairfield, OH)/deionized water, 85:15 (v/v) at a flow rate of 1.3 ml min^{-1}. Each sugar or polyol was identified using the authentic sugar or polyol (Sigma Chemical Co., St. Louis, MO) and quantified by the calibration curve of the authentic compound.

2.3. Free amino acid assay

Mushroom slurry or broth (5 g) was shaken with 50 ml of 0.1 N HCl (Union Chemical Co., Hsinchu, Taiwan) for 45 min at ambient temperature and filtered through Whatman No. 4 filter paper. The filtrate was then passed through a Millex-HV filter unit (13 mm), and filtered using a 0.45-μm PVDF filter. This filtrate was mixed with *o*-phthalaldehyde reagent (Sigma) in an Eppendorf tube, shaken to facilitate derivatisation and then immediately injected onto HPLC.

The HPLC system was the same as for sugar analysis but included a Hitachi L-7485 fluorescence detector with fluorescence excitation at 340 nm and emission at 450 nm, and a LiChrospher 100 RP-18 column (4.6 × 250 mm, 5 μm, Merck, Darmstadt, Germany). The mobile phases were A, 50 mM sodium acetate (pH 5.7) containing 0.5% tetrahydofuran; B, deionized water; and C, methanol. The gradient was A:B:C (80:0:20–33:0:67 for 0–38 min, 0:33:67 for 38–40 min, and 0:100:0 for 40–43 min). The flow rate was 1.2 ml min^{-1}. Each amino acid was identified using the authentic amino acid (Sigma) and quantified by the calibration curve of the authentic compound.

2.4. 5′-Nucleotide assay

5′-Nucleotides were extracted and analyzed as described by Taylor, Hershey, Levine, Coy, and Olivelle (1981). Mushroom slurry or broth (5 g) was extracted with 25 ml of deionized water. This suspension was heated to boiling for 1 min, cooled, and then centrifuged at 11,800*g* for 15 min. The extraction was repeated once with 20 ml of deionized water. The combined filtrate was then evaporated, and filtered prior to HPLC injection in the same manner as in soluble sugar or polyol assay.

The HPLC system consisted of a Hitachi L-6000 pump, a Rheodyne 7161 injector, a 20-μl sample loop, a Hitachi D-2500 chromato-integrator, Shimadzu UV detector and a LiChrospher 100 RP-18 column (4.6 × 250 mm, 5 μm, Merck). The mobile phase was 0.5 M KH_2PO_4/H_3PO_4 (pH 4.3, Wako Pure Chemical Co., Osaka, Japan) at a flow rate of 1 ml min^{-1} and UV detection at 254 nm. Each 5′-nucleotide was identified using the authentic 5′-nucleotide (Sigma) and quantified by the calibration curve of the authentic compound.

2.5. Equivalent umami concentration

The equivalent umami concentration [EUC, mg monosodium glutamate (MSG)/100 g] is the concentration of MSG equivalent to the umami intensity of that given by the mixture of MSG and the 5′-nucleotide and is represented by the following addition equation (Yamaguchi, Yoshikawa, Ikeda, & Ninomiya, 1971):

$$Y = \sum a_i b_i + 1.218\left(\sum a_i b_i\right)\left(\sum a_j b_j\right),$$

where Y is the EUC of the mixture in terms of mg MSG/100 g; a_i is the concentration (mg/100 g) of each umami amino acid [aspartic acid (Asp) or glutamic acid (Glu)]; a_j is the concentration (mg/100 g) of each umami 5′-nucleotide [5′-inosine monophosphate (5′-IMP), 5′-gua-

nosine monophosphate (5′-GMP), 5′-xanthosine monophosphate (5′-XMP) or 5′-adenosine monophosphate (5′-AMP)]; b_i is the relative umami concentration (RUC) for each umami amino acid to MSG (Glu, 1 and Asp, 0.077); b_j is the RUC for each umami 5′-nucleotide to 5′-IMP (5′-IMP, 1; 5′-GMP, 2.3; 5′-XMP, 0.61 and 5′-AMP, 0.18); and 1.218 is a synergistic constant based on the concentration of mg/100 g used.

2.6. Statistical analysis

For each of the mushrooms and broths, three samples were used for the determination of every quality attribute. The experimental data were subjected to an analysis of variance for a completely random design to determine the least significant difference among means at the level of 0.05.

3. Results and discussion

The weights of fruit bodies were 150.4–164.6 g whereas total weights of the cans were 431.6–444.2 g (Table 1). Mushroom cans of *V. volvacea* and *F. velutipes* had similar weights whereas the cans of *A. bisporus* were lighter. Fruit bodies from three cans also showed the same finding. However, broths from three cans had similar weights. The volumes for three mushroom cans were the same and those for broths were considered to be the same. Therefore, the volumes for fruit bodies that were calculated by subtracting the volume of broth from the total volume of the cans should the same. From the density of fruit bodies, i.e., the ratio of weight to volume, fruit bodies of *A. bisporus* were less dense. Soluble solids were significantly different and in the descending order: *F. velutipes* > *A. bisporus* > *V. volvacea*. The pH values of broth were also different and their order was exactly opposite to that of soluble solids.

Contents of soluble sugars and polyols were in the ranges 22.9–30.9 and 5.62–14.2 mg g^{-1} for fruit bodies and broth, respectively (Table 2). Generally, the contents of soluble sugars and polyols were higher in fruit bodies. However, a relationship between contents of soluble sugars and polyols of fruit bodies and broth of three cans was not observed. Contents of soluble sugars and polyols in *F. velutipes* were the highest for both fruit bodies and broth. The profiles of soluble sugars and polyols were similar for *A. bisporus* and *V. volvacea* but different for *F. velutipes*. One possible reason for this discrepancy is that both *A. bisporus* and *V. volvacea* were cultivated in compost whereas *F. velutipes* was grown in sawdust inside the plastic bag. The difference in sources of the nutrients might result in the difference in their profiles of soluble sugars and polyols.

With regard to individual sugar or polyol of fruit bodies, contents of sucrose and trehalose were high in *A. bisporus*; contents of ribose and trehalose were high in *V. volvacea*; and the content of arabinose was particularly high in *F. velutipes*. Soluble sugars and polyols usually contributed a sweet taste (Litchfield, 1967). However, the contents of soluble sugars and polyols in canned mushrooms were below 5%. Therefore, the results revealed that the fruit bodies and broth would give a weak sweet perception.

The contents of total free amino acids varied widely and were in the descending order: *F. velutipes* (247 and 146 μg g^{-1}) > *A. bisporus* (42.8 and 33.3 μg g^{-1}) > *V. volvacea* (27.2 and 12.4 μg g^{-1}) for fruit bodies and broth, respectively (Table 3). The major amino acids found in *A. bisporus* were lysine, glutamic acid and alanine, those in *V. volvacea* were lysine, alanine, and those in *F. velutipes* were arginine, tyrosine, phenylalanine and glutamic acid. However, the three mushrooms were considerably different in their profiles of free amino acids.

Not surprisingly, γ-aminobutyric acid (GABA), a hypotensive agent (Kohama et al., 1987; Kushiro et al., 1996), was found in the canned mushrooms. Canned mushrooms of *F. velutipes* contained the highest amount of GABA, whereas the contents of GABA in *A. bisporus* and *V. volvacea* were similar for fruit bodies and broth. Moreover, Tsai (2004) found that the contents of GABA in*Agaricus blazei*, *Agrocybe cylindracea*, *Boletus edulis* and *Coprinus comatus* were the range of 0.11–0.63 mg g^{-1} dry matter. However, the contents of GABA were in the μg level, much lower than those found (mg level) in mushrooms (Tsai, 2004). Since GABA is a biologically active compound, the presence of GABA in canned mushrooms would be beneficial to humans in addition to their palatable taste and other therapeutic effects.

Table 1
Parameters for mushroom cans

	Agaricus bisporus	*Volvariella volvacea*	*Flammulina velutipes*
Mushroom (g)	150.4 ± 5.4B[a]	162.6 ± 1.7A	164.6 ± 5.9A
Broth (g)	281.2 ± 9.8A	280.7 ± 3.1A	279.6 ± 6.7A
Total (g)	431.6 ± 4.9B	443.3 ± 1.4A	444.2 ± 1.7A
Degree of brix of broth	1.9 ± 0.1B	1.2 ± 0.1C	3.0 ± 0.1A
pH of broth	4.8 ± 0.1B	5.9 ± 0.1A	4.5 ± 0.1C

[a] Each value is expressed as mean ± standard error ($n = 3$). Means with different letters within a row are significantly different ($p < 0.05$).

Table 2
Content of soluble sugars or polyols of canned mushrooms

Sugar or polyol	Content (mg g^{-1})					
	Agaricus bisporus		*Volvariella volvacea*		*Flammulina velutipes*	
	Fruit body	Broth	Fruit body	Broth	Fruit body	Broth
Arabinose	3.37 ± 0.05B[a]	0.27 ± 0.03C	3.19 ± 0.42B	0.36 ± 0.03C	11.48 ± 1.43A	0.21 ± 0.04C
Fructose	1.59 ± 0.10C	0.50 ± 0.05D	2.26 ± 0.28B	0.23 ± 0.04D	0.61 ± 0.12D	3.54 ± 0.26A
Glucose	0.85 ± 0.17C	1.61 ± 0.30B	0.81 ± 0.03C	0.59 ± 0.03C	1.43 ± 0.28B	2.85 ± 0.14A
Myo-inositol	1.14 ± 0.04B	0.57 ± 0.04C	1.20 ± 0.20B	1.84 ± 0.36A	2.16 ± 0.24A	0.15 ± 0.02C
Mannose	1.38 ± 0.04C	0.42 ± 0.01D	2.40 ± 0.21B	0.50 ± 0.03D	5.54 ± 0.44A	0.47 ± 0.03D
Ribose	4.89 ± 0.37A	0.47 ± 0.07B	5.07 ± 0.91A	0.57 ± 0.06B	5.49 ± 0.09A	6.10 ± 0.28A
Sucrose	7.08 ± 0.15A	0.30 ± 0.05D	2.13 ± 0.14C	0.51 ± 0.07D	3.08 ± 0.08B	0.34 ± 0.06D
Trehalose	7.45 ± 0.84A	1.48 ± 0.24D	5.86 ± 0.20B	3.65 ± 0.07C	1.11 ± 0.09D	0.51 ± 0.05D
Total	27.75 ± 0.96B	5.62 ± 0.47E	22.92 ± 0.87C	8.25 ± 0.36E	30.90 ± 1.02A	14.17 ± 0.80D

[a] Each value is expressed as mean ± standard error ($n = 3$). Means with different letters within a row are significantly different ($p < 0.05$).

Table 3
Content of free amino acids of canned mushrooms

Amino acid	Content (μg g^{-1})					
	Agaricus bisporus		*Volvariella volvacea*		*Flammulina velutipes*	
	Fruit body	Broth	Fruit body	Broth	Mushroom	Broth
L-Alanine	6.70 ± 0.01B[a]	3.44 ± 0.05E	6.41 ± 0.04C	3.14 ± 0.01F	8.83 ± 0.04A	4.74 ± 0.11D
L-Arginine	3.44 ± 0.03C	2.42 ± 0.12C	1.77 ± 0.14C	0.63 ± 0.04C	50.3 ± 3.07A	36.7 ± 3.22B
L-Aspartic acid	2.46 ± 0.05C	2.45 ± 0.06C	0.47 ± 0.01D	0.32 ± 0.01D	5.72 ± 0.42A	4.05 ± 0.09B
L-Cysteine	1.03 ± 0.01C	0.98 ± 0.01C	0.63 ± 0.02C	0.28 ± 0.01C	14.3 ± 0.99A	9.29 ± 0.04B
L-Glutamic acid	8.25 ± 0.21B	8.87 ± 0.26B	0.54 ± 0.01C	0.35 ± 0.01C	24 ± 1.55A	10.5 ± 0.32B
L-Histidine	ND[b]	ND	0.18 ± 0.02B	0.11 ± 0.02B	4.91 ± 0.67A	4.29 ± 0.92A
L-Isoleucine	0.81 ± 0.01B	0.58 ± 0.01B	0.46 ± 0.01B	0.23 ± 0.00B	6.63 ± 0.52A	5.96 ± 0.03A
L-Leucine	1.34 ± 0.01C	0.99 ± 0.01CD	0.55 ± 0.04D	0.39 ± 0.01D	12.6 ± 0.42A	8.27 ± 0.51B
L-Lysine	11.6 ± 0.09A	5.52 ± 0.01D	10.9 ± 0.18B	5.15 ± 0.04D	7.57 ± 0.30C	3.57 ± 0.17E
L-Phenylalanine	0.54 ± 0.06C	0.87 ± 0.02C	0.41 ± 0.05C	0.28 ± 0.01C	25.2 ± 0.17A	8.37 ± 1.13B
L-Serine	0.71 ± 0.03D	1.41 ± 0.25C	0.87 ± 0.01D	0.24 ± 0.01E	9.91 ± 0.28A	7.14 ± 0.06B
L-Threonine + glycine	0.68 ± 0.02C	0.59 ± 0.04C	0.30 ± 0.05C	0.16 ± 0.01C	11.6 ± 0.41A	6.79 ± 0.30B
L-Tryptophan + L-methionine + L-valine	1.17 ± 0.01CD	1.45 ± 0.11C	1.09 ± 0.04D	0.39 ± 0.07E	2.48 ± 0.10B	3.83 ± 0.14A
L-Tyrosine	2.75 ± 0.09C	2.91 ± 0.13C	1.25 ± 0.03C	0.39 ± 0.01C	37.6 ± 0.48A	13.7 ± 2.11B
γ-Aminobutyric acid	1.38 ± 0.33C	0.78 ± 0.12C	1.31 ± 0.07C	0.34 ± 0.04C	25.8 ± 2.56A	18.7 ± 1.49B
Total	42.8 ± 0.06C	33.3 ± 0.28CD	27.2 ± 0.15D	12.4 ± 0.08E	247.3 ± 7.71A	146 ± 2.44B

[a] Each value is expressed as mean ± standard error ($n = 3$). Means with different letters within a row are significantly different ($p < 0.05$).
[b] ND, not detected.

Table 4 shows the free amino acids divided into several classes on the basis of their taste characteristics, as described by Komata (1969). Aspartic and glutamic acids were monosodium glutamate-like (MSG-like) components, which gave the most typical mushroom taste, the umami taste or palatable taste that was the characteristic taste of MSG and 5′-nucleotides (Yamaguchi, 1979). As compared with other taste components, contents of MSG-like components were relatively lower and insignificant in *V. volvacea* (1.01 and 0.67 μg g^{-1}) but significantly higher in *F. velutipes* (29.8 and 14.6 μg g^{-1}) for fruit bodies and broth, respectively. Contents of bitter components in *F. velutipes* were significantly higher than contents of MSG-like and sweet components. Obviously, the bitter components were predominantly present and may contribute the taste to *F. velutipes*.

Chen (1986) conducted a series of sensory evaluations on synthetic mushroom extracts prepared by omitting and adding soluble components and found that alanine, glycine, and threonine (sweet), and aspartic and glutamic acids (MSG-like) were taste-active amino acids in common mushrooms, whereas none of the bitter components were found to be taste-active in the overall taste perception. Therefore, MSG-like and sweet components would be responsible for the natural taste of mushrooms. However, contents of MSG-like and sweet components and total soluble sugars were considerately higher in fruit bodies and broth of *F. velutipes* cans and might be sufficient to suppress and cover the bitter

Table 4
Content of taste characteristics of free amino acids in canned mushrooms

Component[a]	Content (μg g^{-1})					
	Agaricus bisporus		*Volvariella volvacea*		*Flammulina velutipes*	
	Fruit body	Broth	Fruit body	Broth	Mushroom	Broth
MSG	10.7 ± 0.27C[b]	11.3 ± 0.32D	1.01 ± 0.01C	0.67 ± 0.02E	29.8 ± 1.14A	14.6 ± 0.40B
SWE	8.09 ± 0.07C	5.44 ± 0.26D	7.58 ± 0.08C	3.54 ± 0.01E	30.3 ± 0.17A	18.7 ± 0.47B
BIT	7.30 ± 0.10C	6.31 ± 0.04CD	4.46 ± 0.02CD	2.03 ± 0.04D	102 ± 2.42A	69.5 ± 0.50B
TAL	16.7 ± 0.17C	10.2 ± 0.26DE	14.1 ± 0.10CD	6.16 ± 0.03E	85.2 ± 4.32A	45.2 ± 0.83B
Total	42.8 ± 0.06C	33.3 ± 0.28CD	27.2 ± 0.15D	12.4 ± 0.08E	247 ± 7.71A	146 ± 2.44B

[a] MSG, taste-like monosodium glutamate, Asp + Glu; SWE, sweetness, Ala + Ser + Gly + Thr; BIT, bitterness, Leu + Phe + Ile + Val + Met + His + Arg + Try; TAL, tasteless, Lys + Cys + Tyr + γ-aminobutyric acid.
[b] Each value is expressed as mean ± standard error ($n = 3$). Means with different letters within a row are significantly different ($p < 0.05$).

taste arising from the higher contents of bitter components.

Flavour 5′-nucleotides were found to be 5′-GMP, 5′-IMP and 5′-XMP (Chen, 1986). Like contents of total free amino acids, the contents of total 5′-nucleotides were significantly higher in fruit bodies and broth of *F. velutipes* cans (Table 5). However, contents of flavour 5′-nucleotides were in the range 14.8–36.5 μg g^{-1}. Although they were different in contents of total 5′-nucleotides, *A. bisporus* and *V. volvacea* showed similar profiles in 5′-nucleotides.

5′-GMP gave the meaty flavour, and is a flavour enhancer, much stronger than MSG (Litchfield, 1967). The synergistic effect of flavour 5′-nucleotides with MSG-like components might greatly increase the umami taste of mushrooms (Yamaguchi et al., 1971). Based on the contents of MSG-like components and flavour 5′-nucleotides, the umami intensities of canned mushrooms were expected to be in the descending order of *F. velutipes* (29.8 + 20.6 μg g^{-1}) > *A. bisporus* (10.7 + 36.5 μg g^{-1}) > *V. volvacea* (1.01 + 20.7 μg g^{-1}) for fruit bodies, and *F. velutipes* (14.6 + 24.8 μg g^{-1}) > *A. bisporus* (11.3 + 26.0 μg g^{-1}) > *V. volvacea* (0.67 + 14.8 μg g^{-1}) for broth, respectively.

Mau et al. (1997) found that the contents of MSG-like components and flavour 5′-nucleotides in *V. volvacea* at stages 1–2 (egg- to bell-shaped) were 11.2–12.4 and 5.15–4.42 mg g^{-1} dry weight, respectively. When the dry weight was converted into the fresh weight, using the arbitrary moisture of 90% and expressed as μg basis, the contents of MSG-like components and flavour 5′-nucleotides in *V. volvacea* at stages 1–2 (egg- to bell-shaped) were 1120–1235 and 515–442 μg g^{-1} fresh weight, respectively. Tseng and Mau (1999) reported that the contents of MSG-like components and flavour 5′-nucleotides in *A. bisporus* were 22.7 and 4.19 mg g^{-1} dry weight, i.e., 2267 and 419 μg g^{-1} fresh weights, respectively. Yang, Lin, and Mau (2001) showed that the contents of MSG-like components and flavour 5′-nucleotides in white and yellow strains of *F. velutipes* were 1.57–7.06 and 6.32–8.60 mg g^{-1} dry weight, i.e., 1570–7060 and 6320–8600 μg g^{-1} fresh weight, respec-

Table 5
Content of 5′-nucleotides of canned mushrooms

Nucleotide[a]	Content (μg g^{-1})					
	Agaricus bisporus		*Volvariella volvacea*		*Flammulina velutipes*	
	Fruit body	Broth	Fruit body	Broth	Fruit body	Broth
5′-AMP	ND[c]	0.07 ± 0.01C[d]	ND	0.08 ± 0.01C	28.8 ± 0.26B	36.6 ± 1.87A
5′-CMP	18.0 ± 0.30C	21.4 ± 1.31C	6.23 ± 0.07D	4.10 ± 0.10D	58.2 ± 7.28B	75.9 ± 1.48A
5′-GMP	5.91 ± 0.76BC	4.42 ± 0.12D	5.16 ± 0.24CD	1.44 ± 0.08E	9.81 ± 0.37A	7.20 ± 0.38B
5′-IMP	3.13 ± 0.12B	2.35 ± 0.04B	5.70 ± 0.21A	3.57 ± 0.64B	3.75 ± 0.86B	6.66 ± 0.09A
5′-UMP	6.44 ± 0.93C	5.00 ± 0.01CD	3.23 ± 0.19CD	2.09 ± 0.37D	33.3 ± 2.19B	39.1 ± 1.33A
5′-XMP	27.4 ± 0.17A	19.3 ± 2.01B	9.81 ± 1.18CD	9.81 ± 0.36CD	7.07 ± 0.49D	11 ± 0.08C
Flavour 5′-nucleotide[b]	36.5 ± 0.47A	26.0 ± 1.86B	20.7 ± 1.15C	14.8 ± 0.92D	20.6 ± 0.74C	24.8 ± 0.21B
Total	60.9 ± 1.10C	52.5 ± 3.17C	30.1 ± 1.41D	20.2 ± 1.46D	141 ± 8.99B	176 ± 1.93A

[a] 5′-AMP, 5′-adenosine monophosphate; 5′-CMP, 5′-cytosine monophosphate; 5′-GMP, 5′-guanosine monophosphate; 5′-IMP, 5′-inosine monophosphate; 5′-UMP, 5′-uridine monophosphate; 5′-XMP, 5′-xanthosine monophosphate.
[b] Flavour 5′-nucleotide, 5′-GMP + 5′-IMP + 5′-XMP.
[c] ND, not detected.
[d] Each value is expressed as mean ± standard error ($n = 3$). Means with different letters within a row are significantly different ($p < 0.05$).

Table 6
Equivalent umami concentration of canned mushrooms

	Agaricus bisporus		*Volvariella volvacea*		*Flammulina velutipes*	
	Fruit body	Broth	Fruit body	Broth	Fruit body	Broth
EUC (mg MSG/100 g)	4.28 ± 0.27C[a]	3.58 ± 0.21D	0.22 ± 0.01E	0.10 ± 0.06E	13.1 ± 0.41A	5.90 ± 0.32B

[a] Calculated based on the equation: $Y = \sum a_i b_i + 1.218(\sum a_i b_i)(\sum a_j b_j)$ (Yamaguchi et al., 1971), where Y is the RUC of the mixture in terms of mg MSG/100 g; a_i is the concentration (mg/100 g) of each umami amino acids (Asp or Glu); a_j is the concentration (mg/100 g) of each umami 5′-nucleotides (5′-IMP, 5′-GMP, 5′-XMP or 5′-AMP); b_i is the relative umami concentration (RUC) for each umami amino acid to MSG (Glu, 1 and Asp, 0.077); b_j is the RUC for each umami 5′-nucleotide to 5′-IMP (5′-IMP, 1; 5′-GMP, 2.3; 5′-XMP, 0.61 and 5′-AMP, 0.18); and 1.218 is a synergistic constant based on the concentration (mg/100 g) used.

tively. Apparently, a great loss of contents of MSG-like components and flavour 5′-nucleotides in the canned mushrooms occurred during the canning process, especially the blanching stage.

During water blanching, a certain amount of water-soluble components of mushrooms were lost in the blanch water. The final blanching water from a batch process contained about 2% solids, and had a strong flavour and aroma (Wu, Wu, Chen, & Chang, 1981). Using the drum drying method, a dried product that had high contents of free amino acids (especially glutamic acid) and 5′-nucleotides, could be recovered from the blanching water (Wu et al., 1981). The blanched mushrooms were then canned with less mushroom flavour. Therefore, with regard to contents of taste components, canned mushrooms were less taste-appealing and were not comparable to fresh cooked mushrooms.

Using the equation derived from sensory evaluation (Yamaguchi et al., 1971), EUC values of fruit bodies were higher than those of broth for each mushroom (Table 6). EUC values of fruit bodies and broth were in the descending order: *F. velutipes* > *A. bisporus* > *V. volvacea*. However, EUC values were low and in the range 0.10–13.13 mg MSG/100 g moist weight. After total EUC values of each can were calculated from fruit bodies and broth and then divided by the total weight of fruit bodies, the EUC values were 11, 0.39 and 23.2 mg MSG/100 g moist weight for *A. bisporus*, *V. volvacea* and *F. velutipes*, respectively.

Mau (2005) reported the EUC values from mushroom taste components using the equation of Yamaguchi et al. (1971). The EUC values were grouped into four levels: >1000% (>10 g MSG g^{-1} dry matter), 100–1000%, 10–100% and <10%. An EUC value of 100% means that the umami intensity per 1 g dry matter is equivalent to the umami intensity given by 1 g of MSG, or, in other words, 1 g MSG g^{-1} dry matter. EUC values of *V. volvacea* (egg- to bell-shaped) *A. bisporus* and *F. velutipes* (yellow and white strains) were 1048–1181%, 1144% and 139–363%, respectively (Mau, 2005). Fruit bodies of *V. volvacea* and *A. bisporus* were >1000% whereas those of *F. velutipes* were in the range 100–1000%.

Interestingly, the EUC value of *F. velutipes* was higher than those of *V. volvacea* and *A. bisporus* in canned mushrooms. However, compared with the EUC values calculated above, based on the dry weight of mushrooms, these EUC values were insignificant in canned mushrooms. Mushrooms have long been used as a food or food-flavouring material, due to their unique and subtle flavour, mainly their taste. This research uses the sensory calculation to examine the umami taste of canned mushrooms. However, the results reveal that the umami taste of canned mushrooms could be relatively weak due to few remaining taste components.

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