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Non-volatile taste components of several commercial mushrooms

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Abstract

Winter (strains white and yellow), shiitake (strains 271 and Taichung 1) and oyster mushrooms (abalone and tree oyster mushrooms) were collected from commercial sources. Strain yellow contained 26.7% of proteins (higher than other mushrooms). Shiitake and the two oyster mushrooms contained more than 60% of carbohydrates. Arabitol was found in the highest amounts only in winter mushrooms. Glucose, mannitol and trehalose were found in varied amounts. Total soluble sugar contents were in the order: winter mushrooms > shiitake > abalone and tree oyster mushrooms. Total contents of free amino acids also varied and ranged from 4.08 to 31.5 mg g^{-1} dry weight. Contents of total 5′-nucleotides were similar in the two winter mushrooms, whereas the content of flavour 5′-nucleotides was higher in strain white. Contents of total and flavour 5′-nucleotides were higher in strain 271 than in strain Tainung 1. The two oyster mushrooms were comparable in contents of flavour 5′-nucleotides. The umami taste was in the order: strain 271 > winter mushrooms > two oyster mushrooms and strain Tainung 1.

Keywords: Mushrooms; *Flammulina velutipes*; *Lentinula edodes*; *Pleurotus cystidiosus*; *Pleurotus ostreatus*; Soluble sugars; Free amino acids; 5′-Nucleotides

1. Introduction

Currently, five kinds of mushrooms are popular in Taiwan, including common, paddy straw, winter, shiitake and oyster mushrooms. These mushrooms are highly valued as a centrepiece of Taiwanese cooking. Shiitake mushroom (*Lentinula edodes* [Berk.] Pegler), also called forest mushroom and shiang-ku (fragrant mushroom), are traditional delicacies in Japan, Korea, Taiwan and China (Stamets, 1993). Although taste components are well documented in Taiwan (Lin, 1988), new strains have been developed and continually cultivated. Strain 271 is a stable crossbred hybrid and becoming the predominant strain, representative of Taiwan dry shiitake. Strain Tainung 1 is newly developed by the Taiwan Agricultural Research Institute, for fresh market of shiitake. Taste information about these two strains is not available.

Winter mushroom (*Flammulina velutipes* [Curtis: Fries] Sing.), also called enokitake and golden mushroom, is notable for its abnormal feature of small caps and long stipes (Stamets, 1993). Two strains are currently available in the Taiwan market. Strain yellow is famous of its delicious taste and unique texture, whereas strain white, originating from Japan is anecdotally noted for its strong aroma. However, the taste components between these two strains have not been compared.

Two *Pleurotus* mushrooms, i.e. abalone and tree oyster mushrooms, are commercially popular in Taiwan. Abalone mushroom (*Pleurotus cystidiosus* O. K. Miller), also called summer oyster mushroom, tastes like its trivial name but is of vegetable nature (Stamets, 1993). Tree oyster mushroom (*Pleurotus ostreatus* [Jacquin: Fries] Kummer), also called hsiu-jen-ku (mini oyster mushroom), is apparently smaller and lighter than the abalone mushrooms. Apart from the differences in their size and colour, the taste components for these two species are also not reported.

The taste components of common mushrooms (*Agaricus bisporus*) and paddy straw mushrooms (*Volvariella volvacea*) have been reported (Mau, Chyau, Li & Tseng, 1997; Tseng & Mau, 1999). However, the nutritional values and taste components of three further kinds of commercial mushrooms, namely shiitake and oyster

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mushrooms, are not clearly understood. Our objective was to examine the non-volatile taste components in these three kinds of commercial mushrooms, including their proximate compositions, soluble sugars, free amino acids and 5′-nucleotides. The differences between strains and species were also compared.

2. Materials and methods

2.1. Mushrooms

Winter mushrooms (strains white and yellow), shiitake (strains 271 and Tainung 1), abalone mushrooms and tree oyster mushrooms were purchased at a local market in Taichung City, Taiwan. Fresh mushrooms from each species or strain were randomly selected as three samples, ~500 g each. Mushrooms were air-dried in an oven at 60°C before analysis.

2.2. Proximate analysis

The proximate compositions of four species of mushrooms, including moisture, ash, carbohydrate, crude fat, crude fibre and crude protein, were determined according to the methods of AOAC (1990). The nitrogen factor used for crude protein calculation was 4.38 (Crisan & Sands, 1978).

2.3. Soluble sugar assay

Soluble sugars were extracted and analysed as described by Ajlouni, Beelman, Thompson and Mau (1995). Air-dried mushroom powder (600 mg) was extracted with 50 ml of 80% aqueous ethanol (95% pure, Taiwan Tobacco & Wine Monopoly Bureau, Taipei) and xylose (50 mg, Sigma Chemical Co., St. Louis, MO) was added as an internal standard. 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 deionised water to a final volume of 10 ml. The aqueous extract was passed through a filter unit (13 mm, Lida, Corp., Kenosha, WI), and filtered using 0.45-μm CA non-sterile filter (Lida) prior to injection onto a high-performance liquid chromatograph (HPLC).

The HPLC system consisted of a Hitachi L-6000 pump, a Rheodyne 7161 injector, a 20-μm sample loop, a Hitachi D-2500 chromato-integrator, a Bischoff RI 8110 detector, and a Phase Sep-NH2 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, 17:3 (v/v) at a flow rate of 2 ml/min. Each sugar was quantified by comparing the peak area of the sugar to that of the internal standard.

2.4. Free amino acid assay

Air-dried mushroom powder (500 mg) 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 filter unit (13 mm, Lida), and filtered using a 0.45-μm CA non-sterile filter (Lida). The purified filtrate was mixed with *o*-phthalaldehyde reagent (Sigma) in an Eppendorf tube, shaken to facilitate derivatisation and then immediately injected onto the HPLC.

The HPLC system was the same as for sugar analysis but included a Hitachi F-1050 fluorescence detector with fluorescence excitation at 340 nm and emission at 450 nm, and a Prodigy 5 ODS-2 column (4.6×250 mm, 5 μ, Phenomenex Inc., Torrance, CA). The mobile phases and gradient conditions were the same as described in Mau et al. (1997). Each amino acid was quantified by the calibration curve of the authentic amino acid.

2.5. 5′-Nucleotide assay

5′-Nucleotides were extracted and analysed as described by Taylor, Hershey, Levine, Coy and Olivelle (1981). Air-dried mushroom powder (500 mg) was extracted with 25 ml of deionised water. This suspension was heated to boiling for 1 min, cooled, and then centrifuged at 22,200 ***g*** for 15 min. The extraction was repeated once with 20 ml of deionised water. The combined filtrate was then evaporated, and filtered prior to HPLC injection in the same manner as in soluble sugar assay.

The HPLC system was the same as for sugar assay except for a Hitachi L-4000 UV detector and a Prodigy 5 ODS-2 column (4.6×250 mm, 5 μm, Phenomenex). The mobile phase was 0.5 M KH_2PO_4/H_3PO_4 (pH 4.0, Wako Pure Chemical Co., Osaka, Japan) at a flow rate of 1 ml/min and UV detection at 254 nm. Each 5′-nucleotide was quantified by the calibration curve of the authentic 5′-nucleotide.

2.6. Statistical analysis

For each mushroom, 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 as described by Steel, Torrie and Dickey (1997), to determine the least significant difference among means at the level of 0.05. After multiple comparisons, the means in the following tables were followed with different small letters "a–e" based on their values and statistical differences. Where a mean is followed with "ab", this mean was not significantly

different from a mean with "a", and was not significantly different from another mean with "b". However, means with different letters were significantly different at the level of 0.05.

3. Results and discussion

No differences were found in moisture contents between strains white and yellow of winter mushrooms, and between abalone and tree oyster mushrooms, whereas significant difference was observed in moisture contents between strains 271 and Tainung 1 of shiitake (Table 1). Crisan and Sands (1978) reported that most fresh mushrooms contained ~90% moisture. However, strain 271 seemed to be less moist and denser. Ash contents varied among species and strains and ranged from 9.62 to 5.27% of dry weight. Generally, mushrooms are a good source of protein, and their proteins range from 19 to 35% of dry weight (Crisan & Sands). Strain yellow of winter mushrooms contained 26.7% of proteins (higher than strain white and shiitake and two oyster mushrooms) whereas abalone mushrooms contained the least amount (15.4%).

Shiitake and two oyster mushrooms contained more than 60% dry weight of carbohydrates. The carbohydrate content in strain white of winter mushrooms (48.2%) was higher than that in strain yellow (39.6%). However, these carbohydrate contents were in the range of 44.0–74.3% (Crisan & Sands, 1978) and of 46.6–81.8% (Bano & Rajarathnam, 1988). The lipid contents were significantly different among species, and in the order: winter mushrooms > shiitake and two oyster mushrooms. The lipid contents in the mushrooms ranged from 1.1 to 8.3% dry weight, with the mean being ~4.0% (Crisan & Sands). The lipid contents in oyster mushrooms, mentioned earlier, ranged from 1.1 to 2.2% (Chang & Miles, 1989) and from 1.0 to 2.4% (Bano & Rajarathnam). The fibre contents were high in winter mushrooms and slightly high in abalone mushrooms. The fibre contents in winter mushrooms were higher than that reported by Crisan and Sands (3.7%). However, the fibre contents in two oyster mushrooms were slightly below the range of 7.5–12% (Chang & Miles) and of 7.5–12.0% (Bano & Rajarathnam) for oyster mushrooms, and comparable to 5.97–9.15% in king oyster mushrooms (*Pleurotus eryngii*; Mau, Lin, Chen, Wu & Peng, 1998).

Arabitol was found in the highest amounts only in winter mushrooms (187 and 190 mg g^{-1} dry wt.; Table 2). In addition, glucose, mannitol and trehalose were found in varied amounts in winter mushrooms, shiitake and oyster mushrooms. Mannitol and trehalose were two major components found in common mushrooms (Hammond & Nichols, 1976), paddy straw mushrooms (Mau et al., 1997) and other oyster mushrooms (*P. ostreatus* and *Pleurotus flabellatus*) (Bano & Rajarathnam, 1988). Shiitake contained high amounts of mannitol, abalone mushrooms contained high amounts of mannitol and trehalose, and tree oyster mushrooms contained a high amount of glucose. Surprisingly, the total soluble sugar contents varied and were in the order: winter mushrooms > shiitake > abalone and tree oyster mushrooms. Two strains of winter mushrooms seemed to be comparable in total soluble sugar contents, and so did two strains of shiitake. However, the two oyster mushrooms were not the same in their profiles of soluble sugars.

Total contents of free amino acids also varied and ranged from 4.08 to 31.5 mg g^{-1} dry weight (Table 3). Strain yellow of winter mushrooms contained the highest amount of total free amino acids whereas tree oyster mushrooms contained the lowest amount. Alanine, glutamic acid, methionine and threonine were found to be four major free amino acids. Table 4 divides the free amino acids 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). Although two strains of winter

Table 1
Proximate composition of *Flammulina velutipes*, *Lentinula edodes, Pleurotus cystidiosus* and *Pleurotus ostreatus*

Component[a]	Content[b] (%)					
	F. velutipes (white)	*F. velutipes* (yellow)	*L. edodes* (271)	*L. edodes* (Tainung 1)	*P. cystidiosus*	*P. ostreatus*
Moisture	89.06±0.87 a	87.16±0.09 ab	81.79±0.66 c	87.71±0.92 ab	86.73±0.82 b	88.60±0.65 ab
Dry matter	10.94±0.87 c	12.84±0.09 bc	18.21±0.66 a	12.29±0.92 bc	13.27±0.82 b	11.40±0.65 bc
Ash	6.93±0.10 c	7.51±0.10 b	5.27±0.02 e	5.85±0.02 d	9.62±0.05 a	7.59±0.13 b
Carbohydrate	48.2±3.82 b	39.6±2.96 c	62.3±0.55 a	63.9±0.30 a	63.1±1.09 a	61.1±1.90 a
Crude fat	8.89±0.29 a	9.23±0.59 a	6.34±0.40 b	5.71±0.28 b	3.10±0.07 c	2.16±0.05 c
Crude fibre	15.99±0.08 a	16.98±0.30 a	5.63±0.21 c	4.88±0.18 c	8.74±1.03 b	5.33±0.11 c
Crude protein	20.0±3.45 bc	26.7±3.19 a	20.5±0.18 bc	19.7±0.20 bc	15.4±0.21 c	23.9±1.91 ab

[a] Moisture and dry matter are presented based on fresh weight, others are presented based on dry weight.
[b] Each value is expressed as mean ± S.E. ($n = 3$). Means with different letters within a row are significantly different ($P < 0.05$).

Table 2
Content of soluble sugars of *Flammulina velutipes*, *Lentinula edodes*, *Pleurotus cystidiosus* and *P. ostreatus*

Sugar	Content[a] (mg g^{-1} dry wt.)					
	F. velutipes (white)	*F. velutipes* (yellow)	*L. edodes* (271)	*L. edodes* (Tainung 1)	*P. cystidiosus*	*P. ostreatus*
Arabitol	187±2.47 a	190±7.50 a	nd[b]	nd	nd	nd
Glucose	42.3±2.50 a	35.6±1.71 a	28.6±1.08 b	14.2±0.66 c	11.6±0.08 c	10.6±0.44 c
Mannitol	28.5±0.39 c	8.70±0.19 d	83.8±1.06 b	134±4.32 a	24.6±1.50 c	3.60±0.62 d
myo-Inositol	7.77±0.36 a	2.33±0.41 b	nd	nd	nd	1.27±0.11 c
Trehalose	59.7±4.32 a	60.0±3.25 a	29.2±3.91 b	3.74±0.21 c	28.6±4.48 b	2.73±0.51 c
Total	325±8.56 a	296.90±11.01 b	141.55±3.89 c	152±4.08 c	64.9±4.11 d	18.2±0.68 e

[a] Each value is expressed as mean ± S.E. ($n=3$). Means with different letters within a row are significantly different ($P<0.05$).
[b] nd, not detected.

Table 3
Content of free amino acids of *Flammulina velutipes*, *Lentinula edodes*, *Pleurotus cystidiosus* and *Pleurotus ostreatus*

Amino acid	Content[a] (mg g^{-1} dry wt.)					
	F. velutipes (white)	*F. velutipes* (yellow)	*L. edodes* (271)	*L. edodes* (Tainung 1)	*P. cystidiosus*	*P. ostreatus*
L-Alanine	5.54±0.78 b	7.06±0.06 a	3.47±0.79 c	1.92±0.17 d	3.94±0.92 c	2.13±0.46 d
L-Arginine	1.42±0.30 a	1.71±0.10 a	0.49±0.05 c	0.93±0.08 b	nd[b]	0.08±0.03 c
L-Aspartic acid	0.03± < 0.01 d	0.24±0.02 b	0.41±0.05 a	0.40±0.04 a	0.05±0.01 d	0.13±0.02 c
L-Glutamic acid	1.54±0.05 b	6.82±0.28 a	1.30±0.18 b	1.53±0.14 b	1.16±0.21bc	0.71±0.14 c
Glycine	nd	1.94±0.28 a	0.43±0.03 b	0.51±0.04 b	0.14±0.03 c	0.12±0.03 c
L-Histidine[c]	nd	nd	0.43±0.07 a	0.29±0.07 b	nd	0.12±0.04 c
L-Isoleucine[c]	0.42±0.05 b	0.93±0.25 a	nd	0.21±0.01 b	0.23±0.04 b	0.19±0.02 b
L-Leucine[c]	1.41±0.11 b	2.73±0.27 a	nd	nd	nd	nd
L-Lysine[c]	0.76±0.10 a	1.03±0.11 a	0.51±0.05 b	0.37±0.06 b	0.32±0.06 b	0.19±0.01 b
L-Methionine[c]	2.14±0.30 b	2.73±0.06 a	1.01±0.16 c	0.92±0.14 c	nd	0.16±0.07 d
L-Phenylalanine[c]	nd	0.19±0.02 ab	0.22±0.05 ab	0.16±0.04 b	0.28±0.02 a	0.19±0.06 ab
L-Serine	0.68±0.03 c	0.87±0.08 b	1.05±0.18 a	0.88±0.06 b	0.51±0.06 c	nd
L-Threonine[c]	4.28±0.27 a	3.73±0.34 ab	2.82±0.36 bc	2.11±0.18 c	0.42±0.04 d	nd
L-Tryptophan[c]	0.10±0.01 b	0.32±0.04 a	nd	nd	0.14±0.01 b	0.02± < 0.01 c
L-Tyrosine	nd	nd	nd	nd	0.05±0.01 a	0.02±0.01 a
L-Valine[c]	0.89±0.07 b	1.17±0.10 a	0.38±0.09 c	0.27±0.06 cd	0.09±0.01 de	0.02± < 0.01 e
Total	19.2±0.70 b	31.5±0.71 a	12.5±0.77 c	10.5±0.69 c	7.33±0.83 d	4.08±0.48 e

[a] Each value is expressed as mean S.E. ($n=3$). Means with different letters within a row are significantly different ($P<0.05$).
[b] nd, not detected.
[c] Essential amino acid.

Table 4
Contents of free amino acids with taste characteristics in *Flammulina velutipes*, *Lentinula edodes*, *Pleurotus cystidiosus* and *Pleurotus ostreatus*

Taste characteristic[a]	Content[b] (mg g^{-1} dry wt.)					
	F. velutipes (white)	*F. velutipes* (yellow)	*L. edodes* (271)	*L. edodes* (Tainung 1)	*P. cystidiosus*	*P. ostreatus*
MSG-like	1.57±0.05 bc	7.06±0.30 a	1.71±0.14 bc	1.93±0.11 b	1.21±0.21 cd	0.84±0.15 d
Sweet	10.5±1.01 b	13.6±0.45 a	7.77±0.64 c	5.42±0.35 d	5.01±0.93 d	2.25±0.45 e
Bitter	6.38±0.47 b	9.78±0.15 a	2.53±0.16 c	2.78±0.14 c	0.74± 0.06 d	0.78±0.13 d
Tasteless	0.76±0.10 b	1.03±0.11 a	0.51±0.05 c	0.37±0.06 cd	0.37±0.05 cd	0.21±0.02 d
Total	19.2±0.70 b	31.5±0.71 a	12.5±0.77 c	10.5±0.69 c	7.33±0.83 d	4.08±0.48 e

[a] MSG-like, monosodium glutamate-like, Asp + Glu; Sweet, Ala + Gly + Ser + Thr; Bitter, Arg + His + Ile + Leu + Met + Phe + Trp + Val; Tasteless, Lys + Tyr.
[b] Each value is expressed as mean ± S.E. ($n=3$). Means with different letters within a row are significantly different ($P<0.05$).

mushrooms were comparable in contents of sweet components, MSG-like components were relatively higher in strain yellow. Although two strains of shiitake were similar in total contents of free amino acids and contents of MSG-like components, sweet components were significantly higher in strain 271. The two oyster mushrooms contained much less free amino acids, while total contents and contents of MSG-like and sweet components were relatively higher in abalone mushrooms.

Contents of MSG-like components were found to be 22.7–47.1 mg g^{-1} dry weight in common mushrooms (Tseng & Mau, 1999), 11.2–26.2 mg g^{-1} in paddy straw mushrooms (Mau et al., 1997), 10.9–11.9 mg g^{-1} in black poplar mushrooms (*Agrocybe cylindracea*; Mau & Tseng, 1998), 3.75–9.06 mg g^{-1} in shiitake (Lin, 1988), 1.01–1.77 mg g^{-1} in king oyster mushrooms (Mau, Lin et al., 1998), and 0.05–0.34 mg g^{-1} in ear mushrooms (*Auricularia* spp. and *Tremella fuciformis*; Mau, Wu, Wu & Lin, 1998). In addition, Mau, Lin, Ma and Song (2000) found that contents of MSG-like components in four speciality mushrooms, including *Dictyophora indusiata*, *Grifola frondosa*, *Hericium erinaceus* and *Tricholoma giganteum*, ranged from 0.68 to 1.09 mg g^{-1}. Contents of MSG-like components in medicinal mushrooms, including *Ganoderma lucidum*, *Ganoderma tsugae* and *Coriolus versicolor*, were in the range 0.17–0.50 mg g^{-1} (Mau, Lin & Chen, 2000). Based on the previous results, the contents of MSG-like components in strain white of winter mushrooms, shiitake and two oyster mushrooms were in the low range (< 5 mg g^{-1}), whereas that in strain yellow of winter mushrooms was in the middle range (5–20 mg g^{-1}). However, those in two strains of shiitake were much lower than those reported 12 years ago (Lin, 1988).

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. Therefore, MSG-like and sweet components would be responsible for the natural taste of mushrooms. Due to the low contents of the bitter components in winter, shiitake and oyster mushrooms, the bitterness from the bitter components could be unequivocally masked by high contents of sweet components and total soluble sugars.

Flavour 5′-nucleotides were found to be 5′-guanosine monophosphate (5′-GMP), 5′-inosine monophosphate (5′-IMP) and 5′-xanthosine monophosphate (5′-XMP) (Chen, 1986). The contents of total 5′-nucleotides were similar in two strains of winter mushrooms, whereas the content of flavour 5′-nucleotides was higher in strain white (Table 5). The contents of total and flavour 5′-nucleotides were substantially higher in strain 271 (24.2 and 11.6 mg g^{-1}) than in strain Tainung 1 of shiitake (9.51 and 1.60 mg g^{-1}, respectively). Although the content of total 5′-nucleotides was slightly higher in abalone mushrooms, two oyster mushrooms were comparable in the contents of flavour 5′-nucleotides.

Contents of flavour 5′-nucleotides were found to be 4.19–6.30 mg g^{-1} dry weight in common mushrooms (Tseng & Mau, 1999), 4.42–9.00 mg g^{-1} in paddy straw mushrooms (Mau et al., 1997), 1.63–4.89 mg g^{-1} in king oyster mushrooms (Mau et al., 1998a), 1.73–3.67 mg g^{-1} in shiitake (Lin, 1988), 0.39–2.17 mg g^{-1} in ear mushrooms (Mau, Lin et al., 1998), and 0.21–0.63 mg g^{-1} in black poplar mushrooms (Mau & Tseng, 1998). In addition, Mau, Lin, Ma & Song (2000) found that contents of flavour 5′-nucleotides in *D. indusiata*, *Grifola frondosa*, *H. erinaceus* and *T. giganteum*, were 9.04, 0.64, 0.62 and 13.6 mg g^{-1}, respectively. Contents of flavour 5′-nucleotides in medicinal mushrooms, including *Ganoderma lucidum*, *Ganoderma tsugae* and *Coriolus versicolor*, were in the range 1.18–5.65 mg g^{-1} (Mau, Lin & Chen, 2000). Based on the previous results, the contents of flavour 5′-nucleotides in two strains of winter mushrooms and those in strain 271 of shiitake and two oyster mushrooms were in the high range (> 5 mg g^{-1}), whereas that in strain Tainung 1 was in the middle range (1–5 mg g^{-1}). However, content of flavour 5′-nucleotides in strain 271 of shiitake was much higher than those reported 12 years ago (Lin, 1988), whereas that in strain Tainung 1 was slightly below the range.

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, Yoshikawa, Ikeda & Ninomiya, 1971). The content of MSG-like components was higher in strain yellow of winter mushrooms, whereas the content of flavour 5′-nucleotides was higher in strain white. The umami taste resulted from synergistic effects of MSG-like components and flavour 5′-nucleotides needed to be sensory-evaluated. The content of flavour 5′-nucleotides was much higher in strain 271 of shiitake, whereas the contents of MSG-like components were similar in two strains. This revealed that the umami taste of strain 271 was more intensive than that of strain Tainung 1. The two oyster mushrooms contained similar contents of MSG-like components and flavour 5′-nucleotides. It is obvious that the two oyster mushrooms should exhibit the same umami intensity.

Based on contents of the total soluble sugar and sweet components, it was anticipated that the sweetness would be consistent with their sugar contents and in the order: winter mushrooms > shiitake > abalone and tree oyster mushrooms. Based on the contents of MSG-like components and flavour 5′-nucleotides, the umami taste is expected to be in the order: strain 271 of shiitake > winter mushrooms > two oyster mushrooms and strain

Table 5
Content of 5′-nucleotides of *Flammulina velutipes*, *Lentinula edodes, Pleurotus cystidiosus* and *Pleurotus ostreatus*

5′-Nucleotide[a]	Content[b] (mg g^{-1} dry weight)					
	F. velutipes (white)	*F. velutipes* (yellow)	*L. edodes* (271)	*L. edodes* (Tainung 1)	*P. cystidiosus*	*P. ostreatus*
5′-AMP	0.53±0.08 c	0.42±0.04 c	nd[c]	nd	1.56±0.03 b	4.37±0.12 a
5′-CMP	2.33±0.39 d	5.05±0.26 c	10.0±0.73 a	7.25±0.41 b	5.71±0.17 c	4.89±0.29 c
5′-GMP	1.16±0.04 b	0.22±0.05 d	nd	nd	1.38±0.09 a	0.57±0.01 c
5′-IMP	0.17±0.01 c	0.13±0.01 c	2.78±0.18 a	0.63±0.02 b	0.05± < 0.01 c	nd
5′-UMP	1.49±0.09 b	1.41±0.07 b	2.64±0.03 a	0.66±0.06 d	1.06±0.03 c	0.46±0.09 d
5′-XMP	7.27±1.09 ab	5.97±0.60 bc	8.80± < 0.01 a	0.97±0.15 d	4.09±0.21 c	5.52±0.41 c
Flavour 5′-nucleotides[d]	8.60±1.08 b	6.32±0.62 c	11.6±0.18 a	1.60±0.13 d	5.52±0.15 c	6.09±0.40 c
Total	13.0±1.14 c	13.2±0.56 c	24.2±0.55 a	9.51±0.37 d	13.9±0.56 c	15.8±0.85 b

[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] Each value is expressed as mean ± S.E. ($n = 3$). Means with different letters within a row are significantly different ($P < 0.05$).
[c] nd, not detected.
[d] Flavour 5′-nucleotide, 5′-GMP + 5′-IMP + 5′-XMP.

Tainung 1. Strain Tainung 1 was a shelf-stable strain and mainly for fresh market of shiitake. However, the profile of strain Tainung 1 showed that it was less tasty than strain 271. For winter mushrooms, the results indicated that these two strains were comparable and sensory evaluation is needed to compare these two strains. The two oyster mushrooms were comparable in umami intensity with abalone mushrooms, being sweeter. To determine the relationship of the palatability of these mushrooms with their taste compounds, and determine the taste threshold of these components, further sensory evaluation is needed.

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