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Non-volatile taste components of various broth cubes

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Abstract

Commercial soup bases, in the form of broth cubes available in the market, include chicken, mushroom, pork and seafood broth cubes. The non-volatile taste components of four broth cubes were studied. Equivalent umami concentration (EUC) values of these broth cubes were evaluated and compared with their sensory results from hedonic tests. Only two soluble sugars, lactose and sucrose, were found. Contents of total free amino acids and monosodium glutamate (MSG)-like components ranged from 0.51 to 1.04 mg g^{-1} and 0.48 to 0.56 mg g^{-1}, respectively. Contents of 5′-nucleotides and flavour 5′-nucleotides ranged from 2.67 to 3.66 mg g^{-1} and 2.58 to 3.33 mg g^{-1}, respectively. EUC values were low and the umami intensities of one gramme of four soup bases were equivalent to those given by 0.14–0.32 g MSG. Mushroom and pork soups were more preferred, whereas seafood soup was less preferred. Correlations of EUC values with sensory scores were established for chicken, pork and seafood soups.

Keywords: Soup base; Broth cube; Soluble sugars; Free amino acids; 5′-Nucleotides; Equivalent umami concentration

1. Introduction

Soup is a staple in the diet and it can increase appetite by stimulating the secretion of saliva and also assist peristalsis of the stomach to facilitate food intake. However, in modern life, less time is available for a cook to make a soup with delicious and palatable taste. An easy and convenient way of making a soup is to use a soup base in the form of a broth cube, granule or powder. Currently, commercial broth cubes available in the market include chicken, mushroom, pork and seafood broth cubes.

Flavour represents one of the most important quality attributes contributing to the widespread consumption of soup. In addition to volatile compounds, the typical flavour of soup consists of non-volatile taste components. Regardless of some granules and particles present, the taste of soup is primarily due to the presence of several small molecular weight water-soluble substances, including 5′-nucleotides, free amino acids and soluble sugars and polyols (Litchfield, 1967). Umami taste, also called the palatable taste or the perception of satisfaction, is a good taste commonly provided by the soup and an overall food flavour induced or enhanced by monosodium glutamate (MSG) (Yamaguchi, 1979). Besides the four basic tastes, namely sour, sweet, bitter and salty, as well as other chemical feeling factors, such as pungency, astringency and cooling, the umami taste is the fifth taste in mouth perception.

Generally, food possesses four functionalities, including nutritional values, tasty properties, physiological effects and cultural characteristics (DaSilva, 2005; Mau, 2005). Mushrooms have long been used as a food or food-flavouring material due to their unique and subtle flavour including aroma and taste components, which add functionality to foods. Mau (2005) calculated the equivalent umami concentrations (EUC) of mushrooms, based on their contents of non-volatile components. EUC value is the concentration of MSG equivalent to the umami intensity given by the mixture of MSG and the 5′-nucleotide. However, the profile of taste components in soup base was not available. Accordingly, this research was designed to analyze the non-volatile taste components of soup bases, in the form of broth cubes, including chicken, mushroom, pork and

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seafood broth cubes. Also, EUC values of these four broth cubes were evaluated and compared with their sensory results from hedonic tests.

2. Materials and methods

2.1. Broth cubes

Commercial chicken, mushroom, pork and seafood soup bases in the form of broth cubes, were products of the Knorr soup division, Unilever Taiwan Co., and stored at −4 °C before analyses. For all soup bases, each cube, with a nominal weight of 11 g, was standardized for making a soup of 500 ml.

2.2. Proximate analysis

The proximate compositions of four soup bases, including moisture, crude ash, 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 for mushroom soup base (Crisan & Sands, 1978) and 6.25 for other soup bases (AOAC, 1990). The carbohydrate content (%) was calculated by subtracting the contents of moisture, crude ash, fat, fibre and protein from 100%.

2.3. Soluble sugar assay

Soluble sugars were extracted and analyzed as described by Ajlouni, Beelman, Thompson, and Mau (1995). A portion from each cube (2 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, 80:20 (v/v) at a flow rate of 1.0 ml min^{-1}. Each sugar was identified using the authentic sugar (Sigma Chemical Co., St. Louis, MO) and quantified by the calibration curve of the authentic compound. Sugars and polyols tested were arabinose, arabitol, fructose, glucose, lactose, mannitol, mannose, myo-inositol, ribose, sucrose and trehalose.

2.4. Free amino acid assay

A portion from each cube (2 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 into the HPLC.

The HPLC system included a Shimadzu LC-10AT*VP* pump, a Rheodyne 7725i injector, a 20 μl sample loop, Hitachi L-7485 fluorescence detector with fluorescence excitation at 340 nm and emission at 450 nm, and a Synergi 4μ Fusion-RP 80 column (4.6 × 250 mm, 4 μm, Phase Separation Inc., Norwalk, CT). 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 76:0:24 (v/v/v) to 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 1.0 ml min^{-1}. Each amino acid was identified using the authentic amino acid (Sigma) and quantified by the calibration curve of the authentic compound. Amino acids tested were L-alanine, L-arginine, L-aspartic acid (Asp), glycine, L-glutamic acid (Glu), L-histidine, L-isoleucine, L-leucine, L-lysine, L-methionine, L-phenylalanine, L-serine, L-threonine, L-tryptophane, L-tyrosine and L-valine.

2.5. 5′-Nucleotide assay

5′-Nucleotides were extracted and analyzed as described by Taylor, Hershey, Levine, Coy, and Olivelle (1981). A portion from each cube (2 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 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. 5′-Nucleotides tested were 5′-adenosine monophosphate (5′-AMP), 5′-cytosine monophosphate(5′-CMP), 5′-guanosine monophosphate (5′-GMP), 5′-inosine monophosphate(5′-IMP), 5′-uridine monophosphate (5′-UMP) and 5′-xanthosine monophosphate (5′-XMP).

2.6. Equivalent umami concentration

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

$$Y = \sum a_i b_i + 1218\left(\sum a_i b_i\right)\left(\sum a_j b_j\right)$$

where Y is the EUC of the mixture in terms of g MSG/100 g; a_i is the concentration (g/100 g) of each umami amino acid (Asp or Glu); a_j is the concentration (g/100 g) of each umami 5′-nucleotide (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 1218 is a synergistic constant based on the concentration of g/100 g used.

2.7. Sensory evaluation

For comparison of the acceptability of various soup bases, a nine-point hedonic test for each soup was used. The method was described by Meilgaard, Civille, and Carr (1991). Nineteen volunteers, including undergraduate students and university staff (15 females and 4 males, age rang from 20 to 50 years old), participated in the study. For each of four soup bases, broth was prepared by stirring each cube (weighed 11 g) in 500 ml boiling water, following the instruction of the manufacturer and then keeping below under 60 °C until each test. In addition, pH value of broth was measured using a Suntex SP-701 pH meter (Suntex Instruments Co., Taipei, Taiwan).

2.8. Statistical analysis

For each of four soup bases, 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. For the correlations, the CORR procedure (SAS Institute Inc., Cary, NC, USA, 1988) was used to determine the Pearson's correlation coefficient (r).

3. Results and discussion

The ash contents of four broth cubes were the highest among the proximate components and in the range of 38.62–44.75% whereas fat contents were the second highest (21.30–24.63%, Table 1). The carbohydrate and protein contents were 17.21–21.6% and 11.4–14.7%, respectively. Generally, these broth cubes were high in sodium chloride and calories, as labelled. After the soup was made (a cube of 11 g in 500 ml), the fat content and calorie were reduced and the salt concentration was calculated to be 116–122 mM, higher than the salt detection threshold of 100 mM (Li et al., 2002). Obviously, the salty taste would be perceived.

Only two soluble sugars, lactose and sucrose, were found in these four broth cubes and contents of the two sugars were higher in chicken and pork broth cubes than in mushroom and seafood broth cubes (Table 2). Soluble sugars and polyols usually contribute a sweet taste (Litchfield, 1967). However, only 8.26–16.8 mg g^{-1} of sugars would give a relatively weak sweet perception. After the soup was made, the total sugar concentration was calculated to be 0.53–1.08 mM, much less than the sucrose detection threshold of 100 mM (Li et al., 2002). It seems that the sweet perception would be insignificant.

The contents of total free amino acids were considerately low and ranged from 0.51 to 1.04 mg g^{-1} (Table 3). Twelve free amino acids were detected in the chicken broth

Table 2
Contents of soluble sugars of various broth cubes

Sugar	Content[a] (mg g^{-1} dry weight)			
	Chicken	Mushroom	Pork	Seafood
Lactose	0.99 ± 0.02C	3.64 ± 0.22A	2.58 ± 0.35B	2.18 ± 0.27B
Sucrose	15.8 ± 0.02A	4.62 ± 0.34D	14.0 ± 0.38B	6.87 ± 0.95C
Total	16.8 ± 0.04A	8.26 ± 0.25B	16.6 ± 0.59A	9.05 ± 1.22B

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

Table 1
Proximate composition of various broth cubes

Components	Content[a] (%)			
	Chicken	Mushroom	Pork	Seafood
Moisture	1.83 ± 0.15A[a]	2.21 ± 0.54A	2.56 ± 0.67A	2.01 ± 0.13A
Carbohydrate	17.2 ± 0.18C	19.2 ± 0.27B	19.7 ± 0.57B	21.6 ± 0.42A
Crude ash	44.75 ± 0.16A	38.76 ± 0.42B	43.63 ± 1.09A	38.62 ± 0.09B
Crude fat	24.63 ± 0.99A	24.48 ± 0.49A	21.30 ± 1.21B	23.12 ± 0.79A
Crude fibre	0.14 ± 0.03C	0.67 ± 0.05A	ND[b]	0.28 ± 0.06B
Crude protein	11.4 ± 1.09C	14.7 ± 0.37A	12.8 ± 0.31B	14.4 ± 0.24A

[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 3
Contents of free amino acids of various broth cubes

Amino acid	Content[a] (mg g^{-1} dry weight)			
	Chicken	Mushroom	Pork	Seafood
L-Alanine	0.05 ± 0.01A	ND[b]	0.01 ± <0.01B	ND
L-Arginine	0.08 ± 0.01A	0.06 ± 0.01B	0.03 ± <0.01C	ND
L-Aspartic acid	0.01 ± <0.01	ND	ND	ND
L-Glutamic acid	0.55 ± 0.01A	0.54 ± 0.01A	0.48 ± 0.01B	0.48 ± 0.02B
L-Histidine	0.03 ± 0.01B	0.22 ± 0.03A	0.01 ± <0.01B	0.03 ± 0.01B
L-Isoleucine	0.01 ± <0.01	ND	ND	ND
L-Leucine	0.02 ± <0.01	ND	ND	ND
L-Lysine	0.01 ± 1.67	ND	ND	ND
L-Phenylalanine	0.02 ± <0.01	ND	ND	ND
L-Serine	0.15 ± 0.01A	ND	0.04 ± 0.01B	ND
L-Tyrosine	0.10 ± 0.01A	ND	0.06 ± 0.01B	ND
L-Valine	0.01 ± <0.01	ND	ND	ND
Total	1.04 ± 0.03A	0.82 ± 0.03B	0.63 ± 0.02C	0.51 ± 0.02D

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

cubes, whereas several amino acids were not detected in the mushroom, pork and seafood broth cubes. Surprisingly, only two free amino acids, glutamic acid and histidine, were found in seafood broth cubes.

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 MSG-like components, which gave the umami taste that was the characteristic taste of MSG and 5′-nucleotides (Yamaguchi et al., 1971). Contents of MSG-like components were considerately low and ranged from 0.48 to 0.56 mg g^{-1} for four broth cubes. However, contents of sweet and bitter components were even lower than contents of MSG-like components. After the soup was made, the concentrations of sweet and bitter components were calculated to be 0–0.05 mM and 0.01–0.05 mM, respectively, much below the serine and leucine detection thresholds of 10 mM (Li et al., 2002). Apparently, the sweet and bitter tastes were also insignificant.

Contents of 5′-nucleotides ranged from 2.67 to 3.66 mg g^{-1} and were higher than contents of total free amino acids for these four broth cubes (Table 5). 5′-IMP contents were high in these four broth cubes whereas 5′-GMP was high in chicken and pork broth cubes and 5′-XMP was high in mushroom and seafood broth cubes. Flavour 5′-nucleotides were found to be 5′-GMP, 5′-IMP and 5′-XMP (Chen, 1986). Contents of flavour 5′-nucleotides ranged from 2.58 to 3.33 mg g^{-1} and were very close to the contents of 5′-nucleotides for four broth cubes.

5′-GMP gave a 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 soups (Yamaguchi et al., 1971). Based on the contents of MSG-like components and flavour 5′-nucleotides, the contents of umami components of various broth cubes were expected to be in the descending order: mushroom (0.54 + 3.29 mg g^{-1}) ∼ pork (0.48 + 3.33 mg g^{-1}) > chicken (0.56 + 2.71 mg g^{-1}) > seafood broth cubes (0.48 + 2.58 mg g^{-1}).

Using the equation derived from sensory evaluation (Yamaguchi et al., 1971), EUC values of broth cubes were quite different from contents of umami components simply calculated from contents MSG-like components and flavour 5′-nucleotides and were in the descending order: chicken ∼ pork > mushroom > seafood broth cubes (Table 6). Mau (2005) grouped EUC values into four levels: first level of > 1000% dry weight (> 10 g MSG g^{-1} dry weight),

Table 4
Contents of taste characteristic free amino acids in various broth cubes

Component[a]	Content[b] (mg g^{-1} dry weight)			
	Chicken	Mushroom	Pork	Seafood
MSG-like	0.56 ± 0.01A	0.54 ± 0.01A	0.48 ± 0.01B	0.48 ± 0.02B
Sweet	0.20 ± 0.02A	ND[c]	0.05 ± 0.01B	ND
Bitter	0.17 ± 0.01B	0.28 ± 0.03A	0.06 ± 0.01C	0.03 ± 0.01C
Tasteless	0.11 ± 0.01A	ND	0.04 ± 0.01B	ND
Total	1.04 ± 0.03A	0.82 ± 0.03B	0.63 ± 0.02C	0.51 ± 0.02D

[a] MSG-like, Glu + Asp; sweet, Ala + Ser; bitter, Arg + His + Ile + Leu + Phe + Val; tasteless, Lys + Tyr.
[b] Each value is expressed as mean ± SE ($n = 3$). Means with different letters within a row are significantly different ($P < 0.05$).
[c] Not detected.

Table 5
Contents of 5′-nucleotides of various broth cubes

5′-Nucleotide[a]	Content[c] (mg g^{-1} dry weight)			
	Chicken	Mushroom	Pork	Seafood
5′-AMP	0.07 ± 0.01B	ND[d]	0.10 ± 0.01 A	ND
5′-CMP	0.03 ± 0.01B	0.16 ± 0.01A	0.03 ± 0.01B	0.03 ± 0.01B
5′-GMP	1.43 ± 0.01B	0.11 ± 0.02C	1.64 ± 0.02A	0.04 ± 0.01D
5′-IMP	1.11 ± 0.01D	1.82 ± 0.01A	1.33 ± 0.03C	1.53 ± 0.05B
5′-UMP	0.03 ± 0.01C	0.21 ± 0.01A	0.03 ± 0.01C	0.06 ± 0.01B
5′-XMP	0.17 ± 0.01D	1.36 ± 0.01A	0.36 ± 0.01C	1.01 ± 0.02B
Flavour *5′-Nucleotides*[b]	2.71 ± 0.03B	3.29 ± 0.01A	3.33 ± 0.02A	2.58 ± 0.03C
Total	2.84 ± 0.04C	3.66 ± 0.02A	3.49 ± 0.02B	2.67 ± 0.03D

[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] Each value is expressed as mean ± SE ($n = 3$). Means with different letters within a row are significantly different ($P < 0.05$).
[d] Not detected.

Table 6
Equivalent umami concentration of various broth cubes

EUC[a] (g MSG/100 g)			
Chicken	Mushroom	Pork	Seafood
30.3 ± 1.24A	19.1 ± 0.81B[b]	32.0 ± 0.28A	14.1 ± 1.73C

[a] Calculated based on the equation: $Y = \sum a_i b_i + 1218\ (\sum a_i b_i)\ (\sum a_j b_j)$ (Yamaguchi et al., 1971), where Y is the RUC of the mixture in terms of g MSG/100 g; a_i is concentration (g/100 g) of each umami amino acid (Asp or Glu); a_j is concentration (g/100 g) of each umami 5′-nucleotide (5′-IMP, 5′-GMP, 5′-XMP or 5′-AMP); b_i is the RUC for each 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 1218 is a synergistic constant based on the concentration of g/100 g used.
[b] Each value is expressed as mean ± SE ($n = 3$). Means with different letters within a row are significantly different ($P < 0.05$).

Table 7
Sensory evaluation of various broths using hedonic test

Chicken	Mushroom	Pork	Seafood
5.16 ± 1.06AB[a]	6.05 ± 1.02A	5.68 ± 1.30A	3.89 ± 1.32B

[a] Each value is expressed as mean ± SE ($n = 19$). Means with different letters within a row are significantly different ($P < 0.05$). Hedonic scale: 1, dislike extremely; 5, neither like nor dislike; 9, like extremely.

second level of 100–1000% (1–10 g MSG g^{-1}), third level of 10–100% (0.1–1 g MSG g^{-1}), and fourth level of < 10% (< 0.1 g MSG g^{-1}). Consequently, the EUC values of these four broth cubes were at the third level. In other words, the umami intensities of one gramme of four soup bases were equivalent to those given by 0.14–0.32 g MSG. After soup was made, the EUC values of chicken, mushroom, pork and seafood soups were 0.67, 0.42, 0.70 and 0.31 g MSG/100 ml, respectively. It seems that the umami intensities of soups made from four broth cubes were considerately low and these soups would be perceived to have slight umami taste.

Four soups were made from broth cubes and the sensory results showed that mushroom and pork soups were more preferred whereas seafood soup was less preferred (Table 7). However, the scores of chicken, mushroom and pork soups were slightly above 5 but that of seafood soup was less than 5. Low scores found might be due to the fact that these were plain soup bases and contained less amounts of taste-active components. In addition, the lowest score of seafood soup might due to its special flavour which might be not appeal to the test panel.

The correlations of EUC values with sensory scores were established for chicken, pork and seafood soups. The correlation equation was as follows: $Y = -26.17 + 110.51X$, where X was the EUC value and Y was the sensory score with the Pearson's correlation coefficient (r) being 0.98. However, mushroom soup would not fit into the equation due to its higher sensory score. Generally, EUC values of four broth cubes were calculated on the basis of their non-volatile taste components, especially MSG-like components and flavour 5′-nucleotides. However, the sensory scores of four soups involved aroma and non-volatile taste components present. The higher score of the mushroom soup might be due to the alleged characteristic mushroom aroma, which is responsible for the widespread consumption of mushrooms (Maga, 1981).

The pH values of chicken, mushroom, pork and seafood soups were measured to be 6.72, 7.54, 6.53 and 7.11, respectively. The pH values of four soups were close to neutral and these soups would not be perceived as having any sour taste. For a soup base, spicy ingredients are not expected to be supplemented into broth cubes. Therefore, no hot taste would be perceived. As mentioned earlier, soups made from broth cubes would be perceived as salty, and a little sweet but with no sour on bitter tastes. Nevertheless, both EUC values and sensory scores were low. Soup has been consumed in the diet due to its unique and subtle flavour, but mainly its palatable taste. To improve the quality of these four soup bases, the palatable umami taste, brought by non-volatile compounds, would be another area of investigation.

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