Asian Journal of Chemistry; Vol. 28, No. 3 (2016), 589-595

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2016.19422

Physico-Chemical Properties of Salt-Fermented Commercial Fish Sauces in Thailand

BYOUNG-MOK KIM[1], SUJINDA SRIWATTANA[2] and IN-HAK JEONG[3,*]

[1]Division of Strategic Food Industry Research, Korea Food Research Institute, Seongnam 463-763, Republic of Korea
[2]Division of Biotechnology, Faculty of Agro Industry, Chiangmai University, Chiangmai 50100, Thailand
[3]Department of Marine Food Science & Technology, Gangneung National University, Gangneung 210-702, Republic of Korea

*Corresponding author: Fax: +82 33 6402340; Tel: +82 33 6402341; E-mail: ihjeong@gwnu.ac.kr

Received: 20 June 2015; *Accepted*: 19 August 2015; *Published online*: 5 December 2015; AJC-17657

In this study, the characteristic components of commercially available fish sauces from Thailand were investigated. Moisture, ash, crude protein and crude fat content was 51.8-59.5 %, 20.8-28.3 %, 11.4-20.6 % and 0.1-0.6 %, respectively. Salinity was 19.1-28.0 % and the volatile base nitrogen content was the highest in TF10 (298.8 mg %) and the lowest in TF3 (19.1 mg %). pH was in the range of 5.1-5.8. The total nitrogen content was 1.8-3.5 g % and was the highest in TF5. Amino nitrogen content was 406.0-1,750.0 mg % and was the highest in TF6. Lightness, redness and yellowness were 34.7-53.3, 10.68-28.79 and 4.74-36.06, respectively. Major organic acids were acetic acid, lactic acid, propionic acid and butyric acid and the total amount of organic acid was 1.11-7.06 mg/L. The total amount of free amino acids was 1,103.7-9,581.8 mg % and the major free amino acids were aspartic acid, glutamic acid, glycine, alanine, methionine, isoleucine and phenylalanine. Umami amino acid was the highest in TF11, while sweet amino acid (SA) and bitter amino acid (BA) were the highest in TF1 and TF11, respectively. The ratio of SA/BA was the highest in TF8; essential and non-essential amino acid were the highest in TF11 and TF1, respectively. The aroma pattern measured using an electronic nose differed depending on each product.

Keywords: Fish sauce, Sweet amino acid, Bitter amino acid, Thailand.

INTRODUCTION

Fermented fish, prepared by adding salt and by fermentation, can be largely classified into fermented fish with its flesh remaining intact and liquefied fish sauce. Fermented fish retaining the flesh include those for which the body of fish such as salted shrimp, salted manila clam and salted oysters is used as well as those for which the intestines and other byproducts such as salted guts of hairtail, sauced intestines and salted Pollock gills are used. Fish sauces, in which proteins from the flesh are completely degraded during fermentation and have been liquefied, include anchovy sauce and sand lance extract. Fermentation of fish with salt is one of the hallmarks of the Asian food culture whose staple food is rice. Fish sauce is used not only as a main condiment to flavour kimchi, but also as a cooking condiment used as a substitute for soybean sauce. In Southeast Asian countries such as Thailand, Vietnam and Philippines, fish sauce has established itself as an important food item that is used as a condiment in most of the cooking. Although known as a product unique to the Asian food culture, fish sauce has also been widely used in Ancient Rome. It has a long history and has become the major marine fermented food that has been used throughout the world in the east as well as in the West [1,2]. In rice culture, high-quality liquefied fermented products have also been developed as products that carry equal or more significance as condiments [3,4]. Korea primarily uses soybean sauce, which has been fermented from soybeans, as a cooking condiment, similar to that in the Japanese and Chinese cultures. In Southeast Asian countries such as Vietnam, Thailand and Philippines, on the other hand, fish sauce is still mostly used in cooking. Varieties of fish fermented products are used in Thailand and liquefied fish sauce (Nam pla) is used not only as a condiment to flavour most dishes, but also as a substitute for table salt. Therefore, there have been various types and qualities of commercially available fish sauces, with large differences in their price. In Korea, fermented fish has been accepted as the typical high-sodium product with a high salt content and therefore, there has been a sharp decline in its consumption in recent years. Although it has been largely consumed as an additive, while making kimchi, it is predicted that the decreased consumption of kimchi in the current young generation will further dampen the future consumption of fermented fish. According to the recently expanding FTA flow, if, in the future, Korea is introduced to fish sauce produced in Southeast Asia such as in Thailand where there is massive production and circulation, the domestic fish sauce market will be confronted with a new challenge. The quality of fish sauce is determined by various factors, but the most important key will be the management process to prevent deterioration of quality during the fermentation process. In particular, if salinity is not sufficient during the fermentation process, there will be an increase in pH and in the production of biogenic amines, including histamine, as well as a decrease in functional quality, including development of a taste like that of ammonia. Accordingly, most countries prepare and manage quality standards for fish sauce, but the management standards fail to guarantee product quality. In our study, we purchased fish sauces that have been manufactured and commercially sold in Thailand, one of the representative countries for fish sauce production and investigated their physiochemical qualities. We attempted not only to offer data on the fish sauces already in circulation domestically in Thailand, but also to provide a database that can help improve the quality of domestic fish sauces.

EXPERIMENTAL

Preparation of samples: The fish sauce of 13 types used in this study were purchased from Traditional Market in Chiangmai, Thailand and the preserved at -70 °C for subsequent analysis. The information of fish sauce was same as the Table-1.

Biochemical analysis: Proximate composition was determined according to the method of AOAC [5]. The pH of the samples were measured using a pH meter (SG2-ELK, Mettler, Zurich, Switzerland). Briefly, a 10 g sample was homogenized with 40 mL of distilled water and centrifuged, the supernatant was measured using a pH meter. The salt content was determined by modified Mohr's method [6]. The colour of the samples was measured in the L*, a*, b* space using a Hunter meter (Model ZE 2000, Nippon Denshoku, Tokyo, Japan). L*, a* and b* indicate lightness, redness/greenness and yellowness/blueness, respectively. The volatile basic nitrogen (VBN) was determined using Conway's diffusion method [7]. The total nitrogen content was determined according to the method of semi-micro Kjeldahl [5] and the amino nitrogen content was determined by formal nitrogen [8,9]. Briefly, a 5 mL of sauce was mixed with 250 mL of distilled water and stirred for 0.5 h at room temperature and then filtered and the supernatant was adjusted to pH 8.5 with 0.1 N NaOH and then 20 mL of formaldehyde solution (38 %, v/v) was added to the neutralized sauce. Titration was continued to pH 8.5 with 0.1 N NaOH. The thiobarbituric acid (TBA) value was determined by modified of Witte's method [10].

Determination of organic acids: The organic acids was determined using HPLC (Agilent 1200, Agilent, Santa Clara, CA, USA). Briefly, a 5 g of sauce mixed with 25 mL of 85 % ethanol and stirred for 48 h and filtered through a filter paper (Toyo No. 5) and the filtrates were evaporated using vaccum evaporater (KR/AUTOSPIN 4080C, Hanil, Korea) and made up to final volume of 200 μL using distilled water. The sample subjected to the organic acid analysis using HPLC.

Composition of free amino acids: After 3 h homogenization of 10 g sauce with 50 mL of 70 % ethanol, centrifugation was performed at 4 °C, 6000 rpm for 0.5 h and the supernatant was evaporated to remove the ethanol. The supernatant were collected and made up to final volume of 100 mL using distilled water and subjected to the amino acid analysis using an amino acid analyzer (L-8800, Hitachi, Tokyo, Japan). The column was ion exchange column (4.6 mm × 60 mm) and oven temperature was 30-70 °C and flow was 0.35 mL/min.

Aroma pattern analysis using electronic nose: The aroma pattern of fish sauce was measured using electronic nose system (zNose 7100, Electronic Sensor Technology, Newbury Park, CA, USA) which contained SAW (surface acoustic wave) sensor. A 1 g of sauce put in the headspace vial (Pharma-Fix, Chemmea, Slovakia) and incubated at 90 °C, 350 rpm for 10 min and collected an aroma component and the collected aroma component injected using 65 °C syringe (HS 100 autosampler, Alpha MOS, France). To analysis of headspace, the syringe purge was maintained a 9.9 seconds. The electronic nose used in this study was connected with a mass spectrometer (Quadrupole mass spectrometer, Balzers Instruments, Masin-Epagniger, Switzerland).

Statistical analysis: For the results of this experiment, means and standard deviation were computed using a statistical analysis program (SPSS package program v18.0, SPSS Inc., Chicago, IL, USA). The average value analysis of the two groups verified the significant difference at $p < 0.05$ using

TABLE-1
INFORMATION OF A SALT-FERMENTED COMMERCIAL THAI FISH SAUCE

Sample[1)]	Ingredients (Fish species)	Additives claimed
TF1	Anchovy (70 %)	Salt (27 %), sugar (3 %), iodine (3 ppm)
TF2	Anchovy (60 %)	Salt (25.5 %), sugar (4.5 %), iodine (N.A)
TF3	N.A[2)]	Fish sauce (40 %), potassium chloride (10 %), sorbitol (N.A), disodium 5'-inosinate (N.A), disodium 5'-guanylate (N.A)
TF4	Anchovy (60 %)	Salt (25 %), sugar (5 %), iodine (N.A)
TF5	Anchovy (50 %)	Salt (34.9 %), mono-sodium glutamate (N.A), sugar (5 %)
TF6	Anchovy (75 %)	Salt (24 %), sugar (1 %), iodine (3 ppm)
TF7	Anchovy (65 %)	Salt (30.5 %), sugar (4.5 %), iodine (2 ppm)
TF8	Anchovy (70 %)	Salt (27 %), sugar (2 %), fructose (1 %), iodine (N.A)
TF9	Anchovy (66 %)	Salt (29 %), sugar (5 %), iodine (N.A)
TF10	Anchovy (70 %)	Salt (28 %), sugar (2 %), iodine (3 ppm)
TF11	Anchovy (70 %)	Salt (29 %), sugar (1 %), iodine (N.A)
TF12	Anchovy (70 %)	Salt (29 %), sugar (1 %), iodine (N.A)
TF13	Anchovy (70 %)	Salt (29 %), sugar (1 %), iodine (N.A)

[1)]Sample : a salt-fermented commercial Thai fish sauce; [2)]N.A : not available independent t-test and the average value analysis of three or more groups were carried out according to the one-way analysis of variance (ANOVA) method. Significance of mean values was tested using Duncan's multiple comparison test ($P < 0.05$).

RESULTS AND DISCUSSION

Biochemical analysis: General components, salinity and pH of commercially available fish sauce products from Thailand were determined and the results are summarized in Table-2. Moisture content was 51.8-59.5 %, the highest in TF1 (59.5 %) and the lowest in TF5. Ash content was 20.8-28.3 % and the lowest in TF3. Crude protein content was 11.4-20.6 %, the highest in TF5 and the lowest in TF1, TF6 and TF11. Crude fat content was 0.1-0.6 %, the highest in TF3, TF6 and TF10 and the lowest in TF4, TF8 and TF13. Salinity was 19.1-28.0 %, the highest in TF1 and the lowest in TF3. Salinity of other products, excluding TF3 and TF4, was found to be greater than 24 %. Because there is a high chance of decomposition during fish sauce fermentation depending on conventional manufacturing methods, environment and temperature, the salt content was relatively high. Moreover, several products showed higher salt content compared to what was acceptable according to Korean Industrial Standards [11] and quality standards for Fishery Traditional Food for each component of fish sauce [12], showing that high-sodium products that do not conform to domestic quality standards are being produced. Significant differences in general components and salinity between fish sauce products are due to manufacturing conditions, mixture ratio of raw materials and manufacturing environment. The volatile base nitrogen content was in the range of 58.1-289.8 mg %; it was the highest in TF10 and the lowest in TF3. The volatile base nitrogen shows a close correlation with the level of freshness of the fish, but using it as an absolute quality scale is difficult because there are large differences in the price that depend on the condition of raw materials and aging. Nevertheless, because it is deeply related to flavour and can be used as supplemental data for judging over-fermentation, it is often used as an indicative molecule for fermentation experiments, even when it is not used as an objective quality indicator. In this study, distinct differences in the volatile base nitrogen content between products were attributed to differences in various manufacturing conditions, such as freshness, aging conditions, diluting fish sauce during production and raw fish steaming process. pH was in the range of 5.1-5.8 and was similar to that of commercially available anchovy and sand lance sauce (5.3-6.7) from Korea [13]. It has been reported that, instead of adding excessive salt for safe storage and for increasing the quality of fish sauce products, decreasing the pH below 5.0 by adding organic acid can be a good option [14]. The younger generation has been showing more interest in health by changing their diets, seeking health-oriented life and preferring low-sodium diets. Therefore, to target products that are currently commercially available in Thailand, or to follow appropriate quality standards of each consumer country, various studies on manufacturing standards for high-quality products and improvement of the manufacturing process will need to be pursued.

Total nitrogen and amino nitrogen content: We studied the total nitrogen (TN) and amino nitrogen (AN) content of commercially available fish sauce products from Thailand and summarized the results in Table-3. Total nitrogen ranged from 1.8-3.5 g %, showing large differences between products; the highest total nitrogen was in TF5 (3.5 %) and the lowest was in TF1, TF6 and TF11 (1.8 %). Amino nitrogen ranged from 406-1,750 mg %, again showing large differences between products. In particular, TF6 presented the lowest total nitrogen, but the highest amino nitrogen (1,750.0 mg %) and TF5 presented the highest total nitrogen, but the lowest amino nitrogen (406 mg %). In addition to these, other products also showed a similar trend where those with lower total nitrogen generally presented higher amino nitrogen. This result differs from products with high total nitrogen generally having high amino nitrogen [15]. Differences in content between products as clear as these are due to differences in the manufacturing environment and conditions and in the manufacturing processes. Korean fish sauce products, for example, also show clear differences in amino nitrogen and total nitrogen depending on the manufacturer and this is supposedly due to mixing salt water with crude liquid or mixing with similar fish sauces [13]. Furthermore, although all products, excluding TF5, were above 1 % in total nitrogen and above 600 mg % in amino

TABLE-2
PROXIMATE COMPOSITION, SALINITY, VBN CONTENT AND pH OF A SALT-FERMENTED COMMERCIAL FISH SAUCES IN THAILAND

Sample[1)]	Moisture (%)	Ash (%)	Crude protein (%)	Crude lipid (%)	Salinity (%)	VBN (mg/100 g)	pH
TF1	$59.5 \pm 1.9^{2)a3)}$	28.3 ± 4.3^{a}	11.6 ± 0.2^{i}	0.2 ± 0.0^{c}	28.0 ± 4.3^{a}	275.8 ± 1.6^{b}	5.5 ± 0.0^{c}
TF2	56.6 ± 0.6^{ab}	27.7 ± 1.4^{a}	13.5 ± 0.3^{f}	0.2 ± 0.0^{c}	26.6 ± 1.8^{ab}	194.6 ± 3.1^{d}	5.6 ± 0.0^{c}
TF3	56.6 ± 5.0^{ab}	20.8 ± 2.3^{e}	18.6 ± 0.2^{b}	0.6 ± 0.0^{a}	19.1 ± 2.4^{e}	58.1 ± 3.1^{k}	5.8 ± 0.0^{a}
TF4	55.5 ± 2.7^{abc}	23.9 ± 0.3^{cd}	18.0 ± 0.1^{c}	0.1 ± 0.0^{d}	21.9 ± 0.2^{d}	93.8 ± 4.6^{j}	5.1 ± 0.0^{h}
TF5	51.8 ± 1.7^{c}	26.6 ± 0.8^{abc}	20.6 ± 0.0^{a}	0.2 ± 0.0^{c}	27.5 ± 0.3^{ab}	172.2 ± 3.8^{f}	5.1 ± 0.0^{gh}
TF6	54.2 ± 1.9^{bc}	27.3 ± 0.4^{a}	11.4 ± 0.1^{i}	0.6 ± 0.0^{a}	26.7 ± 0.1^{ab}	266.0 ± 2.5^{c}	5.6 ± 0.0^{b}
TF7	56.8 ± 0.6^{ab}	26.9 ± 0.6^{ab}	12.5 ± 0.3^{g}	0.4 ± 0.0^{b}	24.7 ± 0.9^{bcd}	161.0 ± 9.6^{g}	5.6 ± 0.0^{c}
TF8	54.6 ± 0.6^{bc}	26.0 ± 0.5^{abcd}	12.4 ± 0.3^{g}	0.1 ± 0.0^{d}	25.5 ± 0.9^{abc}	165.9 ± 7.3^{fg}	5.5 ± 0.0^{c}
TF9	56.8 ± 2.4^{ab}	27.9 ± 0.8^{a}	14.6 ± 0.3^{e}	0.2 ± 0.0^{c}	26.7 ± 0.7^{ab}	137.9 ± 8.8^{i}	5.2 ± 0.0^{e}
TF10	57.8 ± 2.6^{ab}	23.5 ± 0.3^{d}	17.9 ± 0.1^{cd}	0.6 ± 0.0^{a}	23.2 ± 0.3^{cd}	289.8 ± 2.9^{a}	5.2 ± 0.0^{f}
TF11	56.1 ± 1.5^{ab}	26.4 ± 0.9^{abc}	11.4 ± 0.1^{i}	0.2 ± 0.0^{c}	25.8 ± 1.3^{abc}	153.3 ± 3.8^{h}	5.3 ± 0.0^{d}
TF12	58.4 ± 1.1^{ab}	24.2 ± 0.5^{bcd}	17.2 ± 0.1^{d}	0.2 ± 0.0^{c}	26.6 ± 0.9^{ab}	186.9 ± 1.9^{e}	5.1 ± 0.0^{g}
TF13	56.2 ± 2.6^{ab}	26.9 ± 1.4^{ab}	11.9 ± 0.3^{h}	0.1 ± 0.0^{d}	25.8 ± 1.4^{abc}	144.2 ± 7.2^{i}	5.3 ± 0.0^{d}

[1)]Group are the same as in Table-1; [2)]Values are expressed as the mean ± S.D. of at least three independent experiments, each performed in triplicate (n = 3); [3)]Means with different letters in the row are significantly different at $p < 0.05$ by Duncan's multiple range test.

TABLE-3
CONTENTS OF TOTAL NITROGEN (TN), AMINO NITROGEN (AN) AND THE RATIOS OF AN/TN OF A SALT-FERMENTED COMMERCIAL FISH SAUCES IN THAILAND

Sample[1)]	Total nitrogen content (g-N/100 mL)	Amino nitrogen content (mg-N/100 mL)	AN/TN (%)
TF1	1.85 ± 0.03[2)i3)]	1,666.0 ± 22.8[b]	90.0 ± 3.4[b]
TF2	2.15 ± 0.04[f]	1,246.0 ± 0.0[f]	57.8 ± 0.0[e]
TF3	2.97 ± 0.03[b]	749.0 ± 14.0[i]	25.2 ± 1.9[h]
TF4	2.88 ± 0.00[c]	833.0 ± 14.0[h]	28.9 ± 7.6[g]
TF5	3.56 ± 0.00[a]	406.0 ± 0.0[j]	11.4 ± 2.3[i]
TF6	1.81 ± 0.01[i]	1,750.0 ± 0.0[a]	96.2 ± 0.0[a]
TF7	2.00 ± 0.04[g]	1,393.0 ± 42.0[d]	69.7 ± 5.0[d]
TF8	1.98 ± 0.04[g]	1,337.0 ± 14.0[e]	67.2 ± 1.5[d]
TF9	2.33 ± 0.04[e]	1,232.0 ± 16.2[f]	52.9 ± 1.8[f]
TF10	2.85 ± 0.01[cd]	903.0 ± 14.0[g]	31.6 ± 3.8[g]
TF11	1.82 ± 0.03[i]	1,582.0 ± 0.0c	86.7 ± 0.0[c]
TF12	2.80 ± 0.00[d]	896.0 ± 16.2[g]	31.9 ± 8.8[g]
TF13	1.90 ± 0.04[h]	1,323.0 ± 14.0[e]	69.3 ± 1.7[d]

[1)]Group are the same as in Table-1; [2)]Values are expressed as the mean ± SD of at least three independent experiments, each performed in triplicate (n = 3); [3)]Means with different letters in the row are significantly different at $p < 0.05$ by Duncan's multiple range test.

nitrogen, which meet Korea's Food Code standards and quality standards for Fishery Traditional Food by item, various efforts such as improving manufacturing processes are needed to rank and differentiate the products.

Colour: The chromaticity of commercially available fish sauce products from Thailand was studied and the results are summarized in Table-4. Lucidity was 34.76-53.39, showing clear differences between products, the highest in TF6 (53.39) and the lowest in TF12 and TF13 (34.76 and 34.07, respectively). Redness was 10.68-28.79, showing distinct differences between products, the lowest in TF8 (10.68) and the highest in TF4 (28.79). Yellowness ranged from 4.74-36.06, showing significant differences between products, the highest in TF4 (36.06) and the lowest in TF8 (4.74).

Organic acid content: Organic acid content of commercially available fish sauce products from Thailand was studied and the results are summarized in Table-5. Detected organic acids from commercially available fish sauce products were the acetic acid and butyric acid and the total amount of organic acid ranged from 1.11-7.06 mg/L, showing significant differences between products. The total amount of organic acid was the highest in TF5 (7.06 mg/L), followed by TF6 > TF1 > TF2 and the lowest in TF10 and TF12 (1.24 mg/L and 1.11 mg/L, respectively). Acetic acid was the highest in TF13 out of all the products (2.26 mg/L), followed by TF11 > TF1 > TF2 and the lowest in TF10 (0.07 mg/L). Produced when glycogen is degraded through glycolysis, lactic acid was the highest in TF5 (5.65 mg/L), followed by TF6 > TF9 > TF2 and the lowest in TF10 (0.65 mg/L). Because it represents 43.4-80.0 % of the total amount of organic acid, lactic acid accounts for the majority of organic acids. The total amount of organic acid for a commercially available 90 day aged salt-fermented Toha shrimp was 791.7 mg/100 g. It has been reported that the total amount of lactic acid was 752.3 mg/100 g, showing similar trend with the finding that it accounts for most of the organic acids [16], but the total amount of organic acid was significantly lower. Although there has been a report on a similar trend showing that lactic acid content of a 60-day aged anchovy soy extract represents 68.2-71.8 % of the total amount of organic acid [17], that content was significantly low. Lactic acid content was significantly low compared to prior studies, but because the ratio of the total amount of organic acid was high, it has been speculated that organic acid enhances the unique taste of fish sauce by complementing the savory and sweet tastes of free amino acids together with the salt included in the fermented fish. Propionic acid ranged from 0.06-0.38 mg/L and showed significant differences between products. It was the highest in TF5 (0.38 mg/L), the lowest in TF10 (0.06 mg/L) and undetectable in TF3, TF11 and TF13. Butyric acid ranged from 0.03-0.91 mg/L and also showed significant differences between products. It was the highest in TF6 (0.91 mg/L), the lowest in TF12 (0.03 mg/L) and undetectable in TF3, TF8, TF11 and TF13.

Free amino acid: Free amino acid content of commercially available fish sauce products from Thailand was studied and the results are summarized in Table-6. Free amino acid content ranged from 1,103.7-9,581.8 mg %, showing distinct differences between products. It was the highest in TF11 (9,581.8 mg %), followed by that in TF12 > TF7 > TF6 and was the lowest in TF5 (1,103.7 mg %). The main amino acids

TABLE-4
COLOUR VALUES OF A SALT-FERMENTED COMMERCIAL FISH SAUCES IN THAILAND

Sample[1)]	L	a	b	ΔE
TF1	36.92 ± 0.09[2)ef3)]	16.53 ± 0.46[f]	7.70 ± 0.05[h]	24.93 ± 0.49[h]
TF2	37.83 ± 0.38[e]	18.75 ± 0.12[e]	10.49 ± 0.46[g]	29.17 ± 0.95[ef]
TF3	39.31 ± 0.57[d]	16.25 ± 0.45[f]	8.14 ± 0.09[h]	26.53 ± 0.90[g]
TF4	52.70 ± 0.34[a]	28.79 ± 0.48[a]	36.06 ± 1.04[a]	51.40 ± 0.35[a]
TF5	45.04 ± 0.47[b]	19.05 ± 0.44[e]	13.32 ± 0.66[f]	34.90 ± 0.72[c]
TF6	53.39 ± 0.88[a]	25.32 ± 1.51[c]	23.96 ± 2.48[c]	43.30 ± 1.31[b]
TF7	45.24 ± 0.38[b]	27.68 ± 0.82[ab]	17.77 ± 0.77[d]	32.63 ± 0.55[d]
TF8	36.62 ± 0.77[f]	10.68 ± 0.46[g]	4.74 ± 0.33[i]	23.87 ± 1.22[h]
TF9	44.22 ± 0.78[b]	27.33 ± 1.17[b]	26.42 ± 1.74[b]	43.97 ± 0.65[b]
TF10	40.98 ± 0.54[c]	18.01 ± 0.66[e]	11.75 ± 0.73[fg]	33.03 ± 0.81[d]
TF11	40.37 ± 0.81[c]	21.71 ± 0.62[d]	11.57 ± 0.37[fg]	28.00 ± 0.26[f]
TF12	34.76 ± 0.83[g]	18.28 ± 0.44[e]	13.33 ± 0.17[f]	34.83 ± 1.46[c]
TF13	34.07 ± 0.35[g]	26.61 ± 0.39[b]	15.46 ± 0.52[e]	30.10 ± 0.50[e]

[1)]Group are the same as in Table-1; [2)]Values are expressed as the mean ± S.D. of at least three independent experiments, each performed in triplicate (n = 3); [3)]Means with different letters in the row are significantly different at $p < 0.05$ by Duncan's multiple range test.

TABLE-5
ORGANIC ACID CONTENTS OF A SALT-FERMENTED COMMERCIAL FISH SAUCES IN THAILAND (unit: mg/L)

Sample[1)]	Acetic acid	Lactic acid	Propionic acid	Ethanol	Butyric acid	Total
TF1	1.59	3.17	0.25	–	0.50	5.50
TF2	1.32	3.56	0.22	–	0.28	5.38
TF3	0.69	1.43	–	–	–	2.12
TF4	0.53	2.44	0.25	–	0.50	3.71
TF5	0.27	5.65	0.38	–	0.75	7.06
TF6	1.13	4.13	0.25	–	0.91	6.42
TF7	1.36	2.28	0.12	–	0.27	4.02
TF8	1.36	2.77	0.14	0.64	–	4.91
TF9	0.53	4.02	0.32	–	0.35	5.22
TF10	0.07	0.65	0.06	–	0.45	1.24
TF11	2.07	1.65	–	–	–	3.72
TF12	0.11	0.86	0.11	–	0.03	1.11
TF13	2.26	1.73	–	–	–	3.99

[1)]Group are the same as in Table-1

TABLE-6
FREE AMINO ACID CONTENTS OF A SALT-FERMENTED COMMERCIAL FISH SAUCES IN THAILAND (unit: mg %)

Amino acids	TF1	TF2	TF3	TF4	TF5	TF6	TF7	TF8	TF9	TF10	TF11	TF12	TF13
Phosphoserine	16.3	0.0	0.00	6.0	0.0	14.0	12.7	18.1	0.0	0.0	0.0	0.0	14.2
Taurine	98.8	107.2	48.41	40.5	33.1	118.9	87.7	93.6	60.4	79.6	129.6	57.2	123.6
Phosphoethanlamine	44.2	0.0	0.0	7.1	0.0	0.0	0.0	74.9	5.0	2.1	0.0	0.0	0.0
Urea	0.0	0.0	0.0	0.0	5.3	0.0	0.0	0.0	162.7	70.0	0.0	115.4	0.0
Aspartic acid	538.5	589.2	327.6	311.8	21.2	370.4	448.7	630.4	459.3	153.2	437.7	179.9	409.1
Threonine	292.8	340.7	203.9	187.2	13.0	430.9	433.1	347.3	273.9	79.2	502.5	125.7	481.4
Serine	209.5	257.7	120.2	129.4	4.8	244.9	338.5	235.9	181.0	53.7	336.4	53.8	312.1
Glutamic acid	1009.6	888.6	550.3	642.0	151.3	1244.1	1163.7	896.3	963.7	641.4	1393.3	713.1	1323.0
Sarcosine	0.0	12.7	2.4	2.6	0.0	8.4	17.9	17.4	10.6	6.2	19.5	6.5	18.9
α-Amino adipic acid	15.8	39.0	15.4	18.5	2.4	58.6	42.9	23.3	34.8	13.2	55.8	10.4	56.8
Glycine	2078.1	436.7	205.5	617.3	16.5	402.0	550.1	1817.5	1215.6	385.6	411.0	148.8	374.2
Alanine	518.7	551.1	577.7	309.4	106.9	712.2	657.2	571.2	471.0	285.5	731.8	344.8	694.4
Citrlline	437.4	573.7	199.3	302.9	40.4	780.8	745.9	431.1	503.1	171.9	459.7	259.0	473.7
α-Amino-*n*-butyric acid	26.0	19.4	8.8	12.2	4.4	39.4	26.7	27.0	17.6	11.6	25.1	18.8	24.5
Valine	418.0	464.2	250.9	273.3	87.7	570.3	545.5	448.6	399.8	204.3	605.3	299.5	579.5
Cysteine	34.8	40.5	22.1	26.9	7.1	55.1	49.6	27.8	41.5	16.4	55.2	20.0	55.5
Methionine	191.6	227.1	111.8	159.0	22.5	279.5	269.2	179.4	200.1	68.3	288.8	140.7	280.1
Isoleucine	374.7	388.4	171.1	303.2	85.4	433.9	405.4	314.3	375.4	225.0	432.1	326.4	426.5
Leucine	562.1	599.3	236.0	530.1	149.6	584.1	582.6	422.9	613.2	414.6	578.9	582.6	570.8
Tyrosine	132.7	146.3	76.6	81.0	40.1	157.8	168.2	126.3	111.8	59.7	185.4	84.3	182.2
Phenylalanine	298.6	345.1	174.7	214.9	65.4	425.0	399.3	288.3	301.8	146.0	437.6	224.8	425.0
β-Alanine	46.3	19.6	8.1	8.9	4.3	27.3	18.3	67.3	13.8	11.8	10.8	14.7	9.9
β-Amino isobutyric acid	30.9	28.7	14.8	11.6	4.4	34.5	30.2	30.8	18.0	16.1	34.0	15.6	34.3
γ-Amino butyric acid	15.3	4.8	2.9	1.9	7.1	11.9	5.2	11.9	4.7	21.2	4.6	17.2	4.6
Ammonia	227.4	143.6	68.2	83.2	138.8	198.2	139.5	145.4	133.0	242.0	146.0	178.1	140.0
Ornithine	77.8	88.2	91.2	54.6	26.9	83.5	83.6	107.8	64.8	58.9	207.2	76.6	181.1
Lysine	634.9	764.6	455.2	398.4	60.5	949.0	949.5	726.4	617.0	266.0	1069.7	407.8	1016.9
1-Methylhistidine	0.0	0.0	0.0	0.0	0.0	0.0	252.0	0.0	0.0	0.0	0.0	0.0	0.0
Histidine	172.7	207.0	130.5	95.1	4.6	207.0	11.1	199.6	130.2	37.1	368.3	71.4	342.3
3-Methylhistidine	0.0	1.5	0.0	4.4	0.0	12.3	216.8	0.0	6.1	0.0	0.0	0.0	0.0
Anserine	115.3	153.6	62.3	82.2	0.0	217.9	0.0	88.8	124.9	42.5	213.0	33.4	216.0
Carnosine	0.0	0.0	0.0	0.0	0.0	0.0	17.7	0.0	0.0	0.0	5.3	0.0	5.1
Arginine	51.4	26.6	58.9	0.0	0.0	0.0	8.0	56.2	0.0	3.1	188.4	8.7	177.7
Hydroxyproline	0.0	6.5	1.5	0.0	0.0	4.1	222.2	7.3	0.0	0.0	10.5	0.0	10.8
Proline	129.4	163.6	94.1	82.3	0.0	188.2	0.0	172.2	106.0	31.9	238.3	39.7	224.0
Total	8,799.6	7,635.2	4,290.4	4,997.9	1,103.7	8,864.2	8,899.0	8,605.3	7,620.8	3,818.1	9,581.8	4,574.9	9,188.2

in the commercially available fish sauce products were aspartic acid, glutamic acid and tyrosine. Aspartic acid was the highest in TF8 (630.4 mg %), followed by that in TF2 > TF1 > TF9 and the lowest was in TF5 (21.2 mg %). Glutamic acid was the highest in TF11 (1,393.3 mg %), followed by that in TF12 > TF6 > TF7 and the lowest was in TF5 (151.3 mg %). Taurine was the highest in TF11 (129.6 mg %), followed by that in TF13 > TF6 > TF2 and the lowest was in TF5 (33.1 mg %). Umami amino acid content was the highest in TF11 (1,831.1 mg %), followed by that in TF13 > TF6 > TF7 and the lowest was in TF5 (172.6 mg %) (Table-7). Sweetness amino acid (SA) content were the highest in TF1 (4,238.3 mg %), followed

TABLE-7
AMINO ACID COMPOSITION OF A SALT-FERMENTED COMMERCIAL FISH SAUCES IN THAILAND (unit: mg %)

Items[1)]	TF1	TF2	TF3	TF4	TF5	TF6	TF7	TF8	TF9	TF10	TF11	TF12	TF13
Umami	1,548.2	1,477.9	878.0	953.8	172.6	1,614.6	1,612.5	1,526.8	1,423.1	794.7	1,831.1	893.1	1,732.1
Sweet	4,238.3	2,638.7	1,752.0	1,967.9	292.8	3,222.6	3,142.8	4,040.6	3,211.6	1,477.5	3,613.6	1,426.1	3,409.4
Bitter	2,202.2	2,404.4	1,210.9	1,656.9	455.5	2,657.9	2,389.7	2,036.0	2,132.6	1,158.3	3,085.1	1,738.8	2,984.5
SA/BA	1.9	1.1	1.4	1.2	0.6	1.2	1.3	2.0	1.5	1.3	1.2	0.8	1.1
Essential	2,824.4	3,156.5	1,662.8	2,066.5	484.4	3,673.0	3,593.1	2,783.8	2,781.5	1,406.7	4,103.7	2,116.6	3,958.3
Non-essential	4651.5	3,074.1	1,974.5	2,200.4	348.2	3,375.1	3,376.2	4,477.9	3,550.4	1,627.7	3,789.4	1,584.7	3,574.8

[1)]Umami: umami amino acids, aspartic acid, glutamic acid; Sweet, sweetness amino acids, glutamic acid, alanine, threonine, glycine, serine, proline; Bitterness, bitterness amino acids, valine, methionine, isoleucine, histidine, arginine, tyrosine, phenylalanine, leucine; SA/BA, sweetness amino acids/bitterness amino acids; Essential, essential amino acids, arginine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, valine; Non-essential, non-essential amino acids, serine, aspartic acid, glutamic acid, glycine, alanine, proline, tyrosine, cysteine.

by that in TF8 > TF11 > TF13 and the lowest was in TF5 (292.8 mg %). Bitterness amino acid (BA) content were the highest in TF11 (3,085.1 mg %), followed by that in TF13 > TF6 > TF2 and the lowest was in TF5 (455.5 mg %). SA/BA was the highest in TF8 (2.0) followed by that in TF1 (1.9) > TF9 (1.5) > TF3 (1.4) and the lowest was in TF5 (0.6). Essential amino acid content were the highest in TF11 (4,103.7 mg %), followed by that in TF13 > TF6 > TF7 and the lowest was in TF 5 (484.4 mg %). Non-essential amino acid content were the highest in TF1 (4,651.5 mg %), followed by that in TF8 > TF11 > TF13 and the lowest was in TF5 (348.2 mg %).

Analysis of aroma pattern using an electronic nose: Unlike GC-MS that allows qualitative and quantitative analyses, an electronic nose has a built-in chemical sensor that reacts with the sample volatile compounds, thereby allowing a non-destructive analytical method that shows characteristic patterns [18,19]. Because analysis using this kind of electric nose detects the overall mixed aroma by using a quick and convenient method, its response is similar to that of humans or can even respond to chemical substances that humans cannot detect [19]. The results of analyzing the aroma pattern of commercially available fish sauce products using the electronic nose analysis are summarized in Figs. 1 and 2. Fig. 1 is a three-dimensional graph that represents the derived pattern recognition value, which uses the detection sensitivity value of commercially available fish sauces from Thailand. Accumulation contribution of the three main ingredients (PC1-3) was 98.7 %. Clear distinction was possible due to ingredients in TF1, TF2, TF5, TF7 and TF12, but other products, excluding these, formed small clusters and showed marginal differences. Fig. 2 is a graph representing the difference in the principal component analysis (PCA) of the peaks that appear during the electronic nose analysis of commercially available fish sauces from Thailand. Results show that TF7 is located in the bottom line right area and TF6 and TF1 in the upper left. TF3 is located in the uppermost right and TF2 in the middle upper right. TF5, TF9 and TF10 are located in the upper right area and it was difficult to clearly differentiate them. Moreover, TF8, TF11 and TF13 are located in the upper right area and it was also difficult to clearly differentiate them. Although it was difficult to compare the pattern of products that were already clustered, it was confirmed that the overall aroma pattern for each product was indeed different from that of the others. The differences in aroma pattern between each product are supposedly due to differences in quality caused during fermentation, depending on minor ingredients used during production, manufacturing environment and manufacturing conditions, therefore resulting in differences in the aroma pattern of the final product.

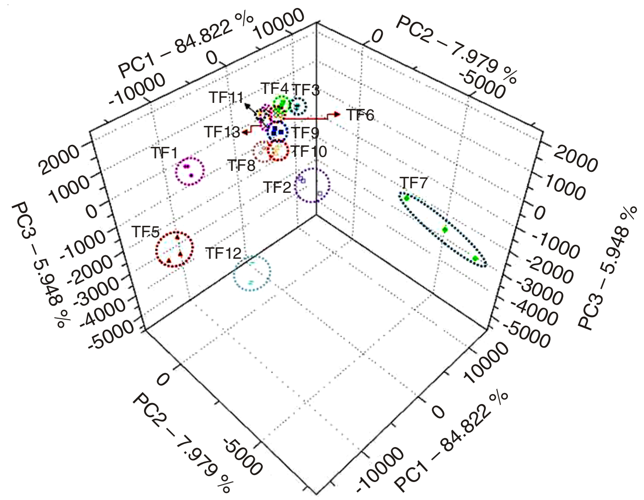

Fig. 1. 3D principal component analysis (PCA) plot of a salt-fermented commercial fish sauces in Thailand

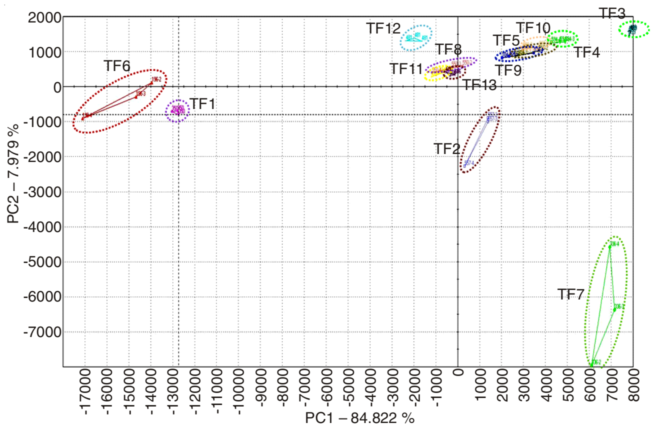

Fig. 2. 2D principal component analysis (PCA) plot of a salt-fermented commercial fish sauces in Thailand

Conclusion

In this study, we investigated the component characteristics of commercially available fish sauces from Thailand. Moisture content was 51.8-59.5 % and was the highest in TF1 (59.5 %). Ash content was 20.8-28.3 % and was the lowest in TF3. Crude protein content was 11.4-20.6 % and was the highest in TF5. Crude fat content was 0.1-0.6 % and was the highest in TF3, TF6 and TF10. Salinity was 19.1-28.0 % and was the highest in TF1. The volatile base nitrogen content was the highest in

TF10 and the lowest in TF3. pH was in the range of 5.1-5.8. The total nitrogen content was 1.8-3.5 g % and was the highest in TF5. Amino nitrogen content was 406.0-1,750.0 mg % and was the highest in TF6. Lucidity was 34.7-53.3, showing clear differences between products and the highest was in TF6. Redness was 10.68-28.79 and was the highest in TF4. Yellowness was 4.74-36.06 and was the highest in TF4. Major organic acids were acetic acid and butyric acid. The total amount of organic acid was 1.11-7.06 mg/L and was the highest in TF5. Acetic acid, lactic acid and propionic acid contents were the highest in TF13, TF5 and TF5, respectively. Butyric acid content was 0.03-0.91 mg/L, showing significant differences between products and the highest was in TF6. The total amount of free amino acid was 1,103.7-9,581.8 mg % it was the highest in TF11 and the lowest in TF5. Major amino acids were aspartic acid, glutamic acid and tyrosine. Aspartic and glutamic acid were the highest in TF8 and TF11, respectively. Umami amino acid was the highest in TF11. Sweet and bitter amino acid were higher in TF1 and TF11, respectively. SA/BA was the highest in TF8 (2.0) and the lowest in TF5 (0.6). Essential and non-essential amino acid were the highest in TF11 and TF1, respectively. The aroma pattern of each product tested occupied different areas depending on the product, confirming that differentiation is possible. Fish sauce aroma pattern determined using an electronic nose can be utilized to distinguish quality differences between products. As international trade increases nowadays, imports in various processed marine products have increased. Therefore, results of this study can not only be used as a database to provide information on Thailand fish sauces, but also have value for practical use as basic research data to improve the quality of domestic fish sauces.

ACKNOWLEDGEMENTS

This study was supported, in part, by grants from the KIMST (Korea Institute of Marine Science and Technology Promotion), Fishery Commercialization Technology Development Program (GA142600-03) and we thank the institute for the support.

REFERENCES

1. M. Smriga, T. Mizukoshi, D. Iwahata, S. Eto, H. Miyano, T. Kimura and R.I. Curtis, *J. Composition Anal.*, **23**, 442 (2010).
2. J.N. Park, Y. Fukumoto, E. Fujita, T. Tanaka, T. Washio, S. Otsuka, T. Shimizu, K. Watanabe and H. Abe, *J. Food Compos. Anal.*, **14**, 113 (2001).
3. T. Dincer, S. Cakli, B. Kilinc and S. Tolasa, *J. Animal Vet. Adv.*, **9**, 311 (2010).
4. S.U. Shin, M.A. Kwon, M.S. Jang and T.J. Kang, *Korean J. Food Sci. Technol.*, **34**, 666 (2002).
5. AOAC, Official Methods of Analysis, Association of Official Analytical Chemists, Washington DC, edn 15, pp. 210-219 (2006).
6. H.W. Doughty, *J. Am. Chem. Soc.*, **46**, 2707 (1924).
7. E.J. Conway, Microdiffusion Analysis and Volumetric Error, The MacMillian Co., New York, USA, p. 303 (1958).
8. H.S. Choi, S.J. Joo, H.S. Yoon, K.S. Kim, I.G. Song and K.B. Min, *Korean J. Food Preserv.*, **14**, 356 (2007).
9. S.G. Chae, Standard Food Analysis, Jigumunwhasa Co., Seoul, Korea, pp. 299-301 (2000).
10. V.C. Witte, G.F. Krause and M.E. Bailey, *J. Food Sci.*, **35**, 582 (1970).
11. KFDA, Food Code, Korean Food and Drug Administration, Seoul, Korea (2002).
12. KSA, Korean Industrial Standards KSH 6022, Korean Standards Association, Seoul, Korea (2002).
13. M.R. Jang, I.Y. Kim, M.-S. Hong, J.-M. Shin and K.-Y. Han, *Korean J. Food Sci. Technol.*, **36**, 423 (2004).
14. T. Fuji and H. Sakai, *Bull. Tokai Rg. Lab.*, **119**, 9 (1986).
15. Y.J. Cho, Y.S. Im, K.W. Lee, G.B. Kim and Y.J. Choi, *J. Korean Fish Soc.*, **32**, 612 (1999).
16. E.H. Lee, J.S. Lee, D.S. Joo, J.J. Park, H.K. Kim and S.Z. Chang, *J. Korean Soc. Food Nutr.*, **25**, 325 (1996).
17. E.H. Lee, C.B. Ahn, J.S. Kim, K.H. Lee, M.C. Kim and B.K. Chung, *J. Korean Soc. Food Nutr.*, **18**, 131 (1989).
18. B.S. Noh, Y.M. Yang, T.S. Lee, H.K. Hong, C.H. Kwon and Y.K. Sung, *Korean J. Food Sci. Technol.*, **30**, 356 (1998).
19. H.-K. Hong, H.W. Shin, H.S. Park, D.H. Yun, C.H. Kwon, K. Lee, S.-T. Kim and T. Moriizumi, *Sens. Actuators B*, **33**, 68 (1996).