Chemical compositions, sensory and antioxidative properties of salted shrimp paste *(Ka-pi)* in Thailand

[1]Pongsetkul, J., [1,]*Benjakul, S., [1]Sampavapol, P., [2]Osako, K. and [1]Faithong, N.

[1]Department of Food Technology, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, 90112, Thailand
[2]Department of Food Science and Technology, Tokyo University of Marine Science and Technology, 5-7 Konan 4, Minato-ku, Tokyo, 108-8477, Japan

Abstract

Chemical compositions, sensory and antioxidative properties of 11 salted shrimp paste *(Ka-pi)* obtained from various places of Thailand were determined. Different salted shrimp pastes had varying amino acid compositions. Glu/Gln and Asp/Asn were the major amino acids. Among all samples, S9 (*Kapi* Rayong), which had the highest total amino acid (68.95 mg/g sample), generally had the highest sensory score for all attributes. Volatile compounds varied in types and abundance among samples, but pyrazine derivatives were the major volatile components in all samples. Browning intensity and intermediate browning products were different between samples. The highest antioxidative activities as determined by DPPH, ABTS, H_2O_2 radical and singlet oxygen scavenging activities, FRAP and metal chelating activity were found for S1 (*Kapi* Satun). Therefore, salted shrimp pastes having nutritive value and antioxidative activity were different in sensory property, thereby determining the consumer acceptability.

Introduction

Kapi is a traditional salted shrimp paste of Thailand. It is mainly produced from the marine shrimp or krill (*Acetes* or *Mesopodopsis* species), which are mixed with salt at a ratio of 3-5:1. The moisture content is decreased by sun drying, and then it is thoroughly blended or homogenized to produce semi-solid paste. The paste is fermented for two months until the desired flavor is developed (Phithakpol, 1993). *Kapi* is usually used as a condiment to enhance the palatability of foods (Yoshida, 1998). *Kapi* is very rich in umami taste and contains high amounts of free glutamic acid (647 mg/100 g) (Mizutani *et al.*, 1987). Salted shrimp paste has slight cheese-like flavor and an appetite-stimulating aroma (Peralta *et al.*, 2008). More than 150 volatile compounds have been identified in fish and shrimp pastes (Cha *et al.*, 1998). The compounds consist of aldehydes, ketones, alcohols, aromatic compounds, N-containing compounds, esters, S-containing compounds and some other compounds. Previous studies noted that the presence of these S-containing compounds may affect the overall flavor because of their low thresholds (Maga and Katz, 1979; Agrahar-Murugkar and Subbulakshmi, 2006). During fermentation, the transformation of organic substances into simpler compounds such as peptides, amino acids, and other nitrogenous compounds either by the action of microorganisms or endogenous enzymes takes place. Peptides and amino acids are important contributors to the flavor and aroma of fermented products (Raksakulthai and Haard, 1992). Furthermore, the fermented fish products containing active peptides or free amino acids generated throughout fermentation from both endogenous and exogenous enzymes (Rajapakse *et al.*, 2005). Recently, some fermented shrimp and krill products have been reported to exhibit strong antioxidant activities (Faithong *et al.*, 2010). However, a little information regarding amino acid compositions, volatile compounds, antioxidative activities and sensory properties of salted shrimp paste *(Kapi)* produced in Thailand has been reported. Thus, the objective of this study was to determine chemical composition, sensory and antioxidative properties of salted shrimp pastes collected from various regions of Thailand.

Materials and Methods

Chemicals

All chemicals were of analytical grade. 2,4,6-trinitrobenzene-sulphonic acid (TNBS), 2,20-azinobis(3-ethylbenzothiazoline-6-sulphonic

*Corresponding author.
Email: *soottawat.b@psu.ac.th*
Tel: 66 7428 6334; Fax: 66 7455 8866

acid) (ABTS), 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,4,6-tripyridyltriazine (TPTZ), 3-(2-pyridyl)-5,6-diphenyl-1,2,4-triazine-4',4''-disulphonic acid sodium salt (ferrozine), ethylenediaminetetraacetic acid (EDTA), hydrogen peroxide (H_2O_2), 5,5-dimethyl-1-pyrroline N-oxide (DMPO), N,N-dimethyl ρ-nitrosoaniline (DPN), histidine, sodium hypochlorite (NaOCl) and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) were purchased from Sigma Chemical Co. (St. Louis, MO, USA).

Collection and preparation of samples

Salted shrimp paste samples were purchased from different provinces in Thailand, including Songkhla (2 samples), Ranong (2 samples), Krabi (2 samples), Satun (1 sample), Samut Sakorn (1 sample), Rayong (1 sample), Chachoengsao (1 sample) and Samut Songkram (1 sample). Each sample was separated into several portions (100 g each), placed in polyethylene bag and heat-sealed. The samples were kept at -20°C and the storage time was not longer than 2 months. All samples were subjected to analyses.

Determination of amino acid compositions

Amino acid compositions of salted shrimp pastes were determined according to the method of Minh Tauy *et al.* (2014) with a slight modification. Twenty milligrams of sample were hydrolyzed in 6 M HCl at 110°C for 22 h under vacuum. The hydrolysate was neutralized with 6 M and 0.6 M NaOH, and filtered through a cellulose membrane filter (0.45 μm; Toyo Roshi Kaisha, Ltd., Tokyo, Japan). The filtrate was used for amino acid analysis using an amino acid analysis system (Prominence; Shimadzu, Kyoto, Japan) equipped with a column (Shim-pack Amino-Li, 100 mm × 6.0 mm i.d.; column temperature, 39.0°C; Shimadzu) and pre-column (Shim-pack ISC-30/S0504 Li, 150 mm × 4.0 mm i.d.; Shimadzu). Amino acids were detected using a fluorescence detector (RF-10AXL; Shimadzu, Kyoto, Japan).

Determination of volatile compounds

The volatile compounds of different salted shrimp pastes were determined using a solid-phase microextraction gas chromatography mass spectrometry (SPME GC-MS) following the method of Iglesias and Medina (2008) with a slight modification.

Extraction of volatile compounds by SPME fiber

To extract volatile compounds, 5 g of salted shrimp paste was mixed with 10 ml of deionized water. The mixture was homogenized at a speed of 13,000×g for 1 min to disperse the sample. The homogenate was placed in a 20-ml headspace vial (Supelco, Bellefonte, PA, USA) for each SPME. The vials were tightly capped with a PTFE septum and heated at 60°C with equilibrium time of 10 h. The SPME fiber (50/30 lm DVB/Carboxen™/PDMS StableFlex™) (Supelco, Bellefonte, PA, USA) was conditioned at 270ºC for 15 min before use and then exposed to the headspace. The 20 ml-vials (Agilent Technologies, Palo Alto, CA, USA) containing the sample extract and the volatile compounds were allowed to absorb into the SPME fiber at 60ºC for 1 h. The volatile compounds were then desorbed in the GC injector port for 15 min at 270ºC.

GC-MS analysis

GC-MS analysis was performed in a HP 5890 series II gas chromatography (GC) coupled with HP 5972 mass-selective detector equipped with a splitless injector and coupled with a quadrupole mass detector (Hewlett Packard, Atlanta, GA, USA). Compounds were separated on a HP-Innowax capillary column (Hewlett Packard, Atlanta, GA, USA) (30 m ± 0.25 mm ID, with film thickness of 0.25 μm). The GC oven temperature program was: 35ºC for 3 min, followed by an increase of 3ºC/min to 70ºC, then an increase of 10ºC/min to 200ºC, and finally an increase of 15ºC/min to a final temperature of 250ºC and holding for 10 min. Helium was employed as a carrier gas, with a constant flow of 1 ml/min. The injector was operated in the splitless mode and its temperature was set at 270ºC. Transfer line temperature was maintained at 260ºC. The quadrupole mass spectrometer was operated in the electron ionization (EI) mode and source temperature was set at 250ºC. Initially, full-scan-mode data was acquired to determine appropriate masses for the later acquisition in scan mode under the following conditions: mass range: 25-500 amu and scan rate: 0.220 s/scan. All analyses were performed with ionization energy of 70 eV, filament emission current at 150 μA, and the electron multiplier voltage at 500 V.

Analyses of volatile compounds

Identification of the compounds was done by consulting ChemStation Library Search (Wiley 275.L). Quantitative determination was carried out using an internal calibration curve that was built using stock solutions of the compounds in ultra-pure water saturated in salt and analyzing them by the optimized HS-SPME method. Quantification limits were calculated to a signal-to-noise (S/N) ratio of 10. Repeatability was evaluated by analyzing 3 replicates

of each sample. The identified volatile compounds were presented in the term of abundance.

Sensory properties

Samples were evaluated by 30 untrained panelists, who consume salted shrimp paste regularly. The samples were cut to obtain a thickness of 1 cm. The sample (2×2 cm^2) was wrapped with aluminum foil and heated in hot air oven at 60°C for 30 min. The samples were served in white paper plate at room temperature. All samples was coded with three digit random numbers and divided into 3 groups (4, 4 and 3 samples). Each group was randomly served. The panelists were allowed to rest for at least 15 min between different groups. Panelists were instructed to rinse their mouths with water or cucumber between different samples. Evaluations were made in individual sensory evaluation booths under fluorescent white light. The panelists were asked to assess samples for appearance liking, color liking, odor liking, flavor liking, texture liking and overall liking using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) (Mellgard *et al.*, 2007).

Browning and Maillard reaction product

Preparation of water extract

The extract was prepared according to the method of Peralta *et al.* (2008) with a slight modification. The salted shrimp paste (2 g) was mixed with 50 ml of distilled water. The mixtures were homogenized using an IKA Labortechnik homogenizer (Selangor, Malaysia) at a speed of 10,000×g for 2 min. The homogenates were then subjected to centrifugation at 13,000×g for 15 min at room temperature (Model RC-B Plus centrifuge Newtown, CT, USA). The supernatant was collected. The pellet was re-extracted as described above. The supernatants were combined and adjusted to 50 ml using distilled water.

Measurement of absorbance at 280 and 295 nm

A_{280} and A_{295} of the extract were determined according to the method of Ajandouz *et al.* (2001). The absorbance of the appropriately diluted extract was measured at 280 and 295 nm using UV-1601 spectrophotometer (Shimadzu, Kyoto, Japan) to monitor the formation of Maillard reaction intermediate products.

Measurement of browning intensity

The browning intensity of the extract was measured according to the method of Benjakul *et al.* (2005). Appropriate dilution was made using distilled water and the absorbance was measured at 420 nm using UV-1601 spectrophotometer.

Measurement of fluorescence intensity

Fluorescent intermediate products from Maillard reaction in the extract were determined as described by Morales and Jimenez-Perez (2001). The fluorescence intensity of appropriately diluted extract was measured at an excitation wavelength of 347 nm and emission wavelength of 415 nm using a fluorescence spectrophotometer RF-1501 (Shimadzu, Kyoto, Japan).

Antioxidative properties

Water extract from different salted shrimp pastes were subjected to determination of antioxidative activity using various assays.

DPPH radical scavenging activity

DPPH radical scavenging activity was determined according to the method of Wu *et al.* (2003) with a slight modification. The extract (1.5 ml) was added with 1.5 ml of 0.15 mM 2,2-diphenyl-1-picrylhydrazyl (DPPH) in 95% ethanol. The mixture was then mixed vigorously and allowed to stand for 30 min in dark at room temperature. The resulting solution was measured at 517 nm using an UV-1601 spectrophotometer. The blank was prepared in the same manner except that distilled water was used instead of the sample. The standard curve was prepared using Trolox in the range of 10-60 μM. The activity was expressed as μmol Trolox equivalents (TE)/g sample.

ABTS radical scavenging activity

ABTS radical scavenging activity was determined as described by Amao *et al.* (2001) with a slight modification. The stock solutions included 7.4 mM ABTS solution and 2.6 mM potassium persulfate solution. The working solution was prepared by mixing two stock solutions in equal quantities and allowed them to react in the dark for 12 h at room temperature. The solution was then diluted by mixing 1 ml of ABTS solution with 50 ml of methanol to obtain an absorbance of 1.1 (± 0.02) at 734 nm using an UV-1601 spectrophotometer. ABTS solution was prepared freshly for each assay. To initiate the reaction, 150 μl of sample was mixed with 2.85 ml of ABTS$^{\bullet+}$ solution. The mixture was incubated at room temperature for 2 h in dark. The absorbance was then read at 734 nm using an UV-1601 spectrophotometer. A Trolox standard curve (50-600 μM) was prepared. Distilled water was used instead of the sample and prepared in the same manner to obtain the control.

ABTS radical scavenging activity was expressed as µmol Trolox equivalents (TE)/g sample.

Ferric reducing antioxidant power (FRAP)

FRAP was evaluated by the method of Benzie and Strain (1996). The stock solutions included 10 mM TPTZ (2,4,6-tripyridyl-s-triazine) solution in 40 mM HCl, 20 mM $FeCl_3.6H_2O$ solution and 300 mM acetate buffer (pH 3.6). The working solution was prepared freshly by mixing 25 ml of acetate buffer, 2.5 ml of TPTZ solution and 2.5 ml of $FeCl_3.6H_2O$ solution. The mixture was incubated at 37°C for 30 min and was referred to as FRAP solution. The sample (150 µl) was mixed with 2.85 ml of FRAP solution. The mixture was allowed to stand in dark for 30 min at room temperature. Ferrous tripyridyltraizine complex, colored product, was measured by reading the absorbance at 593 nm. The standard curve was prepared using Trolox ranging from 50 to 600 µM. The activity was expressed as µmol Trolox equivalents (TE)/g sample.

Metal chelating activity

Metal chelating activity was investigated as described by Decker and Welch (1990) with a slight modification. Sample (220 µl) was mixed with 5 µl of 2 mM $FeCl_2$ and 10 µl of 5 mM ferrozine. The mixture was allowed to stand at room temperature for 20 min. Absorbance at 562 nm was read. EDTA with the concentrations of 0-30 µM was used as standard. Metal chelating activity was expressed as µmol EDTA equivalent (EE)/g sample.

Hydrogen peroxide radical scavenging activity

Hydrogen peroxide scavenging activity was assayed according to the method of Kittiphattanabawon *et al.* (2012). The extract (3.4 ml) was mixed with 600 µl of 43 mM hydrogen peroxide in 0.1 M phosphate buffer (pH 7.4). The absorbance at 230 nm of the reaction mixture was recorded after 40 min of reaction at 25°C. For sample blank, hydrogen peroxide was omitted and replaced by 0.1 M phosphate buffer (pH 7.4). Trolox (0-10 mM) was used as standard. The hydrogen peroxide scavenging activity was expressed as µmol Trolox equivalents (TE)/g sample.

Singlet oxygen scavenging activity

Singlet oxygen scavenging activity was determined as described by Kittiphattanabawon *et al.* (2012). The chemical solutions and the extract were prepared in 45 mM sodium phosphate buffer (pH 7.4). The reaction mixture consisted of 0.4 ml of extract, 0.5 ml of 200 µM N,N-dimethyl para-nitro-soaniline (DPN), 0.2 ml of 100 mM histidine, 0.2 ml of 100 mM sodium hypochlorite, and 0.2 ml of 100 mM H_2O_2. Thereafter, the total volume was made up to 2 ml with 45 mM sodium phosphate buffer (pH 7.4). The absorbance of the reaction mixture was measured at 440 nm after incubation at room temperature (25°C) for 40 min. Sample blank was run for each sample in the same manner, except DPN, histidine, and NaOCl solutions were replaced by sodium phosphate buffer. A standard curve of Trolox (0-10 mM) was prepared. Singlet oxygen scavenging activity was expressed as µmol Trolox equivalents (TE)/g sample.

Statistical analysis

All analyses were conducted in triplicate. Statistical analysis was performed using one-way analysis of variance (ANOVA). Mean comparison was carried out using Duncan's multiple range test (Steel *et al.*, 1980). SPSS statistic program (Version 10.0) (SPSS, 1.2, 1998) was used for data analysis.

Results and Discussion

Amino acid compositions

Amino acid compositions of 11 salted shrimp pastes are presented in Table 1. Total amino acid content varied among the samples. S9 (*Kapi* Rayong) had the highest total amino acid (68.95 mg/g sample). Coincidentally, the highest total essential amino acid content (25.16 mg/g sample) was also found for S9. In general, Glu/Gln and Asp/Asn were the major amino acids in salted shrimp paste. Gly, Leu and Lys were also found at a high extent in all samples. Xu *et al.* (2008) reported that fish sauce produced from squid by-product was rich in Glu, Asp, Cys, Leu and Ala (12.10, 9.33, 8.44, 7.32 and 7.22 mg/g sample respectively). The differences in amino acid compositions among the samples were more likely due to the difference in fermentation and processes used. Differences in raw material, especially shrimp or krill, were also presumed. Amino acids mainly contributed significantly to the taste and odor of salted shrimp paste. The typical flavor of Glu is meaty (Xu *et al.*, 2008). Taste of salted shrimp paste was influenced by Glu for umami and by Asp for sweetness (Kim *et al.*, 2005). Gly, Ala, Ser and Thr are also associated with sweetness (Liu, 1989). The contribution of amino acids to the aroma of fish sauce was reported by Lopetcharat *et al.* (2001). Based on the result, salted shrimp paste could be an excellent source of amino acids, particularly essential amino acids. Additionally, those amino acids more likely contributed to taste and flavor of salted shrimp paste.

Table 1. Amino acid composition of different salted shrimp pastes[*]

Amino acid composition (mg/g sample)	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Alanine (Ala)	2.57	1.93	4.59	1.69	4.03	5.01	3.26	3.74	6.65	4.66	4.36
Arginine (Arg)	1.69	0.77	2.55	2.13	3.7	1.16	0.66	2.21	2.49	0.91	0.77
Aspartic acid and Asparagine (Asp/Asn)	2.99	2.29	7.31	2.64	5.42	6.32	3.74	4.57	7.1	4.36	5.21
Cysteine (Cys)	0.06	0.08	0.17	0.05	0.13	0.18	0.11	0.11	0.04	0.14	0.12
Glycine (Gly)	1.87	1.52	3.86	1.33	2.79	4.29	2.33	2.79	4.48	2.76	3.06
Glutamic acid and Glutamine (Glu/Gln)	0.25	4.12	15.43	7.87	16.39	9.39	6.01	6.27	12.08	10.17	11.4
Histidine (His)[B]	0.46	0.37	0.83	0.36	0.71	0.54	0.51	0.59	0.98	0.74	0.64
Hydroxylysine (Hyl)	0.01	0.01	0.02	0.01	0.02	0.05	0.05	0.03	0.06	0.03	0.03
Hydroxyproline (Hyp)	0	0	0	0	0	0	0	0	0	0	0
Isoleucine (Ile)[A]	1.45	1.27	3.07	1.23	2.78	3.19	1.74	2.13	4.11	2.43	2.63
Leucine (Leu)[A]	2.58	2.08	4.1	1.79	4.67	5.14	3.08	3.39	6.42	3.62	3.99
Lysine (Lys)[A]	2.23	1.99	3.76	1.69	3.97	4.58	2.73	3.11	6.23	3.26	3.49
Methionine (Met)[A]	0.55	0.74	1.47	0.57	1.46	1.69	1.05	1.22	1.73	1.31	1.24
Phenylalanine (Phe)[A]	1.49	1.23	2.48	1.25	2.46	2.76	1.54	1.74	2.61	1.67	2.26
Proline (Pro)	3.45	2.66	5.8	1.9	4.21	4.58	3.74	3.4	5.68	3.87	3.3
Serine (Ser)	0.6	0.4	0.83	0.42	1.84	0.61	0.2	1.23	1.62	1.21	0.71
Tryptophan (Trp)[A]	0	0.03	0.02	0	0.05	0	0	0	0	0	0
Tyrosine (Tyr)	1.19	1.03	2	0.71	2	2.46	1.54	1.74	2.61	1.67	2.26
Valine (Val)[A]	1.41	1.25	2.98	1.12	2.66	3.04	1.65	2.14	4.06	2.53	2.33
Total EAA[C]	9.71	8.59	17.88	7.65	18.05	20.4	11.79	13.73	25.16	14.82	15.94
Total NEAA[D]	14.68	14.81	42.56	18.75	40.53	34.05	21.64	26.09	42.81	29.78	31.22
Total amino acid	24.85	23.77	61.27	26.76	59.29	54.99	33.94	40.41	68.95	45.34	47.8

[*]S1 (*Kapi* Satun); S2 (*Kapi* Ranong1); S3 (*Kapi* Ranong2); S4 (*Kapi* Krabi1); S5 (*Kapi* Krabi2); S6 (*Kapi* Songkhla1); S7 (*Kapi* Songkhla2); S8 (*Kapi* Samut Sakorn); S9 (*Kapi* Rayong); S10 (*Kapi* Chachoengsao); S11 (*Kapi* Samut Songkram)
A: Essential amino acid in adults.
B: Essential amino acid in children.
C: Essential amino acid.
D: Non-essential amino acid.

Volatile compounds

Volatile compounds of different salted shrimp samples produced in Thailand were determined using a solid-phase microextraction gas chromatography mass spectrometry (SPME GC-MS). Different volatile compounds were identified. Those consisted of alcohols, aldehydes, ketones, hydrocarbon and nitrogen-containing compounds.

Nitrogen-containing compounds, especially pyrazine derivatives, seemed to be the major volatile components in salted shrimp pastes. 2,5-dimethyl pyrazine, 2,6-dimethyl pyrazine, 3-ethyl, 2,5-dimethyl pyrazine and 6-ethyl, 2,3,5-trimethyl pyrazine were found in all samples. Pyrazines were reported to contribute to nutty, roasted and toasted aromas in many foods (Wong and Bernhard, 1988). Sanceda *et al.* (1990) found that pyrazines could be responsible for the burnt and sweet odors of Vietnamese fish sauce *(nouc-mam)*. Pyrazines were reported to be formed by Maillard reaction through strecker degradations from various nitrogen sources such as amino acids (Jaffres *et al.*, 2011). Slightly high pH of shrimp paste (pH 7.2-8.4) could favor the formation of pyrazine (Sanceda *et al.*, 1990). S6 (*Kapi* Songkhla1) showed the highest abundance in 2,5-dimethyl-pyrazines, whereas S8 (*Kapi* Samut Sakorn) exhibited the highest level of 2,6-dimethyl-

pyrazines. S6 (*Kapi* Songkhla1) had the highest abundance in 3-ethyl-2,5-dimethyl-pyrazines and 2,3,5-trimethyl-6-ethyl-pyrazine.

2-butanol and 3-methyl-butanol were found at high abundance in most samples. Michihata *et al.* (2002) noted that butanol derivatives might be formed by microbial fermentation, especially regulated by lactic acid bacteria. 1-hexanol, 1-penten-3-ol, 1-octen-3-ol and benzeneethanol were also found in most samples. Those alcohols might be the degradation products from lipid oxidation. 3-methyl-butanol was dominant in S9 (*Kapi* Rayong) and S10 (*Kapi* Chachoengsao), whereas 2-butanol was highest in S5 (*Kapi* Krabi2). Furthermore, other alcohols varied with samples. 2-ethyl, 1-hexanol was found only in S1 (*Kapi* Satun), while 1-octen-3-ol was dominant in S10 (*Kapi* Chachoengsao).

Abundance of aldehydes e.g. pentanal, hexanal, etc. in salted shrimp pastes was quite low. It was noted that benzaldehyde, with a pleasant almond, nutty and fruity aroma (Vejaphan *et al.*, 1988) was found in all samples. Aldehydes were more likely generated from lipid oxidation during fermentation. Branched short chain aldehydes or aromatic aldehydes plausibly resulted from deamination of amino acids (Steinhaus and Schieberle, 2007). Groot and Bont (1998) noted that some bacteria had aminotransferase

Table 2. Volatile compounds of different salted shrimp pastes[*]

Volatile compounds	Peak area (Abundance) $\times 10^5$										
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Nitrogen-containing compounds											
Methyl-pyrazine	709	714	ND	ND	ND	1521	ND	925	ND	805	ND
Ethyl-pyrazine	ND	ND	ND	ND	ND	703	ND	ND	ND	ND	ND
Trimethyl-pyrazine	4833	3100	ND	ND	ND	ND	ND	ND	ND	ND	1895
Tetramethyl-pyrazine	1780	476	ND	436	368	4538	795	ND	ND	672	1596
2,5-dimethyl-pyrazine	3301	3427	3163	2315	5198	22098	3901	6470	2206	4568	954
2,6-dimethyl-pyrazine	1149	2831	2128	3401	7017	15345	3250	25357	2367	3948	1167
2-ethyl-6-methyl-pyrazine	358	537	ND	528	628	4835	ND	1988	408	1168	ND
3-ethyl-2,5-dimethyl-pyrazine	1842	2042	2630	1214	3766	59015	2273	2702	2507	4568	338
2-ethyl-3,5-dimethyl-pyrazine	2418	ND	ND	ND	ND	ND	1573	ND	ND	ND	ND
2,3-diethyl, 5-methyl-pyrazine	ND	ND	ND	ND	ND	7155	ND	ND	ND	1883	ND
2,3,5-Trimethyl-6-ethyl-pyrazine	869	315	2960	1837	3642	17713	2067	2796	1204	3026	342
Alcohols											
Furanmethanol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	793
2-methyl, 1- propanol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	470
3-methylthio, 1-propanol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	262
1-butanol	141	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-butanol	2626	11302	11427	9666	51622	6871	10567	5633	982	7701	11917
3-methyl-butanol	19862	10329	9589	ND	7548	14042	ND	ND	20973	20147	14689
1-Pentanol	ND	1485	ND	ND	ND	1820	999	ND	ND	1213	1133
1-Penten-3-ol	ND	2742	ND	641	1591	1282	2541	1880	2023	2310	1702
1-Pentaethiol	ND	ND	2735	ND	ND	ND	ND	ND	ND	ND	ND
1-Hexanol	ND	1121	881	294	527	2314	1195	ND	ND	701	ND
2-ethyl, 1-hexanol	3922	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyclohexanol	514	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-hepten-1-ol	ND	382	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis-hept-4-enol	ND	ND	366	ND	ND	ND	ND	ND	ND	ND	ND
1-Octanol	253	ND	ND	ND	ND	2262	ND	ND	219	ND	ND
2-Octen-1-ol	ND	235	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,7- Octadiene-1-ol	142	393	ND	ND	ND	312	ND	ND	ND	ND	ND
1-Octen-3-ol	ND	2682	835	606	1553	ND	1950	ND	ND	3963	ND
3-methyl-phenol	ND	ND	ND	ND	ND	388	ND	ND	ND	ND	ND
Benzeneethanol	584	776	749	1040	3266	1993	845	407	ND	458	846
Aldehydes											
Pentanal	ND	ND	ND	ND	ND	788	ND	ND	1594	1790	ND
Hexanal	ND	698	36	33829	43	ND	ND	ND	ND	ND	ND
4-heptenal	ND	1102	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Octenal	ND	3789	ND	ND	ND	ND	ND	ND	1939	ND	ND
Benzaldehyde	4900	27352	18088	19763	12030	23931	5096	8234	5177	6375	1143
Ketones											
1-phenyl-ethanone	ND	503	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-diphenyl-ethanone	ND	ND	ND	ND	ND	2091	ND	ND	ND	ND	ND
2-Pentanone	ND	ND	ND	ND	760	ND	ND	ND	ND	ND	ND
2-heptanone	ND	1344	ND	ND	825	2788	ND	2302	4951	4330	ND
2-hexanone	893	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Octanone	ND	361	ND	ND	ND	ND	ND	701	ND	1956	ND
3-Octanone	ND	ND	ND	449	1271	ND	ND	ND	ND	ND	ND
7-Octen-2-one	ND	ND	277	ND	271	ND	ND	ND	570	1105	ND
3,5- Octadiene-2-one	331	1578	645	ND	ND	ND	ND	ND	ND	ND	ND
Hydrocarbon											
1-phenylpropane	ND	256	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3-butanediene	ND	ND	2401	ND	ND	ND	ND	ND	ND	ND	ND
Pentan	251	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6-cyclohexadien	1165	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3- dodecyne	197	614	454	ND	314	ND	279	229	207	341	ND
3-Tetradocene	163	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyclododecane	905	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	1455	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Others											
Propaonic acid	583	ND	ND	ND	ND	ND	ND	ND	846	ND	ND
Butanic acid	ND	ND	ND	ND	ND	ND	ND	1948	ND	ND	ND
Pentanoic acid	358	ND	ND	1360	317	687	461	ND	2507	2349	938
Benzoic acid	ND	ND	ND	ND	736	ND	ND	ND	ND	ND	ND
Phenol	5625	10845	14174	8337	2592	4969	10687	2061	7516	693	31179
Indole	696	973	1597	345	269	772	344	163	622	1852	ND

[*]S1 (*Kapi* Satun); S2 (*Kapi* Ranong1); S3 (*Kapi* Ranong2); S4 (*Kapi* Krabi1); S5 (*Kapi* Krabi2); S6 (*Kapi* Songkhla1); S7 (*Kapi* Songkhla2); S8 (*Kapi* Samut Sakorn); S9 (*Kapi* Rayong); S10 (*Kapi* Chachoengsao); S11 (*Kapi* Samut Songkram)
ND: non-detectable

Table 3. Likeness score of different salted shrimp pastes[*]

Attributes	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Appearance	7.30±1.59[bc]	7.60±1.39[ab]	7.25±1.07[bc]	7.85±1.31[ab]	7.55±1.28[ab]	6.90±1.25[bc]	6.95±1.79[bc]	7.10±1.52[bc]	8.30±0.92[a]	7.85±1.04[ab]	6.45±1.76[c]
Color	7.15±1.46[c]	7.55±1.39[ab]	6.95±1.32[c]	7.65±1.18[ab]	7.55±1.15[ab]	6.75±1.07[c]	7.20±1.85[ab]	6.75±1.86[c]	8.15±0.81[a]	7.65±1.18[ab]	6.95±1.64[c]
Odor	7.30±1.42[ab]	6.50±1.79[bc]	5.45±1.43[cd]	6.65±1.79[ab]	7.40±1.57[ab]	6.95±1.85[ab]	5.05±1.82[d]	7.00±1.92[ab]	7.80±1.64[a]	6.85±1.76[ab]	4.90±2.02[d]
Texture	7.20±1.54[b]	7.25±1.33[b]	6.10±1.41[c]	7.80±1.47[ab]	7.35±1.63[ab]	7.55±1.57[ab]	6.10±1.25[c]	7.75±1.16[ab]	8.35±0.99[a]	8.00±0.92[ab]	5.65±2.23[c]
Flavor	7.50±1.85[ab]	7.50±1.67[ab]	6.05±1.67[cd]	6.95±1.76[bc]	7.40±1.35[ab]	7.40±1.43[ab]	6.25±1.55[cd]	7.40±1.35[ab]	8.15±1.18[a]	7.70±1.13[ab]	5.60±1.67[d]
Overall	7.25±1.83[ab]	7.35±1.76[a]	6.25±1.52[bc]	7.30±1.53[ab]	7.30±1.30[ab]	7.25±1.45[ab]	6.20±1.51[c]	7.40±1.35[a]	8.30±1.08[a]	7.55±1.28[a]	5.80±2.04[c]

[*]S1 (*Kapi* Satun); S2 (*Kapi* Ranong1); S3 (*Kapi* Ranong2); S4 (*Kapi* Krabi1); S5 (*Kapi* Krabi2); S6 (*Kapi* Songkhla1); S7 (*Kapi* Songkhla2); S8 (*Kapi* Samut Sakorn); S9 (*Kapi* Rayong); S10 (*Kapi* Chachoengsao); S11 (*Kapi* Samut Songkram)
Values are given as mean ± SD (n = 3).
Score are based on a 9-point hedonic scale (1: Dislike extremely, 5: Neither like nor dislike, 9: Like extremely).
Different lowercase superscripts within the same row indicate the significant differences ($p<0.05$).

in cell extract, which converted phenylalanine into phenylpyruvic acid. Keto acid was further transformed to benzaldehyde. Takeungwongtrakul *et al.* (2012) reported that shrimp contained high amounts of ω-3 fatty acids, which were highly susceptible to lipid oxidation. Most of alkanals and alkenals were known to contribute to slightly rancid odors (Vejaphan *et al.*, 1988). However, salted shrimp paste had low fat content (1.41-3.67 %) (Pongsetkul *et al.*, 2014). Moreover, Ho *et al.* (1989) reported that some aldehydes with unpleasant odors, may act as the important precursor of heterocyclic compounds.

Ketones were notably low in salted shrimp paste. Ketones found in salted shrimp paste included 2-pentanone, 2-heptanone, etc. Ketones seem to be responsible for the cheesy note in fish sauce odor (Peralta *et al.*, 1996). However, such compounds with low concentrations and high odor threshold values might not contribute to flavor of salted shrimp paste (Cha and Cadwallader, 1995).

Additionally, all samples contained phenol, but varied in abundance. Among the phenolic or aromatic compounds, toluene was more abundant in shrimp pastes, while phenol was more abundant in fish pastes (Vejaphan *et al.*, 1988). Toluene and phenol were reported to give an undesirable aroma in seafoods (Vejaphan *et al.*, 1988). S11 (*Kapi* Samut Songkram) and S7 (*Kapi* Songkhla2) had the higher abundance in phenol than other samples.

All samples, except S11 (*Kapi* Samut Songkram), consisted of indole. The highest indole was found in S3 (*Kapi* Ranong2) sample. Indole is the degradation product from tryptophan and has been used as the index for shrimp spoilage (Chang *et al.*, 1983). The result indicated that the raw material might be varied in freshness and the decomposition of tryptophan during fermentation was different among samples. Overall, the abundance of the lipid-derived compounds was low in salted shrimp paste. Nitrogen-containing compounds, especially pyrazine, were probably the potent contributors to odors and flavors of salted shrimp paste. Different volatile compounds in different samples more likely affected their sensory properties.

Sensory properties
Likeness score of different salted shrimp pastes is shown in Table 3. Generally, S9 (*Kapi* Rayong) had the highest likeness score for all sensory characteristics including appearance, color, odor, texture, flavor and overall ($p<0.05$). However, based on overall likeness, S9 (*Kapi* Rayong) showed similar score with S1 (*Kapi* Satun), S2 (*Kapi* Ranong1), S4 (*Kapi* Krabi1), S5 (*Kapi* Krabi2), S6 (*Kapi* Songkhla1), S8 (*Kapi* Samut Sakorn) and S10 (*Kapi* Chachoengsao) ($p>0.05$). S11 (*Kapi* Samut Songkram) generally had the lowest score ($p<0.05$) but there was no difference in overall likeness in comparison with S3 (*Kapi* Ranong2) and S7 (*Kapi* Songkhla2) ($p>0.05$). The differences in sensorial characteristics among samples could be influenced by the differences in raw material used, ingredients, fermentation process and conditions (Beriain *et al.*, 2000). Therefore, it was likely that chemical compositions and physical properties contributed to the varied likeness of different salted shrimp pastes. In the present study, taste or flavor mainly affected the sensory quality (overall-liking) of foods. Different tastes or flavors were possibly caused by differences in amino acid composition (Table 1) and volatile compounds (Table 2). S9 (*Kapi* Rayong), which had the highest likeness score, contained the highest total amino acid content (68.95 mg/g sample). It contained high Glu/Gln (12.08 mg/g sample) and Asp/Asn (7.1 mg/g sample). Kim *et al.* (2005) reported that taste of salted shrimp paste was influenced by Glu and Asp, affecting umami and sweetness, respectively. For color likeness, S1 (*Kapi* Satun), S3 (*Kapi* Ranong2), S6 (*Kapi* Songkhla1), S8 (*Kapi* Samut Sakorn) and S11 (*Kapi* Samut Songkram) showed the lowest score ($p<0.05$). S3

Table 4. A_{280}, A_{295}, browning intensity (A_{420}) and fluorescence intensity of water extracts from different salted shrimp pastes*

Samples	A_{280}	A_{295}	Browning intensity (A_{420})	Fluorescence intensity
S1	1.31±0.00[c]	0.97±0.04[d]	0.26±0.00[b]	665.27±4.31[abc]
S2	1.19±0.05[d]	0.52±0.00[j]	0.28±0.00[a]	683.72±21.99[a]
S3	0.43±0.00[h]	0.64±0.00[f]	0.25±0.00[c]	665.00±3.67[abc]
S4	1.10±0.02[e]	0.86±0.00[e]	0.27±0.00[a]	671.80±1.11[ab]
S5	1.67±0.03[b]	1.01±0.01[c]	0.24±0.00[e]	649.67±2.65[c]
S6	1.07±0.01[e]	0.54±0.00[hi]	0.20±0.00[h]	603.78±13.72[e]
S7	1.73±0.01[a]	1.28±0.00[a]	0.26±0.00[c]	662.37±6.71[bc]
S8	1.70±0.01[ab]	1.06±0.05[b]	0.25±0.00[d]	662.31±10.38[bc]
S9	1.08±0.04[e]	0.59±0.01[g]	0.21±0.00[g]	629.21±7.69[d]
S10	1.00±0.01[f]	0.57±0.01[gh]	0.22±0.00[f]	625.81±13.99[d]
S11	0.90±0.01[g]	0.47±0.01[j]	0.25±0.01[c]	670.71±9.80[ab]

*S1 (*Kapi* Satun); S2 (*Kapi* Ranong1); S3 (*Kapi* Ranong2); S4 (*Kapi* Krabi1); S5 (*Kapi* Krabi2); S6 (*Kapi* Songkhla1); S7 (*Kapi* Songkhla2); S8 (*Kapi* Samut Sakorn); S9 (*Kapi* Rayong); S10 (*Kapi* Chachoengsao); S11 (*Kapi* Samut Songkram)
Values are given as mean ± SD (n=3).
Different lowercase superscripts in the same column indicate the significant difference (p<0.05).
The sample was 5-fold diluted prior to measurement.

(*Kapi* Ranong2) and S11 (*Kapi* Samut Songkram) had the lowest texture likeness score (p<0.05). This was more likely due to the differences in processes, ingredients as well as individual perception.

Browning and Maillard reaction product

UV-absorbance and browning intensity

UV-absorbance (A_{280} and A_{295}) of water extract of different salted shrimp pastes is shown in Table 4. The different extracts had varying UV-absorbance (p<0.05). A_{280} and A_{295} have been used to determine the formation of non-fluorescent intermediate compounds of the Maillard reaction (Ajandouz *et al.*, 2001). Among all samples, water extract of S7 (*Kapi* Songkhla2) had the highest A_{280} and A_{295}. The higher A_{280} and A_{295} suggested the higher formation of an uncolored compound, which could be the precursor of the Maillard reaction (Benjakul *et al.*, 2005).

Browning intensity (A_{420}) of all samples is shown in Table 4. The different salted shrimp pastes had different browning intensity (p<0.05). Water extract of S2 (*Kapi* Ranong1) showed the highest A_{420}, whereas S6 (*Kapi* Songkhla1) had the lowest A_{420} (p<0.05). Generally, the higher A_{420} indicated higher browning development in the final stage of the Maillard reaction (Ajandouz *et al.*, 2001; Morales and Jimenez-Perez, 2001). Therefore, the differences in browning intensity were more likely affected by raw material, ingredient and process used, which could vary from place to place.

Fluorescence intensity

Fluorescence intensity of water extracts from salted shrimp pastes is shown in Table 4. Among all samples, water extract of S2 (*Kapi* Ranong1) had the highest fluorescence intensity, whereas that

of S6 (*Kapi* Songkhla1) had the lowest intensity (p<0.05). The results of fluorescence intensity were in accordance with those of browning intensity (Table 4). The relationship between browning intensity and fluorescence intensity suggested that a large proportion of fluorescent intermediate product was converted into a brown polymer. Jing and Kitts (2002) reported that the development of fluorescent compounds occurred in the Maillard reaction prior to the generation of brown pigments. Fluorescent compounds are possible precursors of brown pigments (Labuza and Baisier, 1992). Therefore, the lower fluorescence intensity was presumably due to the lower precursor for browning reaction. Generally, both non-fluorescent and fluorescent intermediates are formed and turn into brown pigments in the Maillard reaction (Morales *et al.*, 1996). The difference in fluorescence intensity and UV-absorbance of samples suggested that different types of intermediate products, either fluorescent or non-fluorescent compound, were formed and underwent the final stage of reaction at different rates (Benjakul *et al.*, 2005). However, the fluorescent intermediate was more reactive in formation of brown color than non-fluorescent compounds (Benjakul et al., 2005). The browning development could affect the color and acceptability of salted shrimp paste differently.

Antioxidative activities

DPPH radical scavenging activity

The antioxidative activities of the water extracts of different salted shrimp pastes are shown in Table 5. Water extract of S1 (*Kapi* Satun) showed the highest DPPH radical scavenging, whereas that of S6 (*Kapi* Songkhla1) had the lowest DPPH radical scavenging (p<0.05). All samples had the ability

Table 5. Antioxidative properties of water extract from different salted shrimp pastes

Samples	DPPH radical scavenging activity (µmol TE/g sample)	ABTS radical Scavenging activity (µmol TE/g sample)	FRAP (µmol TE/g sample)	Chelating activity (µmol EE/g sample)	H$_2$O$_2$ radical scavenging activity (µmol TE/g sample)	Singlet oxygen scavenging activity (µmol TE/g sample)
S1 (*Kapi* Satun)	8.99±0.58^a	17.87±0.33^a	26.97±0.09^a	16.54±1.46^a	38.48±2.18^a	76.96±2.02^a
S2 (*Kapi* Ranong1)	2.83±0.11^d	15.65±0.02^d	13.86±0.27^{de}	8.86±0.29^{fg}	32.54±0.57^{de}	34.23±2.78^{de}
S3 (*Kapi* Ranong2)	2.35±0.11^d	13.67±0.45^e	14.47±0.07^{de}	9.15±0.43^{ef}	31.56±0.54^{ef}	53.62±1.15^b
S4 (*Kapi* Krabi1)	2.71±0.57^d	16.62±0.58^c	17.51±0.85^{bc}	11.39±0.42^d	30.34±1.94^{ef}	76.23±5.17^a
S5 (*Kapi* Krabi2)	3.65±0.14^c	13.91±0.04^e	17.84±0.50^{bc}	12.26±0.23^{cd}	32.00±0.27^{def}	71.69±2.73^a
S6 (*Kapi* Songkhla1)	1.12±0.02^e	13.04±0.08^f	12.70±0.34^e	7.86±0.31^g	30.12±1.77^f	8.57±1.68^e
S7 (*Kapi* Songkhla2)	8.28±0.09^b	17.24±0.23^b	19.80±0.18^b	13.75±0.51^b	38.61±0.16^a	76.17±3.24^a
S8 (*Kapi* Samut Sakorn)	3.51±0.28^c	16.73±0.50^{bc}	19.33±1.27^b	13.31±0.20^{bc}	34.17±2.05^{cd}	56.09±0.37^b
S9 (*Kapi* Rayong)	3.75±0.03^c	16.67±0.13^c	15.65±0.21^{cd}	8.85±0.42^{fg}	35.92±0.20^{bc}	21.58±3.62^{de}
S10 (*Kapi* Chachoengsao)	2.78±0.08^d	15.50±0.24^d	15.87±3.91^{cd}	10.20±0.75^e	36.92±0.09^{ab}	29.51±3.16^{cd}
S11 (*Kapi* Samut Songkram)	3.36±0.42^c	16.23±0.11^c	16.29±1.58^{cd}	12.02±1.01^d	36.39±0.26^{ab}	40.67±5.54^c

Values are given as mean ± SD (n=3).
Different lowercase superscripts in the same column indicate the significant difference (p<0.05).

to quench DPPH radicals. The DPPH radical had an absorbance at 515-520 nm. The color changed from purple to yellow by acceptance of a hydrogen radical and it became a stable diamagnetic molecule (Benjakul *et al*., 2009). This indicated that peptides or free amino acids in the salted shrimp paste possessed the ability to donate the hydrogen atom to free radicals, in which the propagation process could be retarded (Faithong *et al*., 2010). Water extract of all samples had DPPH radical scavenging in the range of 1.12-8.99 µmol TE/g sample. Antioxidant peptides in salted shrimp paste were more likely water soluble peptides. Furthermore, other antioxidative compounds including MRPs were also present in salted shrimp paste. Those peptides or MRPs were mostly hydrophilic in nature and were extracted into water effectively (Binsan *et al*., 2008).

ABTS radical scavenging capacity

Water extracts from different salted shrimp pastes showed different ABTS radical scavenging capacities (Table 5). ABTS assay is an excellent tool for determining the antioxidant activity of hydrogen-donating antioxidants (scavengers of aqueous phase radicals) and of chain breaking antioxidants (scavenger of lipid peroxyl radicals) (Leong and Shui, 2002). This method can determine both hydrophilic and lipophilic antioxidants (Sun and Tanumihardjo, 2007). ABTS radical-scavenging activities of water extracts were generally similar to those observed for DPPH radical-scavenging activity. Water extract of S1 (*Kapi* Satun) showed the highest ABTS radical scavenging capacity (17.87 µmol TE/g sample), whereas that of S6 (*Kapi* Songkhla1) had the lowest ABTS radical scavenging capacity (13.04 µmol TE/g sample) (p<0.05). The result suggested that water soluble fractions from salted shrimp paste might scavenge ABTS$^{\bullet}$, mainly by hydrophilic antioxidants.

Ferric reducing antioxidant power (FRAP)

FRAP is generally used to measure the capacity of a substance in reducing TPTZ-Fe(III) complex to TPTZ-Fe(II) complex (Benzie and Strain, 1996; Kittipattanabawon *et al*., 2012). Varying FRAP was found among water extracts from different samples (Table 5), suggesting different capability of providing the electron. Among all samples, water extract from S1 (*Kapi* Satun) showed the highest FRAP, whereas that of S6 (*Kapi* Songkhla1) had the lowest FRAP (p<0.05). This result was in agreement with DPPH and ABTS radical scavenging activities. Generally, low molecular weight peptides and amino acids have been reported to possess antioxidant activity (Binsan *et al*., 2008; Benjakul *et al*., 2009; Faithong *et al*., 2010; Kittipattanabawon *et al*., 2012). It has been reported that commercially available *Kapi*, traditional shrimp paste in Thailand, showed antioxidant activities including DPPH, ABTS radical scavenging activity and FRAP (Faithong *et al*., 2010). Hydrolysis of proteins or peptides was progressed throughout the prolonged fermentation. Those free amino acids or peptides might undergo Maillard reaction, in which the resulting products possessed antioxidative activity (Lertittikul *et al*., 2007).

Metal chelating activity

Metal chelating activity of water extracts from different salted shrimp pastes is shown in Table 5. Transition metal irons catalyze the generation of reactive oxygen species, including hydroxyl radical ($\bullet$OH) and superoxide radical (O$_2$$^{\bullet-}$), leading to oxidation of unsaturated lipids and promoting oxidative damage at different levels (Saiga *et al*., 2003; Carrasco-Castilla *et al*., 2012). Water extract from S1 (*Kapi* Satun) showed the highest metal chelating activity (16.54 µmol EE/g sample) and

the lowest activity was found in the extract from S6 (*Kapi* Songkhla1) (7.86 μmol EE/g sample) (p<0.05). Among all samples, the different iron chelating activity might be related to the differences in amino acid composition of peptides. It has been reported that chelation of iron was also associated with Asp/Asn, Glu/Gln, His, and Cys contents (Carrasco-Castilla *et al.*, 2012). Asp and Glu might be responsible for iron chelation (Xia *et al.*, 2008; Peng *et al.*, 2010; Carrasco-Castilla *et al.*, 2012). However, chelating activity of peptides also depends on other factors such as peptide structure, steric effects and molecular weight (Carrasco-Castilla *et al.*, 2012).

H_2O_2 radical scavenging activity and singlet oxygen scavenging activity

Capacity of scavenging of hydrogen peroxide (H_2O_2) and singlet oxygen ($^1O_2$) of water extracts from different salted shrimp pastes is presented in Table 5. Hydrogen peroxide and singlet oxygen as reactive oxygen species (ROS) can cause oxidative stress and damage of biomolecule in the cell, leading to cell death and serious chronic diseases (Suh *et al.*, 2011). Hydrogen peroxide, which is a weak oxidizing agent, is not directly involved in the initiation of lipid oxidation because its reduction potential is lower than that of unsaturated fatty acids (Choe and Min, 2005; Kittipattanabawon *et al.*, 2012). However, hydrogen peroxide can be implicated indirectly in lipid oxidation (Intarasirisawat *et al.*, 2013). Furthermore, hydrogen peroxide is a reactive non radical, which can permeate biological membranes and be converted to more reactive species such as hydroxyl radical and singlet oxygen (Choe and Min, 2005; Intarasirisawat *et al.*, 2013).

Among water extracts of all samples, H_2O_2 radical scavenging activity varied from 30.12 to 38.61 μmol TE/g sample and singlet oxygen scavenging activity was in range of 8.57-76.96 μmol TE/g sample. Kittiphattanabawon *et al.* (2012) suggested that peptides with the shorter chain length might be able to trap or bind with singlet oxygen to a higher extent. Singlet oxygen, which is a highly reactive, electrophilic and non-radical molecule, can be formed by the reaction between photosensitizers and triple oxygen in the presence of light. Singlet oxygen had low activation energy and its reaction rate with foods is much greater than that of triplet oxygen (Min and Boff, 2002). Singlet oxygen can directly react with electron-rich double bonds of unsaturated fatty acids without the formation of free-radical intermediates (Choe and Min, 2005). Composition and sequence of amino acid, structure of peptide, and the solvent accessibility of the amino acids in the peptide had the impact on antioxidative activity of peptides (Lertittikul *et al.*, 2007; Binsan *et al.*, 2008). Therefore, different salted shrimp pastes showed varying antioxidative activities, most likely associated with varying peptides and MRPs.

Conclusion

Different salted shrimp pastes had varying amino acid compositions. Glu and Asp were the major amino acids, which might contribute significantly to the taste and flavor of salted shrimp pastes. Volatile compounds in samples were different in abundance. Pyrazine derivatives were the major volatile components in salted shrimp paste. Water extract contained intermediate and final products of Maillard reaction. All samples possessed antioxidant activity, which could be an important source of natural antioxidants.

Acknowledgement

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