Iranian Journal of Fisheries Sciences
DOI: 10.22092/ijfs.2019.118094

Chemical compositions, volatile compounds and sensory property of salted shrimp paste (*Kapi*) produced from *Acetes vulgaris* and *Macrobrachium lanchesteri*

Pongsetkul J.[1]; Benjakul S.[1*]; Sumpavapol P.[1]; Vongkamjan K.[1]; Osako K.[2]

Received: March 2017 Accepted: October 2017

Keywords: *Acetes vulgaris*, *Macrobrachium lanchesteri*, *Kapi*, volatile compounds, sensory properties

1-Department of Food Technology, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, Thailand, 90112
2-Department of Food Science and Technology, Tokyo University of Marine Science and Technology, 5-7 Konan 4, Minato-ku, Tokyo 108-8477, Japan
*Corresponding author's Email: soottawat.b@psu.ac.th

Introduction

Salted or fermented krill or shrimp pastes are widely consumed in many Asian countries including Thailand (*Kapi*), Indonesia (*Terasi Udang*), Malaysia (*Belacan*), Philippines (*Bagoong-alamang*) or Vietnam (*Mam ruoc*), etc (Hajeb and Jinab, 2015). It is often used to enhance palatability of many foods by providing desirable flavor and salty or umami taste. In general, raw material, shrimp or krill/salt ratio, fermentation process and time can be varied, depending on regions or countries. The different characteristics and properties of those products were reported (Peralta *et al.*, 2008).

Kapi, traditional salted shrimp paste of Thailand, is traditionally made from planktonous krill (*Mesopodopsis orientalis*). Since the last decade, krill stocks have drastically dropped by 3% per year (Meland and Willassen, 2007). Two species of small shrimps: *Acetes vulgaris* and *Macrobrachium lanchesteri* became potentially alternative sources for *Kapi* production, because their high availability throughout the years, especially in the southern part of Thailand. To produce salted shrimp paste, shrimps are mixed with salt and ground into a fine paste. Then, salted shrimps are sun-dried to reduce their moisture content, followed by fermentation at room temperature for approximately for 1 month (Pongsetkul *et al.*, 2014). During fermentation, the protein hydrolysis occurs and is mediated by the action of indigenous and microbial proteases. These phenomena yield short chain

peptides and free amino acids, which enhance the flavor and taste of final product (Pongsetkul *et al.,* 2015a, b). Kim *et al.* (2014) reported that short chain peptides and free amino acids of Korean shrimp paste significantly increased during the fermentation period and could be responsible for the unique flavor of the product. The formation of Maillard reaction products (MRPs) was also observed throughout fermentation of Philippine salt-fermented shrimp paste and related with the darker/browner color of the final product (Peralta *et al.,* 2008). Moreover, some fermented shrimp products exhibited the strong antioxidant activities (Faithong *et al.*, 2010; Kleekayai *et al.*, 2015).

Flavor or aroma is one of the most important factors in *Kapi* quality (Phithakpol, 1993). The characteristic flavor and aroma are primarily due to protein and lipid degradation by autolytic and bacterial enzymes during fermentation, governed by different raw material, process employed, as well as strains of microorganism involved (Saisithi *et al.,* 1966). Several volatile components of shrimp paste products were associated with their flavors (Cha and Cadwallader, 1995; Wittanalai *et al.,* 2011; Kang and Baek, 2014; Pongsetkul *et al.,* 2014). Nevertheless, a little information regarding chemical compositions, especially volatiles as well as sensory property of *Kapi*, produced from *A. vulgaris* and *M. lanchesteri* has been reported. Therefore, this investigation aimed to comparatively characterize *Kapi* produced from both shrimps. Furthermore, relationship between volatile compounds and sensory properties of both *Kapi,* and commercial *Kapi* was also studied using principal component analysis (PCA).

Materials and methods

Sample collection

Shrimps (*A. vulgaris* and *M. lanchesteri*) were caught from the coast in Ko-yo and The-Pha in Songkhla province, Thailand, respectively. After capture, shrimp were transported in ice with a shrimp/ice ratio of 1:2 (w/w) in a polystyrene container to the Department of Food Technology, Prince of Songkla University, Hat Yai, Thailand, within approximately 2 h.

Preparation of Kapi

Shrimps were mixed with salt at the ratio of 5:1 (w/w) and transferred into the basket, covered with the cheese cloth. The mixture was kept at room temperature (28-32°C) overnight. Then, the drained samples were mashed or pounded thoroughly and spread out on fiberglass mats to dry with sunlight. The drying step was continued until samples disintegrate and turned from pink to dark purplish brown (with the moisture content of 35-40%). Subsequently, samples were transferred into earthen jars, covered with plastic bag tightly (close system), and allowed to ferment at room temperature. After 30 days of fermentation, *Kapi* were collected and referred to as KA (*Kapi* produced from *A. vulgaris*) and KM (*Kapi* produced from *M. lanchesteri*).

The obtained samples were subjected to analyses.

Characterization of Kapi produced from A. vulgaris and M. lanchesteri

pH and water activity (A_w)

The pH of samples was measured according to the method of Nirmal and Benjakul (2009) using a pH meter (Sartorius, Gottingen, Germany). Aw of *Kapi* was determined using a water activity analyzer (Thermoconstanter, Novasina, Switzerland).

Proximate composition

Moisture, ash, fat, protein and carbohydrate contents of *Kapi* were determined according to AOAC method (2000) with the analytical No. of 35.1.13, 35.1.14, 35.1.25, 35.1.15 and 35.1.16, respectively.

Salt content

Salt content was determined as per AOAC (2000) with the analytical number of 35.1.18 and was expressed as %NaCl.

Color

The color of samples was determined using a colorimeter (ColourFlex, Hunter Lab Reston, VA) with the CIE system. *L** (lightness), *a** (redness/greenness), *b** (yellowness/blueness), *ΔE** (total difference of color) and *ΔC** (the difference in chroma) were recorded as described by Pongsetkul *et al.* (2014).

Browning products

Preparation of water extract

Kapi (1 g) was mixed with 25 ml of distilled water. The mixtures were homogenized at a speed of 11,000 rpm for 2 min, followed by centrifugation at 8,500 ×*g* for 15 min at room temperature. The supernatant was collected and adjusted to 25 mL using distilled water before analyses.

Measurement of browning products

After being diluted, the water extracts were measured for browning intensity (A_{420}) and Maillard reaction products (A_{280} and A_{295}) using the UV-1601 spectrometer (Shimadzu, Kyoto, Japan). The fluorescence intensity at an excitation wavelength of 347 nm and emission wavelength of 415 nm was also determined using a fluorescence spectrophotometer RF-1501 (Shimadzu, Kyoto, Japan).

Volatile compounds

To extract volatile compounds, samples (5 g) were 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) and determined using a solid-phase micro-extraction gas chromatography mass spectrometry (SPME GC-MS) as per the method of Iglesias and Medina (2008) as detailed by Takeungwongtrakul and Benjakul (2013). Volatile compounds were identified and expressed in the terms of relative abundance.

Sensory evaluation

The 50 untrained panelists, who consumed *Kapi* regularly, were used for evaluation. The samples were wrapped with aluminium foil and heated in hot air oven at 60°C for 30 min. After cutting into small pieces (2×2×1 cm^2), samples were placed in 15-mL plastic cup, covered with lids and left at room temperature for 30 min before serving. The panelists were asked to open the lid and sniff. Between the samples, panelists rinsed their mouth with water or cracker. Scores for appearance, color, odor, flavor, texture and overall likeness using a 9-point hedonic scale were recorded.

Principal component analysis (PCA)

PCA was performed to access the relationship between volatile compounds, odor-liking, flavor-liking and overall-liking score of *Kapi* produced from *A. vulgaris* and *M. lanchesteri*, as well as commercial *Kapi* produced from krill (*Mesopodopsis orientalis*) obtained from different provinces in Thailand, including Krabi, Samut Sakhon and Rayong.

Statistical analysis

Completely randomized design (CRD) was used throughout the study. All experiments were run in triplicate. Data were subjected to analysis of variance (ANOVA), and mean comparisons were carried out by the Duncan's multiple range test. Independent T-test was performed for pair comparison (Steel *et al.*, 1980). Analysis was performed by using SPSS statistic program (Version 10.0) (SPSS, 1.2, 1998). For PCA (Principal Component Analysis), the XLSTAT Software (XLSTAT, 2008, Addinsoft, New York, NY, USA) was used.

Results and discussion

Characteristics and properties of Kapi

pH, water activity (A_w) and proximate composition

As shown in Table 1, *Kapi* produced from *A. vulgaris* (KA) and *M. lanchesteri* (KM) had the neutral pH. KM had the slightly higher basic pH (7.27), compared with KA (7.16) (p<0.05). The slightly basic pH might be caused by the basic degradation products generated during postmortem storage of raw material or the formation of volatile base compounds such as ammonia during fermentation of samples (Pongsetkul *et al.*, 2014). The pH of Korean dried shrimp paste was in the range of 6.83-7.23 (Cho and Kim, 2010), while Fillipino fermented shrimp paste had pH of 7.50 (Montano *et al.*, 2001). The pHs of those shrimp pastes were similar to those of *Kapi* in the present study. Both samples had no differences in water activity (A_w) (p>0.05). A_w of both *Kapi* was in the range of 0.6-0.7, which could be classified as an intermediate moisture food (Fennema, 1996). This was associated with the prolonged shelf-life of this product due to the lowered growth of food pathogens and spoilage microorganisms (Chirife, 1989). Low A_w of *Kapi* samples were in agreement with the low moisture content. There was no difference in moisture content between KA (33.93%) and KM (34.28%) (p>0.05). No differences in carbohydrate, ash and salt contents

were found between KA and KM (p>0.05). KM had the higher protein content (28.48%), compared with KA (26.20%) (p<0.05). Conversely, KA had the higher fat content (3.91%) than KM (2.36%) (p<0.05). KA and KM had a high salt content (22.45-22.88%), related with their low A_w. The large amount of salt was added. The presence of inorganic substances in the shell of shrimp used as raw material resulted in the high ash content in both samples (33.13-32.94%). It could be inferred that different shrimps yielded *Kapi* with different compositions.

Color

KA and KM had different color characteristics as depicted in Table 1. KA showed the lower L^*-value but higher b^*, ΔC^* and ΔE^*-value (p<0.05). However, no difference in a^*-value between both samples was observed (p>0.05). The result suggested that KA showed browner and more yellowish color than KM. Differences in color of both samples might be due to the different amount and type of pigments in raw material (*A. vulgaris* and *M. lanchesteri*). In general, carotenoids, especially astaxanthin, provide the desirable reddish-orange color in crustaceans (Higuera-Ciapara *et al.,* 2006). During fermentation, free amino acids and small peptides could undergo Maillard reaction, thereby contributing to the brown color development (Lopetcharat *et al.,* 2001). Lipid oxidation was also associated with browning mediated by Maillard reaction (Yarnpakdee *et al.,* 2014). The carbonyl groups of aldehydes and ketones, the oxidation products, could react with amino groups of free amino acids or peptides generated during hydrolysis, leading to yellow or brown color development (Yarnpakdee *et al.,* 2014).

Browning and Maillard reaction products

Non-fluorescent and fluorescent intermediate products of Maillard reaction as well as browning intensity of both water extracts of KA and KM are presented in Table 1. A_{280} and A_{295} have been used to determine the formation of non-fluorescent intermediate compounds of the Maillard reaction (Binsan *et al.,* 2008). There were no differences in A_{280} and A_{295} between both samples (p>0.05). However, the differences in fluorescent intermediate products were observed. KA had the higher fluorescence intensity (403.91), compared with KM (315.88) (p<0.05). The result was in accordance with the higher browning intensity (A_{420}) found in KA. The relationship between browning intensity and fluorescence intensity suggested that a large proportion of fluorescent intermediate products were converted into brown polymers. Jing and Kitts (2002) reported that the development of fluorescent compounds occurred in the Maillard reaction prior to the generation of brown pigments. Generally, both non-fluorescent and fluorescent intermediates are formed and turn into brown pigments in the Maillard reaction (Binsan *et al.,* 2008). Benjakul *et al.* (2005) revealed that the fluorescent intermediate was more

reactive in formation of brown color than non-fluorescent compounds. The higher browning intensity of KA sample was in agreement with the browner color of this sample (Table 1). Thus, the differences in browning could affect the color and acceptability of *Kapi* to some degrees.

Table 1: Chemical compositions and characteristics of *Kapi* produced from *Acetes vulgaris and Macrobrachium lanchesteri.*

Compositions/Characteristics	KA	KM
pH	7.16±0.01[b]	7.27±0.03[a]
Water activity (A_w)	0.662±0.00[a]	0.659±0.01[a]
Proximate composition		
Moisture	33.93±0.99[a]	34.28±0.83[a]
Crude protein	26.20±0.54[b]	28.48±0.63[a]
Crude fat	3.91±0.25[a]	2.36±0.87[b]
Ash	32.94±0.99[a]	33.13±0.12[a]
Carbohydrate	2.57±0.55[a]	1.16±0.69[a]
Salt	22.88±1.15[a]	22.45±1.65[a]
Color		
*L**	40.92±0.32[b]	45.23±0.76[a]
*a**	9.53±0.52[a]	9.17±0.08[a]
*b**	18.11±0.14[a]	16.78±0.04[b]
Δ*E**	56.50±0.23[a]	52.13±0.69[b]
Δ*C**	19.55±0.16[a]	18.56±0.94[b]
Browning and Maillard reaction products		
A_{280}	0.90±0.09[a]	1.01±0.05[a]
A_{295}	0.83±0.02[a]	0.85±0.17[a]
Browning intensity (A_{420})	0.46±0.01[a]	0.32±0.02[b]
Fluorescence intensity	403.91±6.31[a]	315.88±6.01[b]

Values are given as mean±SD (n= 3).
Different lowercase superscripts in the same row indicate the significant difference (p<0.05).
* KA, KM: *Kapi* produced from *A. vulgaris* and *M. lanchesteri*, respectively.

Volatile compounds

Forty-two volatile compounds of KA, KM and three commercial *Kapi* samples were detected (Table 2). These were classified into 6 main groups including aldehydes (5), ketones (8), alcohols (10), N-containing compounds (8), hydrocarbon (5) and others (6). For aldehydes, 3-methyl-butanal, pentanal and benzaldehyde were found in all samples, while hexanal was not observed in KA. Among all samples, KC1 showed the highest intensity of aldehydes (8.47%), followed by KC3 and KC2, indicating that commercial *Kapi* had the higher amount of aldehydes, compared with KA and KM. The presence of aldehydes and ketones are related with lipid oxidation during fermentation (Pongsetkul *et al.*, 2015a). Eusebio *et al.* (2010) reported that krill (*M. orientalis*) contained 4.1-10.6% fat, while the fat contents of *A. vulgaris* and *M. lanchesteri* were 4.62 and 3.93% (dry weight basis) as reported by Pongsetkul *et al*. (2015a) and Pongsetkul *et al.* (2016), respectively. Krill or shrimp oil was reported to be

rich in polyunsaturated fatty acids, which were prone to oxidation (Takeungwongtrakul and Benjakul, 2013). Benzaldehyde was reported to have a pleasant almond, nutty and fruity aroma (Cha and Cadwallader, 1995). 3-methyl-butanal is characterized by a green and fruity flavor and is generated via Strecker degradation through Maillard reactions of isoleucine (Cha and Cadwallader, 1995). Strecker aldehydes are present and known to be potent odorants in many seafood products (Casaburi *et al.*, 2008).

Table 2: Volatile compounds of *Kapi* produced from *Acetes vulgaris, Macrobrachium lanchesteri* and three commercial *Kapi*.

Volatile compounds	Peak area (Abundance) × 10^6				
	KA	**KM**	**KC1**	**KC2**	**KC3**
3-methyl-butanal	41.73	36.65	45.65	55.35	65.31
Pentanal	22.02	45.55	26.22	83.54	14.28
Hexanal	ND	81.12	60.06	14.27	51.11
Heptanal	44.45	12.03	55.55	ND	45.45
Benzaldehyde	128.95	44.09	91.02	45.62	133.41
Total Aldehydes (%)	**4.30%**	**6.06%**	**8.47%**	**7.01%**	**7.06%**
1-phenyl-ethanone	24.43	51.92	209.05	ND	13.34
1,2-diphenyl-ethanone	ND	58.06	ND	66.97	ND
1-(2-aminophenyl)-ethanone	55.91	16.32	44.41	29.29	54.41
2-pentanone	18.08	ND	ND	ND	ND
2-hexanone	55.12	72.8	22.88	27.77	105.14
2-heptanone	67.18	65.43	18.84	115.65	105.99
6-methyl-5-hepten-2-one	ND	12.02	15.65	105.59	16.62
3-octanone	ND	79.99	105.99	ND	18.84
Total Ketones (%)	**4.00%**	**9.85%**	**12.68%**	**12.18%**	**7.17%**
Benzenemethanol	152.22	225.09	105.05	24.99	206.12
2-butyl-ethanol	78.12	22.45	ND	13.38	ND
2-methyl, 1- propanol	113.13	ND	ND	95.15	22.25
1-butanol	ND	17.71	103.32	98.45	12.25
2-butanol	28.26	ND	21.13	33.42	44.78
3-methyl-butanol	114.95	ND	104.22	95.11	232.26
1-pentanol	72.28	ND	88.43	22.92	82.22
1-penten-3-ol	105.32	77.62	ND	140.15	125.11
5-methoxy-1-pentanol	622.1	620.53	102.34	ND	14.22
2,4-dimethyl-3-pentanol	ND	71.4	ND	11.41	ND
Total Alcohols (%)	**23.31%**	**29.59%**	**15.95%**	**18.87%**	**16.86%**
Methyl-pyrazine	225.25	205.55	99.55	104.52	351.12
2-ehtyl-6-methyl-pyrazine	338.11	113.95	ND	ND	11.08
3-ethyl-5-methyl-pyrazine	198.11	113.95	214.55	258.29	137.11
2,3-diethyl, 5-methyl-pyrazine	26.62	ND	44.13	ND	11.34
2,5-dimethyl-pyrazine	634.88	85.39	211.35	142.72	330.11
2,6-dimethyl-pyrazine	310.42	197.32	142.77	105.92	299.76
3-ethyl-2,5-dimethyl-pyrazine	505.55	313.14	225.57	129.99	146.52
2-ethyl-3,5-dimethyl-pyrazine	408.22	118.23	213.99	198.14	555.11
Total N-containing Compounds (%)	**47.98%**	**31.71%**	**35.04%**	**33.15%**	**42.01%**
2,6,10,14-tetramethyl-pentadecane	98.15	19.75	ND	ND	ND
3-tetradocene	24.46	5.51	ND	43.35	ND
2,3-butanediene	13.22	ND	28.01	28.01	ND
2-undecane	9.11	55.46	ND	44.13	79/82
Hexadecane	ND	6.63	102.22	18.83	ND
Total Hydrocarbon (%)	**2.63%**	**2.41%**	**3.96%**	**4.74%**	**1.82%**
Propanoic acid	12.28	ND	ND	ND	118.18
Butanoic acid	49.52	39.61	22.28	105.55	105.16

Table 2 continued:					
Methyl-ester-butanoic acid	104.35	23.35	50.05	48.71	12.22
Pentatonic acid	ND	0.95	99.41	ND	13.38
Phenol	209.55	510.01	505.93	455.15	705.66
1H-Indole	605.55	199.34	108.11	72.28	145.55
Total Others (%)	**17.78%**	**21.37%**	**23.90%**	**24.05%**	**25.09%**

ND: non-detectable

* KA, KM: *Kapi* produced from *A. vulgaris* and *M. lanchesteri*, KC1, KC2, KC3: Commercial *Kapi* from Krabi, Samut Sakhon and Rayong, respectively.

Ketones found in all samples included 1-(2-aminophenyl)-ethanone, 2-hexanone and 2-heptanone. Park *et al.* (2014) revealed that 2-hexanone and 2-heptanone were produced by oxidation or pyrolysis of polyunsaturated fatty acids and were involved in a nasty smell in seafood. KM had the higher intensity of ketones (9.85%), compared with KA (4.00%), but lower than all commercial *Kapi* samples (7.17-12.68%).

Among 10 alcohols found in *Kapi*, only benzene-methanol was obtained in all samples. This compound gives the almond-like odor in seafood (Park *et al.*, 2014). Michihata *et al.* (2002) noted that normal and branched alcohol, especially butanol derivatives, might be formed by microbial fermentation or the degradation products from lipid oxidation. The higher amount of 5-methoxy-1-pentanol was obtained in KA and KM, compared with commercial samples. The type and abundance of individual alcohol found in *Kapi* seemed to vary with different raw materials used for production. However, alcohols might not have a paramount impact on *Kapi* flavor because of their high flavor thresholds (Cha and Cadwallader, 1995).

All *Kapi* samples contained N-containing compounds as dominant volatiles. KA had the highest abundance (47.98%), followed by KC3 (42.01%) and KC1 (35.04%), respectively. Major pyrazine compounds found in all samples included methylpyrazine, 3-ethyl-5-methylpyrazine, 3-ethyl-2,5-dimethyl-pyrazine, etc. These compounds contributed to prawn, roasted, nutty and dried seafood like odors, which were the desirable odor in dried fermented food (Jaffres *et al.*, 2011). Rodríguez-Bernaldo *et al.* (2001) reported that pyrazine compounds were generated in the samples dried using thermal conditions i.e. spray drying and tray drying. The drying step with sunlight during *Kapi* production more likely contributed to the formation of these compounds. Pyrazines was thermally generated via Maillard reaction through Strecker degradations from various nitrogen sources such as amino acids in thermally processed foods (Rodríguez-Bernaldo *et al.*, 2001). Furthermore, the presence of pyrazine indicated that browning reaction mediated by Maillard reaction occurred in *Kapi* during fermentation. Pyrazine derivative compounds were the major volatiles found in many fermented products including *Ishiru* (Japanese fish sauce) (Michihata *et al.*, 2002), *Noucmam* (Vietnamese fish sauce)

(Lopetcharat *et al.,* 2001), fermented dried shrimp (*Acetes chinensis*) (Lu *et al.,* 2011) as well as *Kapi* (Cha and Cadwallader, 1995; Pongsetkul *et al.,* 2015a). This compound might contribute to flavor, color as well as antioxidative activity of *Kapi* to some extent.

Low abundance of hydrocarbons (1.82-4.74%) was obtained in *Kapi*. Those included 2,6,10,14-tetramethyl-pentadecane, 3-tetradocene, 2,3-butanediene, etc. Latorre-Moratalla *et al.* (2011) noted that the most hydrocarbons, alkanes and alkenes, are mainly formed from lipid auto-oxidation of fatty acids released from triglycerides. Additionally, some acids were found in some *Kapi* samples. Propanoic acid, which found in KA and KC3, mainly contribute to oily notes in foods (Chung *et al.,* 2005). Butanoic acid and methyl-ester-butanoic acid were noticeable in all samples. These acids are known to have cheesy notes including cheesy, sharp, rancid, sweaty, and pungent (Chung *et al.,* 2005). Additionally, phenol and 1H-indole were also obtained in all samples. Cha and Cadwallader (1995) reported that phenol give an undesirable aroma in seafood. Indole is the degradation product from tryptophan and has been used as the index for shrimp spoilage (Casaburi *et al.,* 2008). Based on volatile compounds, *Kapi* produced from different shrimps contained varying amount and type of volatile compounds. This might be associated with different flavors and acceptability of various *Kapi*.

Sensory evaluation

Likeness scores of KA, KM, as well as three commercial *Kapi* are shown in Table 3. Generally, KC3 had the highest likeness score for all sensory characteristics including appearance, color, odor, texture, flavor and overall-liking score ($p<0.05$). There were no differences in appearance-liking score between all samples ($p>0.05$). The highest color-liking score was obtained for KC1 (7.30), while KM had the lowest color-liking score (6.57). Pongsetkul *et al.* (2015a) suggested that *Kapi* with browner or darker color was more desirable. Lower *L** but higher *b**-value of KA (Table 1) indicated higher intensity of color, especially more yellowish or browner, than KM. This led to the higher color-liking score of KA. Furthermore, the lowest odor and flavor-liking scores were found in KM ($p<0.05$). In general, the differences in sensorial characteristics of fermented food could be influenced by raw material used, ingredients, fermentation process and conditions (Beriain *et al.,* 2000). Therefore, it was likely that differences in compositions as well as autolysis in raw material contributed to varying likeness scores of *Kapi*. In the present study, odor and flavor mainly affected the sensory quality (overall-liking) of this product. Based on overall-liking score, KA and KC1 had the highest overall-liking score, compared with others ($p<0.05$). The result indicated that *A. vulgaris* seemed to have high potential to become an alternative raw material for *Kapi* production.

Principal component analysis (PCA)

Relationships between volatile compounds of different *Kapi* samples including KA, KM and commercial *Kapi* and sensory score (odor, flavor and overall-liking score) were studied using PCA (Fig. 1). The first two principal components could be described as 87.26% of the variations in the data set. It was noticed that the first principal component, which was the direction of the maximum explained variance (47.96%), demonstrated a useful separation between groups of volatiles. From the loadings, the samples placed to the right along PC1 (KA and KC3) were characterized by higher intensity of N-containing compound, associated with the higher odor, flavor as well as overall-liking score. In contrast, samples placed to the left along PC1 (KM, KC1 and KC2) were described as higher intensity of other groups of volatiles including aldehydes, ketones, etc. Moreover, PC2, which explains a lower variance percentage (39.30%), revealed that commercial *Kapi* contained the higher intensity of aldehydes, ketones as well as hydrocarbons, compared with KA and KM. The total separation of high amount of alcohols in KM was also observed. However, alcohols seemed to have less effect on sensorial scores. Based on PCA results, it was possible to confirm that flavor-liking score was closely correlated with overall-liking score of *Kapi*. The highest overall-liking score in KA and KC3 samples (Table 3) might be caused by higher intensity of N-containing compounds. This result confirmed that *A. vulgaris* showed higher potential as an alternative raw material for production of *Kapi*, in comparison with *M. lanchesteri.*

Table 3: Likeness score of *kapi* produced from *Acetes vulgaris, Macrobrachium lanchesteri* and three different commercial *Kapi.*

Sample	Attributes					
	Appearance	**Color**	**Odor**	**Texture**	**Flavor**	**Overall**
KA	7.27 ± 1.07^{a}	7.10 ± 1.03^{b}	7.25 ± 1.02^{a}	7.10 ± 0.97^{a}	7.30 ± 0.80^{a}	7.43 ± 0.22^{a}
KM	7.23 ± 1.11^{a}	6.57 ± 1.05^{c}	6.95 ± 0.44^{b}	7.33 ± 0.49^{a}	6.83 ± 1.05^{bc}	6.85 ± 0.77^{c}
KC1	7.10 ± 0.96^{a}	7.30 ± 1.22^{a}	7.30 ± 0.55^{a}	6.53 ± 2.05^{b}	7.03 ± 1.01^{b}	7.05 ± 0.87^{b}
KC2	7.25 ± 1.13^{a}	7.03 ± 0.54^{b}	7.25 ± 0.63^{a}	6.95 ± 0.67^{ab}	7.10 ± 1.12^{b}	7.10 ± 0.22^{b}
KC3	7.15 ± 1.05^{a}	7.20 ± 0.98^{ab}	7.35 ± 1.01^{a}	7.10 ± 0.58^{a}	7.40 ± 0.22^{a}	7.40 ± 0.53^{a}

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 column indicate the significant differences (p<0.05).
* KA, KM: *Kapi* produced from *A. vulgaris* and *M. lanchesteri*, KC1, KC2, KC3: Commercial *Kapi* from Krabi, Samut Sakhon and Rayong, respectively.

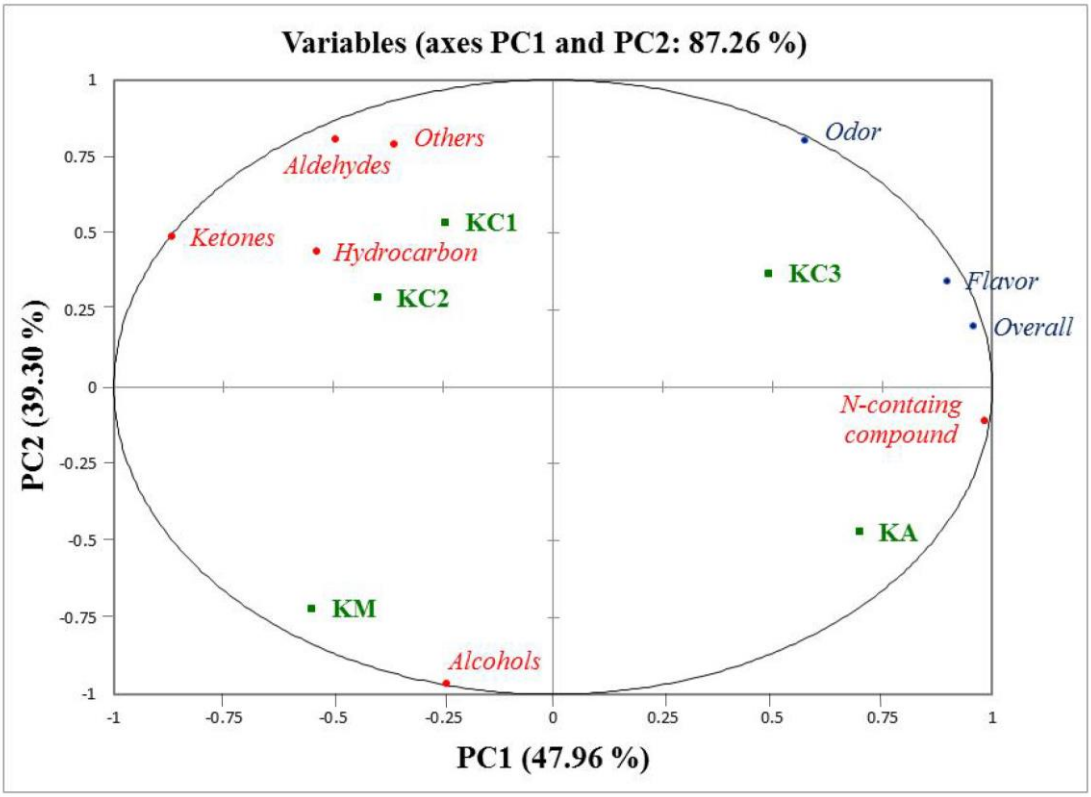

Figure 1: PCA score (samples, in bold) and loading (Groups of volatile compounds and sensorial characteristics, in italic) plots of *Kapi* produced from *Acetes vulgaris*, *Macrobrachium lanchesteri* and three commercial *Kapi* samples.
***KA, KM: *Kapi* produced from *A. vulgaris* and *M. lanchesteri*, respectively. KC1, KC2, and KC3: Commercial *Kapi* from Krabi, Samut Sakhon and Rayong, respectively.**

Kapi produced from *A. vulgaris* and *M. lanchesteri* had different chemical compositions, physical and sensory properties. *Kapi* produced from *A. vulgaris* with browner color showed higher fat content, but lower protein content, compared with *Kapi* produced from *M. lanchesteri*. The former had higher likeness score that the latter. Volatile compounds of both samples were also different. N-containing compounds, which were predominant volatiles in *Kapi*, played a profound role in likeness of this product. Thus, *Kapi* could be prepared from *A. vulgaris* with comparable sensory property to commercial products.

Acknowledgement
This research was supported by Prince of Songkla University and the Grant-in-Aid for dissertation from Graduate School, Prince of Songkla University, Thailand.

References

AOAC, 2000. Official methods of analysis. 17th ed. Association of Official Analytical Chemists. Gaithersburg, MD, USA, 2200 P.

Benjakul, S., Lertittikul, W. and Bauer, F., 2005. Antioxidant activity of Maillard reaction products from a porcine plasma protein-sugar model system. *Food Chemistry*, 93(**2**), 189-196.

Beriain, J.A., Chasco, J. and Lizaso, G., 2000. Relationship between biochemical and sensory quality characteristics of different commercial brands of *salichichon*. *Food Control*. 11(**1**), 231-237.

Binsan, W., Benjakul, S., Visessanguan, W., Roytrakul, S., Tanaka, M. and Kishimura, H., 2008. Antioxidative activity of Mungoong, an extract paste, from the cephalothorax of white shrimp (*Litopenaeus vannamei*). *Food Chemistry*, 106(**1**), 185-193.

Casaburi, A., Monaco, D.R., Cavella, S., Toldra, F., Ercolini, D. and Villani, F., 2008. Proteolytic and lipolytic starter cultures and their effect on traditional fermented sausages ripening and sensory traits. *Food Microbiology*, 25(**2**), 335-347.

Cha, Y.J. and Cadwallader, K.R., 1995. Volatile compounds in salt-fermented fish and shrimp pastes. *Journal of Food Science*, 60(**1**), 19-27.

Chirife, J., 1989. Water activity. *Food Market Technology*, 11(**1**), 23-27.

Cho, S.D. and Kim, G.H., 2010. Changes of quality characteristics of salt-fermented shrimp prepared with various salts. *The Korean Journal of Food and Nutrition*, 23(**2**), 291-298.

Chung, H.Y., Fung, P.K. and Kim, J.S., 2005. Aroma impact components in commercial plain sufu. *Journal of Agricultural and Food Chemistry*, 53(**1**), 1684-1691.

Eusebio, P.S., Coloso, R.M. and Gapasin, R.S.J., 2010. Nutritional evaluation of mysids *Mesopodopsis orientalis* (Crustacea: *Mysida*) as live food for grouper *Epinephelus fuscoguttatus* larvae. *Aquaculture Research*, 306(**1**), 289-294.

Faithong, N., Benjakul, S., Phatcharat, S. and Binson, W., 2010. Chemical composition and antioxidative activity of Thai traditional fermented shrimp and krill products. *Food Chemistry*, 119(**1**), 133-140.

Fennema, O.R., 1996. Water and ice. In O. R. Fennema (Ed.) Food chemistry (pp. 17-94), Marcel Dekker, New York.

Hajeb, P. and Jinap, S., 2015. Umami taste components and their sources in asian foods. *Critical Reviews in Food Science and Nutrition*, 55(**3**), 778-791.

Higuera-Ciapara, I., Felix-Valenzuela, L. and Goycoolea, F.M., 2006. Astaxanthin: A review of its chemistry and applications. *Critical Reviews in Food Science and Nutrition*, 46(**1**), 185-96.

Iglesias, J. and Medina, I., 2008. Solid-phase microextraction method for the determination of volatile compounds associated to oxidation of fish muscle. *Journal of Chromatography A*, 1192(**1**), 9-16.

Jaffres, E., Lalanne, V., Mace, S., Cornet, J., Cardinal, M., Serot, T., Dousset, X. and Joffraud, J.J., 2011. Sensory characteristics of spoilage and volatile compounds associated with bacteria isolated from cooked and peeled tropical shrimps using SPME-GC-MS analysis. *International Journal of Food Microbiology*, 147(**4**), 195-202.

Jing, H. and Kitts, D.D., 2002. Chemical and biochemical properties of casein-sugar Maillard reaction products. *Food and Chemical Toxicology*, 40(**1**), 1007-1015.

Kang, K.M. and Baek, H.H., 2014. Aroma quality assessment of Korean fermented red pepper paste (*gochujang*) by aroma extract dilution analysis and headspace solid-phase microextraction-gas chromatography.olfactometry. *Food Chemistry*, 145(**1**), 488-495.

Kim, Y.B., Choi, Y.S., Ku, S.K., Jang, D.J., Binti-Ibrahim, H.H. and Moon, K.B., 2014. Comparison of quality characteristics between *belacan* from Brunei Darussalam and Korean shrimp paste. *Journal of Ethnic Foods*, 1(**1**), 19-23.

Kleekayai, T., Harnedy, P.A., O'Keeffe, M.B., Poyarkov, C.N., Suntornsuk, W. and FitzGerald, R.J., 2015. Extraction of antioxidant and ACE inhibitory peptides from Thai traditional fermented shrimp pastes. *Food Chemistry*, 176(**3**), 441-447.

Latorre-Moratalla, M.L., Bosch-Fuste, L., Bover-Cid, S., Aymerich, T. and Vidal-Carou, M.C., 2011. Contribution of enterococci to the volatile profile of slightly-fermented. *LWT- Food Science and Technology*, 44(**3**), 145-152.

Lopetcharat, K., Choi, Y.J., Park, J.W. and Daeschel, M.A., 2001. Fish sauce products and manufacturing: A review. *Food Research International*, 17(**3**), 65-88.

Lu, F., Zhang, J.Y., Liu, S.L., Wang, Y. and Ding, Y.T., 2011. Chemical, microbiological and sensory changes of dried *Acetes chinensis* during accelerated storage. *Food Chemistry*, 127(**2**), 159-168.

Meland, K. and Willassen, E. 2007. The disunity of "*Mysidacea*" (Crustacea). *Molecular Phylogenetics and Evolution*, 44(**1**), 1083-1104.

Michihata, T., Yano, T. and Toshiki, E., 2002. Volatile compounds of headspace gas in the Japanese fish sauce *Ishiru*. *Bioscience, Biotechnology, and Biochemistry*, 66(**1**), 2251-2255.

Montano, N., Gavino, G. and Gavino, V.C., 2001. Polyunsaturated fatty acid contents of some traditional fish and shrimp paste condiments of the Philippines. *Food Chemistry*, 75(**1**), 155-158.

Nirmal, N.P. and Benjakul, S., 2009. Effect of ferulic acid on inhibition of polyphenoloxidase and quality changes of Pacific white shrimp (*Litopenaeus vannamei*) during iced storage. *Food Chemistry*, 116(**2**), 323-331.

Park, J.Y., Kim, Y.J. and Lee, Y.B., 2014. Analysis of headspace volatile compounds in cold-stored and freeze-dried krill *Eupausia superba*. *Canadian Journal of Fisheries and Aquatic Sciences*, 17(**1**), 189-195.

Peralta, E.M., Hatate, H., Kawabe, D., Kuwahara, R., Wakamatsu, S., Yuki, T. and Murata, H., 2008. Improving antioxidant activity and nutritional components of Philippine salt-fermented shrimp paste through

prolonged fermentation. *Food Chemistry*, 111(**1**), 72-77.

Phithakpol, B., 1993. Fish fermentation technology in Thailand. In K. H. Steinkraus, and P. J. Reilly (Eds) Fish Fermentation Technology, United Nation, University Press. pp. 155-166

Pongsetkul, J., Benjakul, S., Sumpavapol, P., Kazufumi, O. and Faithong, N., 2014. Chemical composition and physical properties of salted shrimp paste (*Kapi*) produced in Thailand. *International Aquatic Research*, 6(**1**), 155-166.

Pongsetkul, J., Benjakul, S., Sumpavapol, P., Kazufumi, O. and Faithong, N., 2015a. Properties of salted shrimp paste (*Kapi*) from *Acetes vulgaris* as affected be post-mortem storage prior to salting. *Journal of Food Processing and Preservation*, 40(**3**), 636-646.

Pongsetkul, J., Benjakul, S., Sumpavapol, P., Kazufumi, O. and Faithong, N. 2015b. Chemical compositions, sensory and antioxidative properties of salted shrimp paste (*Ka-pi*) in Thailand. *International Food Research Journal*, 22(**3**), 1454-1465.

Pongsetkul, J., Benjakul, S., Sumpavapol, P., Kazufumi, O. and Faithong, N., 2016. Effect of post-mortem storage prior to salting on quality of salted shrimp paste (*Kapi*) produced from *Macrobrachium lanchesteri. Carpathian Journal of Food Science and Technology*, 8(**1**), 93-106.

Rodríguez-Bernaldo A.D., López-Hernández, J., González-Castro, M., Cruz-García, C. and Simal-Lozano, J., 2001. Comparison of volatile components in fresh and canned sea urchin (*Paracentrotus lividus*, Lamarck) gonads by GC-MS using dynamic headspace sampling and microwave desorption. *European Food Research and Technology*, 212(**1**), 643-647.

Saisithi, P., Kasermsarn, B. and Dollar, A.M., 1966. Microbiology and chemistry of fermented fish sauce. *Journal of Food Science*, 31(**1**), 105-112.

Steel, R.G.D., Torrie, J.H. and Dickey, D.A., 1980. Principle and procedure of statistics. In R. G. D. Steel (Ed) General statistics, McGraw-Hill, New York. pp. 457-490

Takeungwongtrakul, S. and Benjakul, S., 2013. Oxidative stability of shrimp oil-in-water emulsions as affected by antioxidant incorporation. *International Aquatic Research*, 5(**3**), 1-12.

Wittanalai, S., Rakariyatham, N. and Deming, R.L., 2011. Volatile compounds of vegetarian soybean *kapi*, a fermented Thai food condiment. *African Journal of Biotechnology*, 10(**1**), 821-830.

Yarnpakdee, S., Benjakul, S., Penjamrus, P. and Kristinsson, H.G., 2014. Chemical compositions and muddy flavour/odour of protein hydrolysate from Nile tilapia and broadhead catfish mince and protein isolate. *Food Chemistry*, 142(**1**), 210-216.