Determination of compositional quality and volatile flavor characteristics of radish-based Kimchi suitable for Chinese consumers and its correlation to consumer acceptability

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Abstract In this study, two prototype radish-based kimchi were developed for Chinese consumer market. The major difference between these samples was the liquid used during the salting stage. Kimchi 1 was salted in soy sauce while Kimchi 2 was salted in saline water. The quality factor differences were observed in Brix (°Brix), salinity, and capsaicin levels ($p < 0.05$). The volatile flavor analysis revealed that a different flavor profile was noted between the two kimchi samples; however, this did not influence consumer acceptance. The overall liking scores for Kimchi 1 and Kimchi 2 were 6.2 and 6.1, respectively, based on a 9-pt hedonic scale ($p > 0.05$). Current work presented two different prototypes of radish-based Kimchi developed for Chinese consumers. Slight differences were observed between the two radish-based kimchi samples, yet these differences did not influence consumer hedonic responses.

Keywords Radish-based Kimchi · Chinese consumers · Consumer acceptability · Volatiles

Introduction

Kimchi is the most well-known Korean dish in the world. The dish is made by fermenting salted vegetables with lactic acid bacteria (LAB). The typical kimchi-making method involves mixing salted vegetables with special kimchi sauces prior to fermentation. These sauces, such as red pepper sauce, may contain red pepper powder, garlic, leeks, and ginger (Jung et al., 2014). Typically, Lactic Acid Bacteria (LAB) is involved during the entire kimchi fermentation process. The health-promoting effects of kimchi are now recognized: antioxidative activity (Hwang et al., 2000; Ryu et al., 2004), anti-stress effects, (Lee and Lee, 2009), antiaging effects (Kim et al., 2000), antimicrobial activity (Sheo and Seo, 2003), and antimutagenic activity (Cho et al., 1997). In 2011, kimchi was recognized as one of the top five healthiest foods in the world (Lee et al., 2011). Similar to kimchi consumption in Korea, salted vegetables—with or without the fermentation process—known as *zha cai*, *yan cai*, and *suan cai* are consumed in China. The main difference between the Korean and Chinese dishes is the sauce used to mix the salted and fermented vegetables. Different recipes exist for the different vegetable bases; for example, there are varying recipes for cabbage-based kimchi. In addition, there are different recipes within different regions of each country. These recipe variations can be attributed to the differing cooking styles and preferred flavors of each region. In order to understand the consumer market for any given food, it is essential to understand regional differences regarding preferred flavor and texture.

While globalization of the food market drives an increasing need for ethnic food products, understanding the fastest-growing market—the Chinese food industry—is a necessity for global food industry. The recently signed Free

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Trade Agreement (FTA) between China and South Korea allows the import of fermented food items manufactured in South Korea to China. This includes kimchi. In order to expand South Korea's current kimchi market, it is imperative to thoroughly understand Chinese consumers' interest toward kimchi prior to developing kimchi-related products targeting the Chinese market. Previously, a comprehensive qualitative consumer study was conducted on Kimchi using Chinese consumers (Lee et al., 2017). Their study revealed that the desirable sensory characteristics of Korean kimchi are also suitable for Chinese consumers. The study also showed that kimchi made from radishes was preferred by the Chinese because they are familiar with radishes. The objective of the current study was to determine the compositional quality and volatile flavor characteristics of radish-based Kimchi developed for Chinese consumers and its correlation to consumer acceptability (Table 1).

Materials and method

Sample preparation

All ingredient, including radish, sugar, oligosaccharides, fish sauce, red pepper powder, green onions, garlic, sesame oil, sesame seeds, and soy sauce, was purchased from a local grocery store in Goyang-si, Korea. The main ingredient was dried radish, made by drying freshly-cut radishes (2 cm × 2 cm × 10 cm) at 70 °C for 16 h using a food dehydrator (L'Equip, Hwasung, Gyeonggi-do, Korea). The weight before and after drying was recorded in order to calculate the weight reduction of each radish. Weight reduction was calculated by dividing the weight difference between the initial and final weight by the initial weight of the radish, as follows:

$$\text{weight reduction (\%)} = \frac{\text{initialwt.} - \text{finalwt.}}{\text{initialwt.}} * 100$$

After 16 h of drying the radish, the weight reduction of each radish was around 87.4%.

Dehydration is one of traditional methods for storing fresh vegetables during the winter in Korea. Dehydrated vegetables including radishes have been utilized as side dishes and/or ingredients for broth making. For radish-based Kimchi making, rehydrating step was a necessity, and this is part of standard method of manufacturing. The dried radishes were soaked in water for 2 h prior to the kimchi-making process. Once fully rehydrated, the radishes were rinsed with tap water and squeezed firmly to remove any excess water. Next, the radishes used in Kimchi 1 were soaked in soy sauce for 30 min while the radishes used in Kimchi 2 were soaked in 20% salt water for 30 min. For Kimchi 1, after the radishes soaked for 30 min, the remaining ingredients were added and mixed well. For Kimchi 2, the radishes were rinsed after being soaked and the remaining water was squeezed out. Then, the radishes were mixed with the remaining ingredients. As is evident, the difference between Kimchi 1 and Kimchi 2 was the liquid used in the soaking step: the radishes for Kimchi 1 were soaked in soy sauce while the radishes for Kimchi 2 were soaked in saline water. Previous study on consumer testing of Kimchi preferred by Chinese consumers, reported that strong sweet and umami tastes were one of the drivers of consumer preference of Korean-style Kimchi among Chinese consumers (Lee et al., 2017). Therefore, soy sauce was added in Kimchi 1 as part of product formulation. The kimchi samples were then stored in plastic containers designed specifically for kimchi storage at two different temperatures (4 and 25 °C) for 9 days.

Compositional analysis

Compositional analyses of the developed radish kimchi, including pH, °Brix, salinity, and color, were conducted according to the standard method of analysis listed in the Korean Food Standard Codex (2012). The samples used for pH, °Brix, and salinity measurements were prepared by adding 5 g of kimchi to 45 mL of distilled water and then mixing it in a blender (HMF-995, Hanil Electric Grinder, Seoul, Korea). The mixture was then filtered using Whatman No. 2 filter paper (Whatman, Maidstone, England). The filtered solution was used for further analysis. The pH of the kimchi was measured using a pH meter (Mettler Toledo, Switzerland), the °Brix was measured with a refractometer (ATAGO®, Japan) with a °Brix range of 0.0–33.0%, and the salinity was measured with a salinity meter (ATAGO®, Japan). The color was examined using a color analyzer (Model CR-300, Minolta, Osaka, Japan).

Table 1 Ingredient list of Radish-based Kimchi

	Radish Kimchi 1 (%)	Radish Kimchi 2 (%)
Radish (dried)	35.5	40.0
Sugar	7.1	8.0
Oligosaccharides	7.1	8.0
Fish sauce	7.1	8.0
Red pepper powder	9.9	11.2
Green onion (chopped)	7.1	8.0
Garlic (minced)	4.3	4.8
Sesame oil	7.1	8
Sesame seed	3.5	4.0
Soy sauce	11.3	0.0

Lightness (L^*), redness (a^*), and yellowness (b^*) values were reported. All measurements were conducted in triplicate. Capsaicin and dihydrocapsaicin levels were analyzed by a third-party contracting lab (Korean Food Research Institute) using high performance liquid chromatography (HPLC).

Microbial analysis

The kimchi samples were stored at two temperatures (4 and 25 °C) and were tested after 0, 3, 5, 7, and 9 days for total microflora and LAB. Microbial analysis was conducted following the standard method of analysis listed in the Korean Food Standard Codex (2012). At each testing time, 10 g of kimchi was mixed with 90 mL of 0.1% peptone water in a bag and was shaken 30 times to rinse off surface microflora. In addition, the contents of the bag were mixed using Stomacher (3M, Maplewood, MN, USA) for 3 min. The liquid portion was utilized for serial dilution after filtration. One mL of the serially diluted sample was plated in aerobic plate count agar using the pour plating method for total bacterial count and in MRS agar using the pour plating method for LAB. Plates were incubated at 37 °C for 48 h. The colonies that formed in the plates were counted. Colony forming unit (CFU) per mL (CFU/mL) was reported by counting triplicate plates with 25–250 colonies.

Volatile flavor analysis

Volatile flavor analysis was conducted using the automated Purge and Trap Sampler (JTD-505III, Japan Analytical Industry, Tokyo, Japan) followed by the Gas Chromatograph-Mass Spectrometry (GC–MS) QP2010 Plus (Shimadzu, Kyoto, Japan). Prior to purge and trap sampling, the AQ-200 Liquid Sampler (Japan Analytical Industry, Tokyo, Japan) was utilized in order to capture the volatile flavor compounds. The temperature of the liquid sampler was set at 60 °C and the samples went through the bubbling process at a rate of 50 mL/min for 30 min. The volatilized compounds were absorbed in Tenax GR (Japan Analytical Industry, Tokyo, Japan). Then, the Tenax GR was transferred to the Purge and Trap Sampler. The desorption temperature in the Purge and Trap Sampler was set at 280 °C for 30 min at a rate of 50 mL/min followed by the cold trap for sample trapping set at – 40 °C. This was followed by pyrolysis at 280 °C. The temperatures for the transfer-line and needle heater were set at 280 °C. The head press for the Purge and Trap Sampler was set at 86 MPa and the column flow rate was set at 1.0 mL/min with a 1/100 split ratio.

The GC–MS QP2010 Plus was used for quantification and qualification of the volatile flavor analysis. The DB-624 column (30 m × 0.251 mm × 1.40 mm) (Agilent

Technologies, Wilmington, DE, USA) was used. The temperature in the GC–MS oven was programed at 40 °C for a 3-min hold. It was raised to a speed of 10 °C/min up to 260 °C and was then held for 5 min at 260 °C. The mass spectrometer was operated in positive electron impact ionization mode with 70 eV of electron energy, and in scan mode. The scan range for full scan mode was between 45 and 500 m/z. The concentrations of volatile compounds in the kimchi samples were expressed by peak area height divided by total peak area. Volatile compounds were identified by mass spectrum in Wiley mass spectral databases (NIST08, Wiley). The volatile flavor analysis was conducted at CURF in the Chonbuk National University.

Consumer acceptance test

Consumer acceptance testing was conducted in China during China's global food and wine exhibition in Shanghai, 2015. The booth with the radish kimchi samples developed for this study was set up on the exhibition floor. Consumer acceptance testing was conducted during the expo. Participants were recruited during normal expo hours. The samples were prepared the morning of the taste test before the expo began and were kept in a refrigerator. One hour prior to the taste test, the samples were taken out and kept at room temperature to build the headspace volatiles. The samples were then served at 10 ± 2 °C in a 59 mL lidded plastic cup, blind-coded with 3-digit random numbers. The sample presentation order was balanced and randomized.

A total of 300 participants were recruited, and 278 subjects were able to complete the questionnaire. Participants were initially asked to fill out a brief questionnaire containing demographic-related questions, including the location of their current residency. Once the demographic questions were completed, the two kimchi samples were presented. The participants were then asked to evaluate their likings of the samples, including overall liking as well as liking for appearance, hardness texture, spiciness, sweetness, and harmony of ingredient. An open-ended question was included in the questionnaire allowing participants to freely express the reason(s) for their likings/dislikings in their own words. The liking attributes were evaluated using a 9-point hedonic scale, with 1 being dislike extremely, and 9 being like extremely. The questionnaires were prepared in Chinese and two Chinese interpreters were on site to help with the experimental procedures. Those who completed the questionnaire received a \$20-value gift as a token of appreciation.

Statistical analysis

Data obtained from the compositional analysis, volatile flavor analysis, and consumer acceptance testing were analyzed using XLSTAT (version 2015, Addinsoft, Paris, France). Mean $\pm$ standard deviation of triplicate analysis was reported for all data except for the consumer acceptance test. Analysis of Variance (ANOVA) followed by mean separation determined by the Fisher's Least Significant Difference (LSD) test ($p < 0.05$) was conducted.

Results and discussion

Compositional analysis result

For this study, two radish-based kimchi samples were manufactured according to the standard kimchi-making method. Analyses of their quality characteristics, including pH, °Brix, salinity, color, capsaicin, and dihydrocapsaicin content were conducted. These results can be found in Tables 2 and 3. The difference between the two kimchi samples was the liquid used during the salting stage. Kimchi 1 was salted in soy sauce while Kimchi 2 was salted in saline water.

Differences in quality factors were noticed between the two samples in °Brix, salinity, and capsaicin levels ($p < 0.05$). pH sampling was conducted on day 9. The pH of the two kimchi samples fell within the normal range for foods typically fermented by LAB, such as cheeses (McMahon et al., 2014), and Kimchi (Kang et al., 2003), which indicated that LAB fermentation occurred properly during storage. The pH was 4.83 for Kimchi 1 and 4.86 for

Kimchi 2. The difference between these pH values was not statistically significant ($p > 0.05$). The °Brix of Kimchi 2 (21.3%) was significantly higher than that of Kimchi 1 (18.0%) ($p < 0.05$). The °Brix value indicates the soluble solid content, therefore high in °Brix value means high in sugar and other micro- and macro-nutrients. Typically, °Brix value negatively correlates with moisture contents of foods (Kim et al., 2018). Higher °Brix in Kimchi 2 may have been attributed from the lower levels of free water in Kimchi 2, as Kimchi 2 was salted in salt water. The salinity of Kimchi 2 (4.30 g/100 g) was significantly higher than the salinity of Kimchi 1 (2.30 g/100 g) ($p < 0.05$). Typical kimchi salinity ranges from 1.5 to 4.0% (Ku et al., 2004; Park et al., 2000). The salinity values obtained in this study were within normal ranges.

No differences in color were observed between the two samples ($p > 0.05$). This was unexpected. It was anticipated that Kimchi 1 would receive a lower L^* value because its radishes were soaked in soy sauce, which has dark color. However, the L^* value was not different between the two samples ($p > 0.05$). In addition a^* levels were not as expected. Radish Kimchi 2 had higher capsaicin levels (4.20 mg/kg) than Kimchi 1 (3.20 mg/kg), though there were no observed differences in dihydrocapsaicin levels (1.30 mg/kg for Kimchi 2 and 1.80 mg/kg for Kimchi 1). Previously, a high correlation between capsaicin levels and redness of color had been reported (Shin and Lee, 1991). Therefore, Kimchi 2 was expected to be higher in a^* , but no such difference was observed. Total capsaicin content (capsaicin and dihydrocapsaicin) was not different to each other (5.5 mg/kg for Kimchi 1 and 6.0 mg/kg for Kimchi 2). This may be because the amount of red pepper powder was not different in two kimchi samples, while red pepper powder is the major contributor for capsaicin content. When comparing the capsaicin levels of radish-based kimchi to other commercial kimchi (cabbage kimchi) in Korea, the levels of capsaicin in commercial cabbage kimchi were reported as 1.55 mg/100 g (Han et al., 2003), 2.43–134 mg/100 g (Oh et al., 2011) and 10.6 mg/100 mg (Shin and Lee, 1991). Capsaicin content can be used as chemical index for estimating the consumer's perceived spiciness (Lee et al., 2011). The spiciness of developed radish-based Kimchi in this study is within the range of spiciness of commercially-available Kimchi in Korea.

Microbial analysis result

Microbial analysis results for the kimchi samples during the 9 days of storage at 4 and 25 °C can be found in Fig. 1. Figure 1(A) shows the total bacteria count and Fig. 1(B) shows the changes of LAB during storage. The initial level of total bacteria was around 5.5–5.6 log CFU/

Table 2 Physiochemical Properties of Radish-based Kimchi

	Radish Kimchi 1	Radish Kimchi 2
pH	4.83 $\pm$ 0.02 a	4.86 $\pm$ 0.09 a
°Brix (%)	18.0 $\pm$ 0.00 b	21.3 $\pm$ 0.12 a
Salinity (g/100 g)	2.30 $\pm$ 1.15 b	4.30 $\pm$ 1.15 a
Color		
L^*	37.6 $\pm$ 0.41 a	38.4 $\pm$ 0.33 a
a^*	25.7 $\pm$ 0.04 a	27.7 $\pm$ 0.23 a
b^*	42.5 $\pm$ 0.42 a	42.9 $\pm$ 0.32 a
Capsaicin (mg/kg)	3.20 $\pm$ 0.20 b	4.20 $\pm$ 0.22 a
Dihydrocapsaicin (mg/kg)	1.80 $\pm$ 0.11 a	1.30 $\pm$ 0.12a

Data is reported as mean $\pm$ standard deviation of triplicate analyses of each physicochemical properties

Means in a row that does not share the same alphabetical letter represent the significant differences ($p < 0.05$)

L^* , a^* and b^* values are the names of what was measured in color

Table 3 Volatile flavor analysis result of Radish-based Kimchi

Peak #	R. Time	Name of compound	Kimchi 1		Kimchi 2	
			Avg	Std	Avg	Std
1	1.92	Sulfur dioxide	0.110	0.191	0.357	0.310
2	2.41	Methanethiol	0.607	0.200	1.720	0.221
3	3.18	Ethanol	2.843	3.556	2.997	1.796
4	5.75	2,3-Butanedione	0.843	0.325	0.867	0.166
5	7.06	Benzene	0.760	0.250	1.037	0.601
6	7.20	Acetic acid	27.837	5.622	16.413	1.749
7	7.38	Thiophene	0.280	0.485	0.827	0.738
8	7.45	2-Butenal	2.913	0.446	3.137	0.947
9	7.93	3-(methylthio)-1-Propene	0.340	0.589	1.870	1.998
10	9.36	Dimethyl disulfide	4.650	1.105	13.737	2.563
11	9.45	Propanoic acid	1.627	0.540	N.D	N.D
12	9.50	Methyl thiocyanate	N.D	N.D	0.423	0.733
13	9.58	1-Pentanol	N.D	N.D	0.260	0.450
14	9.70	3,4-Dimethyl-1-hexene	0.557	0.565	0.253	0.439
15	9.76	Isoamyl valerate	0.297	0.514	2.670	0.862
16	9.96	3-Ethyl 3 Hexene	0.687	0.595	0.307	0.531
17	10.03	1,2,4-trimethyl-Cyclopentane	N.D	N.D	0.200	0.346
18	10.03	3-Methylene heptane	1.270	2.200	N.D	N.D
19	10.25	3-Methyl 2-heptene	1.733	2.201	0.303	0.525
20	10.31	2-Ethyl-1-hexene	1.307	2.263	N.D	N.D
21	10.84	Hexanal	N.D	N.D	0.133	0.231
22	10.89	Tetrahydrothiophene	N.D	N.D	0.350	0.072
23	11.40	Butanoic acid	5.327	2.743	3.350	1.161
24	11.71	2,3-Butanediol	3.040	1.830	4.093	1.597
25	11.94	3,3'-thiobis-1-Propene	0.977	1.217	1.617	1.422
26	12.19	2-Furfural dipropionate	0.207	0.358	0.147	0.254
27	12.30	2-Furancarboxaldehyde	0.443	0.393	0.160	0.277
28	12.54	Isovaleric acid	0.927	0.363	0.430	0.380
29	12.69	2-Methyl butanoic acid	0.667	0.744	0.307	0.267
30	12.80	Styrene	2.393	2.965	1.680	1.750
31	13.27	2,5-Dimethyl pyrazine	0.190	0.329	0.153	0.266
32	13.43	1,3-Dithiane	4.067	3.065	16.960	3.891
33	13.69	Methyl 1-propenyl disulfide	0.183	0.318	1.223	1.301
34	14.71	Dimethyl trisulfide	1.067	0.612	1.540	0.407
35	14.88	Benzaldehyde	0.130	0.225	N.D	N.D
36	15.30	dl-Limonene	0.673	0.100	0.723	0.029
37	15.77	2-Ethylhexanol	0.133	0.231	N.D	N.D
38	16.15	Phenol	1.400	0.539	1.110	0.330
39	16.54	Benzeneacetaldehyde	0.147	0.254	N.D	N.D
40	16.78	Ally disulfide	5.907	1.414	6.833	3.357
41	16.97	1,2-Dithiacyclopentane	1.307	0.231	1.017	0.345
42	17.10	Nonanal	0.343	0.595	0.273	0.473
43	17.16	Dipropyl disulfide	0.563	0.146	0.110	0.191
44	18.00	Benzeneethanol	1.290	1.795	0.170	0.294
45	18.34	Octanoic acid, ethyl ester	0.403	0.699	N.D	N.D
46	19.16	3-Vinyl-[4H]-1,2-dithiin	0.723	0.133	0.677	0.230
47	19.45	Tetrahydro-2-thiopheneacetonitrile	0.537	0.930	0.777	0.676
48	19.93	5-(methylthio)-pentanenitrile	0.413	0.374	0.783	1.357

Table 3 continued

Peak #	R. Time	Name of compound	Kimchi 1		Kimchi 2	
			Avg	Std	Avg	Std
49	21.48	Decanoic acid, ethyl ester	1.037	1.796	0.137	0.237
50	25.22	Nonadecane	1.307	1.800	0.243	0.421
51	25.23	4-methyl-5-propyl-Nonane	N.D	N.D	0.760	0.673
52	25.24	1,1'-oxybis-Octane	1.787	1.952	0.120	0.208
53	26.60	Octadecane	3.270	2.843	0.980	1.051
54	26.94	Tetradecanoic acid, ethyl ester	0.560	0.537	N.D	N.D
55	27.39	Isopropyl myristate	0.480	0.466	0.440	0.426
56	28.15	P-Octyl-oxybenzoic acid	2.767	4.792	1.160	2.009
57	28.17	2,3-Dimethyl heptadecane	0.753	1.305	1.427	1.546
58	29.69	Phenylethyl benzoate	N.D	N.D	0.307	0.531
59	30.00	8-Hexyl-pentadecane	1.883	3.262	N.D	N.D
60	30.02	Docosane	0.510	0.883	1.873	0.199
61	32.27	2,6,10,14-Tetramethylhexadecane	0.400	0.693	N.D	N.D

The concentrations of volatile compounds in the kimchi samples were expressed by peak area height divided by total peak area

Fig. 1 Microbial analysis results on radish-based Kimchi samples stored at 2 different temperatures (4 °C and 25 °C). **(A)** Total bacterial count (log CFU/ml). **(B)** Lactic acid bacteria count (log CFU/ml)

mL, while the level of LAB was 4.3 log CFU/mL. The degree of difference between Kimchi 1 and Kimchi 2 was minimal at day 0 for both total bacterial count and LAB count. This indicates that the differences in recipe (soaked in soy sauce vs. in saline water) did not impact the initial microbial count at day 0. Previously, the initial bacterial count of cabbage kimchi was reported as 5 log in total bacterial count and 2–3 log in LAB count (Cho et al., 2012; Kim et al., 2013). The initial microbial count including total bacteria and LAB is within the levels of commercially-available kimchi in Korea and Japan. When looking at the changes in microorganisms during storage, slight differences were observed according to storage temperature (4 vs. 25 °C) rather than kimchi type. For the total bacterial count, minimal changes were observed after 9 days of storage at 4 °C, while a 1 log increase was observed when stored at 25 °C within same sample. Similarly, a 1 log increase was observed for the growth of LAB, when the kimchi was stored at 4 °C. When stored at 25 °C, a 2 log increase was observed for the total bacteria count. A similar trend was observed for LAB growth: a 4 log increase was observed in both Kimchi 1 and Kimchi 2 after 9 days of storage at 25 °C. The changes of microbial count including LAB in kimchi products during storage period have been reported multiple times in the past. Hwang et al. (2000) reported 5 log increase of lactic acid bacteria after 6 days of fermentation of mustard leaf kimchi. When looking at the LAB count after 9 days storage, 5.5 log CFU/ml in 4 °C storage, and 8.6 log CFU/ml in kimchi stored at 25 °C. Based on LAB count in kimchi stored at 4 °C, it is expected that LAB fermentation has not been fully preceded as fully fermented kimchies typically have LAB count of 8–9 log CFU/ml (Cho et al., 2012; Jung et al., 2014).

Volatile flavor analysis result

The volatile flavor analysis results for the two radish kimchi samples using purge and trap sampling followed by GC–MS can be found in Table 3. A total of 61 volatile compounds were identified among the two samples. Nine out of the 61 volatiles were exclusively found in Kimchi 1: propanoic acid; 3-methylene heptane; 2-ethyl-1-hexene; benzaldehyde; 2-ethyl hexanol; benzeneacetaldehyde; octanoic acid ethyl ester; tetradecanoic acid ethyl ester; and 2, 6, 10, and 14-tetramethyl hexadecane. Eight of the 61 volatile aroma compounds were found solely in Kimchi 2, including methyl thiocyanate; 1-pentanol, 1, 2, and 4-trimethyl-cyclopentane; hexanal; tetrahydrothiophene; 4-methyl-5-propyl-nonane; and phenylethyl benzoate. These differences can possibly be attributed to the use the different liquids for salting (soy sauce vs. saline water). For example, benzeneacetaldehyde, has been identified as key

aroma compounds found in soy sauce (Steinhaus and Schieberle, 2007).

Among the identified volatile compounds in the radish-based kimchi, 8 volatile compounds, mostly sulfur-containing, matched what was reported in Korean cabbage kimchi. These compounds were methanethiol, ethanol, dimethyl disulfide, 3,3'-thiobis-1-propene, dimethyl trisulfide, benzaldehyde, dipropyl disulfide, and 5-(methylthio)-pentanenitrile (Kang et al., 2003). Despite being made from different vegetables (radishes versus cabbage), both kinds of kimchi presented with these 8 volatile compounds since they are byproducts of LAB fermentation. Methanethiol have characteristics aromatics associated with rotting cabbage and vegetables, is an intermediate compounds formed from enzymatic lyase (transaminase) from methionine. Many sulfuric compounds including dimethyl disulfide, and dimethyl trisulfide as well as other sulfur-containing esters were formed from methanethiol (Singh et al., 2003; Smit et al., 2005). During the course of LAB fermentation, the methionine presence in the vegetables including both radish and cabbage, may have been contributed to the formation of sulfur-containing volatile aromatic compounds. These sulfuric compounds were also reported in Potherb mustard (*Brassica juncea*, Coss.) fermentation (Zhao et al., 2007), suggesting that these were the by-products of LAB fermentation. A study analyzing aroma-active compounds in Kimchi during fermentation utilizing vacuum simultaneous steam distillation-solvent extraction/gas chromatography/mass spectrometry (V-SDE–GC–MS) reported the 9 sulfur containing compounds, and 6 garlic-like aroma related compounds. Their work reported that garlic-like aroma was the dominant flavor profile (Kim et al., 2016). This study also finds the sulfur-containing compounds as major volatile flavor compounds found in radish-based Kimchi, which is in agreement with previous work.

These results can be compared to the volatile flavor profiles found in previously conducted research that used SPME–GC–MS: 65 volatile flavor compounds were identified in two types of Korean kimchi (Xian et al., 2009) and 18 headspace volatile compounds were identified (Kang et al., 2003). These studies used the SPME–GC–MS, and current study used Purge & Trap. Therefore, the differences in identified volatile flavor profiles were as expected, including the quantities of the corresponding compounds (Song et al., 1997). Recently, headspace sampling using Solid Phase MicroExtraction (SPME) followed by GC–MS has been widely accepted for volatile flavor analysis of food (including kimchi) because of its efficiency in time and labor. The purge and trap sampling method was widely accepted and used prior to SPME; for example, it has been used for volatile analysis of fruits such as apples and tomatoes (Song et al., 1997). The disadvantage of the purge

and trap sampling method is that it is time-consuming and labor intensive, which has made many researchers in the industry switch to using SPME. Still, Purge and Trap sampling is being used because of its powder to capture the headspace volatiles dynamically (Song et al., 1997), therefore suitable for heterogeneous sample analysis such as fruits, and pizza (Sommezdag et al., 2017; Song et al., 1997). Kimchi is heterogeneous in nature, as it contains various vegetables and sauces; therefore use of Purge and Trap headspace sampling was adequate choice. Also, it is worth noting that the column choice was DB-624 column, which is widely accepted column choice especially in environmental toxicology in analysis of volatile pollutants, and residual substances in water samples. Volatile aromatic flavor analysis conducted in food products involved in GC–MS analysis, yet the column used for GC was slightly different from study to study. Previous studies used different column such as RTX-5 Column in green tea (Kim et al., 2016), HP INNOWAX column in cheeses (Izco and Torre, 2000), HP-5 column in Kimchi (Kang et al., 2003). The column choice in this study may also have influenced the volatile flavor profile of two radish-based Kimchi.

Up until now, volatile compound analysis of kimchi has mainly focused on cabbage kimchi, which is the most representative version of Korean-style kimchi. To our knowledge, this study is the first to fully profile the volatile aroma compounds found in radish-based kimchi. Thus, this study has significance for the kimchi industry.

Consumer acceptability

Consumer acceptance was conducted in order to know how well Chinese consumers accepted the two radish kimchi samples developed for this study. The consumer acceptance testing was done in mainland China in Shanghai. Therefore, the majority of participants were not familiar with radish-based kimchi nor Korean food. The test results for consumer acceptance can be found in Table 4. No significant differences were observed in any of the liking attributes between the two kimchi samples ($p > 0.05$). The overall liking scores for the two kimchi samples ranged from 6.1 to 6.2 on a 9-pt hedonic scale.

Regarding hardness texture liking, Kimchi 1 received 6.4 and Kimchi 2 received 6.3. The two radish kimchi recipes used in this study called for rehydrating dried radishes. Therefore, the texture of the radishes in these samples was not the same as the texture of freshly-cut radishes. Nevertheless, consumer responses to open-ended questions regarding texture included “hardness of radish is just about right (49.4%)”, “crunch and chewy texture is good (12.7%).” This indicates that the Chinese consumers accepted the texture of the radish kimchi.

Table 4 Consumer acceptance testing on Radish-based Kimchi targeted for Chinese consumers

N = 297	Radish Kimchi 1	Radish Kimchi 2
Appearance liking	6.46 ± 1.57 a	6.27 ± 1.60 a
Overall liking	6.21 ± 1.67 a	6.05 ± 1.71 a
Hardness texture liking	6.36 ± 1.62 a	6.31 ± 1.67 a
Spiciness liking	6.32 ± 1.65 a	6.15 ± 1.59 a
Sweetness liking	6.03 ± 1.67 a	5.90 ± 1.76 a
Harmony of ingredient liking	6.24 ± 1.69 a	6.19 ± 1.65 a

Data is reported as mean ± standard deviation of liking attributes measured on a 9-point hedonic scale, where 1 = dislike extremely, and 9 = like extremely

Means in a row that does not share the same alphabetical letter represent the significant differences ($p < 0.05$)

Regarding spiciness, Kimchi 1 and 2 received liking scores of 6.3 and 6.2, respectively ($p > 0.05$). Spiciness is a sensory attribute that varies highly from person to person. From quality characteristics analyses results in this study, the capsaicin levels of the kimchi ranged from 3.20 to 4.20 mg/kg. This level of spiciness was acceptable to the Chinese study participants. For harmony-of-ingredient liking, both kimchi samples received a score of around 6.2, indicating consumers accepted both samples. Thus, according to these consumer test results, which were based on the responses of 278 Chinese participants, both radish-based kimchi samples were well accepted. The difference in the salting method used between samples did not seem to influence consumer acceptance. However, it is also worth to note that all participants were recruited from the food expo, where majority of participants coming to expo, were already open to try new food products (less neophobic). Many studies reported that the food neophobia, consumer unwillingness to try new foods, influence the consumer acceptance of new food products (Backstrom et al., 2004). The elevated overall liking and other liking attributes may have been attributed from the composition of participants in this study. Therefore the high in liking scores obtained for both Kimchi may not directly proportional to actual purchase.

In this study, radish-based kimchi was developed for the Chinese consumer market. Analysis of the quality characteristics of the developed kimchi, including its chemical characteristics, its volatile flavor compound profile, and its consumer acceptability, was conducted. Slight differences were observed between the two samples, which were made using different salting methods. However, these differences did not influence consumer liking of one radish kimchi sample over the other. Both radish-based kimchi samples

were well-liked by Chinese consumers, suggesting the potential market opportunity toward Chinese consumers.

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