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Physicochemical Properties and Sensory Evaluation for the Heat Level (Hot Taste) of Korean Red Pepper Powder

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Abstract

This study investigated the heat level rating of several varieties of Korean red peppers. The chemical constitution of Korean red pepper samples were as follows: 0.54～290.15 mg% capsaicinoids, 79.22～139.09 ASTA value, and 16.76～29.92% free sugar content. The heat level of the Korean red pepper samples was evaluated by trained panelists and the correlation coefficient and F value (0.001%) of the panelist's results were determined to be significant. In the principle component analysis (PCA), PC1 (capsaicinoids) and PC2 (free sugar) were shown to represent 31.98% and 25.77% of the total variance, respectively. The results of panelists trained for red pepper heat rating were evaluated using analysis of variance and correlation analysis. The trained panelists showed a high F value (p=0.05) and high correlation coefficient. A high correlation efficient of 0.84～0.93 for the test samples with a 40 Scoville heat unit (32,000 SHU red pepper powder) was reported in the sensory evaluation of the Korean red pepper heat level by a trained panel. However, the panel showed a low correlation efficiency of 0.70 R^2 when the 60 SHU test samples were included in the analysis.

Key words: Korean red pepper powder, hot taste, panel performance

INTRODUCTION

Red pepper (*Capsicum annuum* L.) is widely used in processed foods, such as spices and sauces, and is also consumed as a fresh fruit. In addition, red pepper is a highly important agricultural product in Korea, with a market value of about one billion dollars a year. It is widely used as the main ingredient in traditional Korean foods such as *Kimchi* and *Gochujang*. Furthermore, about 60% of red pepper is consumed in powder form and its annual consumption is 2.0～2.5 kg red pepper powder per person in Korea. The major factors involved in the international quality control of red pepper powder include hot taste (heat, pungency), color, moisture content and sanitation. The quality properties of the Korean red pepper are its unique sweet taste, as well as its pungency (1,2).

The chemical compound capsaicin is the primary contributor to the heat of capsicums. For many years capsaicin (vanillylamide of 8-methylnontrans-6-enoic acid) was thought to be the only compound responsible for the pungency of peppers; however, four closely related pungent compounds have also been reported: nordihydrocapsaicin (vanillylamide of 7-methyloctanoic acid), dihydrocapsaicin (vanillylamide of 8-methylnonanoic acid), homocapsaicin (vanillylamide of 9-methyldec-trans 7-enoic acid) and homodihydrocapsaicin (vanillylamide of 9-methlyldecanoic acid) (3). These four compounds are structurally similar to capsaicin and also contribute to the heat of red pepper. This family of compounds, including capsaicin, is termed "capsaicinoids". In order to produce a consistent red pepper product, the heat (hot) level of capsicum is monitored using sensory or chemical/instrumental methods. The most commonly used sensory method for determining heat in capsicum products is the Scoville Heat Test (4), which has been a adopted, with modifications, by the American Spice Trade Association (ASTA) Analytical Method 21.0 and by International Organization for Standardization (ISO) (5,6).

Sensory panels are also a unique tool for measuring sensory attributes and intensities for food products, such as processed food and food materials. In addition, sensory panels have been used as an important tool for quality control of raw material, processing and final products. However, strict standards and procedures are needed when selecting and training a panel. Cross et al. (7) reported that a panel's ability can be evaluated using the F value and variance analysis of the sensory test results. In addition, Gacula and Singh, Malek, McDaniel et al. reported that a panel's ability to evaluate a food product could be assessed by correlation analysis of each panel (8-10). Recently, multivariate analysis has been used in the sensory evaluation field to reduce the amount

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of sensory data and classify theoretical and practical subjects. Also, when there are several attributes in a sensory test, principal component analysis can be used as statistical method for the training of a panel. In addition to these methods, cluster analysis and control charts have also been applied. The most common way to assess a panel's performance is analysis of variance, correlation analysis and principal component analysis. The heat level (hot taste) of the Korean red pepper is mainly due to the capsaicin and dihydrocapsaicin content. Korean red pepper varieties have a sweet with hot taste and contain a free sugar content of 15～30%, which includes glucose, fructose and sucrose. In contrast, foreign chili peppers commonly have a hot taste and not a sweet taste. Korean red pepper has been carefully evaluated for its hot taste by ASTM standards (11).

To investigate the heat level rating of Korea red pepper powder, this study analyzed a panel's taste test results, capsaicinoid content, free sugar levels and the ASTA value of various red pepper powders.

MATERIALS AND METHODS

Materials

Fresh red peppers were purchased from 74 cultivated samples in the major red pepper production region (Gochang, Koesan, Imsil, Andong, Youngyang province) in 2009. The samples were de-stemmed, cleaned, cut and dried. Seeds were then separated out of the sample followed by milling. To homogenize the particle size of periscarp, all samples were ground to powder using a roll mill, and the particle size of each sample was controlled to below 1.0 mm using a To-Tap sieve shaker (Cheonggesa CG-213, Seoul, Korea). Fructose, glucose, sucrose, capsaicin and dihydrocapsaicin were purchased from Sigma Aldrich Co. (St. Louis, MO, USA). Solvents used for analyses were of HPLC grade and purchased from Fisher Scientific Korea (Seoul, Korea).

Moisture content and ASTA color value

The moisture content and ASTA (American Spice Trade Association) color value were determined using the AOAC method (12) and ASTA-20.1 method (5), respectively. Red pepper powder (100 mg) was added to 100 mL acetone, and the mixture was stored at room temperature in the dark with intermittent stirring. An aliquot of the transparent extract was taken and the absorbance at 460 nm was measured using a UV/Vis spectrophotometer (V-550, Jasco, Tokyo, Japan). The ASTA color value was then calculated using the following equation.

$$\text{ASTA value} = \text{Absorbance of acetone extracts} \times 16.4 \times \text{If/Sample weight (g)}$$

If, Instrument correction factor = Declared absorbance of the Glass Reference Standard. A NIST SRM 2030 or 930, glass filter with an absorbance specified by NIST in the range of 0.4～0.6 at 460 nm, or equivalent.

Capsaicinoids content

Red pepper powder (2.5 g) and 20 mL of 100% ethanol were placed in a round-bottom glass flask and several glass beads were added to aid boiling. The samples were then refluxed gently for 5 hours and allowed to cool. Samples that had been filtered through a 0.2 μm filter (Millex-HN, Millipore, Bedford, MA, USA) were used for high performance liquid chromatography analysis. The filtered extracts were analyzed on an HPLC system (Jasco). Chromatographic analysis was performed on a XTerra ™RP18 (5 μm, 150×4.6 mm id., Waters, Milford, MA, USA) column with isocractic mobile phase. The mobile phase for analysis was water containing methanol at a methanol : water ratio of 70:30. The HPLC operating parameters were as follows: injection volume, 20 μL; column flow rate, 0.8 mL/min; chromatographic run time, 10 min; UV 280 nm (AOAC method).

Total sugar content

Red pepper powder (2 g) was mixed with 40 mL of 80% ethanol and blended with a vortex mixer for 2 min. The extract was then filtered through a 0.2 μm filter (Millex-HN, Millipore). Total sugar content corresponded to the sum of fructose, glucose and sucrose contents analyzed by HPLC. Chromatographic analysis was performed on a SUPELCOGEL AG2 (5 μm, 300×7.8 mm id., Supelco, Milford, MA, USA) column using an isocractic mobile phase. The mobile phase for analysis was 100% water. The HPLC operating parameters were as follows: injection volume, 20 μL; column flow rate, 0.5 mL/min; chromatographic run time, 30 min; model 2031 RI detector.

Sensory evaluation of red pepper

Samples preparation and panel training were conducted as described by ASTM (American society for testing and materials) E 1083-00. Red pepper powder was steeped in hot water with polysorbate-80 for 20 min, filtered, and the filtrate diluted in room temperature water. Reference standards were prepared according to ASTM (13) Standard Test Methods for sensory evaluation of Red Pepper Heat (E1088-00) guidelines, using 8-methyl N-vanillyl-n-nonomide (Sigma-Aldrich Chemical Co.) The tests were conducted using the highly trained panelists (eight women) and the process was timed by the panel leader. Panelists were served 10 mL portions of each sample in coded medicine cups. Each panelist evaluated three samples, including one standard solution sample (4 ppm), and a total of 15 red pepper samples were presented.

Statistical analysis

Chemical analysis of the red pepper samples were conducted in triplicate and the results are presented as the means±SD. Significant differences between samples means were determined using Duncan's multiple range tests (p<0.001). Duncan's multiple range tests were performed to separate the means of individual sensory scores between samples (SAS V. 8, 2000, SAS Institute, Cary, NC, USA). Principal component analysis (PCA) was conducted to summarize and verify the relationships between the mean values of the chemical properties of the red pepper samples. The PCA method used was covariance matrix extraction with varimax rotation. All of the statistical analyses were conducted using Xstat for Windows software.

RESULTS AND DISCUSSION

Chemical quality characteristics of red pepper

The moisture, free sugar, capsaicinoids content and ASTA were determined for a total of 15 red pepper samples (Table 1). The moisture content of 15 samples was analyzed and determined to range between 9.40 and 11.92%. The moisture content is a very important quality factor in red peppers, because it can affect the chemical components and can causesanitary problems. Thus, Korean Industrial Standard for the quality of red pepper powder (KS standard Number: H2157) requires the moisture content to be below 13% (14). The capsaicin and dihydrocapsaicin content in the red pepper samples was determined to range from 0.54 to 290.15 mg%. Todd et al. (15) demonstrated that the Scoville Heat Unit corresponded to five individual capsaicinoids. He reported that capsaicin, dihydrocapsaicin and nodihydrocapsaicin produce rapid pungent sensations, whereas homocapsaicin and homodihydrocapsaicin tend to produce longer, low intensity sensations in the mid mouth and midpalate regions. In addition, Suzuki and Iwai (16) reported that the components of a variety of red pepper's hot taste are as follows: 46～77% capsaicin, with an average of 70%, 21～40% dihydrocapsaicin, 2～12% norhidyrocapsaicin, 1～2% homocapsaicin, and 0.5% norhydrocapsaicin. These results demonstrated that capsaicin and dihydrocapsaicin had the biggest impact on the hot taste of red peppers.

The capsaicinoid content of samples 1 and 2 was 0.5 mg% and 1.84 mg% respectively, which was too low to produce a hot taste. The capsaicinoid content in samples 3, 4, and 5 was 14.36, 26.08, 36.82 mg%, respectively, and in samples 6～11, the content ranged from 45.57 to 102.30 mg%. Finally, the content in samples 12, 13, 14, and 15 was 125.83 mg%, 142.39 mg%, 193.12 mg%, 290.15 mg%, respectively. In the 47 varieties of Korean red pepper powder, the capsaicinoid content and ASTA color values generally ranged from 10.54～250.87 mg% and 64.55～124.07, respectively (17). The capsaicinoids contents of the 'Chungyang' varieties ranged from 250～400 mg%, and also displayed a strong pungency (18). Meanwhile, the proportion of capsaicin and dihydrocapsaicin ranged from 0.97～2.12, except for sample 6. This result was similar to the range reported by Choi et al. (1.00～2.14) (19), and Ku et al. (1.26～2.23) (20).

Table 1. Chemical composition of red pepper powder (unit: dry basis)

Sample	Moisture	Content (mg%)			CAP/ DHCAP	Sugar content (%)				ASTA
		Capsaicin	Dihydro-capsaicin	Capsaicinoids		Sucrose	Glucose	Fructose	Total	
1	11.41±0.37	0.54±0.01	0±0.00	0.54±0.01	–	2.22±0.14	9.43±0.35	12.87±0.52	22.07±0.19	79.22±0.81
2	9.44±0.13	1.84±0.04	0±0.00	1.84±0.09	–	1.67±0.06	7.98±0.17	12.25±0.25	18.07±0.10	124.53±2.19
3	11.06±0.09	7.52±0.24	6.84±0.16	14.36±0.60	1.10	1.7±0.10	8.36±0.19	11.51±0.30	22.24±0.10	115.62±0.85
4	11.79±0.35	13.02±0.24	13.06±0.36	26.08±0.60	1.00	1.45±0.05	7.35±0.09	11.85±0.25	20.66±0.11	139.09±1.30
5	9.40±0.41	19.11±0.29	17.7±0.51	36.82±0.77	1.08	2.38±0.12	7.76±0.36	11.27±0.46	24.52±0.17	120.15±0.95
6	11.38±0.02	35.88±0.10	9.70±0.13	45.57±0.02	3.70	2.97±0.16	9.37±0.26	12.71±0.26	25.05±0.06	118.67±1.20
7	10.28±0.23	31.39±0.86	22.91±0.63	54.3±1.49	1.37	1.74±0.05	7.34±0.14	11.56±0.21	21.41±0.08	99.08±1.23
8	11.83±0.20	41.75±0.80	26.21±0.39	67.97±0.19	1.59	2.24±0.18	5.60±0.43	8.91±0.63	16.76±0.22	93.01±1.98
9	9.87±0.17	51.52±1.27	26.27±0.54	77.79±1.64	1.96	2.12±0.17	5.81±0.40	9.15±0.54	17.08±0.19	109.79±1.69
10	11.92±0.38	59.76±2.53	29.66±1.41	89.42±2.94	2.01	1.78±0.08	7.50±0.28	10.88±0.26	20.17±0.11	97.49±1.36
11	11.57±0.93	69.69±1.38	32.61±0.95	102.3±2.20	2.14	1.83±0.07	11.2±0.27	16.89±0.64	29.92±0.29	117.37±1.76
12	10.76±0.02	76.42±1.46	49.41±0.02	125.83±1.43	1.55	2.65±0.17	9.34±0.37	14.03±0.51	26.02±0.17	98.13±1.32
13	10.98±0.15	91.46±0.11	50.93±0.22	142.39±0.11	1.80	2.48±0.09	7.68±0.12	11.95±0.20	22.1±0.10	82.68±1.86
14	9.74±0.32	124.3±2.81	68.82±1.60	193.12±4.41	1.81	2.33±0.22	8.92±0.13	13.51±0.39	24.77±0.13	92.64±0.86
15	11.23±0.12	185.01±0.61	105.15±0.63	290.15±1.19	1.76	1.97±0.09	7.16±0.12	10.89±0.28	20.02±0.10	97.69±1.38

Table 2. F ratios determined by analysis of variance and R^2 values determined by correlation analysis for the heat level reported by each panelist

Panelist number	Heat level intensity	
	F ratio	R^2
1	32.61***	0.901***
2	11.85***	0.836***
3	27.71***	0.823***
4	36.61***	0.945***
5	24.04***	0.882***
6	9.21***	0.945***
7	8.90***	0.879***
8	15.89***	0.843***

***Significant at p=0.001.

The total free sugar content of the red pepper samples ranged from 16.76 to 29.92%. In particular, the glucose, fructose and sucrose contents were 5.60～11.20%, 8.91～16.89% and 1.78～2.97%, respectively. The free sugar-related sweetness of red pepper is a very important quality factor that affects consumer acceptability (21). The results were consistent with previous studies, which reported that the Korean red pepper had a free sugar content of about 20% (22).

Evaluation of panel performance and Korean red pepper

The heat level of Korean red pepper samples was evaluated by trained panelists. The panelists' evaluations were analyzed and the results of this analysis showed significant correlation coefficients and F values (0.001 %) among all eight panelists (Table 2). The F value of the panel indicates that the panelists evaluated different samples differently and the same samples equally (23). It has been reported that panels displaying high performance ability have higher F-values and that panels with a high F value can be used in sensory evaluations (7). In general, if the F value and correlation coefficient are not significant, the panels should be retrained. Table 2 shows the F value and correlation coefficient of each panelist. All panelists showed a significant value at 0.001%. Panelist 1 and panelist 4 had a higher F value and correlation coefficient than the others. Fig. 1 shows the evaluation score of each panelist according to the heat level of the red peppers. Panelists 1 and 4, who had the highest F value and correlation coefficient, reported more similar scores for the same samples than other panels; however, panelists 2, 6 and 7 had the lowest F value and correlation coefficient, Fig. 2 shows the results of principle component analysis and cluster analysis for the physicochemical properties of the red pepper samples. In the PCA results, PC1 and PC2 were shown to explain 31.98% and 25.77% of the total variance, respectively. The red pepper samples were separated along the PC1 according to capsaicin and dihydrocapsaicin, which represents the pungency of the red pepper. The position of the red pepper samples on the PC2 was determined by 'glucose' and 'fructose'. In addition, samples No 1, No. 2, No. 3, No. 4 and No. 5 were loaded on the negative PC1 dimension and positively on the PC2. Samples No. 13, No. 14 and No. 15 were loaded positively on PC1 and negatively on PC2. The red pepper samples were divided into three groups in the cluster analysis. Group 1 contained No. 1～No. 6, group 2 contained No. 7～No. 11 and group 3 contained No. 12～No. 15. The results of ANOVA on the heat level of the red pepper samples using the 15 line scale method are given in Table 3. These values represent the heat score of the red pepper samples provided by the trained panel.

Table 3. Heat rating according to capsaicinoids content in the red pepper

Sample	Red pepper (capsaicinoids content)			Heat rating of red pepper
	Red pepper material		Test sample (SHU)	
	mg%	SHU[1)]		
1	0.54±0.01	<200±2	<1.00	1.50±1.30[a]
2	1.84±0.09	310±14	2.25	1.52±1.31[a]
3	14.36±0.60	2154±90	3.28	3.42±2.59[b]
4	26.08±0.60	3912±90	5.39	3.27±1.97[b]
5	36.82±0.77	5923±115	7.41	5.02±2.62[c]
6	45.57±0.02	6835±3	10.94	6.63±2.88[d]
7	54.30±1.49	8145±223	12.93	8.39±2.16[e]
8	67.97±0.19	10195±28	14.88	8.70±3.92[e]
9	77.79±1.64	11668±246	14.59	11.4±1.816[f]
10	89.42±2.94	13413±441	17.61	11.04±3.52[f]
11	102.3±2.20	15345±330	19.96	11.23±2.31[f]
12	125.83±1.43	18874±214	23.59	12.35±2.44[f]
13	142.39±0.11	21358±16	26.79	12.59±1.99[fg]
14	193.12±4.41	28968±661	37.35	13.92±1.35[fg]
15	290.15±1.19	43596±178	54.49	14.00±2.11[fg]

[1)]Scoville Heat Unit.
[a-g]Mean values not sharing a superscript letter are significantly different (p<0.05, Duncan's multiple range test).

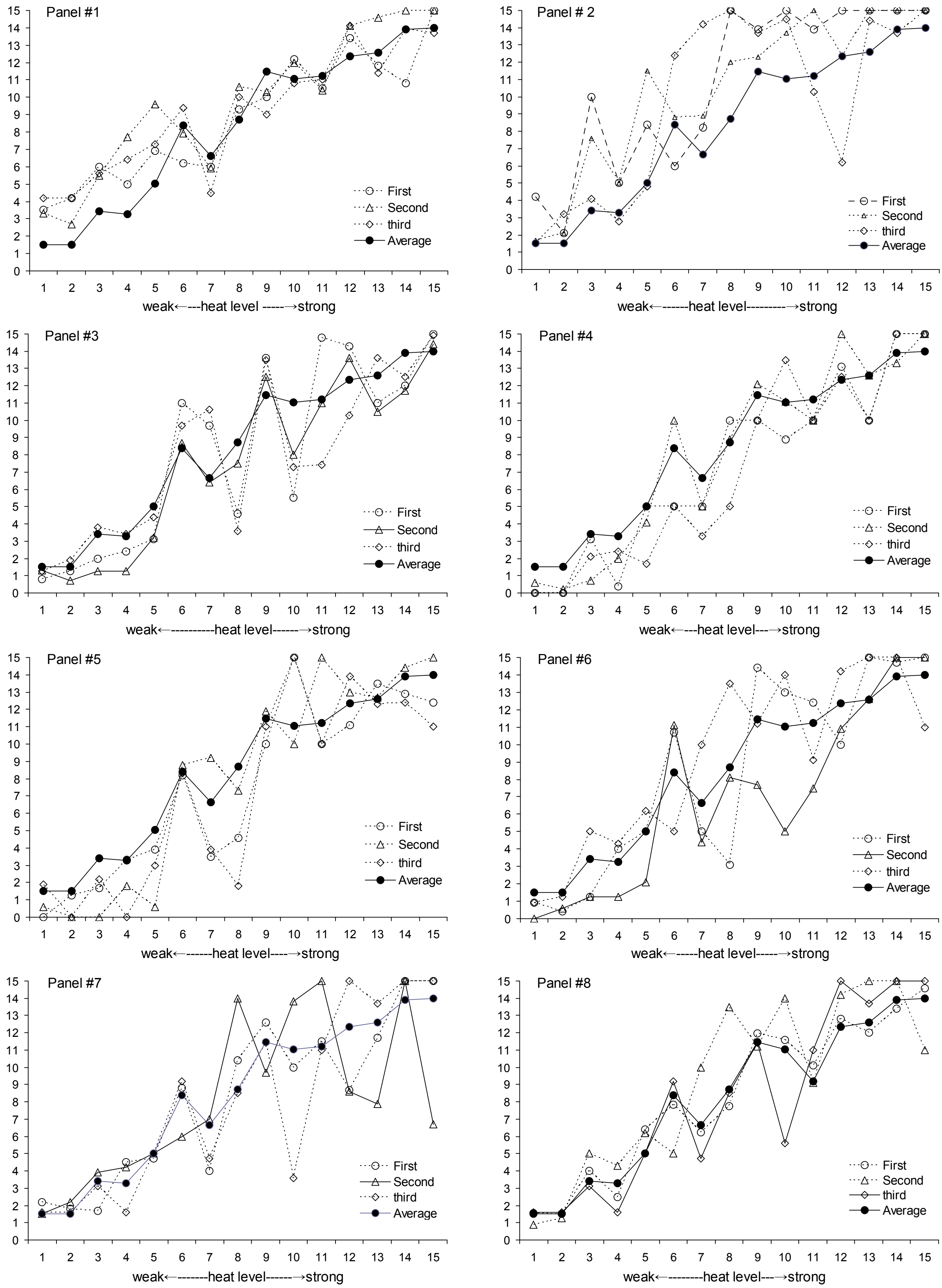

Fig. 1. Comparison of the scores of each panelist depending on the red pepper varieties.

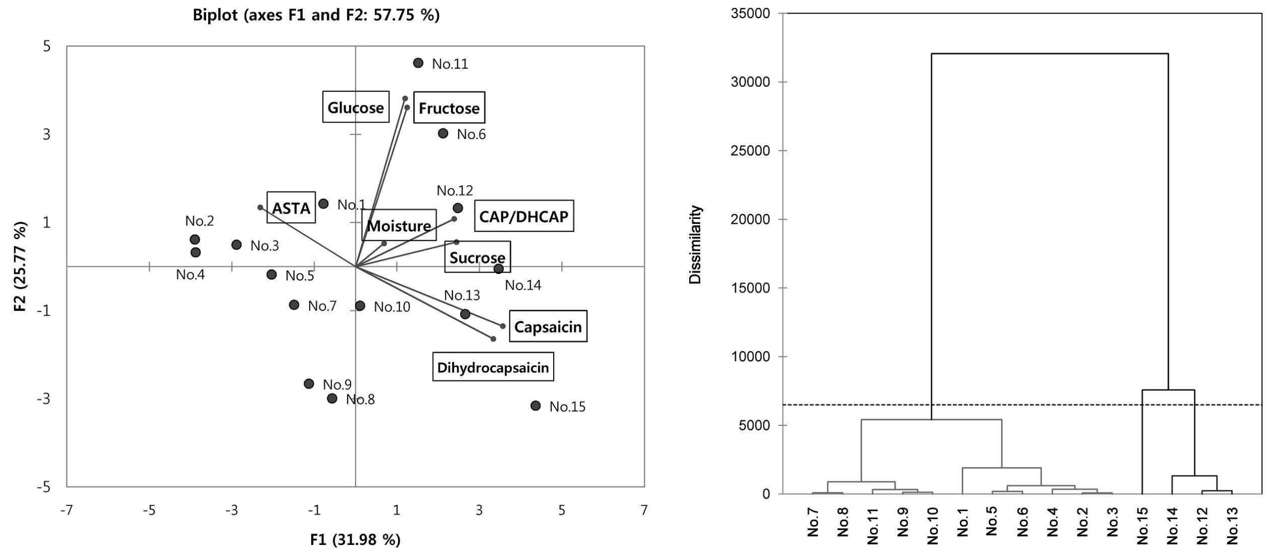

Fig. 2. Principal component analysis and cluster analysis of the chemical component of red peppers.

Sample No.1 and No. 2 had the lowest scores, which ranged from 1.5～1.52, and the samples that contained 14.36～45.58 mg% of capsacinoids had scores ranging from 3.42～6.63. Samples with scores between 7 and 8 contained over 80 mg% of capsaicinoids. Fig. 3 shows the correlation between the converted Scoville Heat Unit and heat level test for the red pepper samples. The determination coefficient between SHU and heat level test was 0.70 R^2 for red pepper samples with a SHU of 60. However, if sample No. 14 and No. 15 were excluded, the determination coefficient was 0.95 R^2. These results indicate that the trained panel could not choose between Korean red pepper samples that contained a capsaicinoid content greater than 150 mg%. Gillette et al. (24) reported that the determination coefficient for red pepper samples with an SHU of 60 and heat level was 0.77 R^2.

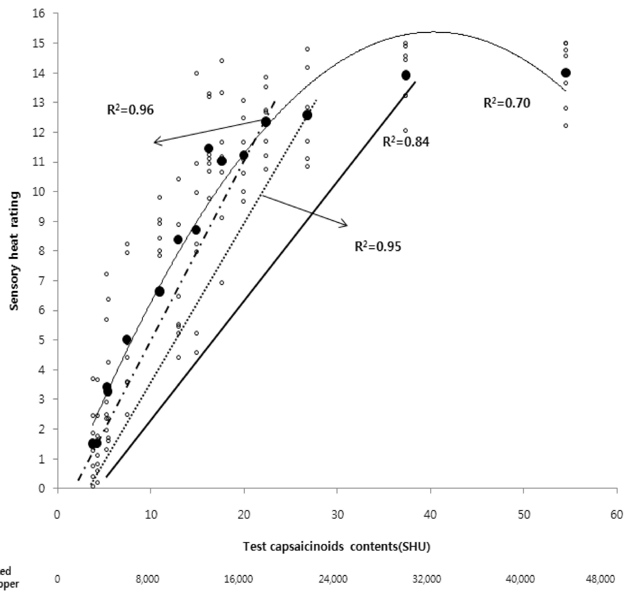

Fig. 3. Sensory heat rating versus calculated Scoville Heat Units for red peppers.

CONCLUSION

The heat level of the Korean red pepper samples was evaluated by trained panelists. The results of this analysis showed that all eight panelists reported significant correlation coefficients and F values (0.001%). In the principle component analysis (PCA), PC1 (capsaicinoids) and PC2 (free sugar) were shown to represent 31.98% and 25.77% of the total variance, respectively. The results of panelists trained for red pepper heat rating were evaluated using analysis of variance and correlation analysis. The results of the trained panelists showed a high F value (p=0.05) and correlation coefficient. A high correlation efficient of 0.84～0.93 for the test samples with a 40 Scoville heat unit (32,000 SHU red pepper powder) was reported in the sensory evaluation of the Korean red pepper heat level by a trained panel. The determination coefficient between SHU and heat level test was 0.70 R^2 for red pepper samples with 60 SHU. When our trained panelists compared the heat of with a known concentration capsaicinoids, they showed reproducible results in the capsaicinoids and sensory analysis, but establishing clear relationships between capsaicinoid content and sensory analyses requires a systematic approach in both instrumental analysis and sensory analysis of red pepper.

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