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Quality and Fermentation Characteristics of Kimchi Made with Different Types of Dried Red Pepper (*Capsicum annum* L.)

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Abstract

The fermentation and quality characteristics of *kimchi*, made by adding different types of red pepper (semi-dried red pepper, fresh red pepper, dried red pepper) according to drying conditions, were examined for 15 days at 10°C fermentation. The initial pH was approximately 5.65～5.72 in all groups, and the pH decreased with increasing fermentation time. The color value of a/b showed the highest in *kimchi* that made with semi-dried red pepper (SDRP-K). The color value of A remained at the initial level for 9 days, regardless of treatments. The color value had a tendency to decrease after 9 days. The lactic acid bacteria increased rapidly during 6 days of storage, but showed no difference among groups. The initial contents of malic acid and succinic acid were in 3.23～4.52 and 6.12～7.97 mg/mL and decreased during fermentation in all groups. The lactic acid and acetic acid were not contained in the beginning, but increased with increasing fermentation periods. The vitamin C content of SDRP-K was 5.20 mg/g, which was significantly higher compared with *kimchi* that made with dried red pepper (DRP-K), but which did not show any significant difference to *kimchi* that made with fresh red pepper (FRP-K). As a result of antioxidant activity in optimally ripened *kimchi*, both $DPPH^+$ and $ABTS^+$ scavenging activities were higher in SDRP-K than any other groups. As a result of the sensory evaluation, overall acceptability was highest in SDRP-K.

Key words: *kimchi*, semi-dried red pepper, capsaicinoids, storage, antioxidant activity

INTRODUCTION

Kimchi, a traditional Korean salted and fermented vegetable food, has an important role in the diet and nutrition of Koreans and has become popular throughout the world (1-3). *Kimchi* contains high levels of vitamins, minerals, dietary fibers, and other functional components. The phytochemicals in *kimchi* have shown antimicrobial, anticancer and anti-atherosclerotic functions. Also, dietary fiber, such as those found in *kimchi*, have been demonstrated to prevent hypertension, diabetes, constipation, and cancer (4). *Kimchi* is made into a fermented vegetable food by adding red pepper powder, green onion, garlic, ginger and fermented fish to the salted Chinese cabbage or radish. The sub-ingredients can be different, depending on the food production and geological characteristics in each district (5-7). *Kimchi* was originally a type of '*jjanji*' (Korean style pickle) without various biochemical reactions, but in the latter part of the Chosen Dynasty (since the 17^{th} century), it was developed into the *kimchi* of today by including red pepper. The red pepper had been added by 2.5～4.0% in weight, compared with the total weight, during the production of *kimchi*. The red pepper in *kimchi* provides harmonious taste, good color, and antimicrobial activity. The red pepper also acts as an antioxidant, is a good source of vitamin C, and has the function of accelerating the growing for lactic acid bacteria (8).

Red pepper (*Capsicum annuum* L.) belongs to the Solanaceae family (9) and is responsible for 30% of the vegetable production in Korea. About 3.5 kg per person are consumed annually, being used widely in *kimchi* and *kochujang* (10), and as a typical spice in sauces. The 2005 survey of the consumer's preference for red pepper revealed that the major factor for deciding the quality of red pepper was color. The attractive red color is due to various carotenoid pigments that include capsorubin, capsanthin, and cryptocapsin, while the yellow pigment includes β-carotene, β-cryptoxanthin, and zeaxanthin (11,12). The color of the red pepper is influenced mainly by the capsanthin, which occupies 34.7% of the total pigmentation, and the next were capsorubin, violaxanthin, and β-carotene. The red pepper also contains high levels of vitamin C, which is considered a preventative for cardiovascular disease and cancer by inhibiting peroxidation through binding singlet oxygen

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molecules and by metal chelating activity (13). The β-carotene from the carotenoids plays an important role for pro-vitamin A activity, antioxidant function and color pigmentation, as well as anti-cancer and anti-aging factors (14). The pigment of xanthophylls, such as capsanthin and capsorubin, has no pro-vitamin A activity, but has an inhibiting effect of active oxygen, and reduces concentrations of reactive oxygen species (15). The element of hot taste, capsaicinoids, acts as a substance for physiological activation and is linked to energy metabolism, antioxidant activity, immune control and anticancer activity (16,17).

The production of red peppers varies considerably because of environmental factors in Korea, such as drought or floods. The supply of red peppers is sufficient from August through harvest time in the beginning of October, but after the harvest in early November and until the following July, acquiring the high quantity of product needed is difficult and expensive. In addition, a fungus grows on the surface of the red peppers and their natural color darkens, because the red pepper crop is stored in bulk in a warehouse, which does not control temperature and humidity for very long after harvest. Quality control for the red pepper is necessary because it influences the quality of the final products, such as *kimchi* and *kochujang*. A previous study (18) reported the nutritional quality of semi-dried red pepper was better than that of dried red pepper and the color (redness/yellowness) was the highest in semi-dried red pepper. Dried red peppers are used for *kimchi* production, but the *kimchi* is made by mixing the dried red peppers and fresh red peppers. In a recent study by Hwang et al. (8), a good sensory result was obtained with the use of this mixed group of fresh and dried peppers. In addition, the *kimchi* made with semi-dried red peppers had a good color and the production cost was economical. A study on the production of *kimchi* to minimize nutrient losses was also performed (19). A study on the semi-dried red peppers was performed by measuring the quality change (20). However, a study on the production of *kimchi* using red peppers with a different type of drying, fermentation characteristics, and quality change is not sufficient. Accordingly, this study proposes to compare the physicochemical characteristics, antioxidant activity and sensory evaluation during fermentation of *kimchi,* using different drying patterns for red peppers.

MATERIALS AND METHODS

Materials

The red pepper (*Capsicum annum* L.) was the species of Wangdaebak in Jungsun. It was purchased as fresh, raw red pepper form Garak market in Seoul on October 2006. The Chinese cabbage, garlic, ginger and green onion used for the *kimchi* production were purchased at Garak market in Seoul. The salt was 80% sun-dried salt from the Korea Salt Cooperative.

Drying of red pepper

Ten kg of red pepper was cut lengthwise and washed in 100 ppm electrolyzed water (EW) to remove seeds and eliminate bacteria. The water was generated using an electrolyzed water system (DIPS-2K, Han Bio, Incheon, Korea) by the electrolysis of a dilute sodium chloride (NaCl) solution. Electrolyzed basic aqueous solution was prepared within the cathode compartment and electrolyzed acidic solution was prepared within the anode compartment. EW is an effective antimicrobial agent which is used in agriculture, dentistry, medicine and food industry. The red pepper quarters were placed on trays in an air-drier (HSED-M, Han-sung industrial Co. Ltd., Seoul, Korea) and were dried at a temperature of $65\pm1^{o}C$. The semi-dried and dried red pepper had a moisture content of 50% and 15% respectively.

Kimchi manufacture

The *kimchi* was manufactured by adding semi-dried red peppers, fresh red peppers and dried red peppers. The Chinese cabbage was cut into 3×3 cm squares and soaked in 15% salt solution for three hours and then rinsed in water three times. After draining, the final salt concentration was adjusted up to $3.0\pm0.1\%$. The recipe used for the *kimchi* was 3.1 g of green onion, 1.5 g of garlic and 0.5 g of ginger in proportion to 100 g of salted Chinese cabbage. The addition of semi-dried red peppers, fresh red peppers and dried red peppers in proportion to 100 g of salted Chinese cabbage was 5.0 g, 17.0 g and 2.8 g (Fig. 1). The prepared *kimchi* was put into PE (polyethylene) film and fermented for 15 days at $10^{o}C$.

pH and acidity

The pH was measured with a pH meter (AB 15, Fisher Scientific, Pittsburgh, PA, USA). The *kimchi* was blended in a commercial blender and filtered using cheese cloth. Then 10 mL of *kimchi* juice was titrated with 0.1 N NaOH to pH 8.2 for titratable acidity. The titratable acidity was calculated on the basis of lactic acid.

Color values

Color values were measured with color meter (CR-200, Minolta Co., Tokyo, Japan). Data was expressed by Hunter L (lightness), a (redness) and b (yellowness) and ΔE value was calculated with the following equation:

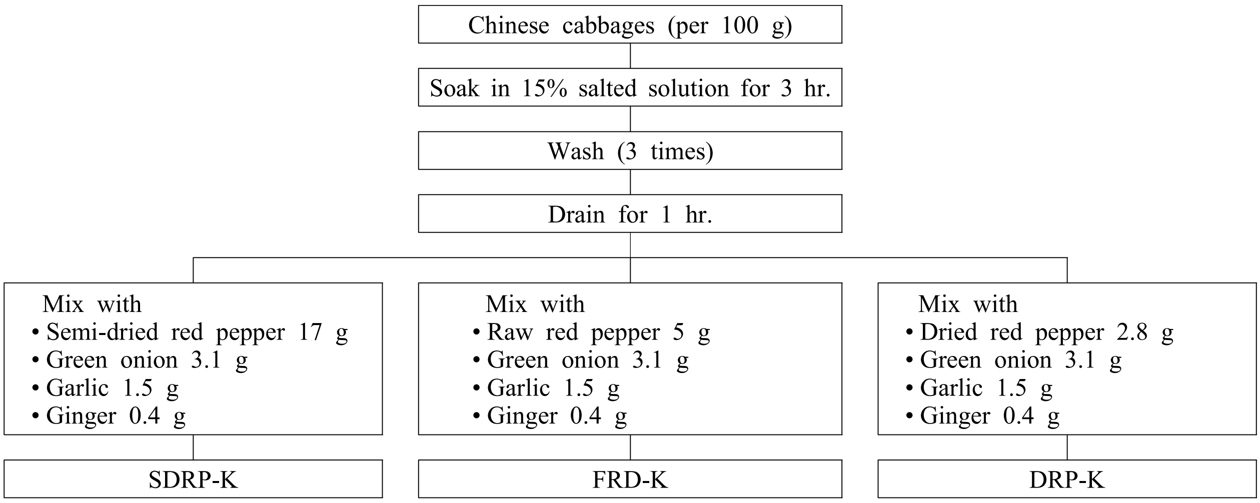

Fig. 1. Flow diagram for *kimchi* preparation.

$$\Delta E=(\Delta L^2+\Delta a^2+\Delta b^2)^{1/2}$$

Lactic acid bacteria

The prepared *kimchi* was diluted with 0.85% sterilized saline by a serial dilution method. Each 1 mL of the diluted solution was plated onto a plate of MRS agar (Merck Co., Darmstadt, Germany) with 0.02% sodium azide for lactic acid bacteria, according to the pour-plate method (21). The plates were incubated at 35°C for 48 hours. The colonies that formed on the plates were counted and expressed as colony-forming units per gram.

Capsaicinoids contents

Freeze-dried *kimchi* samples (2 g) were placed in a 50 mL flask, to which was added 20 mL of acetonitrile; then the flask was mixed by a vortex mixer (VXR B, JANKO & KUNKEL, Riode Janeiro, Brasil) for 2 min. The extract (1 mL) was diluted with 9 mL of water and injected into the Sep-pak, which was conditioned with approximately 5 mL of acetonitrile followed by 5 mL of distilled water. The capsaicinoids were eluted with 4 mL acetonitrile, followed by 1 mL of acetonitrile containing 1% acetic acid. The capsaicinoid content was determined by HPLC (PU 980, Jasco, Tokyo, Japan), using an Eclipse XDB-C18 (Agilent, Santa Clara, CA, USA, 4.6×250 mm, 5 μm) column, coupled with a UV detector set at 280 nm. The mobile phase was methanol : water (70:30), with a flow rate of 0.8 mL/min and the injection volume of 20 μL.

Vitamin C contents

According to a method of the Korea Food Code (22), red pepper powders (0.2 g) were stirred into 20 mL of 5% metaphosphoric acid (HPO_3) solution, using a blender (KA-2600, Kaiser, Seoul, Korea) for 1 min. The mixture was centrifuged at 8,000×*g* for 10 min and the upper solution was filtered using a 0.45 μm filter. The analysis condition was determined by HPLC (PU 980, Jasco), using a μ-Bondapak C_{18} (125A, 3.9×300 mm, 10 μm). The mobile phase was water (1 L), to which was added methanol (10 mL), acetic acid (10 mL) and 1-hexane sulfate sodium (1 g). The flow rate was 0.8 mL/min and the injection volume was 20 μL.

Organic acid contents

Freeze-dried *kimchi* samples (2 g) were placed in a 50 mL flask to which was added 40 mL of water. Then the flask was mixed in a vortex mixer (VXR B, Janko & Kunkel, Morgan Hill, CA, USA) for 2 min. The mixture was centrifuged at 8,000×*g* for 10 min and supernatant was filtered, using a 0.45 μm filter. The organic acid contents were determined by HPLC (PU 980, Jasco), using an Eclipse Ameinex HPX-87H column, coupled with a UV detector set at 210 nm. The mobile phase was methanol : water (70:30), with a flow rate of 0.6 mL/min and injection volume of 20 μL. A standard solution of malic acid, succinic acid, lactic acid and acetic acid (Sigma Chemical Co., St. Louis, MO, USA) was used for this phase.

Scavenging activity on DPPH radicals and ABTS radicals

The scavenging activity on DPPH radicals was determined using the method of Blois (23). The freeze-dried *kimchi* samples (1 mg) were extracted with 1 L of ethanol. The 4 mL of extracted solution was mixed with 1 mL of DPPH solution (1.5×10^{-4} M) and left to stand for 30 min in the dark. The absorbance was measured at 517 nm against a blank.

Scavenging activity on ABTS was measured via the method of Re et al. (24) and Siddhuraju and Beckor (25). ABTS was dissolved in water to 7 mM, and the ABTS radical cation was produced by reacting the ABTS stock solution with 2.45 mM of potassium persulfate (final concentration) and allowing the mixture to stand in the dark at room temperature for 12～16 hours before use. Then the mixture was diluted with ethanol and its absorbance was adjusted to 0.70±0.02 at 734 nm. To determine the scavenging activity, 0.9 mL of ABTS reagent was mixed with 0.1 mL of extract and the absorbance was measured at 734 nm after 6 minutes of reaction at room temperature, using ethanol as a control. The antioxidant activities of *kimchi* were compared with a Trolox equivalent content in 1.0 g extracts.

Sensory evaluation

The samples were evaluated using a 9-point scale for redness, color, off-flavor, texture, pungency, taste, ripeness and overall acceptability. The redness, off-flavor, pungency, and ripeness were evaluated as follows: very low (1 point), medium (5 points), and very strong (9 points). The color, flavor, texture, taste, and all acceptability were evaluated as follows: very poor (1 point), moderate (5 points), and very good (9 points). The results of the sensory evaluations of 10 panelists were expressed as mean±standard deviation (SD). The values were determined using Duncan's multiple range test of Statistical Analysis System's Procedures (SAS) with a 5% level of significance.

RESULTS AND DISCUSSION

pH and acidity

The pH and the titratable acidity of *kimchi* during fermentation are shown in Fig. 2 and 3. They were at similar levels of 5.65～5.72 in every group in the beginning, but the longer the fermentation time, the lower the pH

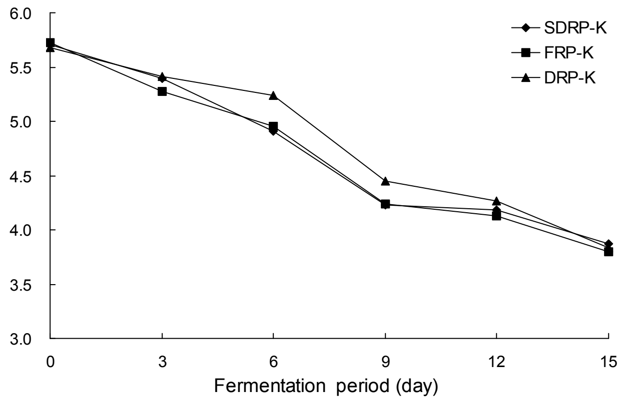

Fig. 2. Changes in pH of *kimchi* prepared with various dry-types of red pepper during fermentation at 10°C. SDRP-K, *Kimchi* made with semi-dried red pepper that dried by 50% moisture content; FRP-K, *Kimchi* made with fresh red pepper; DRP-K, *Kimchi* made with dried red pepper that dried by 15 % moisture content.

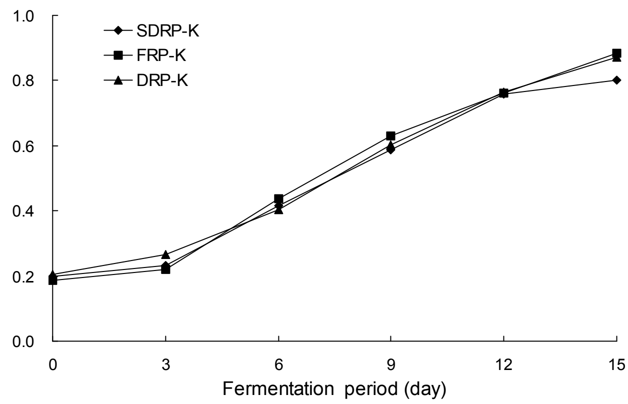

Fig. 3. Changes in acidity of *kimchi* prepared with various dry-types of red pepper during fermentation at 10°C. SDRP-K, *kimchi* made with semi-dried red pepper that dried by 50% moisture content; FRP-K, *kimchi* made with fresh red pepper; DRP-K, *kimchi* made with dried red pepper that dried by 15% moisture content.

became. After 9 days of fermentation, the pH declined sharply and reached the optimum ripening stage of 4.23～4.45, increasing only slightly thereafter. The initial acidity was only 0.2%, but it reached 0.6% after 9 days of fermentation. Acidity and pH are usually chosen as the major quality attributes and fermentation index of *kimchi* because of its characteristic sour taste (26). It was reported pH and acidity of optimum ripening period of *kimchi* were 4.2 and 0.6～0.8% respectively (27,28), which showed a similar tendency at 9 days in this study. Lee and Yang (29) reported the edible acidity range of *kimchi* was 0.40～0.75% and Ku et al. (30) reported that *kimchi* below pH 4.0 was increased in undesirable odor. When the pH of *kimchi* drops below 4.0, homofermentative *Lactobacillus plantarum* strains, which generally proliferate in late stage of *kimchi* fermentation, play an important role in its over-fermentation (27). In this study, the pH decreased below 4.0 at 15 days of fermentation. The increase in acidity was due to the organic acid increase during fermentation (8). The reason that the pH was not lower than three during the fermentation period was due to the smaller degree of dissociation, as the acid in the *kimchi* is a sub-acid.

Color value

The change in color during the fermentation of *kimchi* made by adding different types of red peppers, is shown in Table 1. The values of L (lightness), a (redness), and b (yellowness) in the beginning were 36.01～36.35, 8.97～9.43 and 8.35～9.10. SDRP-K was higher than any other treated group. The a/b value was also the highest in SDRP-K and it was the lowest in FRP-K. The observation on the change during the fermentation period did not show a significant difference in the value of L (lightness). The value of a (redness) was similar or had

Table 1. Changes in color value of *kimchi* prepared with various dry-types of red pepper during fermentation at 10°C

Treatments[1)]	Fermentation period[2)]														
	Initial					Optimally ripening					Over ripening				
	L	a	b	ΔE	a/b	L	a	b	ΔE	a/b	L	a	b	ΔE	a/b
SDRP-K	36.01±0.20[3)]	9.70±0.12^{a}[4)]^{A}[5)]	8.57±0.27^{abB}	0.92±0.55	1.04±0.07	35.75±0.36	9.75±0.18^{aA}	8.71±0.12^{B}	0.84±0.39	0.97±0.01	35.06±2.41	8.57±0.38^{bB}	9.61±0.39^{aA}	1.38±0.48	0.95±0.03
FRP-K	36.07±0.15^{B}	9.02±0.23^{aA}	8.35±0.15^{bC}	0.27±0.12	1.08±0.04	36.14±0.22^{B}	8.41±0.10^{bB}	8.89±0.07^{B}	0.91±0.26	0.95±0.03	36.80±0.90^{A}	8.35±0.40^{bC}	9.63±0.39^{aA}	2.09±0.63	0.81±0.05
DRP-K	36.34±0.71	8.97±0.25^{b}	8.64±0.74^{aB}	1.00±0.36	1.04±0.06	36.16±0.52	8.72±0.29^{b}	8.95±0.31^{AB}	1.22±0.42	0.98±0.11	36.85±0.75	8.63±0.25^{a}	9.28±0.26^{bA}	1.91±0.81	0.87±0.05

[1)]SDRP-K, *kimchi* made with semi-dried red pepper that dried by 50% moisture content; FRP-K, *kimchi* made with fresh red pepper; DRP-K, *kimchi* made with dried red pepper that dried by 15% moisture content.
[2)]Initial: first day of fermentation, optimally ripening: 9 days of fermentation, over ripening: 15 days of fermentation.
[3)]Average±standard deviation of triplicate determinations.
[4)]Means with different letters (a-d) in a column are significantly different at $p<0.05$ by Duncan's multiple range test.
[5)]Means with different letters (A-C) in each L, a and b value at the same row are significantly different at $p<0.05$ by Duncan's multiple range test.

an increasing tendency up to the nine days of fermentation; however, it decreased after 12 days of fermentation and the value of b increased after 9 days of fermentation. The a/b value is commonly used as an index to report the color quality (brightness of red color) (31). The previous study had reported that the a/b value of semi-dried red pepper which contained with 50% moisture contents was the highest value (18) and also the a/b value was highest in SDRP-K ($p<0.05$).

Lactic acid bacteria

The change of lactic acid bacteria during the fermentation of *kimchi* made by adding the different types of red peppers, is shown in Fig. 4. Bang et al. (19) reported that the total bacteria of *kimchi* made by the addition of dried red pepper was higher than that of the *kimchi* made with fresh red pepper because of unhygienic drying and storing environments. The microorganisms grow on the dried red pepper in a polluted processing environment and the quality of the dried red pepper influences the quality of the *kimchi*. In this study, the initial lactic acid bacteria were 5.01～5.44 log CFU/g and showed no difference among treated groups because the red peppers of all treatments were washed using EW before drying. The bacteria levels increased rapidly between the third and sixth days and reached a 7.50 log CFU/g level. Park et al. (32) reported that the maximum number of lactic acid bacteria in *kimchi* was 7.8～8.5 log CFU/g and Bang et al. (19) reported it to be 8.0～8.2 log CFU/g. The bacteria isolated from *kimchi* included *Lactobacillus plantarum*, *Lactobacillus brevis*, *Enterococcus* (*Streptococcus*) *faecalis*, *Leuconostoc mensenteroides*, *Pediococcus cerevisias*, *Achromobacter*, *Flavobacterium*, and *Pseudomonas* (33). The bacteria acting on the *kimchi* fermentation in the beginning were *Leuconostoc mesenteroids*, with a rapid reduction after the middle of the fermentation period. The *Lactobacillus plantarum*, which can be grown under pH 4.0, acts on the acidification at the end of the fermentation (34). The study on the influence of the sub-substance of *kimchi* on the growth of lactic acid bacteria reported that the sub-substance, garlic, was the most effective ingredient in the inhibition of *Lactobacillus plantarum* growth (34). In this study, significant differences among treated groups were not observed in lactic acid bacteria during fermentation.

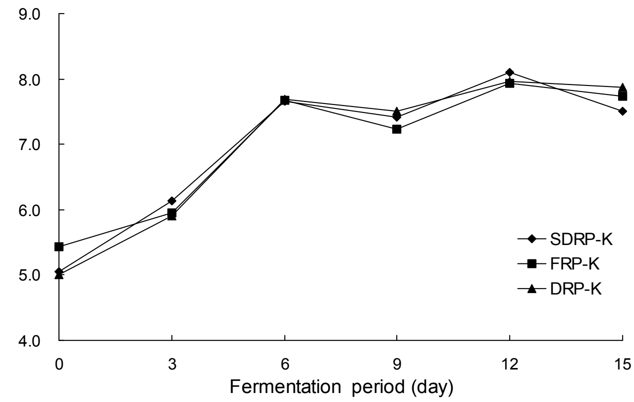

Fig. 4. Changes in lactic acid bacteria cell count of *kimchi* prepared with various dry-types of red pepper during fermentation at 10°C. SDRP-K, *Kimchi* made with semi-dried red pepper that dried by 50% moisture content; FRP-K, *Kimchi* made with fresh red pepper; DRP-K, *Kimchi* made with dried red pepper that dried by 15% moisture content.

Organic acid

The change in organic acid during fermentation of *kimchi* made by adding different types of red peppers, is shown in Table 2. The contents of malic, succinic, lactic and acetic acid were measured as the organic acids of *kimchi*. The malic acid and succinic acid were at 3.23～4.52 and 6.12～7.97 mg/mL in the beginning and decreased as the fermentation progressed. The study of

Table 2. Changes in organic acid of *kimchi* prepared with various dry-types of red pepper during fermentation at 10°C

Treatments$^{1)}$		Fermentation period$^{2)}$		
		Initial	Optimally ripening	Over ripening
SDRP-K	Malic acid (mg/100 g)	3.62±0.16$^{3)a4)B5)}$	1.07±0.08^{bC}	0.75±0.04^{c}
FRP-K		3.23±0.13^{aC}	1.25±0.06^{bB}	0.41±0.01^{c}
DRP-K		4.04±0.28^{aA}	1.55±0.09^{bA}	0.50±0.43^{c}
SDRP-K	Succinic acid (mg/100 g)	6.50±0.24^{aB}	6.07±0.34^{aA}	2.77±0.03^{bAB}
FRP-K		7.97±0.83^{aA}	5.44±0.31^{bB}	2.86±0.25^{cA}
DRP-K		6.12±0.44^{aB}	5.98±0.20^{aA}	2.47±0.22^{bB}
SDRP-K	Lactic acid (mg/100 g)	0.00±0.00^{c}	6.85±0.52^{b}	11.49±0.48^{aA}
FRP-K		0.00±0.00^{c}	6.48±0.29^{b}	9.25±0.17^{aC}
DRP-K		0.00±0.00^{c}	6.49±0.19^{b}	10.14±0.58^{aB}
SDRP-K	Acetic acid (mg/100 g)	0.00±0.00^{c}	1.31±0.22^{b}	2.94±0.04^{a}
FRP-K		0.00±0.00^{c}	1.42±0.01^{b}	3.24±0.02^{a}
DRP-K		0.00±0.00^{c}	1.28±0.02^{b}	2.69±0.55^{a}

$^{1),2)}$Refer to Table 1. $^{3)}$Average±standard deviation of triplicate determinations.
$^{4)}$Means with different letters (a-c) in a row are significantly different at $p<0.05$ by Duncan's multiple range test.
$^{5)}$Means with different letters (A-D) in a column are significantly different at $p<0.05$ by Duncan's multiple range test.

Hawer et al. (35) reported that the content of malic acid was reduced as the fermentation period continued, but the content of succinic acid was maintained at the same level from the beginning. The study of Park et al. (36) showed the reduction in the content of malic acid of *kimchi* in the optimally ripening stage compared to the beginning, and reported that the change in levels of succinic acid differed by the kind of salted fish and temperature. Lactic acid and acetic acid were not observed at the beginning of the process, but they increased during fermentation. The lactic acid at the optimally ripening stage increased rapidly to 6.48～6.85 mg/mL, but significant differences among the treated groups were not found. Acetic acid contents of over ripening *kimchi* (2.94～3.24 mg/100 g) contained 2～3 times that of optimally ripening *kimchi* (1.28～1.42 mg/100 g) due to conversion of malic acid into lactic acid and acetic acid by lactic acid bacteria (37). The kind and quantity of organic acid during *kimchi* fermentation differed by the kind of mixed material for *kimchi*, temperature, fermentation time and salt concentration. The typical organic acid for fermentation was lactic acid, but the flavor of *kimchi* was influenced by the complicated creation of many organic acids (38). The increase of lactic acid during the fermentation period was considered to be the most influential factor for the sour taste of *kimchi*, because it has the same degree of sourness in lactic acid 8.5×10^{-4}, malic 7.5×10^{-4}, tartaric 7.0×10^{-4}, acetic 2.1×10^{-3}, and citric 7.0×10^{-4} on basis of its molar concentration (39).

Vitamin C and capsaicinoids

The change of vitamin C and the contents of capsaicinoids during the fermentation process of *kimchi*, made by adding different types of red peppers, are shown in Table 3. The content of vitamin C was 5.20～6.08

Table 3. Changes in vitamin C, ASTA value and capsaicinoids content of *kimchi* prepared with various dry-types of red pepper during fermentation at 10°C

Treatments$^{1)}$		Fermentation Period$^{2)}$		
		Initial	Optimally ripening	Over ripening
SDRP-K	Vitamin C (mg/g)	5.87±0.02$^{3)a4)}$	5.36±0.23^{ab}	4.78±0.35$^{bA5)}$
FRP-K		6.08±0.33^{a}	5.16±0.62^{ab}	4.73±0.11^{bA}
DRP-K		5.20±0.83^{a}	4.88±0.10^{a}	3.27±0.11^{bB}
SDRP-K	Capsaicin (mg/100 g)	9.94±0.09^{aA}	8.76±0.68^{b}	8.48±0.19^{bA}
FRP-K		10.21±1.04^{aA}	8.73±0.24^{b}	8.05±0.6^{bAB}
DRP-K		7.90±0.28^{bB}	8.55±0.19^{a}	7.47±0.16^{bB}
SDRP-K	Dihydrocapsaicin (mg/100 g)	3.66±0.05^{B}	4.16±0.01^{A}	3.61±0.76
FRP-K		4.62±0.22^{aA}	3.84±0.10^{bB}	3.79±0.48^{b}
DRP-K		4.76±0.40^{aA}	3.93±0.27^{bB}	3.77±0.42^{b}

$^{1),2)}$Refer to Table 1. $^{3)}$Average±standard deviation of triplicate determinations.
$^{4)}$Means with different letters (a,b) in a row are significantly different at $p<0.05$ by Duncan's multiple range test.
$^{5)}$Means with different letters (A,B) in a column are significantly different at $p<0.05$ by Duncan's multiple range test.

mg/g immediately after production, which was the highest in *kimchi* B group, but decreased during the fermentation period. The contents of vitamin C in the over-ripening stage was 3.27～4.78 mg/g and decreased significantly compared with the initial and optimally ripening stage. Vitamin C of DRP-K decreased to 37% in the over-ripening stage and was lower in content than the other groups. Hwang et al. (8) reported that vitamin C decreased as the fermentation period increased. Cho et al. (40) reported the same results of this study. The

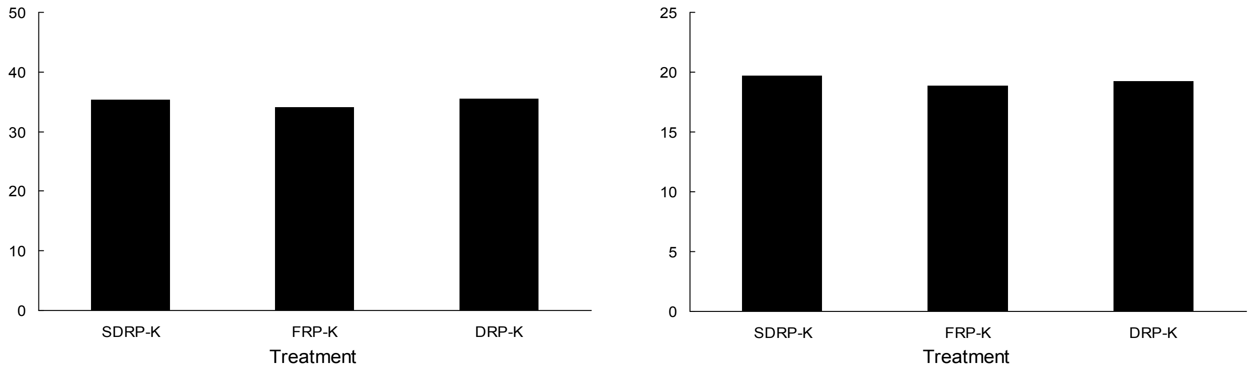

Fig. 5. Changes in DPPH^{+} and ABTS^{+} scavenging activity of the ripened *kimchi* prepared with various dry-types of red pepper during fermentation at 10°C. SDRP-K, *kimchi* made with semi-dried red pepper that dried by 50% moisture content; FRP-K, *kimchi* made with fresh red pepper; DRP-K, *kimchi* made with dried red pepper that dried by 15% moisture content.

Table 4. Changes in sensory characteristics of *kimchi* prepared with various dry-types of red pepper during fermentation at 10°C

Treatments[1)]		Fermentation period[2)]		
		Initial	Optimally ripening	Over ripening
SDRP-K	Redness	5.7±0.9$^{3)ab4)}$	6.1±1.6^{a}	5.1±1.6^{ab}
FRP-K		6.2±1.2$^{aA5)}$	4.7±2.0^{bB}	3.8±1.3^{bB}
DRP-K		5.3±1.6^{b}	5.2±0.9^{ab}	5.4±1.3^{a}
SDRP-K	Color	6.2±1.0^{abAB}	6.6±1.3^{aA}	5.3±1.4^{bB}
FRP-K		6.9±1.3^{aA}	5.0±1.3^{bB}	4.4±2.0^{cB}
DRP-K		5.3±1.4^{b}	5.3±1.1^{b}	6.3±1.3^{a}
SDRP-K	Off-flavor	1.7±0.8^{B}	3.1±1.9^{AB}	3.8±1.9^{A}
FRP-K		1.3±0.7^{B}	3.9±2.6^{A}	3.5±2.2^{A}
DRP-K		1.7±1.1^{B}	3.4±2.0^{A}	4.1±1.9^{A}
SDRP-K	Flavor	6.0±1.8^{AB}	6.5±1.4^{aA}	4.7±1.8^{aB}
FRP-K		6.7±1.8^{A}	5.2±1.7^{bB}	5.1±1.3^{aB}
DRP-K		5.7±1.3	4.9±2.0^{b}	4.6±1.5^{b}
SDRP-K	Texture	6.7±0.9^{aA}	6.8±1.5^{A}	5.0±1.8^{B}
FRP-K		7.2±1.3^{aA}	6.0±1.8^{AB}	5.2±1.6^{B}
DRP-K		5.7±0.8^{b}	5.9±1.4	5.6±1.3
SDRP-K	Pungency	6.7±0.9^{A}	5.7±0.8^{A}	4.0±1.8^{B}
FRP-K		6.9±0.9^{A}	5.7±1.3^{B}	4.0±1.4^{C}
DRP-K		6.8±0.6^{A}	5.2±0.9^{B}	4.3±1.6^{B}
SDRP-K	Taste	6.0±0.8^{aA}	6.2±1.2^{aA}	4.5±1.5^{B}
FRP-K		6.0±1.6^{a}	5.0±1.5^{b}	5.0±1.9
DRP-K		5.4±1.0^{b}	4.6±1.8^{c}	5.5±2.1
SDRP-K	Ripeness	1.7±1.2^{B}	5.1±0.9^{A}	5.7±1.4^{A}
FRP-K		1.5±0.8^{B}	4.6±0.7^{A}	5.6±1.6^{A}
DRP-K		1.4±0.8^{B}	5.3±0.5^{A}	6.3±1.9^{A}
SDRP-K	Overall quality	6.9±1.7^{aA}	6.7±0.8^{aA}	4.7±2.5^{B}
FRP-K		6.4±1.8^{aA}	5.1±1.0^{bA}	3.7±1.5^{B}
DRP-K		5.8±0.9^{b}	4.8±1.2^{b}	4.4±2.0

[1),2)]Refer to Table 1. [3)]Average±standard deviation of triplicate determinations.
[4)]Means with different letters (a-c) in a column are significantly different at $p<0.05$ by Duncan's multiple range test.
[5)]Means with different letters (A-C) in a row are significantly different at $p<0.05$ by Duncan's multiple range test.

initial contents of capsaicin were 7.90～10.21 mg/100 g. DRP-K showed the lowest contents and also decreased during the keeping period. The capsaicin contents of SDRP-K at the excessive maturity time were at the 8.05 mg/100 g level and it showed the biggest reduction by 21% compared with the beginning. The contents of dihydrocapsaicin were similar to capsaicin. The contents ratio of capsaicin and dihydrocapsaicin was 1.80～2.27 mg/100 g.

DPPH and ABTS radical scavenging activity

The results of the DPPH and ABTS radical scavenging activity in the *kimchi*, made by adding different types of red peppers, is shown in Fig. 5. The anti-oxidation activity in *kimchi* in its optimum ripening stage was measured on the basis that the antioxidant activity of Chinese cabbage *kimchi* was the highest in its optimally ripening stage. Sim and Han (41) reported that the DPPH radical ranged from 23～43% in the non-fermented *kimchi* and 34～47% in the fermented *kimchi*. The scavenging activity of $DPPH^+$ was 34.12～37.38% and the SDRP-K showed a bit higher value than the other group. In addition, the scavenging activity of $ABTS^+$ was 19.70 mM TE/g in the SDRP-K, which was higher than 18.87 mM TE/g in the DRP-K, but there wasn't significant different among treatments ($p<0.05$). A high antioxidative effect in Chinese cabbage and sub-ingredients such as garlic and ginger is thought to exist (42).

Sensory evaluation

The sensory results during fermentation of *kimchi* made by adding the different types of red peppers are shown in Table 4. The sensory evaluation showed the redness of SDRP-K and FRP-K was higher than DRP-K. SDRP-K was evaluated as having significantly higher sensory results than the FRP-K in the optimally ripening stage ($p<0.05$). It is thought that the fresh red peppers contained more moisture than the semi-dried red peppers. For the color results, SDRP-K had a high evaluation, and it was shown that the affinity of color was lower after the optimum ripening period of FRP-K. The affinity of color had a high relation with the a/b of color value, because it was the highest in SDRP-K. The off-flavor increased as the fermentation period increased and the flavor decreased. The high score was found in the FRP-K in the beginning and SDRP-K in the optimal ripening stage. The pungency had a high relation with the contents of capsaicinoids, because it was the highest in the beginning and decreased significantly after the over-ripening stage. SDRP-K showed a high score in the initial and optimally-ripening stage and was significantly different than the DRP-K ($p<0.05$). The overall quality of SDRP-K and FRP-K was higher than DRP-K in the beginning. The group of SDRP-K had a higher evaluation than other groups after the optimally ripening stage.

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