Changes in the quality of kimchi with added prickly pear cactus (*Opuntia ficus-indica* var. saboten) extracts during fermentation

HEE SOOK SOHN – YOUNG SOOK LEE – JEONG OK RHO

Summary

The effects of the addition of prickly pear cactus (*Opuntia ficus-indica* var. saboten) extract (0, 0.4, 0.8 and 1.2%) on pH, titratable acidity, lactic acid bacteria, total bacterial populations, texture and sensory qualities of cabbage kimchi were studied to establish an optimum recipe. The total phenol content of the prickly pear cactus extract was 1759.0 mg·kg^{-1}. Upon the addition of prickly pear cactus extract, the pH increased compared to that of kimchi without the extract after 36 days, and the titratable acidity also increased with the addition of prickly pear cactus extract. During the fermentation period, the degree of salinity decreased with the addition of the extract, and the cutting and compression forces were higher during the fermentation period. The prickly pear cactus extract also inhibited total bacterial and lactic acid bacterial growths during fermentation. The 0.8% addition of extract improved the sensory quality (overall taste) of kimchi. Therefore, the addition rate of prickly pear cactus extract was determined to be 0.8%, and the sensory quality, such as the taste of a treated sample, could be maintained high during fermentation.

Keywords

kimchi; prickly pear cactus; *Opuntia ficus-indica* var. saboten; quality; fermentation

Cabbage kimchi is a traditional Korean food, which has a sour, hot, salty and characteristically carbonic taste from the lactic acid fermentation that results from being brined [1]. However, after it reaches a well-aged stage, these microbiological (*Lactobacillus plantarum* and *Lactobacillus brevis*) and enzymatic activities continue and result in a sour and bitter taste, off-odour and softening, due to deterioration of kimchi [2]. Therefore, control of the fermentation process is needed to preserve the quality of kimchi and to extend its shelf-life [3]. Chilled storage (2–8 °C) is generally used to maintain the quality of kimchi [4]. Several studies have been conducted on extending the shelf-life of kimchi using heat treatment [5], antiseptics [6], antimicrobial agents [7], herbal medicine [8] and a pH adjuster [9]. Even though these methods can be used to retard the aging process, it is difficult for these processes to control the deterioration of sensory quality and maintain a good product [10]. Many naturally-occurring compounds or phytochemicals are found in edible and medicinal plants, herbs and spices, that have been shown to possess antimicrobial activities against food spoilage and fermentation bacteria [2, 8]. However, a key drawback of medicinal herbs is the deterioration of colour and sensory properties in foods [7, 11].

The prickly pear cactus (*Opuntia ficus-indica* var. saboten) has a global distribution and is an important nutrient and food source [12]. The fruits are an important source of vitamins for people who live near the natural growth sites of the plant. Both nopal leaves and fruits are consumed as fresh vegetables, added to casseroles, cooked, or used in salads, syrups, and juices [13]. This cactus contains pigments and flavour compounds, particularly betalains and polyphenols, along with nutritionally important components in the fruit (amino acids, saccharides, organic acids, vitamins, minerals, fibre) and seeds (oil contents), having potential use in functional foods [14, 15]. Prickly pear cactus (PPC) is economical and exhibits antibiotic activity that is anticipated to suppress over-ripening. In this study, PPC was added to kimchi and the effects of different concentrations of PPC ex-

Hee Sook Sohn, Young Sook Lee, Jeong Ok Rho, Department of Food Science and Human Nutrition, Chonbuk National University, 664-14 Deokjin-Dong 1Ga Deokjin-Gu Jeonju, Jeonbuk 561-756, South Korea.

Correspondence author:
Jeong Ok Rho, e-mail: jorho@chonbuk.ac.kr

tract on the physicochemical, microbiological and sensory characteristics were examined. As such, the possibility of its use as a natural additive that could prolong the shelf-life of kimchi was assessed, and the value of the use of PPC for the commercial production of kimchi was investigated.

MATERIALS AND METHODS

Materials

Chinese cabbage, radish, minced garlic, minced ginger, pieces of green onion, red pepper powder, waxy rice paste, white sugar, anchovy sauce and salted shrimps were supplied from a local market in Jinan, Jeonbuk, South Korea.

Preparation of prickly pear cactus extract (PE)

Freshly harvested PPC fruits were obtained from a local market on Jeju Island, South Korea. The fruits were brushed under distilled water, air-dried and pulverized to prepare for extraction. The crushed fruits (2 kg) were extracted in a heating mantle (80 °C) with distilled water (10 l) for 3 h. The extract was filtered through Whatman No. 2 filter paper (Whatman International, Maidstone, Kent, United Kingdom), and the filtered samples were then evaporated in order to remove water, using a rotary evaporator at 40 °C. The content of the final extract was controlled to be of 40 °Bx.

Total phenol content

The phenolic content of the PE was assayed according to the method of Folin-Denis [16]. In brief, the extract (150 μl) prepared in different concentrations, was mixed with 750 μl of Folin-Ciocalteu reagent (Sigma, St. Louis, Missouri, USA) in test tubes and 600 μl of sodium carbonate (7.5%; Emir Chemical, Ankara, Turkey). The tubes were then vortexed and incubated at 40 °C for 30 min. Afterwards, the optical absorption was measured at 760 nm. Distilled water was used as a blank [17]. The total phenolic content of the extract was expressed as gallic acid equivalents (GAE; in grams per kilogram of extract; gallic acid was purchased from Fluka Chemical, Taufkirchen, Germany).

Preparation of kimchi

The recipe for preparation of kimchi was that of triplicate manufacture [18]. The raw materials used were Chinese cabbage (76.7%), radish (6.6%), white sugar (0.2%), minced garlic (3.8%), minced ginger (0.5%), pieces of green onion (2.5%), red pepper powder (4.1%), waxy rice paste (0.8%), anchovy sauce (2.5%) and salted shrimps (2.3%). The cleaned and trimmed Chinese cabbage was cut into pieces (3 × 3 cm) and immersed twice in a 20% NaCl solution (w/v) for 3 h. After removing some residual salt with tap water, the Chinese cabbage was drained at room temperature for 1 h. The sliced Chinese cabbage, radish, minced garlic and minced ginger were placed together in a metal bowl. After mixing gently, red pepper powder, waxy rice paste and pieces of green onion, anchovy sauce, salted shrimps and white sugar were added and gently blended. Meanwhile, 0, 0.4, 0.8 and 1.2% (w/w) of PE against the weight of the salted Chinese cabbage were added as a condiment, and spread onto the Chinese cabbage for preparation of kimchi. The prepared kimchi was packed in 1000 ml plastic vessels with headspace, and stored in an incubator KB/B1-699M (JO-TECH, Seoul, South Korea) at 10 °C for 36 days. The prepared kimchi is shown in Fig. 1.

Fig. 1. Appearance of kimchi prepared with different prickly pear cactus hot water extract ratios.

Measurement of pH and acidity

Using the method of Kang et al. [19], pH and acidity of the samples were determined. Ten grams of a sample were homogenized in 100 ml of distilled water and filtered through Whatman No. 2 paper, and the filtrate was used to determine pH and acidity. The pH value was measured with a pH meter Orion 520A (Thermo Fisher Scientific, Waltham, Massachusetts, USA) and the acidity was expressed as the content of lactic acid (weight percent) by measuring the titration volume of 0.1 mol·l^{-1} NaOH to adjust the pH at 8.4.

Measurement of salinity

Salinity was measured with a salinometer SP-80 (Takemura Electric Works, Tokyo, Japan).

Measurement of texture

Texture of the samples was analysed by cutting and compression using a texture analyser TA-XT2I system (Stable Micro Systems, Godalming, United Kingdom). Square-shaped samples (3 × 3 cm) were prepared by cutting the stump of the cabbage at 5 cm distances from the bottom [20]. The operation conditions of the texture analyser were as follows: pre-test speed 5.0 mm·s^{-1}, test speed 1.0 mm·s^{-1}, post-test speed 10.0 mm·s^{-1}, strain 60%, trigger type auto-5 g, and probe type (cutting force: blade set with knife, compression force: 36 mm dia aluminium).

Microbiological analysis

The method of Oh et al. [21] was used to determine the growth of microflora during the treatments. Briefly, 10 g of a sample was aseptically prepared, put in a sterilized bag (10 × 15 cm; Sunkyung, Seoul, South Korea) with 100 ml of peptone water (0.1%), and stomached in a Stomacher Model 400 (Tekmar, Cincinnati, Ohio, USA) for 2 min. The stomached suspension of the sample was used to test the growth of total bacterial populations (TP) and lactic acid bacteria (LAB) on plate count agar (Difco, St. Louis, Missouri, USA) and MRS agar (Difco), respectively. The plates were prepared in triplicate and incubated at 37 °C for 48 h, and viable cell numbers on a plate were determined as colony forming units per gram of product (log CFU·g^{-1}).

Sensory evaluation

Sensory evaluation of the samples was conducted on day 15 by 14 panelists who were trained according to the method described by Park et al. [22]. Briefly, training sessions were conducted to inform panelists on the products and attributes to be evaluated, and were followed by an open discussion. Panelists were trained in three 1 h sessions, in which samples were served to the panelists from a wide variety of treatments to familiarize them with a wide range of colour, sourness, salty fermented odours, crispness and overall acceptance of samples. Sensory scores of samples were referred to using a nine-point descriptive scale where 1 = extreme dislike or extremely weak, and 7 = extreme like or extremely strong. Steamed rice was given as a delivery medium.

Statistical analysis

Samples were analysed in triplicate and the results were presented as mean ± standard deviation. One-way analyses of variance (ANOVA) were used to determine the effects of the combined treatments of kimchi on the growth of microorganisms and the quality properties of the 4 groups, using the Statistical Package for Social Sciences v. 12.0 (SPSS, Chicago, Illinois, USA). Duncan's multiple range test was used to compare the differences among the means at $P < 0.05$.

RESULTS AND DISCUSSION

The yield, pH, brix, moisture and total phenol contents of PE are presented in Tab. 1.

Tab. 1. Yield, pH, brix, moisture and total phenol content of hot water extract of prickly pear cactus.

Yield [%]	13.3
pH	3.6
Brix [°Bx]	40.6
Moisture [%]	49.8
Total polyphenol content [mg·kg^{-1}]	1 759.0 ± 45.1

pH and acidity of kimchi prepared with PE

The changes in pH and acidity of the samples during storage are shown in Fig. 2. The values of pH and acidity of kimchi with PE were reduced and increased on day 0, respectively, and changed slowly compared to the untreated kimchi during the storage period. Moon et al. [23] also reported that the addition of omija extract to kimchi reduced pH and increased acidity due to a variety of organic acids in the extract, including fumaric acid, malic acid and succinic acid. In general, kimchi has the best taste when pH is about 4.2. However, when pH of kimchi drops below 4.0, homo-fermentative *Lb. plantarum* strains, which generally

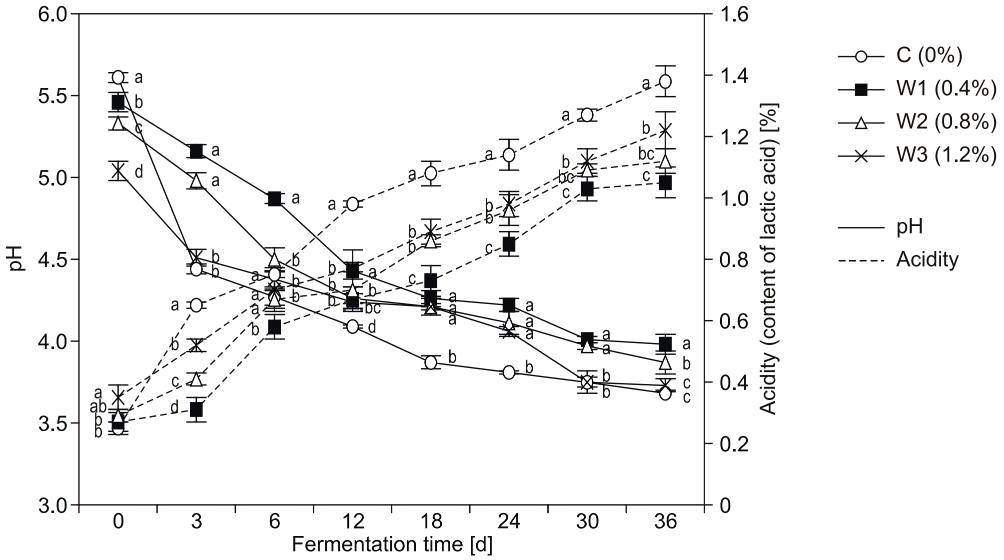

Fig. 2. Changes in pH and titratable acidity of kimchi prepared with different prickly pear cactus hot water extract additions during fermentation for 36 days at 10 °C.

Values are means of triplicate analyses with standard deviation. Lines with different superscript letters are significantly different ($p < 0.05$).

proliferate during the late stage of kimchi fermentation, play an important role in its over-fermentation [24]. According to the present results, the reason for slow changes in pH and acidity in kimchi manufactured with PE is the control of fermentation bacteria *(Lb. plantarum* strains*)*.

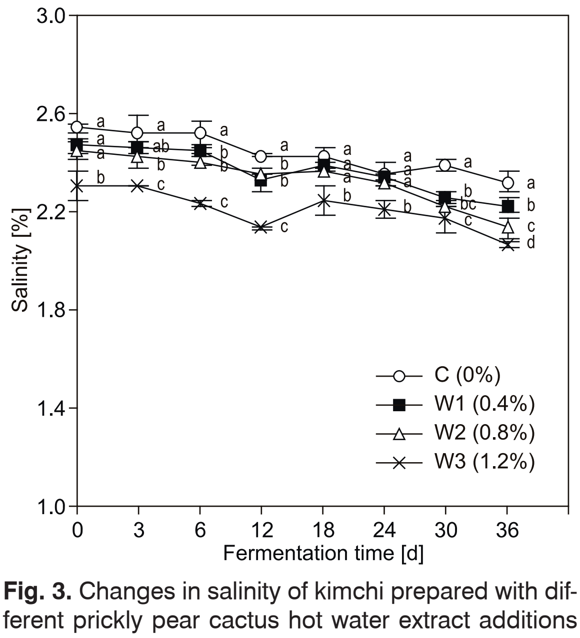

Fig. 3. Changes in salinity of kimchi prepared with different prickly pear cactus hot water extract additions during fermentation for 36 days at 10 °C.

Values are means of triplicate analyses with standard deviation. Lines with different superscript letters are significantly different ($p < 0.05$).

Measurement of salinity in kimchi prepared with PE

The changes in the salinity of the samples during storage are shown in Fig. 3. Generally, the salinity of kimchi is 3%, and it decreases through the leaking of cell liquid from the kimchi tissue during storage [25]. The salinity of kimchi prepared with PE was lower that of the untreated kimchi during the storage period. HA & PARK [26] and HA [27] reported that additions of soft persimmon and apple juice induced leakage of cell liquid, and treated samples had low salinity compared to untreated samples. KIM & HAN [28] also indicated that the salty taste of kimchi decreases its sensory quality, and a suitable salinity increases the taste acceptance of kimchi. Thus, PE is able to improve the sensory properties of kimchi because of decreased salinity.

Cutting and compression force of kimchi

Fig. 4 and Fig. 5 show the changes in the cutting force and compression force of the kimchi samples during storage. The cutting and compression forces of kimchi were decreased during the fermentation time, and the changes in cutting and compression forces were similar. The PE-treated samples were harder than the untreated samples during the storage period. LEE et al. [29] reported that the osmotic pressure of external cells in samples became higher with increased salt concentrations, and cutting and compression forces decreased due to a leakage of cell contents from

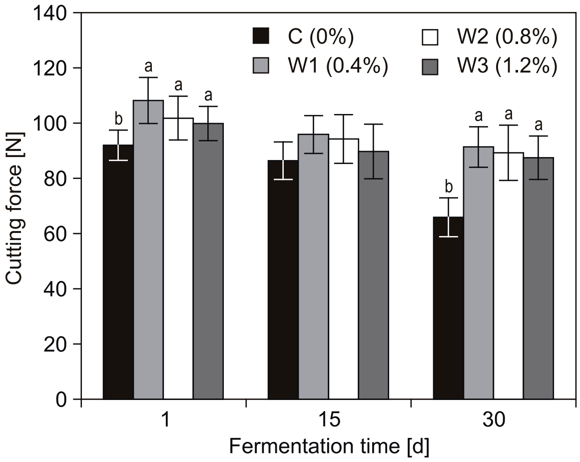

Fig. 4. Changes in the cutting force of kimchi prepared with different prickly pear cactus hot water extract additions during fermentation for 36 days at 10 °C.

Values are means of triplicate analyses with standard deviation. Bars with different superscript letters are significantly different ($p < 0.05$).

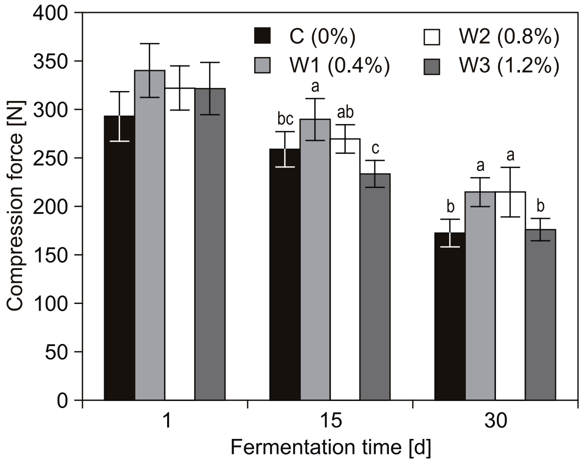

Fig. 5. Changes in the compression force of kimchi prepared with different prickly pear cactus hot water extract additions during fermentation for 36 days at 10 °C.

Values are means of triplicate analyses with standard deviation. Bars with different superscript letters are significantly different ($p < 0.05$).

the tissue. The tenderization of kimchi by over-fermentation is relative to the growth of lactobacilli along with the increase in the activity of polygalacturonase (PG) [30]. PG acts to separate methoxyl groups from pectin, generate free carboxyl groups, dissolve pectin with free carboxyl groups, and directly tenderize the structure of plants [31, 32]. Therefore, it is necessary at the application of any method to inhibit or retard tenderization of kimchi. The present results indicate that the addition of PE to kimchi can improve its texture during fermentation.

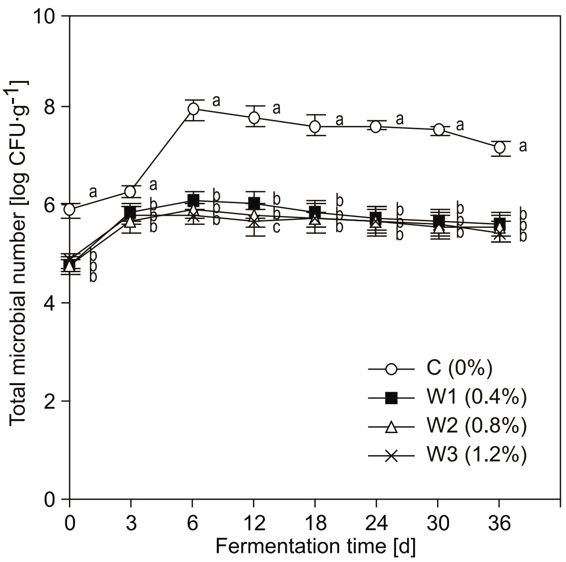

Fig. 6. Changes in total bacterial populations of kimchi prepared with different prickly pear cactus hot water extract additions during fermentation for 36 days at 10 °C.

Values are means of triplicate analyses with standard deviation. Lines with different superscript letters are significantly different ($p < 0.05$).

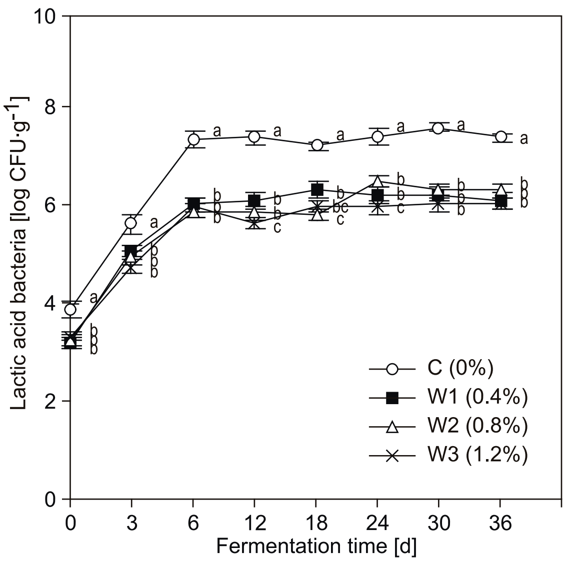

Fig. 7. Changes in lactic acid bacteria of kimchi prepared with different prickly pear cactus hot water extract additions during fermentation for 36 days at 10 °C.

Values are means of triplicate analyses with standard deviation. Lines with different superscript letters are significantly different ($p < 0.05$).

Tab. 2. Sensory properties of kimchi prepared with different prickly pear cactus hot water extract ratios after fermentation for 15 days at 5 °C.

Treatment	Attribute				
	Colour	Sourness	Salted-fermented odours	Crispness	Overall acceptance
C	4.79 ± 1.67b	6.00 ± 2.07a	5.71 ± 1.68a	5.07 ± 1.49b	4.14 ± 1.52b
W1	5.00 ± 1.75b	3.93 ± 1.77b	3.64 ± 1.55b	6.36 ± 1.73ab	6.50 ± 1.69a
W2	6.14 ± 1.65a	3.57 ± 1.65b	3.36 ± 0.49b	6.71 ± 1.73a	6.86 ± 0.94a
W3	4.36 ± 2.09b	3.29 ± 1.06b	3.29 ± 1.72b	6.43 ± 1.98b	6.54 ± 0.66a

Each value is expressed as mean ± standard deviation (n = 3). Means within same columns with different superscript letters are significantly different ($p < 0.05$).

Total bacterial populations and lactic acid bacteria in the kimchi

The changes in total bacterial populations (TP) and lactic acid bacteria (LAB) are shown in Fig. 6 and 7, respectively. The numbers of TP and LAB increased rapidly until they peaked and then began to decrease or maintain their quantity during fermentation. Until the 6th day of fermentation, the numbers of TP and LAB were highest in the control, while the groups treated with PE showed lower numbers of TP and LAB compared to the control sample. However, no great differences were observed among the treatments. Some important species believed to be responsible for kimchi fermentation include *Leuconostoc mesenteroides*, *Leuc*. *pseudomesenteroides*, *Lactococcus lactis* and *Lb*. *plantarum* [33, 34]. Our results regarding the numbers of TP and LAB showed a trend similar to that observed by MOON & JANG [35] and PARK et al. [36]. Addition of PE to kimchi facilitated prolongation of the shelf-life of kimchi.

Sensory characteristics of kimchi

The effects of PE addition on sensory properties of kimchi were investigated after storage for up to 15 days (Tab. 2). The sample treated with 0.8% PE had high scores for properties such as colour, crispness and overall acceptance. The red pigment of PE is known to be betaine, and this pigment is very stable under pH 4–5, in which its bright red colour can be maintained under acidic conditions [37]. The colour acceptance of samples after day 15 increased rapidly with the treatment with PE. However, 1.2% PE decreased colour acceptance because the colour of kimchi became darker. Sourness and salted-fermented odours also decreased because of PE addition. This result demonstrates that adding PE to kimchi could mask off-odours due to the salted-fermented odour. The deterioration of sensory quality, a sour and bitter taste, off-odour and softening of kimchi occur through over-fermentation [38]. According to our results, the addition of PE effectively improved the sensory quality of kimchi during the fermentation period, the optimal addition rate being 0.8% PE.

CONCLUSIONS

The effects of different concentrations of prickly pear cactus (*Opuntiaficus-indica* var. saboten) extract (0%, 0.4%, 0.8% and 1.2%) on the shelf-life, and on physico-chemical and sensory properties of kimchi were studied during fermentation at 10 °C for 36 days. The addition of 0.8% prickly pear cactus extract to kimchi caused a decrease in salinity and salted-fermented odours, and improved taste, colour, texture and overall acceptance during fermentation. Therefore, prickly pear cactus seems to be an economical and natural additive, which has effects on extending the shelf-life and improving the sensory quality of kimchi during fermentation.

Acknowledgments

This study was supported by grants from Chonbuk National University (Jeonju, South Korea) for research-based study, 2007.

REFERENCES

1. Moon, S. W. – Shin, H. K. – Gi, G. F.: Effects of xylitol and grapefruit seed extract on sensory value and fermentation of baechu kimchi. Korean Journal of Food Science and Technology, *35*, 2003, pp. 246–253.
2. Kim, W. J. – Kang, K. O. – Kyung, K. H. – Shin, J. I.: Addition of salts and their mixtures for improvement of storage stability of kimchi. Korean Journal of Food Science and Technology, *23*, 1991, pp. 188–191.
3. Park, B. H. – Cho, H. S. – Oh, B. Y.: Physicochemical characteristics of kimchi treated with chitosan during fermentation. Korean Journal of Human Ecology, *5*, 2002, pp. 85–93.

4. Lee, Y. H. – Yang, W. I.: Studies of the packaging and preservation of kimchi. Journal of the Korean Society for Applied Biological Chemistry, *13*, 1970, pp. 207–218.
5. Kang, K. O. – Ku, K. H. – Lee, H. J. – Kim, W. J.: Effect of enzyme and inorganic salts addition and heat treatment on kimchi fermentation in Korean. Korean Journal of Food Science and Technology, *23*, 1991, pp. 183–187.
6. Lee, S. K. – Kim, L. H. – Choi, S. Y. – Jeon, K. H.: Effect of lysozyme, glycine and EDTA on the kimchi fermentation in Korean. Journal of Korean Society of Food Science and Nutrition, *22*, 1993, pp. 58–61.
7. Moon, K. D. – Byun, J. A. – Kim, S, J. – Han, D. S.: Screening of natural preservatives to inhibit kimchi fermentation. Korean Journal of Food Science and Technology, *27*, 1995, pp. 257–263.
8. Lee, S. H. – Choi, W. J.: Effect of medicinal herbs' extracts on the growth of lactic acid bacteria isolated from kimchi and fermentation of kimchi. Korean Journal of Food Science and Technology, *30*, 1998, pp. 624–629.
9. Lee, M. Y. – Kim, S. D.: Calcium lactate treatment after salting of Chinese cabbage improves firmness and shelf-life of kimchi. Journal of Korean Society of Food Science and Nutrition, *8*, 2003, pp. 270–277.
10. Park, J. G. – Kim, J. H. – Park, J. N. – Kim, Y. D. – Kim, W. G. – Lee, J. W. – Hwang, H. J. – Byun, M. W.: The effect of irradiation temperature on the quality improvement of kimchi, Korean fermented vegetables, for its shelf stability. Radiation Physics and Chemistry, *77*, 2008, pp. 497–502.
11. Paik, J. E.: Effects of potato on the storage of kimchi. Korean Society of Food and Nutrition, *20*, 2007, pp. 421–426.
12. Ramadan, N. F. – Morsel, J. T.: Recovered lipids from prickly pear [*Opuntia ficus-indica* (L.) Mill] peel: a food source of polyunsaturated fatty acids, natural antioxidant vitamins and sterols. Food Chemistry, *83*, 2003, pp. 447–456.
13. Gurbachan, S. – Felker, P.: Cactus: new world foods. Indian Horticulture, *43,* 1998, pp. 29–31.
14. El-Kossori, R. L. – Villlaume, C. E – Boustani, E. – Sauvaire, Y. – Mejean, L.: Composition of pulp, skin and seeds of prickly pears fruit (*Opuntia ficus-indica* sp.). Plant Food for Human Nutrition, *52*, 1998, pp. 263–270.
15. Stintzing, F. C. – Schieber, A. – Carle, R.: Cactus pear, a promising component of functional food. Obst, Gemüse and Kartoffelverarbeitung, *85*, 2000, pp. 40–47.
16. Singleton, V. L. – Rossi, J. A.: Colorimetry of total phenolics with phosphomolybdic – phosphotungstic acid reagents. American Journal of Enology and Viticulture, *16*, 1965, pp. 44–158.
17. Moon, O. H. – Whang, H. J.: Chemical composition of several herb plants. Korean Journal of Food Science and Technology, *35*, 2003, pp. 1–6.
18. Yang, E. S. – Yang, H. S. – Kim, A. J. – Rho, J. O.: Quality characteristics of chungkukjangkimchi and its acceptability by elementary school students. Journal of East Asian Society Dietary Life, *18*, 2008, pp. 507–515.
19. Kang, K. O. – Ku, K. H. – Lee, H. J. – Kim, W. J.: Effect of enzyme and in organic acid salts addition and heat treatment on kimchi fermentation. Korean Journal of Food Science and Technology, *23*, 1991, pp. 183–187.
20. Han, E. S. – Seok, M. S. – Park, J. H. – Lee, H. J.: Quality changes of salted Chinese cabbage with the package pressure and storage temperature. Korean Journal of Food Science and Technology, *28*, 1996, pp. 650–656.
21. Oh, Y. A. – Choi, K. H. – Kim, S. D.: Changes in enzyme activities and population of lactic acid bacteria during the kimchi fermentation supplemented with water extract of pine needle. Journal of Korean Society of Food Science and Nutrition, *27*, 1998, pp. 244–251.
22. Park, J. G. – Kim, J. H. – Park, J. N. – Kim, Y. D. – Kim, W. G. – Lee, J. W. – Hwang, H. J. – Byuna, M. W.: The effect of irradiation temperature on the quality improvement of kimchi, Korean fermented vegetables, for its shelf stability. Radiation Physics and Chemistry, *77*, 2008, pp. 497–502.
23. Moon, Y. J. – Park, S. – Sung, C. K.: Effect of ethanolic extract of *schizandra chinensis* for the delayed ripening kimchi preparation. Korean Society of Food and Nutrition, *16*, 2003, pp. 7–14.
24. Mheen, T. I. – Kwon, T. W.: Effect of temperature salt concentration on kimchi fermentation. Korean Journal of Food Science and Technology, *16*, 1984, pp. 443–450.
25. Hwang, G. H. – Yoo, Y, K, – Chung, D. L. – Cho, C. N. – Jung, L. H.: Effects of sensory acceptability for kimchi prepared with different conditions of fermented seafood and red pepper. Korean Society of Food and Nutrition, *13*, 2000, pp. 201–212.
26. Ha, K. H. – Park, S. W.: An effect of red-ripe persimmon on fermentation and sensory characteristics of kimchi. Korean Society of Food and Nutrition, *11*, 1998, pp. 570–575.
27. Ha, K. H.: Chemical and sensory characteristics of kimchi added apple juice. Korean Society of Food and Nutrition, *11*, 1998, pp. 1–5.
28. Kim, M. S. – Han, J. S.: Studies of whole Chinese cabbage kimchi – An investigation of the method on making kimchi and a taste in the Taegu area. Korean Society of Food Science and Technology, *11*, 1995, pp. 13–19.
29. Lee, M. H. – Lee, G. D. – Son, K. J. – Yoon, S. R. – Kim, J. S. – Kwon, J. H.: Changes in organoleptic and rheological properties of Chinese cabbage with salting condition. Journal of Korean Society of Food Science and Nutrition, *31*, 2002, pp. 417–422.
30. McCready, R. M. – McComb, E. A.: Pectic constituents in ripe and unripe fruit. Food Resources, *19*, 1954, pp. 530–534.
31. Buescher, R. W. – Hudson, J. M. – Adams, J. R.: Inhibition of polygalacturonase softening of cucumber pickes by calcium chloride. Journal of Food Science, *44*, 1979, pp. 1786–1789.
32. Drake, S. K. – Spayd, S. E.: Influence of calcium testament on golden delicious apple quality. Journal

of Food Science, *48*, 1983, pp. 403–406.
33. Lee, C. W. – Ko, C. Y. – Ha, D. M.: Microfloral changes of the lactic acid bacteria during kimchi fermentation and identification of the isolates. Korean Journal of Applied Microbiology and Biotechnology, *20*, 1992, pp. 102–109.
34. Kim, Y. S. – Kim, Y. S. – Kim, S. Y. – Whang, J. H. – Suh, H. J.: Application of omija (*Schiandra chinensis*) and plum (*Prunus mume*) extracts for the improvement of kimchi quality. Food Control, *19*, 2008, pp. 662–669.
35. Moon, S. W. – Jang, M. S.: Effects of water extract from omija (*Schizandra chinsis* Baillon) on nabak kimchi preservation. Journal of Korean Society of Food Science and Nutrition, *29*, 2000, pp. 814–821.
36. Park, B. H. – Cho, H. S. – Oh, B. Y.: Physicochemical characteristics of kimchi treated with chitosan during fermentation. Korean Journal of Human Ecology, *5*, 2002, pp. 85–93.
37. Lee, S. P. – Whang, K. – Ha, Y. D.: Functional properties of mucilage and pigment extracted from *Opuntia ficus-indica*. Journal of Korean Society of Food Science and Nutrition, *27*, 1998, pp. 821–826.
38. Chung, D. K. – Yu, R. N.: Antimicrobial activity of bamboo leaves extract on microorganisms related to kimchi fermentation. Korean Society of Food Science and Technology, *27*, 1995, pp. 1035–1038.

Received 8 August 2011; revised 19 September 2011; accepted 28 October 2011.t