Prev. Nutr. Food Sci. 2014;19(1):49-57
http://dx.doi.org/10.3746/pnf.2014.19.1.049
pISSN 2287-1098 · eISSN 2287-8602

Effects of Cultured Wild-Ginseng Root and Xylitol on Fermentation of Kimchi

Kun-Jong Lee[1], Jung-Min Sung[2], Yong-Suk Kwon[3], and Heajung Chung[4]

[1]Department of Food and Nutrition, Soongeui Women's College, Seoul 100-751, Korea
[2]Korea Food Research Institute, Gyeonggi 463-746, Korea
[3]National Academy of Agricultural Science, Rural Development Administration, Gyeonggi 441-707, Korea
[4]International Culture Foundation of Korean Food, Jeonju University, Jeonbuk 560-759, Korea

ABSTRACT: This study evaluates the effects of cultured wild ginseng root (0.05%, 0.1% v/w) and xylitol in kimchi. The fermented characteristics of kimchi were investigated during 28 days of fermentation at 4°C. The pH value in the sample with the cultured wild ginseng root was higher than that of control group. The total acidity in the sugar groups (SG groups) was higher than that of xylitol groups (XG groups). Comparing total bacterial count, XG groups were lower than SG groups, regardless of the additional ratio of the cultured wild ginseng root. Reducing sugar of XG groups decreased more slowly than SG groups for seven days; glucose and fructose of XG groups were lower than the control group. DPPH radical scavenging activity was higher in groups with cultured wild ginseng root than in control. In the result of sensory evaluation, XG groups were more preferred than other groups. In conclusion, our results indicate that cultured wild-ginseng root and xylitol have a positive effect on the quality of kimchi, such as antimicrobial and antioxidant functions.

Keywords: kimchi, cultured wild-ginseng root, free sugars, xylitol, lactic acid bacteria

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 antiatherosclerotic functions. Also, dietary fibers have been demonstrated to prevent hypertension, diabetes, constipation, and cancer (4).

According to the reports of Born et al. (5) and Scheie et al. (6), xylitol and sorbitol are sugar alcohols and glucose and maltose are saccharides substitutive for sugar produced by adding hydrogen to raw sugar such as xylose. In food processing areas, sugar alcohols provide functionality such as preventing dental caries and inhibiting the rise of blood sugar and furthermore, only 12% of xylitol and 84% of sorbitol are absorbed by the small intestine due to decomposition by bacteria. Concerning efforts to extend the shelf life of kimchi by adding different types of sugars, Kim et al. (7) reported that the addition of xylose and xylitol extended the shelf life of kimchi by affecting the organic acid fermentation of kimchi, while Moon et al. (8) reported the effects of xylitol and grapefruit seed extract on the sensory properties, fermentation and aging of kimchi. Ku et al. (9) reported that the addition of sorbitol and saccharide or the addition of oligo-fructose for kimchi fermentation by bifidobacteria provided nutrition for kimchi lactic acid bacteria and consequently improved the taste and enhanced functionality as probiotics by increasing the survival of bifidobacteria, as reported by Chae and Jhon (10). Several studies (5-10) tried to extend the edible period of kimchi by adding xylitol, a kind of sugar alcohol, to Chinese cabbage kimchi; however, Kim et al. (7) reported that xylitol, which is effective in dental treatment, is not a fermenting sugar and therefore slows down the rate of acid production and extends the edible period.

Wild ginseng (san-sam) grows naturally and is harvested from wherever it is found. Cultured wild ginseng roots are easily obtained by using a plant cell culture technique for the production of natural wild ginseng and have been shown to contain higher levels of ginsenosides and saponin (11,12). Jung et al. (13) confirmed that ginsenoside, with the development of a new proc-

Received 29 October 2013; Accepted 6 December 2013

Correspondence to Heajung Chung, Tel: +82-63-230-1600, E-mail: angiechung@hanmail.net

essing method for enhancing its absorption rate, cultured wild ginseng increased the content of ginsenoside and in particular ginsenoside Rg3 through the fermentation process of kimchi. Lee et al. (14) reported the effects of ginsenoside Rg3 such as platelet agglutination and immune enhancement.

This study examined the fermented characteristics of kimchi using cultured wild ginseng and xylitol. In order to examine health functionality enhanced by the optimal fermentation of lactic acid bacteria and the extension of the edible period, we analyzed the physicochemical characteristics, microbial characteristics and antioxidant ability of kimchi. The results of this study are expected to be useful materials for basic research on the industrialization of kimchi.

MATERIALS AND METHODS

Materials and preparation of kimchi

Kimchi was prepared by adding xylitol and cultured wild ginseng. The control group was prepared by adding sugar only, and the experimental groups were prepared by adding cultured wild ginseng (0.05% or 0.1%) to sugar (SG-0.05, SG-0.1), and by adding cultured wild ginseng (0.05% or 0.1%) to xylitol (XG-0.05, XG-0.1). All the materials used were Korean-produced including cultured wild ginseng (CBN Biotech, Chungbuk, Korea), xylitol (Samin Chemical Co., Gyeonggi, Korea), sugar (Daesang, Seoul, Korea), salt (Jeonnam, Korea), powdered red pepper (Chungbuk, Korea), garlic (Jeonnam, Korea), glutinous rice paste, and mixture ratios showed in Fig. 1. The prepared kimchi was put into PE (polyethylene) film, kept in a refrigerator at 4°C, and used as specimens after different periods of storage.

pH, acidity and salinity

The 100 g of sample was mixed in a blender (KA-2600, Kaiser, Seoul, Korea) and filtered with cheese cloth gauze and the filtered solution was used. The pH was measured with a pH meter (Accumet AB 15, Fisher Scientific, Pittsburgh, PA, USA). Ten 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. Five mL of filtered solution was titrated with 0.1 N $AgNO_3$ at the terminal point of browning while adding 10% K_2CrO_4 by the Mohr method for salinity (15).

Reducing sugar

The reducing sugar content in kimchi was measured by Miller's (16) colorimetry using dinitrosalicylic acid (DNS). DNS reagent was added to the dilute solution of kimchi, the mixture was stirred thoroughly, left 5 minutes for reaction, and cooled down. For the solution with developed color, we measured absorbance at 550 nm using a spectrophotometer (V-550, Jasco Co., Tokyo, Japan) and converted the result into glucose for presentation.

Free sugar content

To measure free sugar content, kimchi was filtered with a 0.45 μm filter, and the filtrate was analyzed by HPLC. In the analysis, fructose, glucose and sucrose (Sigma Chemical Co., St. Louis, MO, USA) were used as standard solutions. The HPLC conditions are described in Table 1.

DPPH radical scavenging activity

The 2,2-diphenyl-2-picrylhydrazyl (DPPH) free radical

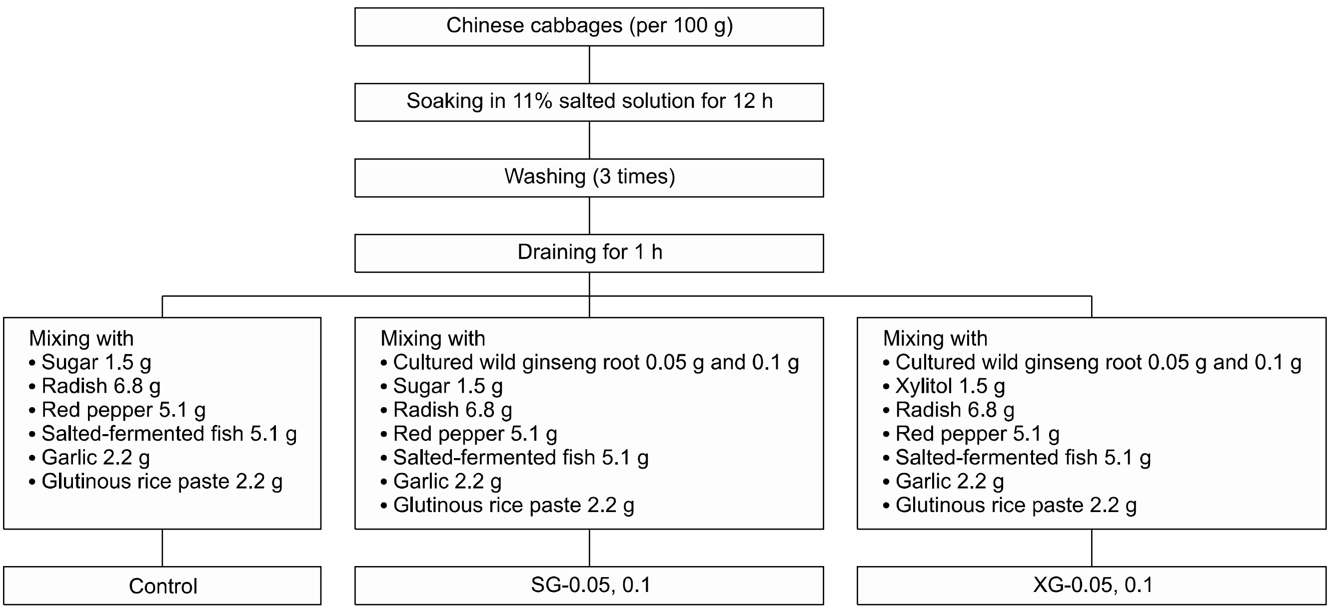

Fig. 1. Flow diagram for kimchi preparation.

Table 1. HPLC conditions for free sugar analysis

Instrument	PU 980 (Jasco)
Solvent	Acetonitrile : Water = 87:13 (v/v)
Flow rate	1.2 mL/min
Detector	RI detector (830-RI, Jasco)
Oven temperature	39°C
Column	Carbohydrate analysis (Waters, Milford, MA, USA, 3.9×300 mm, 10 μm)
Injection volume	10 μL

scavenging activity was analyzed according to the Blois' method (17). Kimchi was extracted with ethanol solution at a ratio of 1:10, and 100 μL of the extracted solution was mixed with 2 mL of 1.5×10^{4} M DPPH solution. The mixture was left at room temperature for 30 minutes and then absorbance was measured at 520 nm using a spectrophotometer (V-570, Jasco Co.). The control group was also measured in the same conditions, and DPPH radical scavenging activity was calculated by the equation below.

$$\text{DPPH radical scavenging activity (\%)} = \left(1-\frac{\text{Sample absorbance}}{\text{Control absorbance}}\right)\times100$$

Color values

Color values were measured with a 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:

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

Texture

Kimchi added with cultured wild ginseng powder and xylitol at different concentrations was ripened at 4°C and its texture was measured on Day 3, 14 and 28. The hardness of kimchi containing cultured wild ginseng was measured 7 times repeatedly using 3×4 cm large pieces taken from the midrib of kimchi with texture profile analyzer (TPA; TA.XT2 Texture Analyzer, Stable Micro Systems, London, UK) by the method of Kim and Kim (18). The measuring conditions of the texture analyzer were: force and time mode, two bites; pre-test speed, 5.0 mm/s; test speed, 5.0 mm/s; post-test speed, 5.0 mm/s; strain, 90% and 2.0 s; trigger type, auto 10 g; contact force, 5.0 g; probe, p/5 mm; and probe distance, 18 mm.

Total bacteria and lactic acid bacteria

The kimchi (15 g from the leaf and 15 g from the stem of kimchi) diluted in 0.85% sterile saline step by step, and then inoculated by the pour plate method. The total bacteria were incubated for 48~72 h at 35±1°C and the lactic acid bacteria for 48 h in 35±1°C and the quantity of colony was checked and express in colony forming unit (CFU/g). The media used for total bacteria was plate count agar (Difco Laboratories Inc., Detroit, MI, USA), the lactic acid bacterial count in MRS agar (Merck Millipore, Billerica, MA, USA).

Sensory evaluation

Kimchi added with cultured wild ginseng and xylitol at different concentrations fermented at 4°C and sensory evaluation was performed by 19 students at the Department of Culinary Arts of Woosong University who were given full explanations about the purposes and methods of experiment in advance. Then, the participants were educated to evaluate the intensity of redness, wild ginseng flavor, tangy taste, spicy taste, sweet taste, sour taste, after taste, salty taste, and hardness. Color, flavor, taste, texture and overall acceptability were rated on a 9-point scale, and a high score meant high overall acceptability.

Statistical analysis

The statistical analysis of all data was performed by SPSS Ver. 12.0 (SPSS Inc., Chicago, IL, USA). The t-test, one-way ANOVA (one-way analysis of variance) and Duncan's multiple range comparison were used to find the level of significant differences ($P<0.05$).

RESULTS AND DISCUSSION

pH and acidity

In order to measure pH and acidity of kimchi added cultured wild ginseng 0.05% and 0.1% (v/w) based on the weight of Chinese cabbage, fermented the kimchi at 4°C, and measured the change of pH during the fermentation process. Initial pH was 5.85~5.89, showing no significant difference among the specimens. With the increase of the fermentation period, pH decreased gradually and showed difference among the specimens containing cultured wild ginseng. On Day 7 of fermentation, pH was 4.92 in the control group, 4.89 in the SG groups and significantly high as 5.0~4.95 in XG groups (Fig. 2). The quantity of xylitol did not make a significant difference in pH. This result was similar to the report of Park and Sohn (19) that pH of *kkakdugi* (radish kimchi) was not different according to the type of sweetener. Particularly on Day 28 of storage, pH was 4.07 in the SG groups, which was significantly different from the XG groups ($P<0.001$).

On the other hand, with the increase of the fermentation period, acidity decreased significantly more in the treated groups than in the control group ($P<0.05$). Previously reported, acidity of optimum ripening period of kimchi were 0.6~0.8% (27,28), which showed a sim-

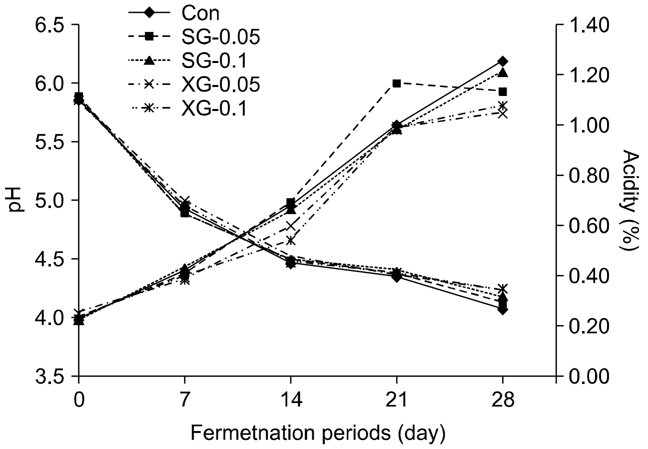

Fig. 2. Changes in pH and acidity of kimchi containing cultured wild ginseng root and xylitol during storage at 4°C. Con, non added with cultured wild ginseng root or xylitol; SG-0.05 or SG-0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or XG-0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).

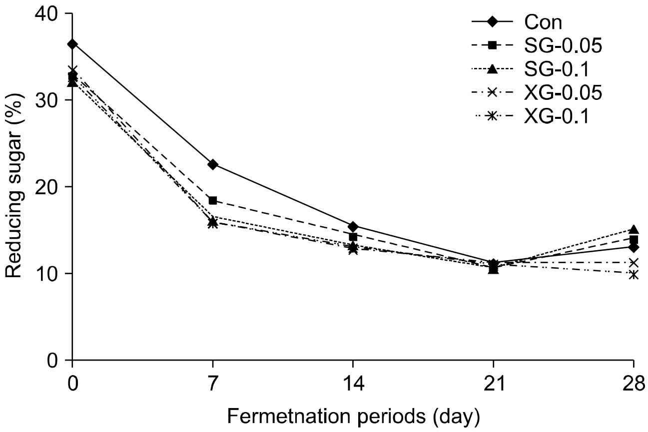

Fig. 3. Changes in reducing sugar content of kimchi containing cultured wild-ginseng root and xylitol during storage at 4°C. Con, non added with cultured wild ginseng root or xylitol; SG-0.05 or SG-0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or XG-0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).

ilar tendency at 14 days in this study. Acidity on that day was 0.68% in the control group, but significantly lower as 0.54% in the XG groups ($P<0.05$), suggesting that the addition of xylitol extends the fermentation period of kimchi effectively. A similar tendency was observed on Day 21 and 28 at the late stage of fermentation but the difference was not statistically significant. The salinity of kimchi was 1.78~2.28% on initial day and was at a similar level during fermentation.

Reducing sugar

The reducing sugar contents during the fermentation period of kimchi are shown in Fig. 3. The result of this study was similar to the report of Moon and Jang (20), whom reported a significant decrease of the reducing sugar content by 50% of the initial level in 7 days ($P<0.001$). Because sugar is used as the food of microbes at the early stage, the reducing sugar in xylitol-containing group decreased at a significantly lower rate. On Day 14 and 28, however, no difference among the groups was observed. In our study, the xylitol-containing groups showed a relatively high reducing sugar like the control group, and was probably because sugar was decomposed in various types of salted-fermented seafood as in the report of Lee et al. (21), stating that part of glutinous rice paste was decomposed and formed sugar and, as a result, a relatively high amount of sugar was decomposed.

Free sugar

The free sugar contents during the fermentation of kimchi containing cultured wild ginseng and xylitol are shown in Table 2. Initial fructose and glucose contents was 79.26~97.62 mg/mL and 60.72~75.89 mg/mL. Fructose and glucose contents, due to use by bacteria, decreased during fermentation period. Especially, glucose was reduced by more than 90% on Day 28. Total of fructose and glucose was the highest in control group during fermentation and had a close correlation with reducing sugar. Initial sugar content was 34.06 mg/mL, decreased to 8.36 mg/mL on Day 7, and was not detected from Day 14. In the XG groups, some sugar was detected at the early stage of fermentation probably because some of the disaccharides was detected, as similarly reported by Lee and Kim (22) in their research on the decomposition of glutinous rice paste.

DPPH radical scavenging activity

The DPPH radical scavenging activity in kimchi containing cultured wild ginseng and xylitol are shown in Fig. 4. The initial DPPH radical scavenging activity was 24.50~26.93%, showing no significant differences among the specimens, but on Day 14 of storage, DPPH radical scavenging activity was significantly higher as 45.33~46.88% in the treated groups than in the control group ($P<0.05$). This is probably because of antioxidant components such as saponins and ginsenoside known to be in cultured wild ginseng (23). Many studies are being conducted on the antioxidant effect of kimchi, and known antioxidant substances include vitamin C, β-carotene, phenolic compound and chlorophyll (24). During the fermentation period, DPPH radical scavenging activity increased and reached the peak on Day 14 (optimum maturity) and decreased to some degree afterwards. Lee et al. (25) also reported that antioxidant ability was higher in optimally fermented kimchi.

Color

The color values of kimchi containing cultured wild ginseng and xylitol are shown in Table 3. As to color, L val-

Table 2. Free sugar contents of kimchi containing cultured wild ginseng root and xylitol during storage at 4°C (unit: mg/mL)

	Fermented period (day)	Treatments[1)]					
		Control	SG-0.05	SG-0.1	XG-0.05	XG-0.1	F-value
Fructose	0	97.62±7.68$^{aA2-4)}$	84.66±7.94^{bA}	81.37±0.07^{bA}	80.63±11.66^{bA}	79.26±10.08^{bA}	4.67*
	7	39.18±11.45^{aB}	31.11±4.29^{abB}	23.00±1.31^{bB}	26.61±0.76^{bB}	29.25±0.53^{abB}	3.79*
	14	15.89±7.89^{abC}	19.15±1.71^{aC}	11.19±2.97^{bC}	10.48±2.97^{dC}	11.55±3.50^{abCD}	2.20
	21	9.52±1.23^{bC}	8.35±1.15^{bD}	6.59±1.88^{bCD}	6.97±2.19^{bC}	13.64±3.87^{aC}	4.36**
	28	8.97±3.87^{aC}	8.72±1.48^{aC}	7.12±2.95^{aD}	9.44±2.23^{aC}	2.74±0.91^{aD}	6.33**
	F-value	93.62***	320.03***	25.85***	2894.26***	113.32***	
Glucose	0	75.89±4.30^{aA}	67.32±0.75^{bA}	60.72±1.57^{cA}	66.36±3.33^{bA}	65.18±2.63^{bcA}	11.59***
	7	48.34±1.85^{aB}	45.26±0.79^{bB}	40.28±1.52^{cB}	37.55±1.41^{dB}	38.84±1.20^{cdB}	32.02***
	14	40.24±8.50^{abBC}	42.26±2.50^{aB}	38.88±1.31^{abBC}	33.12±4.94^{bB}	35.28±5.28^{abB}	1.56$^{NS5)}$
	21	39.31±2.76^{aC}	39.90±1.74^{aB}	34.08±3.73^{abC}	30.64±9.78^{bB}	37.69±2.32^{abB}	2.66^{NS}
	28	41.59±3.25^{aBC}	40.00±0.94^{abB}	34.53±3.45^{abcC}	31.69±4.11^{cB}	32.93±7.07^{bcB}	3.44^{NS}
	F-value	31.04***	10.80**	52.77***	28.95***	26.40***	
Sucrose	0	34.06±4.80^{a}	29.17±1.678^{a}	31.01±1.23^{a}	15.96±0.69^{b}	10.07±4.35^{b}	15.65**
	7	8.36±1.52	3.65±0.94	1.66±0.42	2.59±0.65	0.82±0.31	1.25
	14	—	—	—	—	—	—
	21	—	—	—	—	—	—
	28	—	—	—	—	—	
	F-value	22.74**	4.10*	683.622***	400.20***	9.66**	

1)Control, non added with cultured wild ginseng root or xylitol; SG-0.05 or 0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or 0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).
2)Values are mean±SD, n=3.
3)Means with different superscripts (a-d) in a row are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
4)Means with different superscripts (A-D) in a column are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
5)Not significant.

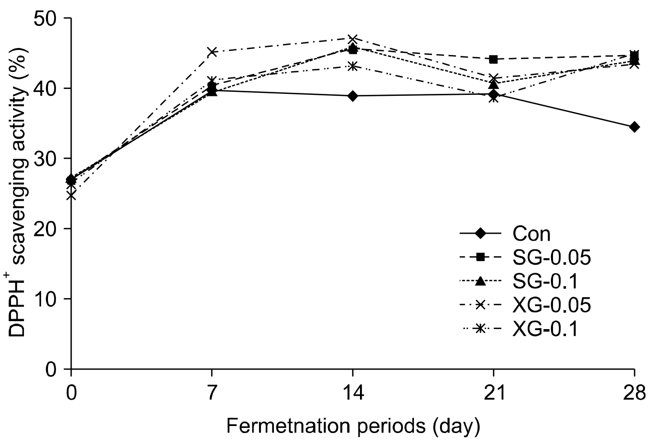

Fig. 4. Changes in DPPH radical scavenging activity of kimchi containing cultured wild-ginseng root and xylitol during storage at 4°C. Con, non added with cultured wild ginseng root or xylitol; SG-0.05 or SG-0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or XG-0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).

ue ranged between 32.71 and 34.06 just after preparation, and decreased significantly over the storage period depending on additive, and this result was consistent with the report of Lee and Kim (22) that L value decreased in *kkakdugi* containing hydrangea leaf extract. However, the significant difference of L value over the fermentation period was not observed in XG-0.1. Over the fermentation period, a value increased significantly in all the groups (P<0.05), probably due to red color eluted from red pepper, and Mo et al. (26) reported a similar result for kimchi containing red ginseng. As to b value just after preparation, no significant difference existed across all groups. On Day 14, 21 and 28, b value was not significantly different between the control group and the treated groups.

Texture

The results of texture in kimchi containing cultured wild ginseng and xylitol are shown in Table 4. Initial hardness was not significantly different among the specimens. XG-0.01 was observed significantly higher hardness than other kimchi. During the fermentation period, hardness of SG groups and control were significantly decreased but XG groups were similar to initial level. Cohesiveness was not significantly different between the control group and the treated groups. Gumminess was not significantly different between the control group and the XG groups. Chewiness increased over the fermentation period, which was quite similar to the results of Ku et al. (9), in which chewiness was somewhat higher in the group containing sugar alcohol sorbitol than in the control group. On Day 28, chewiness decreased in the control group and the SG-0.05 but the difference was not significant. Kim et al. (27) reported that the chewiness of *kkakdugi* decreased with the increase of the edible period, but our result shows that the addition of xylitol extends the shelf life by increasing chewiness compared to the control group. As xylitol improves the texture of kimchi in the process of fermentation, we expect

Table 3. Color value of kimchi containing cultured wild ginseng root and xylitol during storage at 4°C

Hunter value	Fermented period (day)	Treatments[1)]					
		Control	SG-0.05	SG-0.1	XG-0.05	XG-0.1	F-value
L	0	33.09±0.12$^{bA2-4)}$	34.06±0.16^{aA}	33.11±0.62^{bA}	32.76±0.16^{bA}	32.71±0.23^{b}	8.80**
	7	33.16±0.32^{A}	33.24±0.11^{B}	32.86±0.18^{A}	32.92±0.30^{A}	33.02±0.11	1.49
	14	33.31±0.28^{A}	33.44±0.04^{B}	33.27±1.00^{A}	32.80±0.13^{A}	33.95±0.63	1.69
	21	33.38±0.10^{aA}	33.41±0.27^{aB}	32.84±0.05^{cA}	32.98±0.04^{bcA}	33.10±0.04^{b}	10.65***
	28	31.67±0.37^{B}	31.47±0.17^{C}	31.26±0.20^{B}	31.45±0.55^{B}	32.15±1.05	1.07
	F-value	22.32***	99.269***	7.35**	13.89***	0.03$^{NS5)}$	
a	0	5.45±0.18^{aB}	4.78±0.03^{bcC}	4.67±0.23^{cC}	5.13±0.17^{abC}	5.03±0.33^{aC}	8.38**
	7	6.36±0.06^{bA}	6.22±0.01^{bAB}	5.53±0.27^{aB}	5.62±0.19^{aAB}	5.92±0.37^{aAB}	13.32***
	14	6.17±0.30^{aA}	5.86±0.30^{abB}	5.30±0.23^{bB}	5.30±0.34^{bBC}	5.56±0.38^{abB}	4.06*
	21	6.18±0.59^{A}	6.24±0.28^{AB}	5.58±0.13^{B}	5.64±0.13^{AB}	5.74±0.08^{AB}	3.09
	28	6.52±0.13^{bA}	6.55±0.16^{aA}	6.08±0.02^{eA}	5.78±0.15^{cA}	6.05±0.09^{dA}	21.55***
	F-value	5.14*	36.76***	21.68***	4.15**	8.05**	
b	0	5.67±0.30^{b}	6.66±0.07^{aA}	5.94±0.82^{ab}	5.30±0.18^{bAB}	5.43±0.29^{b}	4.99*
	7	5.90±0.17^{a}	5.90±0.04^{aB}	5.30±0.09^{b}	5.44±0.13^{bA}	5.45±0.03^{b}	20.342**
	14	5.68±0.03	5.29±0.27^{D}	5.06±0.73	4.88±0.38^{B}	5.29±0.68	*
	21	5.67±0.64	5.49±0.28^{CD}	5.05±0.18	5.16±0.078^{AB}	5.43±0.06	1.13
	28	6.12±0.22^{a}	5.82±0.11^{aBC}	5.42±0.17^{b}	5.35±0.22^{bA}	5.20±0.23^{b}	1.79
	F-value	1.039^{NS}	24.13***	1.75^{NS}	3.00^{NS}	0.28^{NS}	11.06***
ΔE	0	0.29±0.11^{bC}	1.55±0.07^{aB}	1.17±0.18^{aB}	0.61±0.31^{bB}	0.58±0.33^{bAB}	
	7	0.98±0.10^{aB}	0.82±0.02^{aCD}	0.48±0.15^{bB}	0.46±0.15^{bB}	0.47±0.15^{bAB}	13.21***
	14	0.79±0.23^{B}	0.74±0.08^{D}	1.01±0.86^{B}	0.88±0.45^{B}	1.10±0.74^{AB}	11.50***
	21	0.97±0.52^{B}	0.95±0.13^{C}	0.69±0.18^{B}	0.57±0.02^{B}	0.33±0.28^{B}	0.21
	28	1.87±0.16^{A}	1.96±0.07^{A}	1.96±0.02^{A}	1.71±0.55^{A}	1.37±0.75^{A}	2.68
	F-value	12.99***	92.93***	6.19**	6.20*	2.23	0.984

1)Control, non added with cultured wild ginseng root or xylitol; SG-0.05 or 0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or 0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).
2)Values are mean±SD, n=3.
3)Means with different superscripts (a-e) in a row are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
4)Means with different superscripts (A-D) in a column are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
5)Not significant.

Table 4. Texture of kimchi containing cultured wild ginseng root and xylitol during storage at 4°C

	Fermented period (day)	Treatments[1)]					
		Control	SG-0.05	SG-0.1	XG-0.05	XG-0.1	F-value
Hardness (g/cm^2)	0	2001.66±113.96$^{2)}$	1927.53±87.04	2044.33±69.21$^{A4)}$	2088.56±77.87	1989.34±63.81^{B}	1.43
	14	1896.24±8.34$^{c3)}$	1891.71±29.13^{c}	2018.01±29.13^{bcA}	2237.76±132.43^{a}	2034.32±37.38^{bB}	12.26***
	28	1767.31±35.59^{c}	1873.04±56.45^{bc}	1864.17±30.98^{bcB}	2056.55±210.75^{ab}	2167.58±8.97^{aA}	4.27*
	F-value	5.77	0.54	15.31**	1.24	10.11*	
Cohesiveness (%)	0	0.16±0.02	0.14±0.03^{B}	0.13±0.02	0.13±0.05	0.13±0.02	0.57
	14	0.14±0.02	0.13±0.04^{A}	0.13±0.04	0.12±0.05	0.28±0.21	1.27
	28	0.11±0.02	0.19±0.01^{A}	0.20±0.04	0.21±0.11	0.21±0.11	2.46
	F-value	2.58	4.91*	2.02	2.43	0.60	
Gumminess (g)	0	349.63±58.77^{A}	274.98±51.67^{A}	269.50±47.85	294.28±113.94	253.36±40.99	0.70
	14	248.72±39.69^{AB}	308.41±36.79^{A}	268.45±101.30	269.35±80.26	660.64±394.22	2.25
	28	189.49±38.89^{B}	164.51±10.61^{B}	365.29±87.27	430.48±130.46	448.72±246.26	2.50
	F-value	5.26	7.95*	1.22	1.86	1.09	
Chewiness (g)	0	318.15±30.99	233.60±60.09	206.43±103.02	269.20±121.27	208.16±9.68	0.26$^{NS5)}$
	14	260.88±47.57	229.00±79.58	164.78±100.74	221.94±89.36	560.47±308.66	2.81^{NS}
	28	189.49±38.89	132.78±10.68	306.95±48.51	404.04±116.23	365.65±229.27	2.89^{NS}
	F-value	2.50	1.82	2.22	2.22	1.26	

1)Control, non added with cultured wild ginseng root or xylitol; SG-0.05 or 0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or 0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).
2)Values are mean±SD, n=3.
3)Means with different superscripts (a-c) in a row are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
4)Means with different superscripts (A,B) in a column are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
5)Not significant.

Table 5. Changes in total bacteria and lactic acid bacteria of kimchi containing cultured wild ginseng root and xylitol during storage at 4°C (unit: log CFU/g)

	Fermented period (day)	Treatments[1)]					
		Control	SG-0.05	SG-0.1	XG-0.05	XG-0.1	F-value
Total bacteria	0	4.88±0.01[cA2-4)]	4.74±0.17[eA]	4.99±0.08[eA]	4.55±0.08[eB]	4.89±0.05[dA]	21.05**
	7	7.18±0.76[bA]	7.10±0.01[dA]	6.93±0.04[dB]	6.84±0.06[dBC]	6.76±0.10[cC]	17.89**
	14	8.63±0.05[aA]	8.68±0.05[aA]	8.70±0.00[aA]	8.27±0.72[aB]	8.20±0.12[bB]	35.74***
	21	8.24±0.02[aA]	8.19±0.02[aA]	8.29±0.02[bA]	7.94±0.15[bB]	7.65±0.10[bB]	71.84***
	28	7.90±0.05[aA]	7.86±0.02[cA]	7.80±0.04[cA]	7.60±0.03[cB]	7.59±0.08[bB]	17.66**
	F-value	2778.41***	23798.3***	2147.32***	945.22***	412.68***	10.97*
Lactic acid bacteria	0	3.99±0.01[eBC]	4.06±0.03[dAB]	3.89±0.06[eD]	3.96±0.03[dCD]	4.10±0.02[dA]	
	7	6.17±0.04[d]	6.16±0.14[c]	6.05±0.02[d]	6.15±0.02[c]	6.28±0.05[c]	2.68[NS5)]
	14	7.70±0.08[aA]	7.69±0.14[aA]	7.70±0.01[aA]	7.69±0.01[aA]	7.47±0.08[aB]	3.06[NS]
	21	7.35±0.01[bB]	7.60±0.08[aA]	7.44±0.01[bB]	7.22±0.06[bC]	7.14±0.04[bC]	30.16**
	28	7.08±0.10[cA]	6.82±0.12[bB]	7.08±0.01[cA]	7.21±0.01[bA]	7.04±0.03[bA]	7.57*
	F-value	1238.95***	359.25***	5505.91***	4530.23***	1438.39***	

[1)]Control, non added with cultured wild ginseng root or xylitol; SG-0.05 or 0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or 0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).
[2)]Values are mean±SD, n=3.
[3)]Means with different superscripts (a-e) in a row are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
[4)]Means with different superscripts (A-D) in a column are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
[5)]Not significant.

a texture extension effect in kimchi containing xylitol compared to control.

Total bacteria and lactic acid bacteria

The results of total bacterial count and the lactic acid bacterial count in kimchi containing cultured wild ginseng and xylitol are shown in Table 5. The total bacterial count increased most on Day 14 and decreased on Day 28 similarly to the tendency reported by Moon et al. (20). On Day 14, the total bacterial count was significantly higher in the control and the SG groups than in the XG groups, and the same tendency was observed also on Day 28. The lactic acid bacterial count just after preparation was 3.89~4.10 log CFU/g, and was highest in the SG-0.1 group. Total bacterial count of SG groups was higher than that of XG groups. The lactic acid bacterial count reached the highest level on Day 14 showing optimal fermentation, and decreased significantly on Day 21 and 28 (P<0.001). The total bacterial count of XG groups was lower than the SG groups but the lactic acid bacterial count of SG groups was not significantly different compared to the other groups. This is consistent with the report of Chae and Jhon (10) that xylitol were used prebiotics in the intestines and improved the functionality of kimchi.

Sensory evaluation

The QDA score of the color, flavor, carbohydrate taste, spicy taste, sweet taste, sour taste, salty taste, and texture of optimally fermented kimchi are shown in Fig. 5. The flavor of cultured wild ginseng was higher than in the control group, but spicy taste was similar regardless

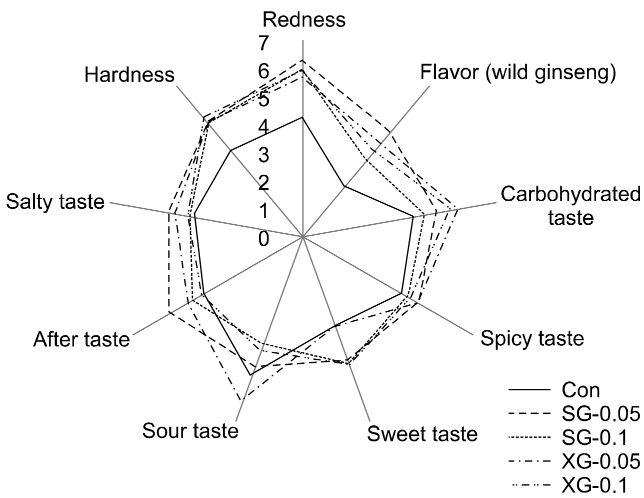

Fig. 5. QDA profiles of kimchi containing cultured wild-ginseng root and xylitol during storage at 4°C. Con, non added with cultured wild ginseng root or xylitol; SG-0.05 or SG-0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or XG-0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).

of treatment. Sweet taste was somewhat higher in the SG groups, and sour taste was not different among the groups, suggesting that xylitol does not affect sour taste. The reducing sugar content was low in XG groups, but according to the results of sensory test in Table 6, sweet taste and salty taste were not significantly different, and carbonated taste was significantly different in the XG groups (P<0.05). Texture was particularly higher in the XG groups as a substitute for sugar. In conclusion, the XG groups were somewhat higher than the SG groups in sensory preference.

Table 6. Sensory evaluation of kimchi containing cultured wild ginseng root and xylitol during storage at 4°C

	Fermented period (day)	Treatments[1)]					
		Control	SG-0.05	SG-0.1	XG-0.05	XG-0.1	F-value
Color	0	3.15±1.64$^{2)B3)}$	6.63±1.16	6.37±1.42	6.68±1.92^{A}	6.47±1.65^{AB}	0.63$^{NS5)}$
	14	4.23±1.36$^{b4)B}$	5.92±1.38^{a}	5.46±1.26^{a}	5.39±1.39^{aAB}	5.77±1.36^{aB}	3.14*
	28	5.50±1.29^{bA}	5.92±1.94^{a}	6.36±1.45^{a}	5.57±1.01^{aB}	7.23±1.09^{aA}	3.43*
	F-value	10.309***	1.24	1.97	3.43*	3.55*	
Flavor	0	3.79±1.34^{aB}	5.79±1.36^{b}	5.53±1.17^{b}	6.21±1.32^{bA}	5.47±1.84^{b}	4.24**
	14	4.15±1.63^{B}	5.00±1.35	5.00±1.41	4.92±1.55^{AB}	5.15±1.57	0.90^{NS}
	28	5.29±0.73^{abA}	5.64±1.39^{ab}	5.00±1.47^{b}	5.64±1.28^{abB}	6.31±1.34^{a}	1.98^{NS}
	F-value	5.463**	1.37	0.87	3.39*	2.04^{NS}	
Taste	0	5.85±1.36^{A}	6.00±1.49^{A}	5.05±1.72	5.95±1.20	5.68±1.67^{AB}	1.41
	14	3.40±1.35^{bA}	4.69±1.44^{aB}	5.00±1.86^{a}	5.00±1.35^{a}	4.83±1.53^{aB}	2.05
	28	5.14±1.61^{A}	5.55±1.87^{AB}	5.14±1.75	5.42±1.40	6.29±1.44^{A}	1.98^{NS}
	F-value	7.96***	2.58*	0.02	1.08^{NS}	2.80	
Texture	0	4.63±1.42^{B}	5.94±1.62	6.00±1.29	6.58±1.34^{A}	6.11±1.44	0.67
	14	4.27±1.19^{bB}	5.08±1.32^{ab}	5.15±1.28^{ab}	5.15±1.28^{abB}	5.62±1.39^{a}	1.64
	28	5.71±1.38^{A}	5.71±1.77	5.78±1.72	5.64±1.33^{AB}	5.86±1.84	0.02^{NS}
	F-value	4.067*	1.18	1.39	4.82	0.38^{NS}	
Overall acceptability	0	3.42±1.26^{B}	5.74±1.63	5.42±1.47	6.16±2.03	5.95±1.58^{AB}	1.07
	14	3.73±1.01^{bB}	5.08±1.38^{a}	4.92±1.75^{a}	5.54±1.27^{a}	4.92±1.50^{aB}	2.60*
	28	5.57±1.02^{A}	5.07±2.20	5.36±1.72	5.71±1.44	6.29±1.49^{A}	0.99^{NS}
	F-value	15.815***	0.79	0.42^{NS}	0.59^{NS}	2.91	

[1)]Control, non added with cultured wild ginseng root or xylitol; SG-0.05 or 0.1, added with sugar and cultured wild ginseng root (0.05% or 0.1%); XG-0.05 or 0.1, added with xylitol and cultured wild ginseng root (0.05% or 0.1%).
[2)]Values are mean±SD, n=3.
[3)]Means with different superscripts (A,B) in a column are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
[4)]Means with different superscripts (a,b) in a row are significantly different (P<0.05) by the Duncan's multiple range test. *P<0.05, **P<0.01, ***P<0.001.
[5)]Not significant.

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

REFERENCES

1. Hahn YS, Oh JY, Kim YJ. 2002. Characteristics of low-salt kimchi prepared with salt replacement during fermentation. *Korean J Food Sci Technol* 34: 647-651.
2. Jang SY, Jeong YJ. 2005. Effect of chitosan-liquid calcium addition on the quality of kimchi during fermentation. *J Korean Soc Food Sci Nutr* 34: 715-720.
3. Choi EJ, Cho SH. 2009. Effects of onion and pear on *kimchi* quality characteristics during fermentation. *Korean J Food Cookery Sci* 25: 243-251.
4. Hawer WD, Ha JH, Seo HN, Nam YJ, Shin DW. 1998. Changes in the taste and flavour compounds of kimchi during fermentation. *Korean J Food Sci Technol* 20: 511-517.
5. Born P, Zech J, Stark M, Classen M, Lorenz R. 1994. Carbohydrate substitutes: comparative study of intestinal absorption of fructose, sorbitol and xylitol. *Med Klin (Munich)* 89: 575-578.
6. Scheie AA, Fejerskov O, Danielsen B. 1998. The effects of xylitol-containing chewing gums on dental plaque and acidogenic potential. *J Dent Res* 77: 1547-1552.
7. Kim DK, Kim SY, Lee JK, Noh BS. 2000. Effects of xylose and xylitol on the organic acid fermentation of *kimchi*. *Korean J Food Technol* 32: 889-895.
8. Moon SW, Shin HK, Gi GE. 2003. Effects of xylitol and grapefruit seed extract on sensory value and fermentation of *baechu kimchi*. *Korean J Food Sci Technol* 35: 246-253.
9. Ku KH, Cho JS, Park WS, Nam YJ. 1999. Effects of sorbitol and sugar sources on the fermentation and sensory properties of *baechu kimchi*. *Korean J Food Sci Technol* 31: 794-801.
10. Chae MH, Jhon DY. 2007. Effects of commercial fructooligosaccharides on bifidobacteria *kimchi* fermentaion. *Korean J Food Sci Technol* 39: 61-65.
11. Li H, Lee JH, Ha JM. 2008. Effective purification of ginsenosides from cultured wild ginseng roots, red ginseng, and white ginseng with macroporous resins. *J Microbiol Biotechnol* 18: 1789-1791
12. Jeong HS, Kang TS, Woo KS, Paek KY, Yu KW, Yang SJ. 2005. Effects of cultured wild ginseng roots on the alcoholic fermentation. *Korean J Food Preserv* 12: 402-410.
13. Jung BM, Kim SM, Jung HJ, Lee KJ, Han GS, Park HP, Park GW. 2011. Kimchi containing cultured wild ginseng root and xylitol. *Korean Patent* 10-1038752.
14. Lee HG, Lee IS, Oh SR, Kim DS, Jung GY, Kim JH. 2001. Antagonists for platelet-activating factor receptor binding, comprising (20S)-ginsenoside Rg3 and/or ginsenoside Rg5. *Korean Patent* 10-0302064.
15. Han KY, Noh BS. 1996. Characterization of Chinese cabbage during soaking in sodium chloride solution. *Korean J Food Sci Technol* 28: 707-713.
16. Miller GL. 1959. Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Anal Chem* 31: 426-428.
17. Blios MS. 1958. Antioxidant determination by the use of stable free radical. *Nature* 181: 1199-1200.
18. Kim HR, Kim MR. 2010. Effect of traditional salt on the quality characteristics and growth of microorganism from *kimchi*. *Korean J Food Culture* 25: 61-69.
19. Park HO, Sohn CY. 2009. Effect of sweeteners on the quality properties of *kakdugi*. *Korean J Food Nutr* 22: 443-448.

20. Moon SW, Jang MS. 2004. Effect of xylitol on the taste and fermentation of *dongchimi*. *Korean J Food Cookery Sci* 20: 42-48.
21. Lee HO, Lee HJ, Woo SJ. 1994. Effect of cooked glutinous rice flour and soused shrimp on the changes of free amino acid, total vitamin C and ascorbic acid contents during *kimchi* fermentation. *Korean J Food Cookery Sci* 10: 225-231.
22. Lee KJ, Kim HY. 2011. The physico-chemical and sensory characteristics of *kakdoogi* containing *Hydrangea serrata* SERINGE extract. *Korean J Community Living* Sci 22: 211-222.
23. Hong MH, Lim HK, Park JE, Jun NJ, Lee YJ, Cho M, Kim SM. 2008. The antihypertensive and vasodilating effects of adventitious root extracts of wild ginseng. *J Korean Soc Appl Biol Chem* 51: 102-107.
24. Kwon MJ, Chun JH, Song YS, Song YO. 1999. Daily kimchi consumption and its hypolipidemic effect in middle-aged men. *J Korean Soc Food Sci Nutr* 28: 1144-1150.
25. Lee YO, Park KY, Cheigh HS. 1996. Antioxidative effect of kimchi various fermetation period on the lipid oxidation of cooked ground meat. *J Korean Soc Food Nutr* 25: 261-266.
26. Mo EK, Kim SM, Yun BS, Yang SA, JeGal SA, Choi YS, Ly SY, Sung CK. 2010. Quality properties of baechu kimchi treated with black *Panax ginseng* extracts during fermentation at low temperature. *Korean J Food Preserv* 17: 182-189.
27. Kim HY, Kim BC, Kim MR. 2001. Physicochemical and sensory properties of *Kakdugi* added with various thickening agents during fermentation. *J Korean Soc Food Sci Nutr* 30: 1060-1067.