J Food Sci Nutr
Vol 15, p 152～158 (2010)
DOI: 10.3746/jfn.2010.15.2.152

J Food Science and Nutrition

Determination of Suitable Kohlrabi (*Brassica oleracea* var. *gongylodes*) Cultivars for Pickle Preparation

－ Research Note －

Myung-Ki Lee[1†], Hye-Jung Yang[1], Su-Kyung Kim[1], Su-Hyoung Park[2], and Sung-Won Moon[3]

[1]*Traditional Food Research Group, Korea Food Research Institute, Gyeonggi 463-420, Korea*
[2]*National Institute of Horticultural & Herbal Science, RDA, Gyeonggi 440-706, Korea*
[3]*Department of Hotel Food Service, Youngdong University, Chungbuk 370-701, Korea*

Abstract

This study was designed to determine the best cultivar of kohlrabi for making pickles among KM-1 (Worldcol), KM-2 (Bejo), KM-3 (Takii), and KM-4 (Monsanto) cultivars. The initial pH of pickles was different in all cultivars; however, they all had a pH in the range of 3.81～3.86 after 28 days of storage. The pickles made from KM-4 had the lowest acidity, while there was no significant difference in acidity among the KM-1, KM-2, and KM-3 pickles. The salinity of all kohlrabi pickles was consistent during the storage period. The changes of color values were accelerated in the following order: KM-4>KM-1>KM-2>KM-3. Though kohlrabi pickles were non-fermented, the change in reducing sugar contents was similar to that of a fermented pickle. The highest value of reducing sugar content was found in pickles made with KM-4. In all cases, the firmness of the pickle decreased as time of storage increased. On the initial day, KM-4 pickle showed the highest firmness with 807.4 g. KM-4 also showed the highest firmness on the 28th day of storage with 602.3 g. In sensory evaluation, the KM-4 pickle exhibited the highest texture (hardness) among the pickles. The pickle made with the KM-4 cultivar showed relatively higher firmness of texture than other cultivars, suggesting that KM-4 could be utilized in other kinds of processed foods, in addition to being pickled.

Key words: kohlrabi (*Brassica oleracea* var. *gongylodes*) cultivars, monsanto, pickle, texture

INTRODUCTION

Various kinds of instant foods or junk foods are consumed because of their convenience and the tend towards the "Westernization" of lifestyles. However, eating too much junk food induces the adult-onset diseases, such as cardiovascular disease. Knowing the dangers associated with unhealthy foods, many people are trying to improve their eating habits (1). Recently, the idea of "slow foods" (healthier, home-cooked foods) has been spreading as a way to pursue a healthier life. The slow food movement also seeks to create a food culture based on various traditional foods (2). As a result, a variety of slow foods, including fermentation products such as kimchi and doenjang (fermented soybean paste), have been largely increased. Stored foods, such as kimchi, jjangachi and pickles are already fermented or salted for storing vegetables longer periods and especially pickles among them are popular in western as well as Asian (3).

Pickles, vegetables stored in high concentration of salt or acidic states, have similar appearance and processing methods with mul-kimchi or jjangachi in Korea and are also popular as side dishes. The kinds of vegetables used for pickling can vary according to areas of the country or seasons. Cucumber, onions, carrots, and cabbages are commonly used. Recently, beet, turnip, red pepper, mushroom, and ginger have also been used for pickling, with the goal of improving physiological properties and preferences obtained from those materials (4-6). However, the probiotic function of pickles caused by microorganisms like kimchi (fermented by lactic acid bacteria) in Korea is low, due to lower pH and higher concentration of salt. One of the problems with pickling foods is the reduction in quality because of the tissue softening that occurs during the storage period (7). The tissue softening is caused by the degradation of pectin in the vegetables. Interestingly, there is no change in the amount of total pectin, rather there is an increase in the amount of soluble pectin (8). Softening is caused by polygalacturonic acid: the basic structure of pectin is degraded by polygalacturonase. This enzyme can be made by aerobic microorganisms, but may also exist in the raw material itself, causing softening even in the absence of aerobic microorganisms (9). There are many ways to prevent the tissue softening, such as using sodium benzoate, controlling the pH (10), heat treatment for in-

†Corresponding author. E-mail: lmk123@kfri.re.kr
Phone: +82-31-780-9047, Fax: +82-31-780-9256

activation of enzymes (11), or adding calcium chloride for the hardening tissue (12). Additionally, choosing a specific cultivar that naturally has a firm texture that will undergo less change during storage is also a way to solve the softening problem.

Kohlrabi is a family of *Brassicacea* specialized from cabbage and a combination word between khol (cabbage) and rabic (turnip) as German. Kohlrabi has been harvested in northwestern parts of Europe since sixteen century and is consumed in Europe, North America, India, China, Vietnam, and some parts of Asia. Recently, kohlrabi has been harvested in Jeju Island in Korea and has become popular because of its nutritional values (high amounts of vitamin C and potassium). Kohlrabi is also popular as a diet food because of its high fiber, pectin, and cellulose levels. Kohlrabi has glucosylglycerides (13) as one of its phytochemicals and the glucosinolates from its flower (14) are being researched. Except for this, little is known about the kohlrabi. The recent interest in the natural benefits of kohlrabi suggests there may be interest in a pickle form of this vegetable. Therefore, this study investigated kohlrabi as a potential material for pickling, and its physicochemical and sensory properties were investigated to find the optimum cultivar of kohlrabi for pickles.

MATERIALS AND METHODS

Materials

The kohlrabi used in this study was harvested in June 2009, and obtained from the National Institute of Horticulture and Herbal Science at Rural Development Administration. We received four kohlrabi cultivars: Worldcol (KM-1), Bejo (KM-2), Takii (KM-3) and Monsanto (KM-4), which were stored at 5°C throughout the process. Bay salt (CJ, Korea), granulated sugar (CJ), and double-strength brewing vinegar (Daesang, Korea) were used as pickling ingredients. To enhance the taste of pickle, mixed pickling spice (ISFI, Belgium) with mustard seed, coriander, dill seed, cinnamon, bay leaf, clove, and black pepper was added. All other chemicals used in the experiment were analytical grade.

Preparation of pickles

The recipe used for pickling was a modified sweet pickle recipe (15,16), as follows: 10 g salt, 90 g granulated sugar and 10 g pickling spice were added to a mixture of 100 mL vinegar and 900 mL water and heated for 20 minutes. The final pH was 3.0 (before adding kohlrabi). The outside layers and leaves of the kohlrabi were removed and diced to the size of 1.5×1.5×1 cm. Diced kohlrabi (1 kg) was added to the pickling solution, which was cooled to 70°C, and stored in a heat resistant glass bottle. The glass bottle was sterilized through boiling and the completed pickles were stored at 10°C. A weekly analysis was conducted over a 28 day period.

Measurement of pH and titratable acidity

The pH was measured using a pH meter (Metrohm 827, USA) and 10 mL pickling solution. The titratable acidity was measured with that 10 mL of pickling solution by titrating with 0.1 N NaOH solution until a pH of 8.3 was reached. The titratable acidity was shown as a percentage of lactic acid converted from consumed NaOH solution.

Measurement of salinity

Salinity was measured using the Mohr method. 10% K_2CrO_4 0.5 mL (indicator) was added to 10 mL of 100 times dilution pickling solution and then titrated with a 0.02 N $AgNO_3$ solution. The reddish brown spots were end points to convert the titration value into salt content.

Measurement of color value

The color value was measured by grinding the kohlrabi at 13,000 rpm for 1 min using a blender (Ultra Turrax T25 basic, IKA labor, Malaysia) and measuring with a colorimeter (CR-300 series, Minolta, Japan). L (lightness), a (redness) and b (yellowness) values were measured and delta E (ΔE) values were calculated according to the Hunter system. The white board for the standard was L=97.57, a=0.00, b=1.79.

Interpretation of ΔE: The score range 0～0.5: no color differences, 0.5～1.5: a little color difference, 1.5～3.0: moderate color difference, 3.0～6.0: a noticeable difference, 6.0～12: absolutely noticeable difference, and more than 12: considered another kind of color (17).

$$\Delta E=[(L_s-L_o)^2+(a_s-a_o)^2+(b_s-b_o)^2]^{1/2}$$
$$=[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]^{1/2}$$

L_s, a_s, b_s = the color value of kohlrabi during storage
L_o, a_o, b_o = the color value of 0 day of kohlrabi after pickle preparation

Measurement of reducing sugar content (DNS method)

The reducing sugar was measured according to the DNS method. Ground kohlrabi (1 g) was diluted with distilled water and filtered using Whatman paper (No 1, Whatman, England). DNS reagent (3 mL) was added to 1 mL of filtered kohlrabi solution. After vortexing, the solution was heated in hot water for 5 min and left to cool to room temperature. After dilution with distilled water up to 16 mL, measurements were made using a UV-spectrometer (V-550, Jasco, Japan) at 550 nm.

Texture analysis (puncture test)

A puncture test was carried out to measure the firmness of the pickled kohlrabi during the storage period

with a texture analyzer (TAXT-s, Stable Micro Systems Ltd., England). The operating condition was 5 mm/s of pretest speed, 1 mm/s of test speed, 10 mm/s of posttest speed, 2 mm/s of puncture test speed, and 15 mm of distance. A piece of kohlrabi that was 15 mm wide and 10 mm high was placed on the pierced analyzer plate. The probe (2 mm diameter) was forced into the kohlrabi tissue at constant speed with 1 mm/s to penetrate kohlrabi on the center hole of the analyzer plate. The puncture test was replicated 10 times and the average force was calculated.

Sensory evaluation

Sensory evaluation for determining texture and intensity characteristics of pickling kohlrabi was conducted on the 28th day of storage. The evaluation was carried by 20 panelists and was categorized into appearance (brightness), smell (sour, sweet, off-flavor), taste (sour, sweet, off-taste), and texture (hardness). The evaluation was based on the 9-point scale from 1-point (extremely weak) to 9-points (extremely strong).

Statistical analysis

All general analyses were carried out in triplicate experiments, except for the puncture test and sensory evaluation. The result of the physicochemical characteristics measurements and sensory evaluations were analyzed by variance analysis (one-way ANOVA) using the Statistical Analysis System (SAS). The significant differences between samples were verified using Duncan's multiple range test (α=0.05).

RESULTS AND DISCUSSION

pH, titratable acidity and salinity

The changes of pH in four types of kohlrabi pickle were showed in Table 1. The initial pickling solution was adjusted to pH 3.0 and then, immediately following kohlrabi addition, was increased more than 1 unit. After this initial change, however, the pH did not show any significant differences during the storage process. This was similar to the results showing little pH change due to leaching components from ingredients during the storage period of kimchi, another type of pickled vegetable (18). Difference of initial pH values among the pickles is likely due to the different kohlrabi cultivars, because all the pickling solutions were adjusted to a pH of 3.0 before the addition of the kohlrabi. However, when the storage period passed, the pH of all samples similarly decreased, regardless of the cultivar. On the last day of storage, all pickles were in the range of pH 3.79～3.86, with no significant differences. Kohlrabi pickles have a slightly higher range of pH compared with other common pickles, which have a pH range of about 3.0～3.5; for example, the pH of cucumber pickles was 3.1 after storage at 25°C for 30 days (19). The kohlrabi pickle used in this experiment was made without lactic acid bacteria for fermentation, therefore during the storage period, the pH changes of the pickles were more gradual than general fermented pickle or mul-kimchi (20). Pickles made from turnips (*Brassica rapa*), in the same species with kohlrabi, showed a similar decreasing pH trend during storage (7).

Changes of titratable acidity in kohlrabi pickle were shown in Table 1. Prior to the addition of kohlrabi, the acidity of pickling solution was 1.41%, and after the addition of kohlrabi, all cultivars were measured in the range of 0.83～0.85%. All pickles displayed a trend of a slow increase in acidity up to 14 days of storage, after which the increase in acidity became greater, such that after 21 days of storage, the acidity of the four cultivars increased 0.1～0.2%. The increasing trend in acidity of

Table 1. Changes of pH, titratable acidity (TA) and salinity in pickle made with different cultivars of kohlrabi

Exam	Cultivar	Storage time (days)				
		0	7	14	21	28
pH	KM-1	4.08 ± 0.07^{a}	4.09 ± 0.05^{a}	3.96 ± 0.02^{a}	3.83 ± 0.03^{ab}	3.81 ± 0.06^{a}
	KM-2	3.98 ± 0.02^{bc}	3.95 ± 0.02^{c}	3.86 ± 0.03^{b}	3.80 ± 0.02^{b}	3.79 ± 0.07^{a}
	KM-3	4.06 ± 0.03^{ab}	4.03 ± 0.02^{b}	3.92 ± 0.04^{a}	3.85 ± 0.01^{a}	3.85 ± 0.02^{a}
	KM-4	3.98 ± 0.03^{c}	3.94 ± 0.01^{c}	3.92 ± 0.02^{a}	3.87 ± 0.01^{a}	3.86 ± 0.01^{a}
TA (%)	KM-1	0.85 ± 0.01^{a}	0.85 ± 0.02^{ab}	0.86 ± 0.03^{a}	0.95 ± 0.04^{a}	1.03 ± 0.02^{a}
	KM-2	0.83 ± 0.01^{ab}	0.86 ± 0.01^{ab}	0.87 ± 0.01^{a}	0.96 ± 0.01^{a}	1.01 ± 0.02^{a}
	KM-3	0.84 ± 0.01^{ab}	0.85 ± 0.01^{ab}	0.86 ± 0.01^{a}	0.97 ± 0.01^{a}	1.01 ± 0.03^{a}
	KM-4	0.83 ± 0.01^{b}	0.84 ± 0.01^{b}	0.85 ± 0.01^{a}	0.90 ± 0.02^{b}	0.94 ± 0.01^{b}
Salinity (%)	KM-1	0.78 ± 0.07^{b}	0.78 ± 0.03^{c}	0.80 ± 0.05^{b}	0.80 ± 0.09^{b}	0.76 ± 0.06^{b}
	KM-2	0.94 ± 0.02^{a}	0.93 ± 0.05^{b}	0.94 ± 0.04^{a}	0.90 ± 0.03^{ab}	0.90 ± 0.07^{a}
	KM-3	1.03 ± 0.03^{a}	1.05 ± 0.01^{a}	0.94 ± 0.06^{a}	0.90 ± 0.07^{ab}	0.92 ± 0.03^{a}
	KM-4	1.01 ± 0.02^{a}	1.01 ± 0.07^{ab}	0.99 ± 0.06^{a}	0.97 ± 0.02^{a}	0.98 ± 0.03^{b}

KM-1: Worldcol, KM-2: Bejo, KM-3: Takii, KM-4: Monsanto.
Different superscript letters in column indicate significant difference at α=0.05 as determined by Duncan's multiple range test.

pickle is caused by the acetic acid of vinegar absorbed in solid substance. The pH of general storage food, such as fermented pickles or non-fermented pickles, decreased during the storage time while acidity increased. In this experiment, the pace of acidity change was similar with the changes of pH in pickles (21,22). KM-4 pickles showed the lowest acidity on the 28 days of storage while KM-1, KM-2, and KM-3 pickles did not show significant differences.

The salinity of pickling solution before the addition of kohlrabi was 1.48%, and after adding kohlrabi, the initial salinity of all four pickles was as follows: KM-1 0.78%, KM-2 0.94%, KM-3 1.03%, and KM-4 1.01%. Only the KM-1 pickle was significantly different. All kohlrabi pickles had differing salinities during storage, but the changes did not any show definite patterns. During the 28 days of storage, the salinity of the pickles was observed to be similar to the initial day's measurement: KM-1 0.76%, KM-2 0.90%, KM-3 0.92%, and KM-4 0.98%, respectively. Similar to the observations of this experiment (Table 1), the salinity of kimchi was measured to be constant, regardless of the length of the storage period (23).

Color value

The lightness (L value) of the kohlrabi measured immediately after being pickled was in the range of 58.34～53.06%, with KM-1 and KM-4 being lighter than other pickles. The L value of kohlrabi pickles dimmed during storage, with the KM-3 cultivar showing the lightest value at the end of the storage period. KM-1 was at 47.50, KM-2 at 45.42, KM-3 at 49.56, and KM-4 at 46.17, respectively. After decreasing to half of the initial value in 14 days of storage, the yellowness value was then constant. Among all the samples, the redness values were similar and all decreased slightly, with a small decreasing ratio from 14 days of storage. (Table 2).

The ΔE value, change of color, showed differences among samples from 7 days of storage. After 7 days of storage, ΔE values ranged from 3.85～6.90, as visibly judged by the color difference compared with initial day of storage. As storage time increased, the ΔE values increased consistently, although KM-1 did not show any difference after 14 days of storage, KM-2 and KM-3 were increased slightly, and KM-4 increased after 28 days of storage. Changes of ΔE values were accelerated in the following order: KM-4>KM-1>KM-2>KM-3 (Table 2).

Reducing sugar content

The contents of reducing sugars were 37.45～39.43 mg/g in all four cultivars at the first day of storage. The reducing sugar content of kohlrabi measured by the Rural Development Administration was 21.34 mg/g, which was relatively lower than other pickles made in this study. The changes in reducing sugars were small until 7 days of storage and there were small differences of the reducing sugar content among cultivars though, mostly, the contents were highly decreased during 14～21 days of storage. KM-1 and KM-2 were at 8.02 mg/g and 7.79 mg/g, respectively, on 28 days of storage and these showed 50% lower values than KM-3 and KM-4 with 15.24 mg/g and 17.07 mg/g, respectively. The pattern of decreasing reducing sugar content of kohlrabi pickles was similar with that of fermented pickles, however, the pattern was different with non-fermented pickles (24,25).

Table 2. Changes of color value and ΔE in pickle made with different cultivars of kohlrabi

Color value	Cultivar	Storage time (days)				
		0	7	14	21	28
L	KM-1	57.76±0.35^{b}	55.43±0.44^{b}	49.12±1.20^{c}	48.68±0.45^{b}	47.50±0.11^{b}
	KM-2	53.06±1.32^{c}	50.39±1.01^{d}	47.71±0.56^{d}	47.49±0.56^{b}	45.42±0.24^{c}
	KM-3	54.21±0.86^{c}	52.88±0.51^{c}	52.41±0.12^{a}	50.97±0.11^{a}	49.56±0.44^{a}
	KM-4	58.34±0.24^{a}	57.01±0.24^{a}	51.21±0.55^{b}	50.99±0.48^{a}	46.17±0.90^{a}
a	KM-1	-2.57±0.18^{a}	-1.57±0.18^{a}	-0.97±0.02^{d}	-0.56±0.03^{a}	-0.64±0.05^{b}
	KM-2	-3.15±0.24^{b}	-1.82±0.64^{a}	-0.92±0.02^{c}	-0.85±0.04^{c}	-1.03±0.01^{c}
	KM-3	-2.18±0.50^{a}	-1.28±0.56^{a}	-0.89±0.02^{b}	-0.72±0.05^{b}	-0.65±0.03^{b}
	KM-4	-3.67±0.09^{b}	-2.67±0.09^{b}	-0.84±0.01^{a}	-0.75±0.04^{b}	-0.37±0.06^{a}
b	KM-1	11.58±0.45^{b}	9.58±0.45^{b}	5.38±0.10^{b}	5.73±0.07^{b}	4.78±0.03^{b}
	KM-2	10.34±0.78^{c}	8.67±0.45^{c}	4.70±0.04^{c}	5.38±0.12^{c}	5.56±0.08^{a}
	KM-3	9.17±0.10^{d}	8.17±0.10^{c}	5.26±0.13^{b}	6.22±0.15^{a}	5.35±0.07^{a}
	KM-4	13.29±0.47^{a}	10.96±0.12^{a}	5.57±0.02^{a}	5.62±0.03^{b}	4.42±0.22^{c}
ΔE	KM-1	0.48±0.13^{b}	5.18±0.25^{b}	10.75±0.18^{a}	10.98±0.36^{a}	11.12±2.56^{b}
	KM-2	1.25±0.27^{a}	6.09±0.53^{a}	5.55±1.16^{b}	8.08±0.14^{b}	9.26±0.23^{b}
	KM-3	0.80±0.20^{ab}	3.85±0.66^{c}	4.50±0.07^{b}	4.62±0.04^{c}	6.21±0.31^{c}
	KM-4	0.79±0.34^{ab}	6.90±0.08^{a}	7.44±2.88^{b}	10.89±0.03^{a}	15.43±0.83^{a}

Abbreviations are the same as in Table 1.
Different superscript letters in column indicate significant difference at α=0.05 as determined by Duncan's multiple range test.

The sugar added in pickles was non-reducing sugar, resulting in no effect on the content of reducing sugar. The difference in reducing sugar content resulted from the length of the storage period and from the different cultivars. KM-4 is the cultivar with the highest reducing sugar content in pickles (Table 3).

Texture analysis (puncture test)

KM-4 pickles showed the highest firmness (puncture force) with 807.4 g while KM-1 showed the lowest firmness with 673.5 g. Those measurements were taken as soon as the pickles were made (Table 4). The firmness decreased as the storage period increased, and KM-1, KM-2, KM-3, and KM-4 showed a firmness of 395.2 g, 445.2 g, 599.9 g, and 602.3 g, respectively, on the 28th day of storage. Firmness of KM-1 was decreased drastically upon 28 days of storage, compared with the earlier storage times. In contrast, the pickle prepared with KM-4 softened the least. According to the Rural Development Administration, kohlrabi is a hard textured vegetable, comparable to radish, and has firmer texture by as much as 35%. From the preliminary study, the comparison between pickles made by *Brassica rapa* (turnip) and kohlrabi showed that the former had a firmness of 687.1 g on the initial day, which was lower than the firmness of kohlrabi, with the exception of KM-1. It is important to keep a crunchy texture during the storage period to make a high quality pickle (26). Pickled vegetables that have a hard texture are better for storing for longer periods, because they do not get as soft during the storage time.

Sensory evaluation of pickles

In the sensory characteristic evaluation on 28 days of storage, the exterior brightness of all four cultivars was found to be similar and did not show significant differences. This result of sensory evaluation was different than that of the ΔE value from the colorimeter measurements (Table 2). On the 28th day, L-values were in the range of 45.42～49.56 without many differences among the samples. But the ΔE calculated from the L, a, and b values in the KM-4 sample was greatly changed, and the KM-4 was the darkest sample among different varieties. This difference between the sensory evaluation and the ΔE value is likely the result of how and when samples were examined. ΔE values were calculated during storage period, which could show the change of color in samples, but sensory evaluation was only carried out after 28 days of storage period. At that point, there was a similar L-value result (28th day) and panelists could not find any difference of brightness among samples. Further research is needed in the color change of samples during storage to find out the reason. In terms of the odor in pickles, KM-4 pickle showed significantly higher values of sweetness and KM-1 pickle had the highest sourness. Sweet, sour and off-taste are slightly different among all cultivars. The sweet and sour taste showed about 4～5 points while the off-taste showed lower about 2～3 points. In the intensity test of pickles, tastes with about 5 points were proper level. So, kohlrabi pickles were appropriate in balancing tastes among the sweet, sour, and off-taste. Results of the texture (hardness) in pickles were similar with the results of the texture in cultivars. KM-1 exhibited the lowest score of 5.33, meanwhile KM-4 was the hardest score of 6.89 and there is no significant difference between KM-2 and KM-3 (Table 5). Therefore, the pickle made with cultivar of

Table 3. Changes of reducing sugar content (mg/g) in pickle made with different cultivars of kohlrabi

Cultivar	Storage time (days)				
	0	7	14	21	28
KM-1	38.28±0.93^{a}	34.63±2.85^{a}	28.28±0.27^{b}	12.61±0.55^{c}	8.02±0.10^{c}
KM-2	37.45±1.99^{a}	36.33±5.70^{a}	28.39±0.24^{b}	11.89±0.14^{d}	7.79±0.44^{c}
KM-3	37.97±0.91^{a}	33.59±2.62^{a}	15.54±1.73^{c}	15.91±0.40^{b}	15.24±0.90^{b}
KM-4	39.43±4.01^{a}	37.04±2.95^{a}	30.69±0.43^{a}	17.14±0.12^{a}	17.07±0.38^{a}

Abbreviations are the same as in Table 1.
Different superscript letters in column indicate significant difference at α=0.05 as determined by Duncan's multiple range test.

Table 4. Changes of firmness (puncture force, g) in pickle made with different cultivars of kohlrabi

Cultivar	Storage time (days)				
	0	7	14	21	28
KM-1	673.5±38.8^{b}	631.9±71.5^{a}	610.0±60.0^{a}	561.1±35.8^{b}	395.2±52.2^{b}
KM-2	721.3±56.59^{ab}	641.3±44.63^{b}	650.0±90.8^{a}	550.1±94.7^{b}	445.2±112.0^{b}
KM-3	759.7±51.7^{ab}	677.7±68.2^{ab}	643.8±76.7^{a}	623.0±79.1^{ab}	599.9±117.8^{a}
KM-4	807.4±136.4^{a}	745.2±28.5^{a}	683.8±43.3^{a}	673.6±62.4^{a}	602.3±78.4^{a}

Abbreviations are the same as in Table 1.
Different superscript letters in column indicate significant difference at α=0.05 as determined by Duncan's multiple range test.

Table 5. Sensory evaluation of pickle made with different cultivars of kohlrabi

Item		Cultivar			
		KM-1	KM-2	KM-3	KM-4
Appearance (Brightness)		4.33±1.50[a]	4.67±1.80[a]	4.22±1.64[a]	4.11±1.27[a]
Odor	Sweet	4.67±1.94[ab]	3.78±1.30[b]	4.89±1.54[ab]	5.44±1.33[a]
	Sour	5.11±1.05[a]	3.56±1.51[b]	4.56±1.01[ab]	4.33±2.06[ab]
	Off-odor	2.89±1.62[a]	3.78±2.17[a]	2.56±1.01[a]	2.33±0.87[a]
Taste	Sweet	4.44±2.11[a]	4.78±1.39[a]	4.67±1.12[a]	5.33±1.00[a]
	Sour	6.11±1.27[a]	5.33±1.22[a]	5.33±1.00[a]	5.22±1.39[a]
	Off-taste	3.56±1.59[a]	4.11±2.03[a]	3.00±2.00[a]	3.11±1.69[a]
Texture (hardness)		5.33±1.22[b]	5.89±1.27[ab]	6.00±1.22[ab]	6.89±1.27[a]

Abbreviations are the same as in Table 1.
Different superscript letters in row indicate significant difference at α=0.05 as determined by Duncan's multiple range test.

KM-4 had a firmer texture than other cultivars during storage. Because of its desirable qualities as a pickle, it may also be advisable to develop other kinds of storage foods with KM-4 cultivar.

ACKNOWLEDGEMENT

This work was supported by the Korea Food Research Institute (KFRI). We appreciate to KFRI which sanctioned the project.

REFERENCES

1. Kim AJ, Han MR, Woo N, Kang SJ, Lee GS, Kim MH. 2008. Physicochemical properties of Korean ginseng pickles with Chija and Omija. *Korean J Food Nutr* 21: 524-529.
2. Collins P. 2006. Real slow food. *The New Scientist* 192: 63-65.
3. Park BH, Jeon ER, Kim SD, Cho HS. 2009. Changes in the quality characteristics of lotus root pickle with beet extract during storage. *J Korean Soc Food Sci Nutr* 38: 1124-1129.
4. Jeong JE, Shin JE, Hwang KJ, Lee JW, Kim SI. 2009. Changes in the components and acceptability of cucumber-hot pepper pickles during storage. *Korean J Food Cookery Sci* 25: 345-349.
5. Kim AJ, Han MR, Joung KH, Cho JC, Park WJ, Han CW, Chang KH. 2008. Physiological evaluation of Korea *Ginseng*, *Deoduk* and *Doragi* pickles. *Korean J Food Nutr* 21: 443-447.
6. Jun HA, Yoon JY, Hwang JS, Joo NM. 2004. Optimization on organoleptic characteristics of cauliflower pickles. *Korean J Food Culture* 19: 193-199.
7. Son EJ, OH SH, Heo OS, Kim MR. 2003. Physicochemical and sensory characteristics of turnip pickle added with chitosan during storage. *J Korean Soc Food Sci Nutr* 32: 1302-1309.
8. Bartolome LG, Hoff JE. 1972. Firming of potatoes: biochemical effects of preheating. *J Agric Food Chem* 20: 266-270.
9. Yook C. Chang K, Park KH, Ahn SY. 1985. Pre-heating treatment for prevention of tissue softening of radish root *kimchi*. *Korean J Food Sci Technol* 17: 447-453.
10. Fleming HP, Thompson RL, Mcfeeters RF. 1996. Assuring microbial and textural stability of fermented cucumbers by pH adjustment and sodium benzonate addition. *J Food Sci* 61: 832-836.
11. Mcfeeters RF, Fleming HP, Thompson RL. 1985. Pectinesterase activity pectin methyl methylation and texture changes during storage of blanched cucumber slices. *J Food Sci* 50: 201-205.
12. Fleming HP, Mcfeeters RF, Thompson RL. 1987. Effects of sodium chloride concentration on firmness retention of cucumbers fermented and stored with calcium chloride. *J Food Sci* 52: 653-657.
13. Lee JW, Han EH, Cho JG, Baek NI, Lee YH. 2009. Isolation of glucosylglycerides from the red kohlrabi sprouts (*Brassica oleracea* var. *gongylodes*). Abstract No. 162 presented at Annual Meeting of the Korean J Hort Sci Technol. Gyeongsang National University, Gyeongnam, Korea.
14. Gerendas J, Breuning S, Stahl T, Sundermann MV, Muhling KH. 2008. Isothiocyanate concentration in kohlrabi (*Brassica oleracea* L. var. *gongylodes*) plants as influenced by sulfur and nitrogen supply. *J Agric Food Chem* 56: 8334-8342.
15. Chadwick J. 1995. The busy person's guide to preserving foods. Story books, Vermont, USA. p 115-139.
16. Mustoe S. 2006. *Turkish cookery*. SAQI, England. p 40-157. London.
17. Ku KH, Park WS, Lee KA. 2005. Effects of process conditions on the color and firmness of salted radish root (*Danmooji*) at model system. *J Korean Soc Food Sci Nutr* 34: 1477-1484.
18. Jeong TS, Jeong EJ, Lee SH. 2008. Effects on the quality characteristics of *Mul-kimchi* with *Omija* (*Schizandra chinensis* Baillon) water extract. *J Korean Soc Food Sci Nutr* 37: 1301-1306.
19. Fleming HP, McFeeter RF, Daeschel Ma, Humphries EG, Thompson RL. 1988. Fermentation of cucumbers in anaerobic tack. *J Food Sci* 53: 127-133.
20. Yang YH, Park SH, Ann SM, Kim KM, Kim MR. 2005. Physicochemical and sensory characteristics of *Mul-kimchi* (Watery *Kimchi*) prepared with red cabbage. *J East Asian Soc Dietary Life* 15: 574-581.
21. Kim JG, Choi HS, Kim SS, Kim WJ. 1989. Changes in physicochemical and sensory qualities of Korean pickled cucumbers during fermentation. *Korean J Food Sci Technol* 21: 838-844.
22. Zhao D, Ding X. 2008. Studies on the low-salt Chinese

potherb mustard (*Brassica juncea,* Coss.) pickle. Ⅰ－The effect of a homofermentative L(+)-lactic acid producer *Bacillus coagulans* on starter culture in the low-salt Chinese potherb mustard pickle fermentation. *LWT* 41: 474-482.
23. Lim JW, Moon JS, Kim HD, Na DJ, Son JY. 2004. Changes quality characteristics of *Kimchi* by storage containers. *Korean J Food Nutr* 17: 80-85.
24. Fleming HP, Etcheoos JL, Thompson RL, Bell TA. 1975. Purging of CO_2 from cucumber brines to reduce bloater damage. *J Food Sci* 40: 1304-1310.
25. Der PW, Huang CB, Chi CP. 1988. Desalination of the spent brine from pickled prunes processing by electro-dialysis. *J Food Sci* 53: 134-137.
26. Oh YA, Lee MJ, Kim SD. 1990. Changes in the pectic substances during ripening of salted cucumber pickle. *J Korean Soc Food Nutr* 19: 143-150.

(Received March 16, 2010; Accepted May 28, 2010)