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Effect of Different Salt Concentrations and Temperatures on the Lactic Acid Fermentation of Radish Juice

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Abstract

The characteristics of natural lactic acid fermentation of radish juice were investigated at different salt concentrations (0～2%) and temperatures (10～30°C). Major lactic acid bacteria isolated from the radish juice fermented at 2% salt concentration were *Leuconostoc mesenteroides*, *Lactobacillus plantarum*, and *Lactobacillus brevis*. The percentage of lactic acid bacteria against total microbe in the fermented radish juice was over 80% at 0～1% salt concentrations, suggesting the possibility of fermentation even at low salt concentrations. The growth rate of lactic acid bacteria increased with the increase of temperature at 1% salt concentration, but was still active even at 10°C. The time to reach pH 4.0 during fermentation of juice of 1% salt concentration was 281～301 hrs at 10°C and 50～73 hrs at 30°C. The concentrations of sucrose and glucose in the fermented juice were low at high temperatures and were the lowest at a 1.0% salt concentration. However, the content of mannitol showed the opposite trend. Although sour taste, ripened taste, and acidic odor of the fermented juice showed no significant differences among various temperatures and salt concentrations, sensory values of ripened taste and sour acidic were high at high temperatures. The overall quality was the best at 1.0% salt concentration, irrespective of the temperature.

Key words: fermentation, radish, lactic acid bacteria, salt concentration, temperature

INTRODUCTION

Kimchi is a fermented food made by mixing salted vegetables with red pepper, garlic, ginger and other ingredients, and normal fermentation of *kimchi* is difficult without salt. By treating vegetables with salt, their cell structures become damaged, and the nutrients necessary for the growth of lactic acid bacteria were released. Thus, the size of *kimchi* material has a close relationship with the fermentation rate : the bigger the size of the material, the less damage to cell structure is done by salt, and the fermentation rate, as a result, is slower (1,2). In natural fermentation of *kimchi*, increasing the salt concentration is important because putrefaction can be induced if the fermentation rate is too slow. Thus, to prevent induction of putrefaction at lower salt concentration, promoting the lactic acid fermentation rate together with making the material size smaller or crushing the tissue are needed. Since *kimchi* is fermented naturally by bacteria such as *Achromobacter*, *Flavobacterium* and *Pseudomonas* present in soil or water (3), fungi and yeasts other than lactic acid bacteria are also found. Since *kimchi* is a food that causes people to ingest an excess amount of salt, lowering the salt concentration in *kimchi* is being emphasized more than ever before. Thus, in order to prepare *kimchi* that is more hygienic with less salt content, employment of a controlled fermentation system that uses a starter might be necessary. Until now, few studies has been done with radishes used to make *kimchi* or for lactic acid fermentation; however, various studies have been reported on the fermentation characteristics of radish varieties (4), on the changes in enzymes, microorganisms and physiochemical properties during the salting of "*Kakdugi*" made with radish (5,6), on the antimutagenic activities of radish juice (7), and on the characteristics of odor (8) and taste of "*Kakdugi*" made with different varieties of radish.

In this study, for the purpose of the possible use of radish containing growth promoting factor for a lactic acid bacteria as a medium of lactic acid bacteria during *kimchi* fermentation (9) in controlled fermentation system, the characteristics of the natural lactic acid fermentation of radish juice were investigated.

MATERIALS AND METHODS

Materials

Radishes (*Raphanus sativus* L.) weighing about 1 kg (harvested in fall, 1999), and Chunil salt were purchased from a local market.

Fermentation

Five hundred grams of the washed radish was shredded and crushed in a mixer (Goldstar GFM-S401, Korea). The crushed radish (radish juice) was fermented at salt concentrations of 0, 0.5, 1.0 and 2.0% in 1 L fermentation jars at 10, 20 and 30°C.

Isolation and identification of Lactobacilli

Lactic acid bacteria was isolated from radish juice samples containing 2% salt concentration at 10°C from fermentation day 2, 6, 10, and 14 using MRS agar (10) medium with 0.02%

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sodium azide. Identification of isolated strains was done by investigating their morphological, physiological and biochemical characteristics according to the methods of Bergey's Manuals (11,12).

Measurement of pH and titratable acidity

The juice was filtered with 3-ply cheese cloths. The pH of the filtrate was measured with a pH meter. The acidity of the filtrate was determined by a titration method using a 0.1N NaOH solution and expressed as a percentage of lactic acid (13).

Determination of free sugar

Fermented radish juice was centrifuged at 3,000 rpm for 20 min, and after filtering the supernatant with a 0.2 μm membrane filter, the juice was passed through a Sep-Pak C_{18} cartridge and analyzed with an HPLC (14). The conditions for analysis were waters associates (U6K Injector, M410 RI detector, M745 B data module), using carbohydrate column (3.9 mm i.d. × 30 cm) with the solvent of acetonitrile : water (78 : 22, v/v) at a speed of 1.5 ml/min with the injection volume of 5 μl.

Microbial analysis

Plate count agar (Difco) was used for determining the total viable counts. Lactic acid bacteria were determined on MRS agar (Difco) with 0.002% bromophenol blue (15). All plates were triplicates and incubated at 37°C for 48 hrs. The colony with dark blue in the center and an overall light blue color was presumptively identified as a *Lactobacillius* strain, and the colony with a dark blue color without a circle was identified as a *Leuconostoc* strain (16). Viable cell numbers were counted as colony forming units (cfu) per ml. The ratio of lactic acid bacteria was calculated as the percentage of lactic acid bacteria against total viable counts.

Sensory tests

Sensory tests were performed by 10 well-trained panels using a five points hedonic scale test method (17). The degrees of sour taste, ripened taste, and acidic odor were evaluated from very low (1 point) to very strong (5 point). Overall taste was evaluated from very poor (1 point) to very good (5 point).

RESULTS AND DISCUSSION

Lactobacilli of fermented radish juice

During fermentation of radish juice with 2% salt concentration, 2~5 strains showing the best growth in MRS media were isolated from the fermentation juice at 2, 6, 10 and 14 days. The general characteristics of these strains and the results of identification are shown in Table 1 and 2. As lactic acid bacteria related to the fermentation of radish juice, *Leuconostoc mesenteroides*, *Lactobacillus plantarum*, and *Lactobacillus brevis* were identified. Among these, *Leuconostoc mesenteroides* was seen from 2 days to 10 days of fermentation but was not observed at the 14th day. *Lactobacillus plantarum* was observed during the entire period of fermentation, but *Lactobacillus brevis* was observed from the 6th day to the 14th day of fermentation. These lactic acid bacteria are reported to be present in regular *kimchies* and different kinds of pickles (2,18). Besides these bacteria, *Pediococcus cerevisiae* and *Streptococcus faecalis* have been reported to be isolated from *kimchi*. In different kinds of *kimchi* prepared from radish with red pepper and garlic, *Lactobacillus plantarum*, *Lactobacillus pentosus*, *Leuconostoc citrum*, *Leuconostoc mesenteroides*, *Streptococcus facium* and *Lactobacillus brevis* were identified (19). However, somewhat different results were seen in the present study where only radish juice was used. Mheen and Kwon (2) reported that the major lactic acid bacteria in the fermentation of *kimchi* is *Leuconostoc mesenteroides*, and *Lactobacillus plantarum* has a close relationship with acidification (18). But *Lactobacillus plantarum* has the most strong antimicrobial activity, so it is the lactic acid bacteria that can raise the hygienic effect in *kimchi* (18).

Number of microorganisms

For radish juices fermented until pH dropped to 4.0 at different salt concentrations and fermentation temperatures, the numbers of total microbes and the lactic acid bacteria are shown in Table 3. Regardless of salt concentrations, the numbers of total microbes and the lactic acid bacteria all showed an increasing tendency with increasing temperatures. At temperatures of 10°C, 20°C, and 30°C, the numbers of total microbes and the lactic acid bacteria were the highest at a 1% salt concentration, and were the lowest in case of 0% salt concentration at 10°C and in case of 2% salt concentration at 20°C and 30°C. The ratio of lactic acid bacteria to total microbes was 87.9~95.1% at 10°C at 0.5~2.0% salt concentrations, showing a higher value than that 80.2% of the control (no salt); and at 20°C, the values were between 80.0~89.9% even in case of no salt, showing no significant difference. The ratio of lactic acid bacteria to total viable counts was higher in the case of salt concentrations between 0.5~2.0% compared to when no salt was added at 30°C. Even when no salt was added or a small amount of salt was added with the salt concentrations of 0.5~1.0%, when fermented in the range between 10~20°C, a high rate of lactic acid bacteria with more than 80% was shown, suggesting that the growth promoting factors of lactic acid bacteria are present in the radish juice (9). The numbers of *Lactobacillus* and *Leuconostoc*, the major lactic acid bacteria present in the fermented radish juice, are shown in Table 4. The number of *Lactobacillus* and *Leuconostoc* was highest at a 1.0% salt concentration regardless of the temperature. However as the temperature increased from 10°C to 30°C, the number of the bacteria tended to increase. The ratio of *Leuconostoc* to *Lactobacillus* was higher at 10°C than 20°C or 30°C regardless of the salt concentrations, and in comparison of salt concentrations, it was the highest at 1.0% salt concentration. The results reported by Ahn (20) and Pederson and Margaret (21) indicated that at a salt content below 3%, compared to when the salt content is higher, acid production was high and growth was active in *Leuconostoc mesenteroides*, and in *Lactobacillus plantarum*, even at salt concentrations of 5~8%, growth and acid production were active; and also in the present study, *Leuconostoc* showed higher a growth rate than *Lactobacillus* at a low temperature and salt concentration.

Table 1. The general characteristics of lactic acid bacteria isolated from fermented radish juice

Characteristics	Strain No												
	B-2	B-6	B-7	F-3	F-5	F-7	F-8	F-9	A-3	A-5	A-8	P-1	P-6
Cell form	cocci	rod	cocci	rod	rod	rod	cocci	rod	rod	cocci	rod	rod	rod
Spherical	+	-	+	-	-	-	+	-	-	+	-	-	-
Cell arragement (pairs and chains)	+	+	+	+	+	+	+	+	+	+	+	+	+
Gram stain	+	+	+	+	+	+	+	+	+	+	+	+	+
Mobility	-	-	-	-	-	-	-	-	-	-	-	-	-
Spore formation	-	-	-	-	-	-	-	-	-	-	-	-	-
Facultative anaerobic	+	+	+	+	+	+	+	+	+	+	+	+	+
Catalase	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxidase	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas formation from glucose	+	-	+	-	+	-	+	-	+	+	-	-	+
NH_3 from arginine	-	-	-	-	+	-	-	-	+	-	-	-	+
Dextran form sucrose	+	-	+	-	-	-	+	-	-	+	-	-	-
Growth at 10℃	+	+	+	+	+	+	+	+	+	+	+	+	+
Growth at 45℃	-	-	-	-	-	+	-	+	-	-	-	+	-
Growth at pH 3.6	-	+	-	+	+	+	+	+	+	+	+	+	+
Growth at pH 9.6	+	+	+	+	+	+	+	+	+	+	+	+	+
Growth in 6.5% NaCl	+	+	+	+	+	+	+	+	+	+	+	+	+
Growth in 10% ethanol	+	+	+	+	+	+	+	+	+	+	+	+	+
Acid from amygdalin	+	+	+	+	+	+	+	+	+	+	+	+	+
arabinose	+	+	+	+	+	+	+	+	+	+	+	+	+
arbutin	+	+	+	+	+	+	+	+	+	+	+	+	+
cellobiose	+	+	+	+	+	+	+	+	+	+	+	+	+
esculin	+	+	+	+	+	+	+	+	+	+	+	+	+
fructose	+	+	+	+	+	+	+	+	+	+	+	+	+
galactose	+	+	+	+	+	+	+	+	+	+	+	+	+
glucose	+	+	+	+	+	+	+	+	+	+	+	+	+
lactose	+	+	+	+	+	+	+	+	+	+	+	+	+
mannitol	+	+	+	+	+	+	+	+	+	+	+	+	+
mannose	+	+	+	+	+	+	+	+	+	+	+	+	+
raffinose	+	+	+	+	-	-	+	-	-	+	+	-	-
rhamnose	-	-	-	-	-	-	-	-	-	-	-	-	-
ribose	+	+	+	+	+	+	+	+	+	+	+	+	+
salicin	+	+	+	+	+	+	+	+	+	+	+	+	+
sucrose	+	+	+	+	+	+	+	+	+	+	+	+	+
trehalsoe	+	+	+	+	+	-	+	-	+	+	+	-	+
xylose	-	-	-	-	+	-	-	-	+	-	-	-	+

Symbols : +, positive ; -, negative

Table 2. Identification of lactic acid bacteria isolated from fermented radish juice

Fermentation days	Strain No	Identification
2	B-2	*Leuconostoc mesenteroides* subsp. mesenteroides
	B-6	*Lactobacillus plantarum*
	B-7	*Leuconostoc mesenteroides* subsp. mesenteroides
6	F-3	*Lactobacillus plantarum*
	F-5	*Lactobacillus brevis*
	F-7	*Lactobacillus plantarum*
	F-8	*Leuconostoc mesenteroides* subsp. mesenteroides
	F-9	*Lactobacillus plantarum*
10	A-3	*Lactobacillus brevis*
	A-5	*Leuconostoc mesenteroides* subsp. mesenteroides
	A-8	*Lactobacillus plantarum*
14	P-1	*Lactobacillus plantarum*
	P-6	*Lactobacillus brevis*

Fermentation hours

When radish juice was fermented at different salt concentrations and temperatures, the time required to reach pH 4.0 is shown in Table 5. Results showed that the time period is longer as the fermentation temperature is lower and the salt concentration is higher. The fermentation period at 10°C was shorter by adding salt than by adding no salt, and no definite difference was shown between salt concentrations. At 20°C, fermentation time to reach pH 4.0 was the shortest at 1.0% salt concentration (74.0 hrs). In no salt group and 0.5% salt group, the time was between 82.3~83.5 hrs, and in 2.0% salt group, the time took 101.4 hrs. However, at 30°C the time took between 50.4~59.2 hrs at 0~1.0% salt concentrations, showing no definite difference, but was 73.6 hrs at 2.0% salt concentration.

These results suggested that fermentation is achieved normally even in the case of radish juice with no salt. Especially, fermentation was faster at 1.0% than at 0.5% or 2.0% salt concentration. In the case of fermentation of vegetables including *kimchi*, the appropriate salt concentration is known to be 3% (22), and the edible limit in pH is about 4.0 (2). It was reported that the time period to reach this pH level is different according to salt concentrations and temperatures (2,22). With

Table 3. Total viable counts and lactic acid bacteria counts for radish juice fermented until the pH dropped to 4.0 (log cfu/ml)

Microbial counts	Concentration of salt (%)	Fermentation temperature (°C)		
		10	20	30
Total viable counts (T)	0	7.5 ± 0.6^{Aa}	9.1 ± 0.1^{Bb}	9.6 ± 0.1^{Bc}
	0.5	7.8 ± 0.6^{Ca}	9.3 ± 0.2^{Cb}	9.7 ± 0.0^{Bc}
	1.0	8.1 ± 0.0^{Da}	9.4 ± 0.0^{Db}	9.8 ± 0.0^{Cc}
	2.0	7.6 ± 0.0^{Ba}	8.7 ± 0.0^{Ab}	9.1 ± 0.0^{Ac}
Lactic acid bacteria (L)	0	7.4 ± 0.1^{Aa}	9.0 ± 0.0^{Bb}	9.4 ± 0.1^{Bc}
	0.5	7.7 ± 0.2^{Ca}	9.2 ± 0.0^{Cb}	9.6 ± 0.1^{Cc}
	1.0	8.0 ± 0.0^{Da}	9.4 ± 0.0^{Db}	9.7 ± 0.0^{Dc}
	2.0	7.6 ± 0.0^{ABa}	8.7 ± 0.1^{Ab}	9.0 ± 0.0^{Ac}
% of L/T	0	80.2 ± 7.4^{Ab}	80.0 ± 5.9^{Ab}	66.3 ± 4.9^{Aa}
	0.5	89.4 ± 8.7^{ABa}	86.9 ± 6.9^{Aa}	84.3 ± 6.7^{Ba}
	1.0	95.1 ± 3.4^{Ba}	89.9 ± 4.7^{Aa}	88.1 ± 7.1^{Ba}
	2.0	87.9 ± 7.2^{ABa}	85.8 ± 2.3^{Aa}	82.5 ± 3.1^{Ba}

Data represent mean±SD of three replicates. Different superscripts in the same column (A~D) and the same row (a~c) indicates a significant difference at $p<0.05$.

Table 4. Viable counts of *Lactobacillus* and *Leuconostoc* of radish juice fermented until the pH dropped to 4.0

Microbial counts	Concentration of salt (%)	Fermentation temperature (°C)		
		10	20	30
Lactobacillus (*Lac.*)	0	6.9 ± 0.2^{Aa}	8.5 ± 0.0^{Bb}	9.0 ± 0.0^{Bc}
	0.5	7.2 ± 0.1^{Ba}	8.7 ± 0.0^{Cb}	9.2 ± 0.0^{Cc}
	1.0	7.5 ± 0.1^{Ca}	8.9 ± 0.0^{Db}	9.3 ± 0.0^{Dc}
	2.0	7.1 ± 0.1^{ABa}	8.2 ± 0.0^{Ab}	8.6 ± 0.1^{Ac}
Leuconostoc (*Leu.*)	0	7.0 ± 0.2^{Aa}	8.6 ± 0.1^{Ab}	9.0 ± 0.0^{Bc}
	0.5	7.4 ± 0.3^{Aa}	8.9 ± 0.0^{Cb}	9.3 ± 0.0^{Cc}
	1.0	7.7 ± 0.1^{Ba}	9.1 ± 0.0^{Db}	9.4 ± 0.0^{Dc}
	2.0	7.2 ± 0.2^{Aa}	8.3 ± 0.1^{Ab}	8.7 ± 0.1^{Ac}
Leu./Lac.	0	1.4 ± 0.1^{Ab}	1.2 ± 0.1^{Aa}	1.1 ± 0.0^{Aa}
	0.5	1.5 ± 0.5^{Aa}	1.5 ± 0.0^{Ba}	1.3 ± 0.0^{Ca}
	1.0	1.6 ± 0.2^{Ab}	1.6 ± 0.0^{Bb}	1.3 ± 0.0^{Ca}
	2.0	1.5 ± 0.1^{Ab}	1.2 ± 0.1^{Aa}	1.2 ± 0.1^{Ba}

Values were represented mean±SD of three replicates. Different superscripts in same column (A~D) and same row (a~c) indicates significantly difference at $p<0.05$.

Table 5. Fermentation hours for radish juice until the pH dropped to 4.0

Concentration of salt (%)	Fermentation temperature (°C)		
	10	20	30
0	301.3 ± 5.4^{Bc}	83.5 ± 2.5^{Bb}	51.0 ± 5.4^{Aa}
0.5	286.2 ± 4.1^{Ac}	82.3 ± 3.5^{Bb}	59.2 ± 5.1^{Aa}
1.0	281.4 ± 4.3^{Ac}	74.0 ± 3.0^{Ab}	50.4 ± 4.2^{Aa}
2.0	289.7 ± 3.9^{Ac}	101.4 ± 4.2^{Cb}	73.6 ± 5.0^{Ba}

Data represent mean±SD of three replicates. Different superscripts in the same column (A~C) and the same row (a~c) indicates a significant difference at $p<0.05$.

regular "Dongchimi", the time period to reach pH 4.0 with 0~1.5% salt concentration at 10°C is known to be 144 hrs (23).

Changes in sugars

Table 6 shows the contents of sucrose, glucose, and mannitol of the radish juice fermented until pH 4.0 (24). The sucrose and glucose contents were lower at higher fermentation

Table 6. Free sugar content of radish juice fermented until the pH dropped to 4.0 (mg %)

Organic acids	Concentration of salt (%)	Fermentation temperature (°C)		
		10	20	30
Glucose	0	116.8 ± 2.7^{Dc}	82.0 ± 2.3^{Cb}	10.6 ± 0.9^{Ca}
	0.5	87.5 ± 2.7^{Cc}	28.3 ± 1.9^{Bb}	8.0 ± 0.5^{Ba}
	1.0	53.2 ± 3.0^{Ac}	15.0 ± 1.3^{Ab}	4.1 ± 0.7^{Aa}
	2.0	78.5 ± 2.6^{Bc}	17.2 ± 1.6^{Ab}	5.5 ± 0.9^{Aa}
Sucrose	0	1.0 ± 0.2^{Cc}	0.7 ± 0.1^{Cb}	0.3 ± 0.0^{Ba}
	0.5	0.8 ± 0.1^{Bb}	0.7 ± 0.0^{Cb}	0.1 ± 0.0^{Aa}
	1.0	0.4 ± 0.1^{Ab}	0.1 ± 0.0^{Aa}	0.1 ± 0.0^{Aa}
	2.0	0.7 ± 0.1^{Bc}	0.3 ± 0.0^{Ba}	0.4 ± 0.1^{Cb}
Mannitol	0	0.5 ± 0.1^{Aa}	8.1 ± 0.1^{Ab}	10.6 ± 1.0^{Ac}
	0.5	0.7 ± 0.1^{Ba}	9.9 ± 0.7^{Bb}	19.5 ± 1.3^{Bc}
	1.0	0.7 ± 0.2^{Ba}	11.3 ± 0.8^{Cb}	70.1 ± 3.8^{Cc}
	2.0	0.9 ± 0.1^{Ca}	7.2 ± 0.6^{Ab}	15.3 ± 3.1^{ABc}

Data represent mean±SD of three replicates. Different superscripts in the same column (A~D) and the same row (a~c) indicates a significant difference at $p<0.05$.

temperature, and at 1.0% salt concentration, the contents tended to be low. Also, the content of mannitol was higher at higher temperature and at 1.0% salt concentration. Considering that the contents of residual sugars have a close relationship with the degree of fermentation, these results suggested that at the time of radish juice fermentation, different varieties of lactic acid bacteria show different growth rates according to temperature and salt concentration. At the salt concentration of 1.0% especially, the residual sugar contents were low probably due to the promotion of fermentation. Although the contents of fermentable sugars in radish juice were different with the varieties of radish, in the case of fall radish, a study reported (4) that the content reaches to 4.0~5.3%, and the contents of reducing sugar in "*Kakdugi*" made with different varieties of radish were reported (8) to be higher in fall radish. However, no study was reported on changes in sugar types according to fermentation conditions.

Sensory quality

Table 7 shows the results of sensory quality until the fer-

Table 7. Sensory quality of the radish juice fermented until the pH dropped to 4.0

Attributes	Salt concentration (%)	Fermentation temperature (°C)		
		10	20	30
Sour taste	0	2.9 ± 1.0^{Aa}	2.3 ± 0.8^{Aa}	3.1 ± 1.0^{Aa}
	0.5	3.1 ± 0.5^{Aa}	2.7 ± 0.8^{Aa}	3.2 ± 0.4^{Aa}
	1.0	3.2 ± 0.5^{Aa}	3.5 ± 0.5^{Aa}	4.0 ± 0.7^{Aa}
	2.0	2.6 ± 0.4^{Aa}	3.3 ± 1.2^{Aa}	2.9 ± 0.5^{Aa}
Ripened taste	0	1.6 ± 0.7^{Aa}	2.1 ± 0.2^{Aa}	1.4 ± 0.4^{Aa}
	0.5	2.6 ± 0.5^{Ab}	3.1 ± 0.5^{Aa}	3.2 ± 0.4^{Ab}
	1.0	3.2 ± 0.6^{Ab}	3.0 ± 1.0^{Aa}	3.3 ± 0.2^{Ab}
	2.0	3.2 ± 0.5^{Ab}	2.3 ± 0.8^{Aa}	2.8 ± 0.5^{Ab}
Acidic odor	0	3.0 ± 0.8^{Aa}	2.6 ± 0.5^{Aa}	3.1 ± 1.0^{Aa}
	0.5	3.1 ± 0.7^{Aa}	3.0 ± 0.7^{Aa}	2.8 ± 0.2^{Aa}
	1.0	2.7 ± 0.6^{Aa}	2.5 ± 0.7^{Aa}	3.1 ± 0.3^{Aa}
	2.0	2.4 ± 0.6^{Aa}	2.2 ± 0.9^{Aa}	3.2 ± 0.2^{Aa}
Overall quality	0	2.6 ± 0.4^{Aa}	2.4 ± 0.5^{Ab}	2.3 ± 1.1^{Aa}
	0.5	2.5 ± 0.1^{Aa}	2.7 ± 0.5^{Ab}	2.9 ± 0.2^{Aab}
	1.0	3.1 ± 0.4^{AB}	2.4 ± 0.6^{Ab}	3.3 ± 0.3^{Bb}
	2.0	2.3 ± 0.3^{Cb}	1.2 ± 0.3^{Aa}	2.5 ± 0.3^{Bab}

Data represent mean ± SD of three replicates. Different superscripts in the same column (A ~ C) and the same row (a ~ b) indicates a significant difference at $p<0.05$. Degree of sour taste, ripened taste and acidic odor were evaluated from very low (1 point) to very strong (5 point) and overall quality was evaluated from very poor (1 point) to very good (5 point).

mented radish juice reached pH 4.0. Sour taste, ripening taste, and acidic odor did not show significant differences with changes in temperatures and salt concentrations. However, on the average, sour taste was higher in the groups with salt concentrations of 0.5 ~ 1.0% and at higher temperature; ripened taste and acidic odor were higher at higher temperatures in the no salt group, at 20°C in the group with 0.5% salt content, and at higher temperatures in the 1.0 ~ 2.0% salt added group. The overall quality was the best at 1.0% salt concentration regardless of temperatures. In the case of the no salt and the 2.0% salt added groups, the evaluated scores were low.

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