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Quality Characteristics of Low-Salt *Gochujang* Added with *Glycyrrhiza uralensis* and *Brassica juncea*

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Abstract

The effects of *Glycyrrhiza uralensis* and *Brassica juncea* on the quality and palatability of low-salt *gochujang* were investigated in terms of the microbial characteristics, enzyme activities, pH, acidity, amino nitrogen and sensory evaluation during 40 days of fermentation. The proliferation of fungi in low-salt *gochujang* with added *G. uralensis* and *B. juncea* were inhibited, while the numbers of total viable bacteria and lactic acid bacteria were not affected. In terms of α-amylase and β-amylase activity, no significant difference was observed by the salt concentration or additives. However, lowering the salt concentration increased protease activity. The amount of amino-nitrogen in low-salt *gochujang* at 20 days was similar to that in the control *gochujang* at 40 days. In the sensory test, low-salt *gochujang* was preferred compared to control *gochujang* (8.5% salt). Particularly, the 4.3% salt *gochujang* with additives was the most preferred.

Key words: *Glycyorrhiza uralensis*, *Brassica juncea*, low-salt, *gochujang*

INTRODUCTION

Gochujang (red pepper paste), Korea's starch-based fermented food made of glutinous rice and red pepper powder mixed with Koji and salt, has a unique taste and palatability attributed to the organic acid, alcohol, sugars, amino acids, and other byproducts created from the metabolism and fermentation of microbes. About 10% (w/w) salt is added to *gochujang* to give the food a salty taste and enhance storability by controlling the activities of microbes during fermentation. While salt plays a key role in maintaining the human body's homeostasis, excessive salt or sodium intake is known to cause or worsen high blood pressure and vascular, cardiac, or renal diseases (1-3). According to the Korea National Health and Nutrition Examination Survey, the average amount of sodium intake per person was 4,388 mg in 2007 and 4,553 mg in 2008, more than twice the 2,000 mg recommended amount of sodium intake by the World Health Organization (WHO) (4). To solve this problem, the Korea Food & Drug Administration (KFDA) established the Sodium Reduction Commission in 2010, which promotes the sodium reduction policy that seeks to reduce the average sodium intake per person by at least 10%. To achieve such a goal, it is important to examine the sodium intake pathway and promote sodium reduction by priority among main foods containing high sodium levels. Therefore, sodium reduction in paste foods, such as *gochujang* or *doenjang* (soy bean paste), which account for about 73% of Koreans' sodium intake, is an important measure (5). Additionally, *gochujang* has recently been registered as a codex food and discovered to function against obesity (6) and diabetes (7). To further promote such interest and develop *gochujang* as a global sauce, sodium reduction is essential. However, reducing the salt concentration in *gochujang* can lead to gas formation and deteriorated sensory quality during aging and storage. To solve such problems in manufacturing low-salt *gochujang*, many studies on quality and fermentation properties of *gochujang* with added alcohol and lactic acid (8), sake cake (9), horseradish (10), food preservatives (11), and gamma irradiation (12) have been attempted. However; the results of these studies have not been commercialized.

Glycyrrhiza uralensis, a plant with rich ethnobotanical history, is used as folk medicine both in European and Eastern countries. *Glycyrrhiza uralensis* ethanol extract has an antibacterial activity against *Staphylococcus aureus*, *Listeria monocytogenes*, *Streptococcus mutans* and *Bacillus subtilis* (13), while isolated liquiritigenin and liquiritin are also known to have anti-microbial functions (14). Allyl isothiocyanate, a component of *Burassica juncea*, has strong anti-fungal activity against yeast (15) and inhibits the growth of *Candida boidinii*, the cause of pellicle formation on the surface of *gochujang* (16). In a recent study, the shelf life of low-salt soybean paste was extended by adding *B. juncea*, *G. uralensis* and chitosan (17). Therefore, the purpose of this study was to examine

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the possibility of manufacturing low-salt *gochujang* by adding *B. juncea* powder and *G. uralensis* ethanol extract.

MATERIALS AND METHODS

Material and reagents

G. uralensis, meju, starch syrup, malt, red pepper powder, glutinous rice flour, and salt were purchased from Ilsin (Seoul, Korea) and whole *B. juncea* powder was ground from oriental *B. juncea* seeds #202 (G.S DUNNCO LTD., Ontario, Canada). All of the reagents were purchased from Junsei (Tokyo, Japan) and media were purchased from Difico (Detroit, MI, USA).

Extraction of *Glycyrrhiza uralensis*

Washed and added 1 kg of *G. uralensis* to 4 L of 85% ethanol for extraction using an extractor (Hanbak Scientific Co., Bucheon, Korea) at 40°C for 3 hr. The extract was filtered using Whatman No. 2 and was concentrated down to 3 L. This mixture was prepared for low-salt *gochujang*.

Low salt *gochujang* preparation

The mixing ratio for preparing *gochujang* according to the traditional methods of Moonokraega is given in Table 1. *Gochujangs* were divided into seven groups depending on the addition of salt, *G. uralensis* and *B. juncea*. Control was made with 8.5% salt, and low-salt *gochujangs* were added with 5.9%, 4.3% or 2.0% salt, and low salt *gochujangs* with additives were added with 0.8% of *G. uralensis* ethanol extract and 0.7% of *B. juncea* powder. The amount of added *G. uralensis* ethanol extract and *B. juncea* powder were determined in a pretest. At this concentration, *G. uralensis* ethanol extract and *B. juncea* powder did not affect the taste and flavor of *gochujang*. *Gochujangs* were fermented at 28°C for 50 days, and analyzed every 10 days.

Microbiological analysis

To enumerate the microorganism populations in *gochujang* samples, 25 g of the samples were aseptically transferred to sterile bags containing 225 mL of 0.85% NaCl and pummeled in stomacher (Tekmar Co., Los Angeles, CA, USA) for 2 min. The homogenates were serially diluted with 0.85% NaCl. The 1 mL of diluent was plated on petri dishes, with 15 mL of plate count agar (Difco Co.) for total bacteria, MRS containing 1% bromophenol for lactic acid bacteria, or potato dextrose agar for fungi poured over the diluent. After the media solidified, the plates were incubated at 37°C for 24 hr (for total bacterial and lactic acid bacteria) or at 30°C for 48 hr (for fungi) and the colonies were manually counted.

Enzyme activity

The extracts of *gochujang* (10 g each) were prepared by shaking in 100 mL distilled water for 30 min at room temperature. After centrifugation (Beckman Instruments, Inc., Palo Alto, CA, USA) at 3000 rpm for 10 min, the supernatant was filtered using Whatman No. 2 filter paper. Filtrate was then gathered for determination of amylase and protease activity. To measure α-amylase activity, Fuwa's colorimeric method (18) of iodine-starch color reaction was performed. 0.1 mL of filtrate was added to a mixture of 0.5 mL of 0.5% soluble starch and 4 mL of 0.04 M potassium phosphate buffer (pH 5.9). After the mixture was reacted at 25°C for 10 min, 0.1 mL of 0.1 N HCl was added to stop the reaction. A 0.1 mL aliquot of the reaction mixture was then mixed with 1 mL of 1/3,000 N iodine reagent. After incubating at room temperature for 20 min, the absorbance was measured at 660 nm using a UV-spectrophotometer (V560, Jasco, Tokyo, Japan). One unit of amylase activity was defined as the amount of enzyme that decreased the absorbance at 660 nm by 10% per 1 min. A β-amylase activity was determined by the dinitrosalicylic acid method (19), where a mixture of 0.1 mL of 1% soluble starch

Table 1. The mixing ratio of ingredients for the preparation of *gochujang* (unit: g)

	8.5%	5.9%	5.9%+LM[1)]	4.3%	4.3%+LM	2.0%	2.0%+LM
Meju	210	216	195	219	198	225	204
Water	1,248	1,284	1,260	1,305	1,281	1,338	1,314
Starch syrup	105	108	108	111	111	111	111
Malt	132	135	135	138	138	141	141
Red pepper powder	420	432	432	438	438	450	450
Glutinous rice flour	630	648	648	660	660	675	675
Salt	255 (8.5%)	177 (5.9%)	177 (5.9%)	129 (4.3%)	129 (4.3%)	60 (2%)	60 (2%)
B. juncea	–	–	21	–	21	–	21
G. uralensis extract	–	–	24	–	24	–	24
Total	3,000	3,000	3,000	3,000	3,000	3,000	3,000

[1)]LM: *G. uralensis* 0.8% and *B. juncea* 0.7%.

and 0.1 mL of 0.016 M sodium acetate buffer (pH 6.8) was added to 0.1 mL of the supernatant and warmed for 10 min at 30°C. Zero point three mL of dinitrosalicylic acid was added to the reaction mixture, and the activity level was determined as the absorbance at 550 nm using the UV-spectrophotometer. Using maltose as the standard, a unit of enzyme activity was expressed as the liberation of 1 mg of glucose per 1 mL of the supernatant. Protease activity was determined by modifying the Anson method (20). Zero point 5 mL of filtrate was added to 2 mL of 0.6% casein (pH 7.0), and reacted at 30°C for 30 min. The protease activity was then measured as the absorbance at 660 nm by a UV-spectrophotometer, and the units were expressed as the liberation of 1 μg of tyrosine per 1 mL of filtrate.

pH, acidity and amino nitrogen levels

Five g of *gochujang* was well mixed with 250 mL of distilled water for 1 hr at room temperature, and filtered using Whatman No. 2 filter paper. This filtrate was used for measurement of pH, acidity and amino nitrogen. The pH of test solution (50 mL) was measured using the pH meter (Orion 3 star, Thermo Electron Co., Beverly, MA, USA). Titratable acidity of test solution (50 mL) was determined as the titration volume in mL of 0.1 N NaOH needed to bring the pH to 8.4. For the amino nitrogen test, the pH of filtrate (50 mL) was adjusted to 8.4 using 0.1 N NaOH, and followed by the addition of 30 mL of 50% formalin. The pH was again adjusted to 8.4 with 0.01 N NaOH. The final titrated volume was used to calculate the amino nitrogen content. The distilled water was used as the blank test.

Color

Color of *gochujang* samples was determined using a colorimeter (CR-300, KONICA MINOLTA, Osaka, Japan) calibrated with a calibration plate (L^*=99.48, a^*=-0.07, b^*=-0.6).

Sensory evaluation

The low salt *gochujangs* were evaluated by ten panelists at 40 days. Seven samples were presented in random order. The samples were evaluated using a 9 point scale for color, flavor (savory, salt, unpleasant, sour), taste (savory, sweet, salt, sour), and overall palatability. The color, flavor, taste and overall palatability were evaluated as follows: very poor (1 point), moderate (5 point), very good (9 point). The savory, salty, unpleasant, and sour flavor and taste were evaluated as follows: very low (1 point), medium (5 point), very strong (9 point).

Statistical analysis

Statistical analysis was performed with SAS (Statistical Analysis System). Mean and standard deviations were calculated, and Tukey's multiple range tests were

Table 2. Changes in microbial population of low-salt *gochujang* added with *G. uralensis* and *B. juncea* during fermentation at 28°C (Unit: Log CFU/g)

		Fermentation time (day)					
		0	10	20	30	40	50
Total viable cell	8.5%	8.43±0.10^{AB}	8.44±0.18^{bAB}	8.49±0.10^{A}	8.35±0.07^{AB}	8.31±0.15^{aB}	8.04±0.13^{dC}
	5.9%	8.45±0.12^{A}	8.26±0.08^{cBC}	8.31±0.11^{B}	8.19±0.11^{CD}	8.12±0.08^{bD}	8.07±0.09^{cdD}
	5.9%+LM[1)]	8.29±0.06	8.26±0.15^{c}	8.29±0.14	8.19±0.10	8.28±0.02^{ab}	8.22±0.06^{ab}
	4.3%	8.35±0.20	8.26±0.14^{c}	8.32±0.09	8.30±0.16	8.32±0.18^{a}	8.20±0.11^{bc}
	4.3%+LM	8.30±0.07	8.25±0.15^{c}	8.27±0.22	8.26±0.13	8.27±0.16^{ab}	8.07±0.12^{cd}
	2.0%	8.43±0.21^{AB}	8.53±0.05^{abA}	8.42±0.05^{AB}	8.34±0.18^{B}	8.30±0.03^{aB}	8.27±0.07^{abB}
	2.0%+LM	8.33±0.08^{B}	8.67±0.10^{aA}	8.40±0.25^{B}	8.28±0.12^{B}	8.42±0.18^{aB}	8.34±0.13^{aB}
Fungi	8.5%	4.42±0.17^{bcA}	3.67±0.10^{cB}	3.45±0.20^{bC}	2.97±0.13^{bD}	2.79±0.08^{bE}	2.70±0.13^{bE}
	5.9%	4.43±0.27^{bcA}	3.44±0.08^{dB}	2.85±0.11^{cC}	2.95±0.03^{bC}	2.54±0.03^{cD}	ND^{cE}
	5.9%+LM	4.60±0.17^{abA}	ND^{fB}	ND^{eB}	ND^{dB}	ND^{eB}	ND^{cB}
	4.3%	4.69±0.03^{aA}	3.31±0.10^{eB}	2.26±0.24^{dD}	2.65±0.03^{cC}	1.65±0.03^{dE}	ND^{cF}
	4.3%+LM	4.36±0.21^{cA}	ND^{fB}	ND^{eB}	ND^{dB}	ND^{eB}	ND^{cB}
	2.0%	4.69±0.10^{aB}	4.49±0.10^{bC}	4.56±0.00^{aB}	4.11±0.13^{aD}	6.32±0.00^{aA}	6.14±0.03^{aA}
	2.0%+LM	4.55±0.16^{abcA}	4.04±0.01^{aA}	ND^{eB}	ND^{dB}	ND^{eB}	ND^{cB}
Lactic acid bacteria	8.5%	7.58±0.09^{abAB}	7.34±0.30^{eC}	7.72±0.15^{cA}	7.46±0.09^{cdBC}	7.58±0.15^{cAB}	7.28±0.06^{bC}
	5.9%	7.41±0.33^{bcC}	7.93±0.17^{bcA}	7.55±0.13^{dBC}	7.64±0.18^{abcBC}	7.72±0.04^{abcAB}	7.57±0.20^{aBC}
	5.9%+LM	7.34±0.02^{cBC}	7.65±0.16^{dA}	7.65±0.16^{cdA}	7.40±0.21^{dB}	7.60±0.08^{bcA}	7.21±0.14^{bC}
	4.3%	7.39±0.06^{bcC}	7.80±0.18^{cdA}	7.61±0.08^{cdB}	7.70±0.08^{abAB}	7.63±0.18^{bcAB}	7.57±0.20^{aB}
	4.3%+LM	7.55±0.06^{abcB}	7.79±0.05^{cdA}	7.58±0.14^{cdB}	7.49±0.02^{bcdB}	7.79±0.06^{aA}	7.33±0.08^{bC}
	2.0%	7.51±0.28^{abcE}	8.04±0.11^{bA}	7.92±0.05^{bAB}	7.84±0.08^{aBC}	7.72±0.09^{abcCD}	7.58±0.12^{aDE}
	2.0%+LM	7.67±0.06^{aC}	8.58±0.03^{aA}	8.25±0.13^{aB}	7.62±0.33^{bcdC}	7.74±0.14^{abC}	7.31±0.17^{bD}

[1)]LM: *G. uralensis* 0.8% and *B. juncea* 0.7%. [2)]ND: Not detected.
Values are mean±SD (n=3).
Means with different superscripts in the same column (a-f) and row (A-E) are significantly different ($p<0.05$).

applied. A probability level of less than 0.05 ($p<0.05$) was indicated as statistical significance.

RESULTS AND DISCUSSION

Change in the number of bacteria in *gochujang* depending on the fermentation period

The initial number of bacteria in all the test groups was 8.30 to 8.45 log CFU/g. There was no significant change in the number of bacteria during fermentation, and the approximate level of 8 log CFU/g was maintained until 50 days. This result is similar to that of previous researches in which the total number of bacteria in normal *gochujang* was 7~8 log CFU/g (21,22) and the total number of bacteria was not affected by controlling the amount of salt or adding food additives such as *B. juncea* or *G. uralensis* (23,24). This result is related to the spectrum of anti-bacterial substances added to *gochujang* to control the growth of microbes. We proposed that although *B. juncea* and *G. uralensis* used in this study have excellent anti-bacterial activity against yeast, *Bacillus* spp., and some food poisoning bacteria (25,26), they cannot fully control the growth of all bacteria in *gochujang*. The number of lactic acid bacteria detected in the early storage period was between 7.34 and 7.67 log CFU/g in all the test groups, and the changes in the numbers of lactic acid bacteria in the test groups except 2.0% salt *gochujangs* were negligible. In the 2.0% salt *gochujang* and 2.0% salt *gochujang* with additives groups, however, the lactic acid bacteria increased by 0.5~1.0 log CFU/g after storage for 10 days. The number of fungi in the early fermentation was 4.41~4.70 log CFU/g, lower than that detected in general *gochujang* (about 5~6 log CFU/g). The number of fungi in 8.5, 5.9, and 4.3% salt *gochujang* gradually decreased to 2.7~3.5 log CFU/g during the fermentation, but no fungi were detected in these groups with additives after 10 days. The number of fungi in 2.0% salt *gochujang* rapidly increased up to 6 log CFU/g during fermentation; however, no fungi were detected in the 2.0% salt *gochujang* with additives after 30 days. The fungi in the *gochujang* with *B. juncea* and horseradish were not detected after 60 days of storage, according to Shin et al. (10). Compared to a previous result, adding *B. juncea* and *G. uralensis* is more effective in controlling the proliferation of fungi, including yeast.

Although yeast plays a positive role in the flavor of *gochujang* (27), it can also produce gas causing the package to expand (28) or the pellicle on the surface (16). Restraining the production of gas by controlling yeast and continuously increasing amino acid nitrogen via enzymes and bacteria can result in better-sensory quality of *gochujang* (29). In this study, the addition of additives to *gochujang* also drastically decreased the number of fungi, but did not significantly affect the number of other bacteria. Therefore, the addition of *B. juncea* and *G. uralensis* may positively influence the amount of amino acid nitrogen or the sensory test.

Change in the activity of enzymes

The α-amylase in *gochujang* liquefies its starchy ingredients. The optimal pH for the activity of α-amylase is around 6.0. Thus, the activity of α-amylase generally increases in the early aging process and decreases with fermentation time (30,31), as the pH decreases for the fermentation. In this study, the α-amylase activity also increased significantly until 20 days and gradually decreased in all the test groups. The β-amylase, a diastatic enzyme that decomposes starch and produces reducing sugar during fermentation, increased up to 5.4~6.6 units at first, then decreased to 3.5~3.9 at 10 days. After 10 days, the activity of β-amylase was maintained until 50 days. These results show that lowering salt concentration or adding *B. juncea* and *G. uralensis* to *gochujang* has little effect on α and β-amylase activity. Such results differ from when antibacterial ingredients were added to the *gochujang*, the activity of the enzymes decreased more compared to control (23). In producing *gochujang*, the degradation of the diastatic activity makes the *gochujang* rough and reduces its flavor. Thus, it is recommended that the amylase activity be adequately maintained. Therefore, the amounts of *B. juncea* and *G. uralensis* added to *gochujang* in this study were appropriate to maintain the activity of amylase.

The amount of free amino acids, related to the savory taste of *gochujang*, was affected by the protease activity. Protease activity, therefore, is an important index of the taste of *gochujang*, along with the amount of amino-nitrogen. The activity of protease significantly increased in all the test groups during fermentation, and was higher in the low-salt *gochujang* than in the high-salt; the activity of the enzymes in 8.5% salt *gochujang* increased by about 3 units, 4~5 units in the 5.9 and 4.3% salt; and about 7 units in the 2.0% salt *gochujang*. These results suggest the protease is sensitive to the salt concentration. Protease activity by the addition of *B. juncea* powder and *G. uralensis* extract showed some significant differences in 5.9% and 4.3% salt *gochujang* in the middle of the aging process (at 10~30 days). But, considering that such a difference was negligible and that no regular pattern was observed with the addition of such ingredients, it is considered that the addition of *B. juncea* and *G. uralensis* did not greatly affect the activity of protease.

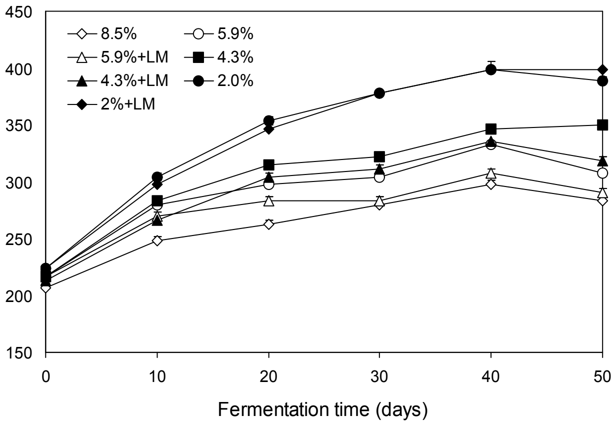

Fig. 1. Changes in amino nitrogen of low salt *gochujang* added with *G. uralensis* and *B. juncea* during fermentation at 28°C. LM: *G. uralensis* 0.8% and *B. juncea* 0.7%. Values are mean±SD (n=3).

Amino-nitrogen content

Amino-nitrogen allows the observation of how much protein was decomposed into free amino acids, making it an important index in determining the quality of *gochujang*. Fig. 1 shows the change in the amino-nitrogen content of *gochujang*. The amino-nitrogen content was initially between 206.50 and 224.00 mg% in all test groups, and consistently increased until 40 days, identical to reports of Park et al. (32) and Shin et al. (33). The effect of salt concentration on amino nitrogen content was similar to the results reported by Lim and Song (24) and Oh et al. (34) whereby amino nitrogen content of *gochujang* rapidly increased with the reduction of its salt (24,34). At 20 days, the amount of amino-nitrogen in the 5.9, 4.3, and 2.0% salt *gochujang* was 297.70, 315.00, and 352.50 mg%, respectively, and 283.50, 303.00, and 386.50 mg% in the same groups with additives, respectively. Therefore, the amount of amino-nitrogen in all the test groups was either similar to or higher than 297.70 mg%, which is the amount of amino-nitrogen in the 8.9% salt *gochujang* (control) at 40 days. These results indicate that if the salt concentration is lowered to or below 5.9%, the fermentation period in the preparation of *gochujang* can be shortened by about 20 days. This may be due to the greater activity of the enzymes that decompose protein in low-salt *gochujang*, paralleling the result in this study, suggesting that the lower the salt concentration, the protease activity increases (Table 3). No significant difference in the amount of amino-nitrogen was observed in the 2.0% salt *gochujang* with and without additives. In the 5.9% and 4.3% salt *gochujang*, however, mixing additives resulted in a significantly lower amount of amino-nitrogen than in the *gochujang* without additives. However, considering that the amount of amino-nitrogen in the low-salt *gochujang* with additives was either higher or about the same as

Table 3. Changes in enzyme activity of low salt *gochujang* added with *G. uralensis* and *B. juncea* during fermentation at 28°C (unit/g)

		Fermentation time (day)					
		0	10	20	30	40	50
α-amylase	8.5%	1.5 ± 0.20^{bC}	2.5 ± 0.34^{B}	5.14 ± 0.07^{A}	4.53 ± 0.16^{A}	1.33 ± 0.28^{C}	1.82 ± 0.03^{C}
	5.9%	1.2 ± 0.41^{bC}	2.35 ± 0.20^{B}	5.29 ± 0.23^{A}	5.0 ± 0.21^{A}	1.32 ± 0.16^{C}	2.00 ± 0.10^{B}
	5.9%+LM[1)]	1.2 ± 0.03^{bD}	2.3 ± 0.16^{C}	5.3 ± 0.09^{A}	4.41 ± 0.27^{B}	1.05 ± 0.11^{D}	2.37 ± 0.18^{C}
	4.3%	2.5 ± 0.50^{aC}	2.37 ± 0.23^{CD}	5.51 ± 0.03^{A}	4.51 ± 0.09^{B}	1.40 ± 0.32^{D}	1.78 ± 0.05^{CD}
	4.3%+LM	2.4 ± 0.25^{aCB}	2.64 ± 0.10^{B}	5.12 ± 0.37^{A}	4.60 ± 0.10^{A}	1.14 ± 0.07^{D}	1.80 ± 0.29^{CD}
	2.0%	2.4 ± 0.05^{aC}	2.41 ± 0.23^{C}	5.39 ± 0.40^{A}	4.54 ± 0.26^{B}	1.22 ± 0.06^{D}	1.99 ± 0.11^{DC}
	2.0%+LM	2.3 ± 0.30^{aCB}	2.37 ± 0.05^{B}	4.98 ± 0.34^{A}	4.55 ± 0.07^{A}	1.54 ± 0.19^{C}	1.56 ± 0.22^{C}
β-amylase	8.5%	6.1 ± 0.20^{abA}	3.6 ± 0.21^{B}	4.1 ± 0.05^{aB}	3.7 ± 0.23^{aB}	4.1 ± 0.13^{B}	3.9 ± 0.11^{B}
	5.9%	6.6 ± 0.50^{aA}	3.6 ± 0.05^{B}	4.0 ± 0.26^{abB}	3.6 ± 0.19^{aB}	4.2 ± 0.10^{B}	3.7 ± 0.45^{B}
	5.9%+LM	5.4 ± 0.22^{bA}	3.5 ± 0.26^{B}	4.2 ± 0.11^{aB}	3.8 ± 0.18^{aB}	4.2 ± 0.26^{B}	3.7 ± 0.16^{B}
	4.3%	6.2 ± 0.01^{abA}	3.9 ± 0.22^{B}	4.0 ± 0.27^{abC}	3.4 ± 0.14^{bC}	4.0 ± 0.11^{C}	3.8 ± 0.16^{C}
	4.3%+LM	5.9 ± 0.20^{abA}	3.7 ± 0.15^{B}	4.1 ± 0.25^{aB}	3.8 ± 0.05^{aB}	4.3 ± 0.24^{B}	4.0 ± 0.24^{B}
	2.0%	6.5 ± 0.17^{aA}	3.5 ± 0.05^{B}	3.8 ± 0.09^{abB}	3.2 ± 0.01^{cB}	3.6 ± 0.40^{B}	3.2 ± 0.45^{B}
	2.0%+LM	6.2 ± 0.17^{abA}	3.8 ± 0.16^{B}	3.4 ± 0.16^{bB}	3.2 ± 0.00^{cC}	4.2 ± 0.08^{C}	3.3 ± 0.01^{C}
Protease	8.5%	6.67 ± 0.35^{aD}	7.48 ± 0.17^{cDC}	7.48 ± 0.40^{bC}	8.65 ± 0.07^{dB}	9.98 ± 0.30^{bA}	9.78 ± 0.22^{bA}
	5.9%	6.72 ± 0.27^{aD}	7.27 ± 0.15^{bcD}	8.30 ± 0.27^{abC}	9.22 ± 0.18^{cdB}	9.75 ± 0.17^{bB}	11.08 ± 0.28^{abA}
	5.9%+LM	6.67 ± 0.08^{aD}	7.88 ± 0.20^{abC}	8.72 ± 0.35^{aBC}	9.65 ± 0.12^{cB}	9.80 ± 0.30^{bA}	10.27 ± 0.33^{bA}
	4.3%	6.77 ± 0.17^{aD}	8.03 ± 0.37^{aC}	8.83 ± 0.18^{aC}	9.87 ± 0.10^{bcB}	10.45 ± 0.25^{bB}	12.02 ± 0.30^{aA}
	4.3%+LM	6.53 ± 0.20^{aD}	5.45 ± 0.28^{cD}	8.30 ± 0.35^{abC}	9.67 ± 0.25^{cB}	10.17 ± 0.18^{bB}	11.43 ± 0.10^{aA}
	2.0%	5.47 ± 0.38^{bD}	8.32 ± 0.00^{aC}	9.37 ± 0.30^{aC}	10.60 ± 0.40^{abB}	11.35 ± 0.42^{aB}	12.48 ± 0.23^{aA}
	2.0%+LM	6.12 ± 0.22^{abD}	8.25 ± 0.08^{aC}	8.73 ± 0.28^{aC}	10.97 ± 0.27^{aB}	11.62 ± 0.12^{aB}	13.00 ± 0.42^{aA}

[1)]LM: *G. uralensis* 0.8% and *B. juncea* 0.7%.
Values are mean±SD (n=3).
Means with different superscripts in the same column (a-d) and row (A-D) are significantly different ($p<0.05$).

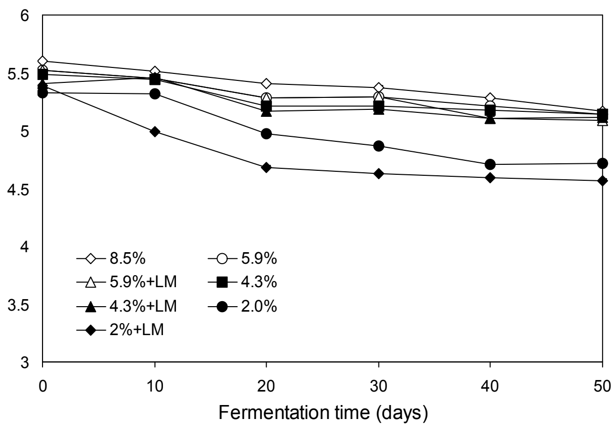

Fig. 2. Changes in pH of low salt *gochujang* added with *G. uralensis* and *B. juncea* during fermentation at 28^{o}C. LM: *G. uralensis* 0.8% and *B. juncea* 0.7%. Values are mean±SD (n=3).

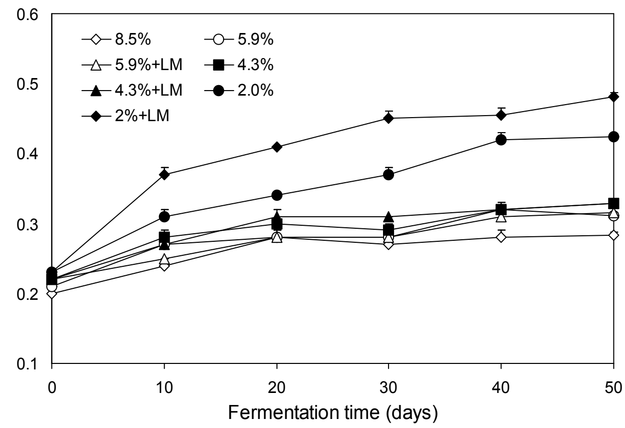

Fig. 3. Changes in acidity of low salt *gochujang* added with *G. uralensis* and *B. juncea* during fermentation at 28^{o}C. LM: *G. uralensis* 0.8% and *B. juncea* 0.7%. Values are mean±SD (n=3).

that in the control, it is expected that adding 0.7% of *B. juncea* and 0.8% of *G. uralensis* does not affect the shortening fermentation period at a low salt concentration.

pH and acidity

Fig. 2 shows that the pH of *gochujang* decreased from 5.39～5.60 in the early fermentation stage to 4.57～5.17 as time passed, which is a typical pH change pattern in *gochujang* (35). The lower the salt concentration, the lower the pH became. Regardless of the additives, the pH in the 5.9% and 4.3% salt *gochujang* were between 5.0 and 5.5, indicating a slight difference with the pH of the control group. The pH of the 2.0% salt *gochujang* tended to decrease to 4.5～4.7. The acidity in all the test groups increased rapidly in the early fermentation process, and tended to slow down as fermentation continued (Fig. 3), suggesting that the organic acids turned into either alcohol or ester in the later fermentation process (36). The change in the acidity, depending on the salt concentration, corresponded to the pH change. As the salt concentration decreased, the higher the acidity became. The acidity of the 2.0% salt *gochujang* with and without *B. juncea* and *G. uralensis* were particularly high. In the 5.9% and 4.3% salt *gochujang*, the acidity did not significantly differ with the use of additives. While such a result is similar to that of the previous test where lowering the salt concentration increased the acidity (35), the acidity of the *gochujang* added with *B. juncea* and secondary ingredients was lower than that of the control group (37). Various bacteria create succinic acid (38), citric acid (39), and pyroglutamic acid (40), among others, in *gochujang* during fermentation. Such organic acids change the acidity and pH, altering the taste of *gochujang*; the acidity is closely related to the sourness of *gochujang*. This study showed that lowering the salt concentration of *gochujang* to 2.0% or lower will degrade the quality and sensory palatability of *gochujang* due to sourness resulting from low acidity.

Color

In this study, the change in color during fermentation, an important factor in consumer evaluation of *gochujang* quality, was measured using a color difference meter (Table 4). Until 40 days of storage, there was no significant change due to the salt concentration, additives, or duration of the storage, with 31～33 for L^*, 17～21 for a^*, and 10～13 for b^*. Such a result is similar to that of a previous study where L^* was 29～32, a^* was 16～18, and b^* was 14～18 during the fermentation process in traditional *gochujang* (41). At 50 days, however, L^* rapidly decreased to 18～20, and a^* and b^* greatly increased to 32～24. Moon and Kim (42) reported that the dominant color wavelength of *gochujang* is between 594 and 597 nm. As *gochujang* ages, its color turns to brown, becoming darker and deeper due to the Maillard reaction. L^* rapidly decreased and a^* and b^* greatly increased at 50 days in this study because as the browning rapidly progressed, the color of the *gochujang* became darker and thicker. While the color of the *gochujang* changed during the aging process in this study, it was not affected by the difference in salt concentration or additives, compared to other studies. Oh et al. (34) and Lim and Song (24) reported that the lower the salt concentration was, the greater the values of L^*, a^*, and b^* increased, while Park and Kim (23) reported that adding anti-bacterial ingredients such as chitosan or *B. juncea* restrained the browning of *gochujang*. The reason for the difference in results under similar process conditions is that fermenting *gochujang* shows a wide variety of color change patterns, depending on the granularity of the red pepper powder, the storage conditions, the use of heat treatment,

Table 4. Changes in color of low salt *gochujang* added with *G. uralensis* and *B. juncea* during fermentation at 28°C

		Fermentation time (day)					
		0	10	20	30	40	50
L*	8.5%	33.24±0.07^A^	31.91±0.10^A^	31.80±0.47^A^	32.36±0.21^A^	32.36±0.53^A^	19.18±0.58^B^
	5.9%	32.84±0.10^A^	31.73±0.57^A^	31.80±0.51^A^	32.59±1.55^A^	32.48±0.21^A^	18.93±0.54^B^
	5.9%+LM[1)]	33.11±1.15^A^	31.91±0.12^A^	32.08±0.35^A^	32.24±0.21^A^	32.61±0.54^A^	18.77±0.32^B^
	4.3%	33.88±0.23^A^	33.29±1.15^A^	33.12±0.51^A^	33.62±2.35^A^	33.54±1.78^A^	19.78±0.10^B^
	4.3%+LM	33.35±0.49^A^	33.91±1.23^A^	33.88±0.69^A^	33.10±1.63^A^	33.51±3.42^A^	20.63±1.48^B^
	2.0%	32.85±1.11^A^	32.04±0.21^A^	32.47±0.25^A^	32.72±0.43^A^	32.61±0.24^A^	19.23±0.52^B^
	2.0%+LM	32.97±0.68^A^	32.79±0.66^A^	32.59±0.96^A^	32.90±0.12^A^	32.74±1.51^A^	19.84±5.13^B^
a*	8.5%	19.52±0.48^bB^	17.85±0.16^bB^	18.15±1.23^bB^	19.26±0.73^B^	18.9±0.67^B^	33.40±0.57^A^
	5.9%	19.78±0.31^abB^	17.49±0.33^bB^	18.50±2.30^bB^	19.35±0.23^B^	18.61±1.20^B^	33.22±0.53^A^
	5.9%+LM	19.89±0.21^abB^	18.16±0.36^bB^	18.33±0.10^bB^	18.58±0.71^B^	18.97±2.13^B^	32.59±0.48^A^
	4.3%	20.04±1.06^abB^	20.17±1.24^abB^	20.19±1.00^abB^	20.79±2.34^B^	20.86±0.65^B^	33.50±1.24^A^
	4.3%+LM	21.94±1.23^aB^	21.66±0.40^aB^	21.18±1.59^aB^	21.44±1.38^B^	21.90±3.48^B^	33.62±0.99^A^
	2.0%	19.75±0.23^abB^	18.92±0.68^abB^	19.14±1.63^abB^	19.70±0.44^B^	19.42±0.82^B^	33.73±0.83^A^
	2.0%+LM	19.68±0.12^abB^	20.07±1.36^abB^	20.11±0.88^abB^	20.64±0.63^B^	20.00±0.13^B^	33.84±0.64^A^
b*	8.5%	12.44±0.54^B^	10.89±0.37^B^	11.02±0.46^B^	12.19±1.20^B^	12.00±0.88^B^	33.91±1.20^A^
	5.9%	12.73±0.33^B^	10.53±0.20^B^	11.27±0.56^B^	12.33±1.45^B^	11.78±0.12^B^	32.46±0.24^A^
	5.9%+LM	12.85±0.21^B^	11.37±0.10^B^	11.47±0.43^B^	11.79±1.22^B^	12.36±0.43^B^	32.18±0.72^A^
	4.3%	12.04±0.54^B^	12.95±1.00^B^	11.95±1.23^B^	12.91±2.43^B^	12.94±0.82^B^	33.23±0.81^A^
	4.3%+LM	12.39±0.34^B^	13.11±1.50^B^	12.60±2.34^B^	13.44±1.54^B^	13.54±0.59^B^	34.44±0.33^A^
	2.0%	12.63±0.49^B^	11.63±0.39^B^	11.89±1.20^B^	12.51±0.44^B^	12.35±0.41^B^	32.99±0.56^A^
	2.0%+LM	12.66±0.34^B^	13.00±0.45^B^	12.59±0.75^B^	13.41±1.43^B^	12.83±1.17^B^	34.03±0.24^A^

[1)]LM: *G. uralensis* 0.8% and *B. juncea* 0.7%.
Values are mean±SD (n=3).
Means with different superscripts in the same column (a,b) and row (A,B) are significantly different ($p<0.05$).

or the activity of the enzymes.

Sensory evaluation

In terms of overall palatability, 5.9% and 4.3% salt *gochujang* with and without additives, were significantly higher than control *gochujang*. The high palatability of other low salt *gochujangs*, except the 2.0% salt, is related to taste than flavor. Flavor palatability of *gochujangs* did not result in a significant difference among test groups, and in terms of savory, unpleasant, and salty flavor, sensory intensity did not manifest a significant difference among test groups. In terms of taste, a significant difference was observed in taste palatability; 2.0% salt *gochujang* with and without additives had significantly lower scores than other groups, and 5.9% and 4.3% salt *gochujang* with and without additives had higher scores than the control *gochujang*. In terms of savory and sweet taste, low salt *gochujangs* scored higher than the control and were significantly sweeter and more savory in taste than the other test groups (Table 4). The savory taste was higher in the low salt *gochujang* than in the control group because the lower salt concentration contained more amino-nitrogen. One exception was that while it was expected that the 2.0% salt *gochujang* would be more preferred by the panel due to the protease activity and the high amino-nitrogen content, it scored lower than other low-salt *gochujang* groups in overall preference because of a sourer taste and a peculiar smell due to low pH and high acidity. In conclusion, even when the salt concentration of *gochujang* is reduced up to 4.3%, adding *G. uralensis* and *B. juncea* can inhibit the proliferation of filamentous fungi, which causes quality degradation in low salt *gochujang*, and allows production of high-quality *gochujang* with excellent sensory palatability.

CONCLUSION

When *G. uralensis* extract and *B. juncea* powder, containing an anti-bacterial substance, were added to low-salt *gochujang*, the proliferation of fungi such as yeast was inhibited. The α-amylase activity increased and then subsequently decreased during the aging process, while β-amylase activity tended to decrease during the process. The protease activity tended to increase in correlation with lowering the salt concentration, although the effects of the additives were negligible. The amount of amino-nitrogen in the low-salt *gochujangs* at 20 days was similar to that in the control *gochujang* at 40 days. The result of the sensory evaluation that was conducted on 40 days showed that the low-salt *gochujangs* were more preferred than the control *gochujang*. In particular, the 4.3% low-salt *gochujang* with additives were the most preferred, followed by the 5.9% low-salt *gochujang* with additives. In conclusion, a low-salt *gochujang* adding *G. uralensis* and *B. juncea* is also expected to reduce the

Table 5. Sensory evaluation of low salt *gochujang* added with *G. uralensis* and *B. juncea* during fermentation at 28°C for 40 days

	8.5%	5.9%	5.9%+LM	4.3%	4.3%+LM	2.0%	2%+LM
Color	4.10±0.83[c]	4.90±1.58[abc]	5.20±1.33[abc]	4.20±0.83[bc]	4.60±0.80[abc]	6.00±0.89[a]	5.70±1.27[ab]
Flavor	4.00±0.77	5.00±1.18	5.10±1.45	5.30±1.49	5.20±0.98	4.80±1.33	4.60±1.50
Savory	3.80±0.60	4.30±1.19	5.00±1.26	5.10±0.70	5.10±0.70	4.20±1.25	4.70±0.78
Unpleasant	4.10±1.14	4.20±1.17	4.60±0.66	4.20±0.98	4.10±0.70	4.80±0.87	4.30±0.64
Salt	5.10±0.94	4.70±1.19	5.00±0.63	4.90±0.83	4.80±0.87	5.20±1.25	5.10±1.14
Sour	3.90±0.94[ab]	3.60±0.80[ab]	4.20±0.98[ab]	4.11±0.99[ab]	3.60±0.80[ab]	5.50±0.92[ab]	4.60±0.80[ab]
Taste	4.10±0.94[ab]	5.70±1.49[a]	5.70±1.42[a]	5.20±1.54[ab]	5.50±1.02[ab]	3.70±1.42[b]	3.70±1.35[b]
Savory	3.90±0.70[b]	5.90±0.70[a]	6.00±1.00[a]	5.80±0.98[a]	5.90±1.04[a]	4.60±1.02[ab]	4.20±0.87[b]
Sweet	4.10±0.70[b]	5.30±1.10[ab]	5.20±1.08[ab]	5.60±0.92[a]	5.80±0.60[a]	5.30±1.35[ab]	5.30±1.10[b]
Salt	6.20±0.98[a]	5.70±1.10[ab]	6.00±0.77[ab]	5.70±1.35[ab]	5.80±0.75[ab]	5.80±1.17[ab]	4.70±0.90[b]
Sour	4.30±0.64[c]	4.90±0.70[bc]	5.00±0.45[bc]	5.20±0.87[bc]	5.40±0.80[bc]	6.60±0.66[a]	5.80±1.17[ab]
Overall acceptability	5.00±0.89[ab]	6.40±0.80[a]	6.40±0.92[a]	6.20±1.60[a]	6.50±1.12[a]	3.90±1.22[b]	4.90±1.51[ab]

[1)]LM: *G. uralensis* 0.8% and *B. juncea* 0.7%.
Color, flavor, taste, overall acceptability were evaluated as follows: very poor (1 point), moderate (5 points), very good (9 points), and savory, unpleasant, sweet, salt, sour were evaluated as follows: very low (1 point), medium (5 points), very strong (9 points). Values are mean±SD (n=10). [a-c]Means with different superscripts in the same row are significantly different ($p<0.05$).

duration of the fermentation and improve sensory palatability as well as to prevent quality degradation caused by yeast, which can be observed in low-salt *gochujang*.

REFERENCES

1. Dahl LK. 2005. Possible role of salt intake in the development of essential hypertension. *Int J Epidemiol* 34: 967-972.
2. Tsugane S. 2005. Salt, salted food intake, and risk of gastric cancer: epidemiologic evidence. *Cancer Sci* 96: 1-6.
3. Arlene WC, Rena RW, Mary PN, Milas NC, Seung L, Herbert L. 1985. The measurement of sodium and potassium intake. *Am J Chem Nutr* 42: 391-398.
4. Ministry of Health and Welfare. 2008. The 3rd National health and nutrition examination (KNHANES Ⅲ). Seoul, Korea. p 366.
5. Nam HW, Lee GY. 1985. A study on the sodium and potassium intake and their metabolism of the pregnant women in the Korea. *Korea J Nutr* 18: 194-200.
6. Koo BS, Seong SH, Kown DY, Sohn HS, Cha YS. 2008. Fermented kochujang supplement shows anti-obesity effects by controlling lipid metabolism in C57BL/6J mice fed high fat diet. *Food Sci Biotechnol* 17: 336-342.
7. Kwon DY, Hong SM, Ahn IS, Kim YS, Shin DW, Park S. 2009. Kochujang, a Korean fermented red pepper plus soybean paste, improves glucose homeostasis in 90% pancreatectomized diabetic rats. *Nutrition* 25: 790-799.
8. Yamamoto Y, Higashi K, Yoshii H. 1986. Effect of ethanol and lactic acid on the preparation of low salted Kochujang. *Thesis Collection of Wonkwang Univ (Iksan)* 20: 143-200.
9. Lee KS, Kim DH. 1991. Effect of sake on the quality of low salted Kochujang. *Korean J Food Sci Technol* 23: 109-115.
10. Shin DH, Ahn EY, Kim YS, Oh JY. 2000. Fermentation characteristics of kochujang containing horseradish and *B. juncea*. *Korean J Food Sci Technol* 32: 1350-1357.
11. Kim DH, Kwon YM. 2001. Effect of storage conditions on the microbiological and physicochemical characteristics of traditional kochujang. *Korean J Food Sci Technol* 33: 589-595.
12. Chun MS, Lee TS, Noh BS. 1992. Effect of gamma-irradiation on quality of kochujang during storage. *Foods Biotechnol* 1: 117-122.
13. Kim SJ, Shin JY, Park YM, Chung KM, Lee JH, Kweon DH. 2006. Investigation of antimicrobial activity and stability of ethanol extracts of licorice root (*Glycyrrhiza glabra*). *Korean J Food Sci Technol* 38: 241-248.
14. Ahn EU, Shin DH, Baek NI, Oh JA. 1998. Isolation and identification of antimicrobial active substance from *Glycyrrhiza uralensis* FISCH. *Korean J Food Sci Technol* 33: 680-687.
15. Seo KI, Park SK, Park JR, Kim HC, Chio JS, Shin KH. 1996. Changes in antimicrobial activity of hydrolyzate from mustard seed (*Brassica juncea*). *J Korean Soc Food Nutr* 25: 129-134.
16. Lim SI, Kwak EJ, Choi C. 2004. Isolation of the white pellicle-forming strain from gochujang, growth inhibition, and its effect on quality of gochujang. *Food Sci Biotechnol* 13: 75-79.
17. Lim SI, Song SM. 2010. Fermentation properties of low-salted Doenjang supplemented with licorice, mustard, and chitosan. *Korean J Food Sci Technol* 42: 323-328.
18. Fuwa H. 1954. A new method for microdetermination of amylase activity by the use of amylase as the substrate. *J Biochem* 41: 583-603.
19. Lee NY, Kim YS, Shin DH. 2003. Characteristics of microbes for high temperature fermentation and the effect of high temperature fermentation of soy. *Food Sci Biotechnol* 12: 390-398.
20. Anson ML. 1938. The estimation of pepsin, trypsin, papain, and cathepsin with hemoglobin. *J Gen Physiol* 22: 79-89.
21. Oh JY, Kim YS, Shin DH. 2005. Changes in microorganisms and enzyme activities of low-salted kochujang added with horseradish powder during fermentation. *Korean J Food Sci Technol* 37: 463-467.
22. Shin DH, Ahn EY, Kim YS, Oh JY. 2001. Changes in the microflora and enzyme activities of kochujang prepared with different koji during fermentation. *Korean J Food Sci Technol* 33: 94-99.
23. Park SJ, Kim DH. 2007. Effect of combined use of various anti-microbial materials on brewing of low salted Kochujang. *J Korean Soc Appl Biol Chem* 50: 287-294.
24. Lim SI, Song SM. 2010. Changes in characteristics of

low-salted Kochujang with iicorice (*Glycyrrhiza glabra*), mustard (*Brassica juncea*), and chitosan during fermentation. *J Korean Soc Food Sci Nutr* 39: 560-566.
25. Shim KH, Seo KI, Kang KS, Moon JS, Kim HC. 1995. Antimicrobial substances of distilled components from mustard seed. *J Korean Soc Food Nutr* 24: 948-955.
26. Kim SJ, Shin JY, Park YM, Chung KM, Lee JH, Kweon DH. 2006. Investigation of antimicrobial activity and stability of ethanol extracts of licorice root (*Glycyrrhiza glabra*). *Korean J Food Sci Technol* 38: 241-248.
27. Lee TS, Yang KJ, Park YJ, Yu JH. 1980. Studies on the brewing of Kochjang (red pepper paste) with the addition of mixed cultures of yeast strains. *Korean J Food Sci Technol* 12: 313-323.
28. Lee JS, Choi YJ, Kwon SJ, Yoo JY, Chung DH. 1996. Screening and characterization of osmotolerant and gas-producing yeasts from traditional Doenjang and Kochujang. *Food and Biotechnology* 5: 54-58.
29. Kim MS, Oh JA, Shin DH, Han MS. 1998. Fermentation properties of irradiated Kochujang. *Korean J Food Sci Technol* 30: 934-940.
30. Oh HL, Shon SG, Kim JG. 2000. Changes in microflora and enzyme activities of Kochujang prepared with *Aspergillus oryzae*, *Bacillus licheniformis* and *Saccharomyces rouxii* during fermentation. *Korean J Food Sci Technol* 32: 410-416.
31. Kim MS, Ahn EY, Ahn ES, Shin DH. 2000. Characteristic changes of Kochujang by heat treatment. *Korean J Food Sci Technol* 32: 867-874.
32. Park CH, Lee SK, Shin BK. 1986. Effects of wheat flour and glutinous rice on quality of Kochujang. *J Korean Agric Chem* 29: 375-380.
33. Shin DH, Kim DH, Choi U, Lim MS, Ahn EY. 1997. Physicochemical characteristics of traditional Kochujang prepared with various raw materials. *Korean J Food Technol* 29: 907-912.
34. Oh JY, Kim YS, Shin DH. 2002. Changes in physicochemical characteristics of low-salted Kochujang with natural preservatives during fermentation. *Korean J Food Sci Technol* 34: 835-841.
35. Na SE, Seo KS, Choi JH, Song GS, Choi DS. 1997. Preparation of low salt and functional kochujang containing chitosan. *Korean J Food Nutr* 10: 193-200.
36. Kim YS, Cha J, Jung SW, Park EJ, Kim JO. 1994. Changes of physicochemical characteristics and development of new quality indices for industry produced koji kochujang. *Korean J Food Sci Technol* 26: 389-392.
37. Kim DH, Lee JS, Lee SB. 2002. Effect of storage conditions on the chemical characteristics of traditional kochujang. *Korean J Food Sci Technol* 34: 466-471.
38. Cho HO, Kim JG, Lee HJ, Kang JH, Lee TS. 1981. Brewing method and composition of traditional kochujang (red pepper paste) in Junrabook-do area. *J Korean Agric Chem Soc* 24: 21-28.
39. Shin DH, Kim DHKJ, Choi U, Lim MS, An EY. 1997. Taste components of traditional kochujang prepared with various raw materials. *Korean J Food Sci Technol* 29: 913-918.
40. Kim YS, Oh HI. 1993. Volatile flavor components of traditional and commercial kochujang. *Korean J Food Sci Technol* 25: 494-501.
41. Lee KY, Kim HS, Lee HG, Han OH, Chang UJ. 1997. Studies on the prediction of the shelf-life of Kochujang through the physicochemical and sensory analysis during storage. *J Korean Soc Food Sci Nutr* 26: 588-594.
42. Moon TW, Kim ZU. 1988. Some chemical physical characteristics and acceptability of Kochujang from various starch sources. *J Korean Agric Chem Soc* 31: 387-393.

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