J Food Sci Nutr
Vol 12, p 46~50 (2007)

J Food Science and Nutrition

Physicochemical Properties of Long-term Fermented *Kimchi*

Min-Hee Nam[1], Chang-Suk Kong[1], Soon-Sun Bak[1], Yang-Bong Lee[2], Sook-Hee Rhee[1] and Kun-Young Park[1†]

[1]*Department of Food Science and Nutrition, and Kimchi Research Institute, Pusan National University, Busan 609-735, Korea*
[2]*Department of Food Science and Technology, Pukyong National University, Busan 608-737, Korea*

Abstract

Physicochemical properties of commercial long-term fermented *kimchies* which are widely available in Korea were investigated. The commercial long-term fermented *kimchies* were fermented almost more than 6 months. Average values for saltiness, pH and acidity of the long-term fermented *kimchies* were 3.0±0.5% , 4.0±0.2, and 1.88±0.76% , respectively. The long-term fermented *kimchi* showed similar *Leuconostoc* sp. and *Lactobacillus* sp. counts as *baechu kimchi* ripened properly during fermentation. The amount of *Leuconostoc* sp. and *Lactobacillus* sp. of the long-term fermented *kimchi* were $10^{7\sim8}$ CFU/mL and $10^{4\sim7}$ CFU/mL, respectively. The long-term fermented *kimchi* showed 0.32±0.18 lightness, 1.73±0.98 redness, 0.52±0.31 yellowness. Long-term fermented *kimchi* showed higher lightness, redness, yellowness than well-fermented standardized *baechu kimchi*. Breaking strength of long-term fermented *kimchi* was higher than that of well-fermented standard *baechu kimchi*.

Key words: long-term fermented *kimchi*, *baechu kimchi*, physicochemical properties, color, breaking strength

INTRODUCTION

Kimchi, made by lactic acid fermentation of several kinds of vegetables, is a traditional Korean fermented food. There are approximately two hundred kinds of *kimchi* which can vary according to fermentation period, region and season of manufacture, ingredients, manufacturing methods and other variations (1). The flavor and functionality of *kimchi* depends on fermentation conditions and intermediates formed during fermentation as well as qualities of the major ingredient, *baechu* cabbage, and minor ingredients including: salt, hot pepper, garlic, ginger, green onion and salted fish or shrimp. Fermentation and storage temperatures are especially important variables that influence *kimchi* flavor and functionality.

Both fermented and non-fermented *kimchi* are commonly eaten according to individual and family preferences, but recently consumption of long-term fermented *kimchi* has increased due to its characteristic flavors. In general, long-term fermented *kimchi* is fermented from 6 months to 3 years. Historically, long-term fermented *kimchi* was a main side dishes which was made before winter with cabbages of good texture and flavor and eaten until summer while fermenting at low temperature in clay vessels buried in the earth. Therefore, the long-term fermented *kimchi* provided Korean ancestors with minerals and vitamins through the winter season when fresh fruits and vegetables were not available (2,3).

Few studies have investigated the physicochemical properties of long-term fermented *kimchi* (4,5), so research is needed for determining its nutritional value, flavor quality and fermentation characteristics. The effects of some flavor ingredients, irradiation, and other factors on the stability of *kimchi* during long-term storage have been studied (6,7). Even though there has been considerable *kimchi* research, few studies focused on long-term fermented *kimchi*. Studies of nutritional values of *kimchi*, have typically focused to *baechu kimchi*, made primarily of Chinese cabbage (2,8-11). Long-term fermentation of *kimchi* may produce valuable fermentation characteristics and functionalities, therefore long-term fermented *kimchi* is expected to offer unique benefits which will be attractive to consumers.

Therefore, the objectives of this study were to investigate such physicochemical properties as pH, saltiness, count of lactic acid bacteria and texture of lab-made and long-term fermented *kimchi* as well as commercial *kimchis* during fermentation, and to compare the physicochemical properties of long-term fermented *kimchis* with those of well-fermented *kimchi*.

†Corresponding author. E-mail: kunypark@pusan.ac.kr
Phone: +82-51-510-2839, Fax: +82-51-514-3138

MATERIALS AND METHODS

Materials

Long-term fermented *kimchis*, which were fermented for more than 6 months were purchased from several markets. The physicochemical properties of long-term fermented *kimchi* during fermentation were compared with those of standard *kimchi*. The standard *kimchi* was made by standard manufacturing methods (12-14). The information for the commercial *kimchi* is shown in Table 1. The majority of the long-term fermented *kimchis* were purchased in Seoul and Gyeonggido, and Jeonlado.

Measurement of pH, acidity and saltiness

The pH, acidity and salinity of *kimchi* were measured with the juice which was isolated from each sample with Stomacher 400 Lab Blender (Seward Medical London SEI IPP, UK). The pH was measured with a pH meter (model 410A, Thermo Orion, USA) at room temperature. Acidity was measured by the AOAC method (15). One mL of *kimchi* juice was diluted with deionized water 20 times and 0.1% phenolphthalein was added into the diluted juice. The diluted *kimchi* juice was titrated with 0.01 N NaOH until the color was changed to pink, indicating a pH of 8.3. The amount of NaOH used was calculated as lactic acid percent as shown in the formula below.

$$\text{Lactic acid (\%)} = \frac{\text{mL of 0.1 N NaOH} \times \text{Normality of NaOH} \times 0.09}{\text{Weight of sample (g)}} \times 100$$

Salinity was measured by the AOAC method (15). The juice was measured by a salinity meter (DM-3, Japan) at a room temperature. A three percent NaCl solution was used as a standard solution.

Table 1. Characteristics of commercial long-term fermented *kimchi*

Sample	Area	Fermentation period
A	S-restaurant (Seoul)	over 12 months
B	Naegohwang (Gwangju)	over 6 months
C	Cheonju-sigol*kimchi* I (Jeonju)	10 months
D	Dumei I (Gwangju)	6 months
E	Egalak-omogali-mukeungi (Seoul)	12 months
F	Pureungajok-mukeun*kimchi* I (Seoul)	over 12 months
G	Pureungajok-mukeun*kimchi* II (Seoul)	over 12 months
H	Cheonju-sigol*kimchi* II (Jeonju)	8 months
I	Dumei II (Gwangju)	12 months
J	Gipeunmasmugeun*kimchi* (Jeonbuk)	11 months
K	Jonggazip (Gyeongnam)	over 3 months
L	Pureungajok-mukeun*kimchi* III (Seoul)	over 12 months
M	Leemaleun-mugeun*kimchi* (Jeonnam)	11 months
N	Cheogazip-mugeun*kimchi* (Gwangju)	6 months

Measurement of lactic acid bacteria of *Leuconostoc* sp. and *Lactobacillus* sp.

Counts of lactic acid bacteria were measured by using the plate count technique. The selected medium for *Leuconostoc* sp. was the phenylethyl alcohol sucrose agar medium (PES medium). After *kimchi* juice was injected to the medium, it was incubated for 5 days at 20°C. The medium for *Lactobacillus* sp. was *Lactobacillus* selection medium (m-LBS medium). In the medium, *Pediococcus* was inhibited with acetic acid and sodium acetate. The modified LBS agar medium (m-LBS medium) was used for 3~4 days at 37°C. The colonies on the plate were counted and viable cell numbers were determined as colony forming units per mL (16).

Color measurement

Color of *kimchi* juice was measured by the AOAC method (15) with a colorimeter (Minolta Chroma Meter CT-310, Japan) at a room temperature. Distilled water was used as a standard solution. Hunter L (lightness), a (+: red, −: green), b (+: yellow, −: blue) values were obtained.

Measurement of textural properties

Texture properties of *kimchis* were measured with a rheometer (Sun Scientific Co. CR-100D, Japan). The operating conditions were as follows: max 10 kg, R/H real 3 kg, P/T press 600 mm/m, REP 1 per 3 sec. The *kimchi* cabbage was cut to the dimension of 3 cm×4 cm×0.5 cm apart from 5 cm of the cabbage root. The test was repeated 5 times.

Statistical analysis

Data was statistically analyzed by using analysis of variance (ANOVA) using SAS software (v8.2 SAS Institute Inc., NC, USA) and multiple comparison was done by Duncan's multiple range test at $p<0.05$.

RESULTS AND DISCUSSION

pH and acidity of long-term fermented *kimchi*

Few studies have investigated the properties of long-term fermented *kimchi* (4,5). The first step in studying long-term fermented *kimchi* was to characterize the physicochemical properties of commercially available long-term fermented *kimchi* products in Korea.

The pH and acidity of long-term fermented *kimchis* are shown in Fig. 1. The pHs of the long-term fermented *kimchis* ranged from pH 3.6 to pH 4.4. The average value for the long-term fermented *kimchis* was pH 4.0±0.2 which is lower than the optimum pH of 4.3~4.5 for well-fermented standardized *baechu kimchi* (12). Long-term fermented *kimchis* made in the same manu-

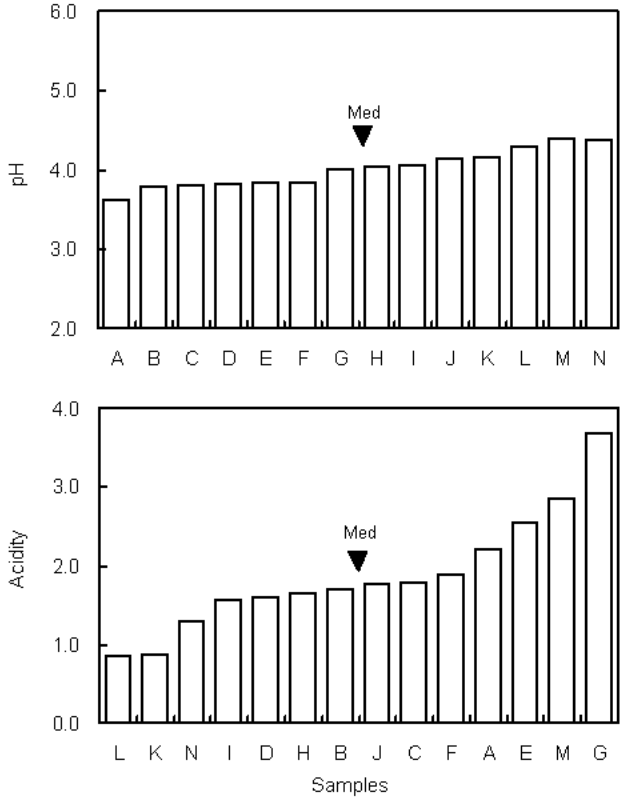

Fig. 1. pH and acidity of the various kinds of commercial long-term fermented *kimchi*.

facturing company ranges from pH 3.8 to pH 4.3. Approximately 50% of the *kimchis* has a pH of 4.0 or less. The acidities of the long-term fermented *kimchis* had a wider than did pH. The lowest acidity was 0.7% and the highest one was 3.7%. Only a few *kimchis* had greater than 3.0% acidity with the majority having around 2.0% acidity. The average acidity was 1.88± 0.76%.

Saltiness

Saltiness of long-term fermented *kimchi* are shown in Fig. 2. Most of the commercial *kimchis* were fermented for more than 6 months. The range of saltiness for the long-term fermented *kimchis* was from 2% to 4% with an average value of 3.0±0.5%. The saltiness of the long-term fermented *kimchis* were a little higher than that of normal *baechu kimchi* which has a typical saltiness of 2.5% (12). The reason for the traditionally high saltiness of long-term fermented *kimchis* was to permit long-term storage over the winter season.

In general, a higher saltiness of *kimchi* retards fermentation, so higher pH and lower acidity are expected. However, in the case of long-term fermented *kimchis*, a relationship was not found in the comparisons with pH and acidity. It might be due to the fermentation or storage temperature and time of year when the long-term

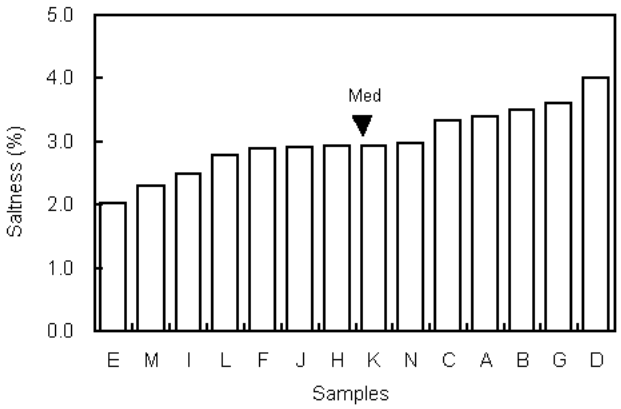

Fig. 2. Saltiness of the various kinds of commercial long-term fermented *kimchi*.

fermented *kimchis* were prepared.

Growth of lactic acid bacteria

The colony counts of lactic acid bacteria for the commercial long-term fermented *kimchi* are shown in Fig. 3. Among the lactic acid bacteria, *Leuconostoc* sp. is known to be associated with a cool taste of *kimchi*, and *Lactobacillus* sp. is associated with a sour *kimchi* flavor. The range of *Leuconostoc* sp. colonies for the long-term fermented *kimchis* was $10^4 \sim 10^8$ CFU/mL. The range of the other *kimchis* except the lowest *Leuconostoc* sp. of

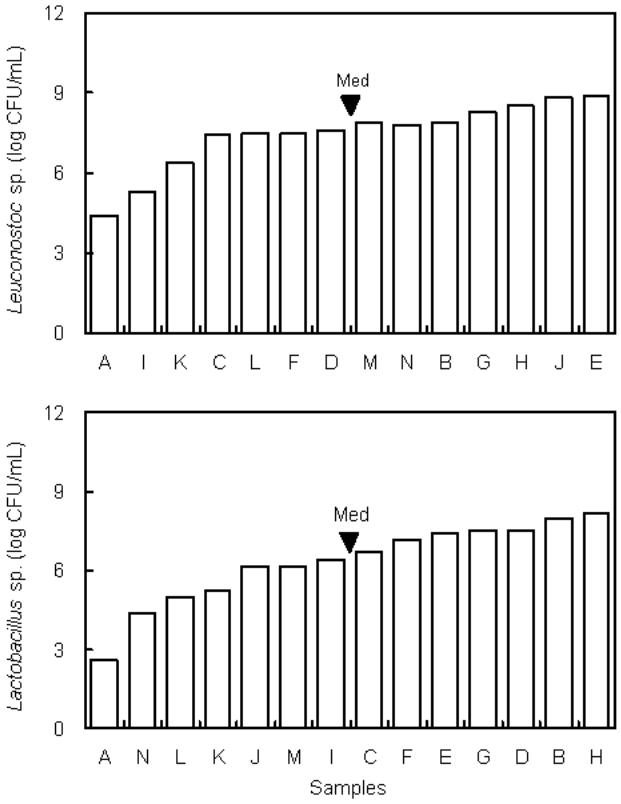

Fig. 3. Numbers of *Leuconostoc* sp. and *Lactobacillus* sp. in the various kinds of commercial long-term fermented *kimchi*.

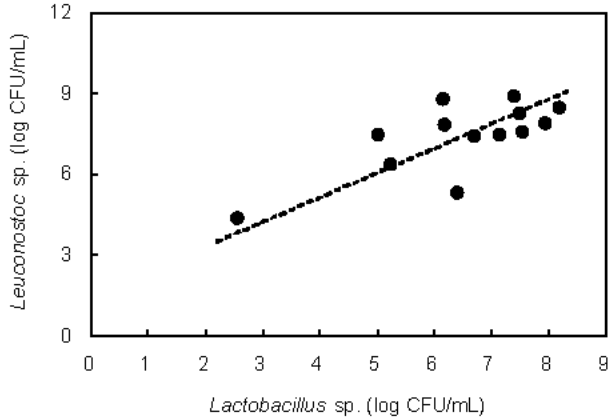

Fig. 4. Relationship between *Leuconostoc* sp. and *Lactobacillus* sp. for the various kinds of commercial long-term fermented *kimchi*.

10^4 CFU/mL was $10^7 \sim 10^8$ CFU/mL, which are normal for optimally fermented *kimchi*. The high amount of *Leuconostoc* sp. was consistent with long-term fermentation. The range of *Lactobacillus* sp. was $10^2 \sim 10^8$ CFU/mL varied more widely than that of *Leuconostoc* sp., which is an indicator of the ripening progression of normal *baechu kimchi*.

The relationship between *Leuconostoc* sp. and *Lactobacillus* sp. in the commercial long-term fermented *kimchis* is shown in Fig. 4, showing the linear relationship of high *Leuconostoc* sp. counts with high counts of *Lactobacillus* sp. Also, the counts of *Leuconostoc* sp. were similar to those of *Lactobacillus* sp..

The long-term fermented *kimchi* is well past the optimum period of well-fermented *kimchi*, and it has a sour taste. Fermentation with *Leuconostoc* sp. and *Lactobacillus* sp. can be regarded as a new fermentation process. It is possible that most of the properties of well-fermented *kimchi* can be preserved in long-term fermented *kimchi*. That is, *Leuconostoc* sp. which gives a cool taste to *kimchi* can be thought to survive during the long-term storage at low temperature. The low amount of *Lactobacillus* sp. is though to be due to the inhibition against *Lactobacillus* sp from the by the high amount of *Leuconostoc* sp.

Color of Hunter L, a and b values

Colors of the long-term fermented *kimchi* juice were observed and their results are shown in Fig. 5. The ranges of lightness (L), redness (a) and yellowness (b) for the commercial long-term fermented *kimchi* juice were 0.2～0.6, 0.9～3.0 and 0.3～1.0, respectively. The average values of lightness, redness and yellowness for the purchased long-term fermented *kimchi* juice were 0.32 ±0.18, 1.73±0.98 and 0.52±0.31, respectively, showing a large difference in the standard deviation of redness. The reason was thought to be due to the amount

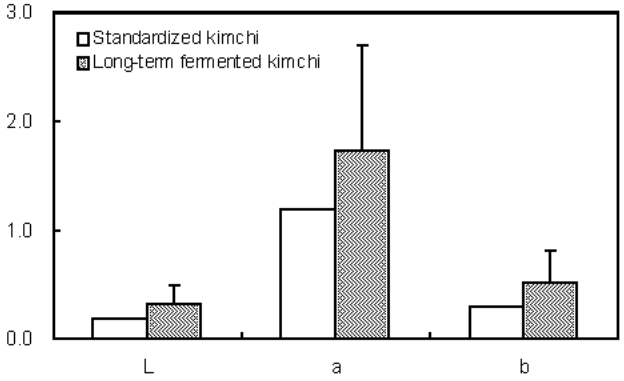

Fig. 5. Hunter color values (L, a, and b) of commercial long-term fermented *kimchi* and well-fermented standard *baechu kimchi*.

of the added red pepper powder.

The Hunter values for lightness, redness and yellowness of the commercial long-term fermented *kimchi* juice were compared with those of the standard *baechu kimchi*. The Hunter values for lightness, redness and yellowness of the standard *baechu kimchi* were 0.2, 1.2, and 0.3, respectively. The Hunter values for lightness, redness and yellowness of the commercial long-term fermented *kimchi* juice showed higher values than those of the standard *baechu kimchi* juice. The differences depend on the different manufacturing procedures, the amounts of ingredients and the storage conditions and time. Also, the increased lightness and yellowness of *kimchi* during long-term storage can be thought be due to be browning reaction occurs during long-term fermentation at low temperature.

Textural properties

In order to measure the textural properties of the long-term fermented *kimchi*, breaking strength of the commercial *kimchi* was measured using a rheometer. The breaking strength of the *kimchi* was obtained by calculating the relationship between initial strength and defor-

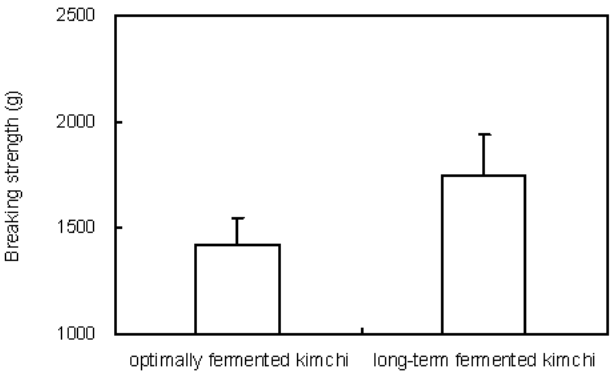

Fig. 6. Textural properties of various kinds of commercial long-term fermented *kimchi* (E, N, I *kimchis*).

mation. The breaking strength of the long-term fermented *kimchi* are compared in Fig. 6. Long term fermentation of *kimchi* resulted in a higher breaking strength of the *kimchi* ($p<0.05$). Good taste and crispy texture were characteristic of the initial stage of fermentation and the surface of *kimchi* was thought to be leathery after long-term fermentation. Actually, the breaking delay was observed on the surface of the *kimchi* during testing.

REFERENCES

1. Son KH. 1991. Classification of *kimchi* and its use. *Korean J Dietary Culture* 6: 503-520.
2. Park KY. 1995. The nutritional evaluation, and antimutagenic and anticancer effects of *kimchi*. *J Korean Soc Food Nutr* 24: 169-182.
3. Cheigh HS, Park KY. 1994. Biochemical, microbiological and nutritional aspects of *kimchi* (Korean fermented vegetable products). *Crit Review Food Sci Nutr* 34: 175-203.
4. You MJ, Kim HR, Chung HJ. 2001. Changes in physicochemical and microbiological properties in low-temperature and long-term fermented kimchi during fermentation. *Korean J Dietary Culture* 16: 431-441.
5. Kim JY, Park EY, Kim YS. 2004. Characterization of volatile compound in low-temperature and long-term fermented *baechu kimchi*. *Korean J Food Culture* 21: 319-324.
6. Song SH, Jo JS, Kim K. 1966. Studies on the storage of *kimchi*: (The 1st report) Effect of the preservatives on the fermentation of *kimchi*. Technical Report 5.
7. Byun MW, Cha BS, Kwon JH, Cho HO, Kim WJ. 1989. The combined effect of heat treatment and irradiation on the inactivation of major lactic acid bacteria associated with *kimchi* fermentation. *Korean J Food Sci Technol* 21: 185-191.
8. Lee KY, Park KY. 1993. Anticancer effect of green yellow vegetables. *Korean J Life Sci* 3: 143-152.
9. Park KY, Kweon MY. 1987. Effect of L-ascorbic acid on the degradation of aflatoxin B_1. *J Korean Soc Food Nutr* 16: 1-9.
10. Kim SH, Park KY, Suh MJ. 1991. Inhibition effect of aflatoxin B_1 mediated mutagenicity by red pepper powder in the Salmonella assay system. *J Korean Soc Food Nutr* 20: 156-161.
11. Park KY, Baek KA, Rhee SH, Cheigh HS. 1995. Antimutagenic effect of *kimchi*. *Food Biotechnol* 4: 141-145.
12. Cho EJ, Park KY, Rhee SH. 1997. Standardization of ingredient ratio of Chinese cabbage *kimchi*. *Korean J Food Sci Technol* 29: 1228-1235.
13. Cho EJ, Lee SM, Rhee SH, Park KY. 1998. Studies on the standardization of Chinese cabbage *kimchi*. *Korean J Food Sci Technol* 30: 324-332.
14. Cho EJ, Rhee SH, Park KY. 1998. Standardization of kinds of ingredient in Chinese cabbage *kimchi*. *Korean J Food Sci Technol* 30: 1456-1463.
15. AOAC. 1990. *Official Methods of Analysis*. 15th ed. Association of official analytical chemist, Washington, D.C. p 60.
16. Lee MK, Park WS, Kang KH. 1996. Selective media for isolation and enumeration of lactic acid bacteria from *kimchi*. *J Korean Soc Food Sci Nutr* 25: 754-760.

(Received January 23, 2007; Accepted February 28, 2007)