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Quality Characteristics of Commercial *Baechukimchi* During Long-term Fermentation at Refrigerated Temperatures

Lan-Hee Jung and Eun-Raye Jeon[1]*

Department of Home Economics Education, Human Ecology Research Institude, Chonnam National University, Gwangju 500-757, Korea
[1]Department of Food Technology, Sunghwa College, Gangjin, Jeonnam 527-812, Korea

Abstract This study addresses the quality characteristics of commercial *baechukimchi* by analyzing its physicochemical characteristics and sensory properties in relation to fermentation time and temperature. The salinity of *baechukimchi* increased to 3.01% after 45 days of fermentation at 2 and 5°C, but decreased to 2.81% by 105 days. The pH decreased gradually at the beginning of fermentation, but decreased after 45 days. The acidity differed most between *kimchi* fermented at 2°C (0.36%) and 5°C (0.48%) at 45 days of fermentation. The vitamin C content was 8.47 mg% in *kimchi* fermented at both 2 and 5°C on the day of initial production, then peaked after 45 to 60 days at 14.10 mg%, and decreased thereafter. The total microbial count gradually increased during the first 75 days of fermentation. The appearance and overall acceptability of *baechukimchi* were highest after 90 days of fermentation at 2°C and after 60 days of fermentation at 5°C.

Keywords: long-term fermentation, commercial *baechukimchi*, quality characteristics

Introduction

Kimchi is a representative traditional fermented food and an important side dish in Korea (1). It has a unique flavor and is made by preserving vegetables such as cabbages, radishes, or cucumbers with added salt, salted sea foods, seasonings, or spices, and fermenting for given periods (2).

At first, *kimchi* was processed as a means of winter storage of vegetables, but it has now become a unique and delicious food. Although homemade *kimchi* has been popular traditionally, industrial *kimchi* has become increasingly important due, in part, to economic efficiency *kimchi* consumption in Korea and overseas exports have increased annually (3-6). Increased demand for *kimchi* is expected since many studies have reported the beneficial effects of *kimchi* on health such as antimutagenic (7) and anticancer (8) effects.

Although *kimchi* has traditionally been eaten after specified periods of fermentation, the introduction of refrigeration has increased the demand for non-fermented *kimchi,* optimum-fermented *kimchi,* and over-fermented *kimchi* (9). Thus, in their attempts to please consumer taste, *kimchi* makers are trying to commercialize optimum-fermented *kimchi* for the international market. Currently *kimchi* has been marketed as a healthy food. *Kimchi* is a live food and its continuous fermentation causes a change in quality, producing a variety of organic acids and carbonic acid gas. *Kimchi* is its most nutritious and freshest after the optimal time of fermentation, however it turns sour after full fermentation, resulting in textural changes and off-flavor. For this reason, optimum fermentation conditions should be determined to inhibit the over-fermentation of *kimchi* and maintain the delicious *kimchi* taste for a longer time.

*Corresponding author: Tel: +82-61-430-5312; Fax: +82-61- 430-5001
E-mail: eunyae-j@hanmail.net
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The most common quality indices of *kimchi* are pH and acidity, which are affected by various factors during fermentation (10, 11). The most important factor affecting the fermentation of *kimchi* is the fermentation temperature (12-16). However, there are few reports on the characteristics of *baechukimchi* under long-term storage at the general fermentation temperatures of a *kimchi* factory.

Accordingly, this study analyzed the physicochemical characteristics and sensory properties of *baechukimchi* under long-term storage at commercial fermentation temperatures. This study thus provides basic data about the optimum fermentation conditions of commercial *baechukimchi.*

Materials and Methods

Materials Asian cabbage those grown in Wando and harvested in January 2005 by an eco-friendly farm products research team from Chonnam National University were used. Other ingredients included sun-dried and powdered hot peppers produced in Haenam, sun-dried salt produced in Sinan, and salted and fermented shrimp and fish sauce stored for 1 year in Mokpo. Flavors such as garlic, ginger, onion, glutinous rice paste, and sea tangle stock were purchased at a traditional market in Gwangju the day before making *kimchi.*

Preparation and fermentation of *kimchi* The Asian cabbage was dried leaves and roots were removed. The cabbages were halved and salted in 4% salt water at a ratio of 1:2 (Asian cabbage/salt water, w/v). The final salt concentration in the Asian cabbage was 14% for 18 hr, then washed 3 times in tap water and drained at room temperature overnight. Hot pepper powder (4.12%), salted and fermented shrimp (2.59%), fish sauce (1.53%), garlic (0.77%), ginger (0.24%), onion (1.41%), glutinous rice paste (1.18%), and sea tangle stock (4.71%) were mixed and finely ground in a mixer mill (AG 2007; Angel, Seoul,

Korea) to make the *kimchi* seasoning mixture. The salted Asian cabbage (83.45%) was blended with *kimchi* seasoning mixture.

The *kimchi* was fermented at the factory fermentation temperature of 2°C and at the refrigeration fermentation temperature of 5°C at home for 165 days.

Chemical and microbial analysis *Kimchi* was classified according to number of days of fermentation ranging from 15 to 165 days. All *kimchi* test samples were ground by a mixer mill (AG 2007; Angel). Salinity was measured by a salinity meter (DR 202; Merbabu, New York, NY, USA), pH was measured by a pH meter (HM-20P; DKK-TOA, Tokyo, Japan), acidity was converted into lactic acid in accordance with AOAC (17), and vitamin C content was measured by the 2,6-dichloroindophenol (DPIP, Sigma, St. Louis, MO, USA) method (18). To measure the total microbial count, 1 mL of *kimchi* liquid was diluted up to 10^6-10^8 fold using 0.1% peptone water, and then a 1 mL sample was spread on plate count agar medium and cultivated for 48 hr at 30°C. Finally, the total microbial count was calculated using a colony counter (19).

Sensory evaluation For sensory evaluation, 60 students, 30 males and 30 females, in the Department of Food and Nutrition who were sensitive at taste discrimination were selected by duo-trio test. The sensory characteristics of *kimchi* were evaluated using a quantitative descriptive analysis (QDA) profile comprising 9 sensory properties items: *kimchi* appearance, salty taste, sour taste, carbonated flavor, off-flavor, crunchiness, hardness, toughness, and overall acceptability. Sensory evaluation was conducting using a 5-point scale (5, very good; 4, good; 3, average; 2, bad; 1, very bad), and was performed at 30-day intervals up to 150 days.

Statistical processing This study used the SPSS (Statistics Package for the Social Science, Ver. 12.0 for Windows) package to obtain averages and standard deviations. ANOVA was conducted to compare physicochemical characteristics and sensory properties according to each fermentation period and to test the significance between average values of each measurement at $p<0.05$ using Duncan's multiple range test.

Results and Discussion

Salinity As shown in Fig. 1, the salinity of *kimchi* increased to 3.01% after 45 days of fermentation at 2 and 5°C, but decreased to 2.81% by 105 days, after which there was little change. In this study, the salinity was somewhat lower (2.81-3.01%) than the optimum salinity of general *kimchi* (3.0%) (13, 16, 20) due to the recent trend toward decreased salt use (21). The optimum salinity of *kimchi* differs according to region and consumer. The *kimchi* of the Seoul or Gyeonggi districts is neither salty nor plain. The *kimchi* of Gyeongsang district is pickled with excessive pickling brine so it tastes salty. In Jeonnam district, much salted fish is used so the *kimchi* is briny (13).

pH As shown in Fig. 2, the pH of *kimchi* decreased gradually at the beginning of fermentation, and decreased further by 45 days, with a large difference between 2°C

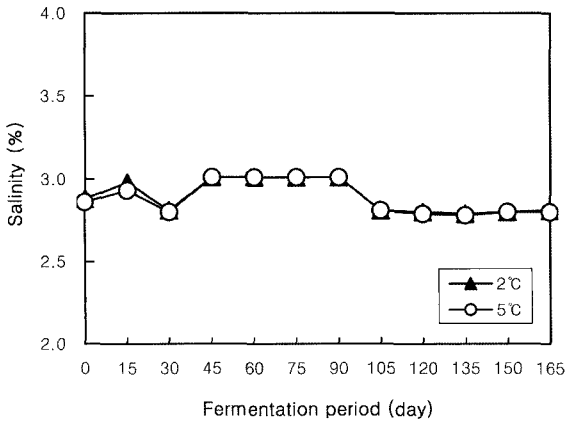

Fig. 1. Changes in salinity of *kimchi* during fermentation at 2 and 5°C for 165 days.

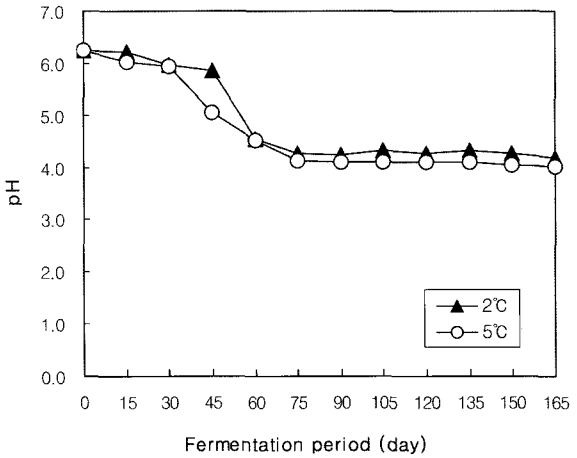

Fig. 2. Changes in pH of *kimchi* during fermentation at 2 and 5°C for 165 days.

fermented *kimchi* (5.86) and 5°C fermented *kimchi* (5.06). The rate of pH decrease slowed after 75 days. This result is similar to that of Kang *et al.* (12) in which the rate of pH decrease was greater with increasing fermentation temperature and longer fermentation periods. Ku *et al.* (10) also suggested that the pH decrease was influenced by fermentation temperature, with the pH of *kimchi* fermented at 2°C having a lower pH than *kimchi* fermented at 5°C. Ku *et al.* (22) reported the optimum fermentation pH for delicious *kimchi* to be 4.1-4.5 (3). In this study, the optimum pH was 4.19-4.54 at 2°C and 4.10-4.51 at 5°C. The pH range was 6.25-4.19 at 2°C and 6.25-4.01 at 5°C, which coincides with another study (22) reporting a wide range of pH from 6.0 to less than 4.0 in commercially available *kimchi*.

Acidity As shown in Fig. 3, the greatest difference in the acidity of *kimchi* fermented at 2°C (0.36%) vs. 5°C (0.48%) was seen at 45 days of fermentation, after which the acidity increased slowly. The acidity of *kimchi* fermented at 5°C increased to a greater degree than *kimchi* fermented at 2°C, which is in agreement with the result of Kang *et al.* (12) in which 20°C fermentation showed a greater increase in pH than 5 fermentation. As Park *et al.* (23) and Hong

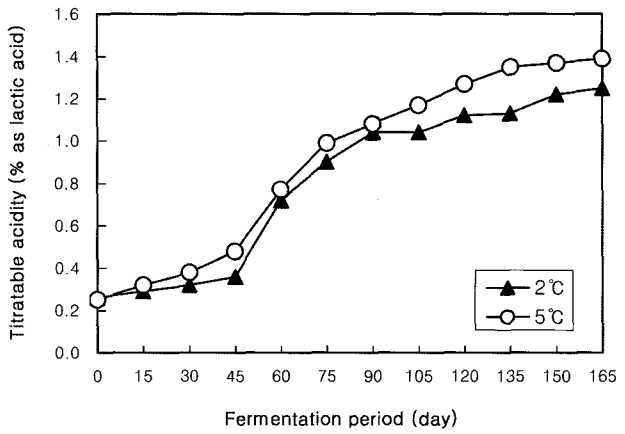

Fig. 3. Changes in acidity of *kimchi* during fermentation at 2 and 5°C for 165 days.

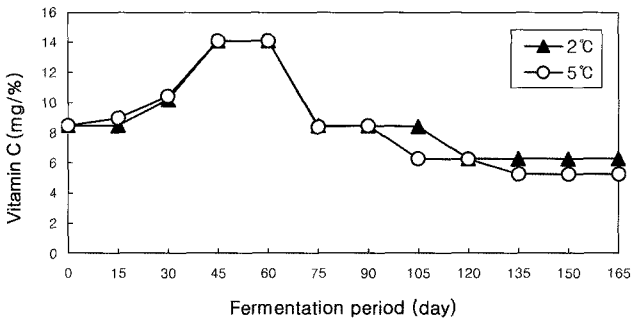

Fig. 4. Changes in vitamin C content of *kimchi* during fermentation at 2 and 5°C for 165 days.

and Park (14) reported, this may have been caused by different kinds and levels of lactic acid bacteria (2, 10). *Ku et al.* (22) reported that commercially available *kimchi* exhibited a wide range of acidity from 0.28% to more than 1%, including excessively fermented *kimchi*, which is consistent with the ranges of 0.26-1.20% at 2°C and 0.26-1.39% at 5°C observed in the present study.

Vitamin C content As shown in Fig. 4, the vitamin C content of *kimchi* was 8.47 mg% in both 2 and 5°C fermented *kimchi* on the day of initial production, then peaked between 45 and 60 days at 14.10 mg%, and decreased thereafter. This result coincides with the result of Yoo *et al.* (9) in which the vitamin C content of fermented *kimchi* decreased at the beginning of fermentation, gradually increased after 2 weeks, peaked after 8 weeks, and then decreased again. They suggested that vitamin C was created from pectin and other ingredients in *kimchi* by aerobic bacteria and reaches 10.18 mg% after the optimum period of fermentation (21).

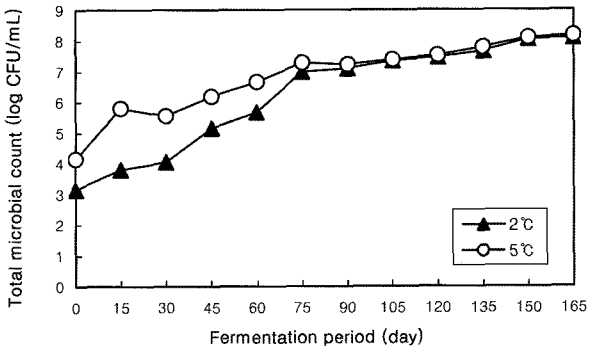

Fig. 5. Changes in total microbial count of *kimchi* during fermentation at 2 and 5°C for 165 days.

Total microbial count As shown in Fig. 5, the total microbial count of *kimchi* gradually increased up to 75 days, although *kimchi* fermented at 5°C had a higher total microbial count than *kimchi* fermented at 2°C, after which it slowly increased. This result is similar to that of Kang *et al.* (12) in which the total microbial count decreased at lower fermentation temperatures, and with the results of Park *et al.* (24) in which the microbial count increased at higher fermentation temperatures. These results confirmed that fermentation temperature has an effect on the growth of bacteria during *kimchi* fermentation (15).

Sensory properties As shown in Table 1, the appearance and overall acceptability of *kimchi* peaked at 2°C for 90 days fermentation and at 5°C for 60 days fermentation. As shown in Fig. 6 and 7, the mean sensory evaluation scores

Table 1. Sensory properties of *kimchi* during fermentation at 2 and 5°C for 150 days

Sample	Fermentation period (day)	Appearance	Salty taste	Sour taste	Carbonated flavor	Off-flavor	Crunchiness	Hardness	Toughness	Overall acceptability
2°C	30	3.00±0.71$^{bc1)}$	3.80±0.45^{a}	3.80±0.45^{a}	4.00±0.00^{a}	3.80±0.45^{a}	3.80±0.45^{a}	3.20±0.45^{a}	3.00±0.00^{b}	3.60±0.89^{a}
	60	3.60±0.55^{ab}	3.40±0.55^{ab}	3.40±0.55^{a}	3.40±0.55^{a}	3.00±0.00^{b}	4.00±0.00^{a}	3.00±0.00^{a}	3.60±0.55^{a}	3.80±0.45^{a}
	90	4.00±0.00^{a}	3.40±0.55^{ab}	3.60±0.55^{a}	3.40±0.55^{a}	3.80±0.45^{a}	3.60±0.55^{a}	3.00±0.00^{a}	2.60±0.55^{bc}	4.00±0.00^{a}
	120	2.60±0.55^{cd}	3.00±0.00^{b}	3.40±0.55^{a}	3.40±0.55^{a}	3.60±0.55^{a}	3.00±0.00^{b}	3.00±0.00^{a}	2.80±0.45^{bc}	2.80±0.45^{b}
	150	2.20±0.45^{d}	3.60±0.55^{ab}	4.00±0.00^{a}	4.00±0.00^{a}	4.00±0.00^{a}	2.60±0.55^{b}	1.80±0.45^{b}	2.20±0.45^{c}	2.60±0.55^{b}
5°C	30	2.20±0.45^{ab}	3.60±0.89^{ab}	3.80±1.79^{ab}	4.80±0.45^{a}	4.60±0.55^{a}	2.20±0.45^{b}	2.20±0.45^{b}	2.00±0.71^{bc}	2.40±0.55^{a}
	60	2.60±0.55^{a}	4.00±0.00^{a}	4.80±0.45^{a}	4.20±0.84^{ab}	3.80±0.45^{b}	3.60±0.55^{a}	3.60±0.55^{a}	4.00±0.00^{a}	3.20±1.10^{a}
	90	2.00±0.00^{ab}	3.20±0.84^{ab}	3.40±0.89^{b}	3.80±0.84^{b}	3.80±0.84^{b}	3.20±0.45^{a}	2.40±0.55^{b}	2.60±0.55^{b}	2.40±0.55^{a}
	120	1.60±0.89^{bc}	3.20±0.45^{ab}	4.80±0.45^{a}	4.80±0.45^{a}	4.80±0.45^{a}	1.60±0.55^{bc}	1.40±0.55^{c}	1.40±0.55^{c}	1.40±0.55^{b}
	150	1.20±0.45^{c}	3.00±0.00^{b}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	1.20±0.45^{c}	1.00±0.00^{c}	1.40±0.55^{c}	1.40±0.55^{b}

[1)]Mean±SD, n=60; Means within the same column with different superscript letters are significantly different at $p<0.05$ by Duncan's multiple range test.

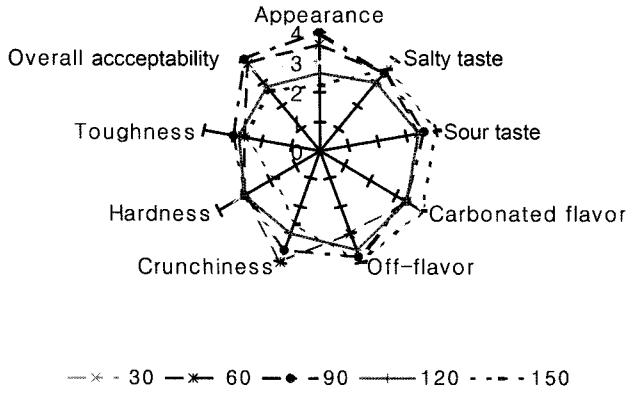

Fig. 6. QDA profile of sensory properties of *kimchi* during fermentation at 2°C for 150 days.

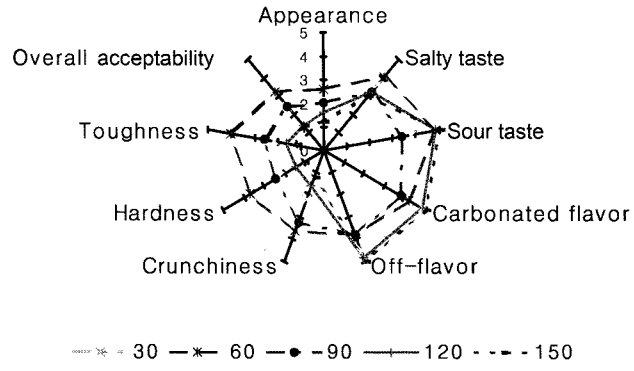

Fig. 7. QDA profile of sensory properties of *kimchi* during fermentation at 5°C for 150 days.

were compared using QDA. Since *kimchi* became sour with prolonged fermentation, the crunchiness, hardness, and toughness decreased. This result is similar to that of Ku *et al.* (10). Off-flavor caused by over-fermented *kimchi* increased with fermentation time, in line with studies on fermented *baechukimchi* by Chung *et al.* (25). During fermentation, the overall acceptability was good after 90 days fermentation at 2°C, and after 60 days fermentation at 5°C, suggesting that fermentation is slower at lower temperatures. This coincides with the result of Song and Kim (26) in that overall acceptability was high when crunchiness, hardness, and toughness were high and off-flavor was low.

In conclusion, the quality characteristics of commercial *baechukimchi* peaked at 60-90 days for fermentation at 2°C, and at 45-60 days for fermentation at 5°C.

Acknowledgments

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