Quality and functional characteristics of *kimchi* made with organically cultivated young Chinese cabbage (*olgari-baechu*)

Su Jin Jung, Min Jung Kim, Soo Wan Chae

**Abstract**

**Background:** Recently, studies on nutritional and functional differences in agricultural products cultivated by organic and conventional farming have been frequently reported. However, there are few studies on the physiochemical and sensory characteristics of *kimchi* made of organically cultivated young Chinese cabbage (*olgari-baechu*) according to agricultural differences.

**Methods:** Different types of *kimchi* were produced using three different types of young Chinese cabbage: young Chinese cabbage cultivated using the nature-friendly compost (YC-FNC) as a way of organic farming; young Chinese cabbage cultivated using commercially available organic compost (YC-GC); and the general young Chinese cabbage cultivated using chemical fertilizers (YC-Control) as a way of conventional farming. Physiochemical, sensory, and functional characteristics of these types of *kimchi* were compared and analyzed according to the passage of ripening.

**Results:** In general nutritional ingredients according to agricultural differences, the YC-Control showed high contents in moisture, crude protein, and crude fat. YC-FNC and YC-GC showed high contents in total dietary fibers, vitamin C, and phytochemicals significantly (*p < 0.01*). In inorganic matter YC-FNC and YC-GC had high contents of P, Ca, Mg, and Fe and YC-Control had high contents of N, K, Cu, Mn, and Zn significantly (*p < 0.01*). YC-Control had a higher rate in approaching the optimum ripening period, pH 4.96, than YC-FNC and YC-GC. Then, it was verified that the ripening of YC-FNC and YC-GC is gradually processed. The total polyphenols and flavonoids contents in YC-FNC and YC-GC were twice as large as YC-Control. Also, it was verified that the contents of the total polyphenol and flavonoid are significantly increased during storage in the *kimchi* made of all young Chinese cabbages regardless of agricultural differences (*p < 0.01*). Lactic acid bacteria in the *kimchi* and in all bacteria were significantly increased according to the ripening period (*p < 0.01*). *Kimchi* made from organic young Chinese cabbage showed higher sensory characteristics and longer storage (*p < 0.01*) than that of the generally cultivated young Chinese cabbage.

**Conclusion:** The storage periods of the organic young Chinese cabbage *kimchi* were extended compared to the general young Chinese cabbage *kimchi* processed by the conventional farming. *Kimchi* made of organic young Chinese cabbage is a possible functional food because it increases the sensory characteristics and tastes. In addition, it enables the intake of highly functional bioactive substances.
advantages in health. However, controversial issues still exist on whether agricultural products cultivated by organic farming include higher contents in healthy bioactive substances than conventional farming [2–4] or not [5–7]. Also, studies on nutritional and functional differences in both organically and conventionally cultivated agricultural products have been constantly reported [8–17]. The nutritional ingredients and bioactive substances in agricultural products can be varied according to geographic environments, varieties and times of cultivation, soils, and fertilization strategies [18]. It was reported that the amount of accumulated nitrate inside a plant increases as the amount of nitrogen fertilization is increased [19]. Also, there were reports that the nitrate is reduced to nitrite in the intestines, which reacts with existing amines in the body and produces nitrosamine, a carcinogen [20,21]. However, this has still not been determined in clinical studies. Good meals for people have to present good tastes and different bioactive substances (phytochemicals) in addition to nutritional ingredients such as vitamins and inorganic matter. The reason that the phytochemicals have been highlighted in recent years is due to its various bioactive functions such as antioxidant, anticancer, anti-inflammatory, and detoxification. Baechu (Chinese cabbage; Brassica campestris L. ssp. pekinensis) is one of the most consumed vegetables in Korea. The cabbage is used as a major ingredient of kimchi [22]. Olari-baechu is classified as spring-baechu, summer-baechu, or autumn-baechu according to its cultivation season. Also, it is divided into three different types, kyolku, semi-kyolku, and non-kyolku, in which the kyolku shows a closely packed baechu head. Kimjang kimchi is usually made of the kyolku baechu, and the spring and summer kimchis are made of the semi-kyolku spring cabbage (bombaeng baechu) and olgari-baechu [23], respectively. The characteristics of the ingredient of cabbages represent high nutritional values due to its high contents of vitamin C, inorganic matter (Ca, K, Fe, P, etc.), and dietary fibers. Also, it includes a large amount of functional phytochemicals such as benzyl isothiocyanate, indoles, thiocya-nates, and sitosterols [24,25]. Lactobacilli in kimchi produce organic acids and fermentation products using sugars in baechu through a fermentation process. Also, the kimchi inhibits the proliferation of harmful bacilli by producing antibiotics, such as bacteriocin, and increase functional compounds through generating unique flavors and piquancy [26]. In particular, it has been reported that various phytochemicals, such as vitamins, chlorophylls, flavonoids, and polyphenols, included in both the staple ingredient, baechu, and the subingredients, such as red pepper powder, garlic, and ginger, and different compounds generated by microorganisms during the ripening process of the kimchi [23] represent different effects such as anticancer and reverse mutation [27,28], antioxidant [29], antiatherogenic [30], antidiabetic [31], antiaging [32], and fibrinolytics [33]. Studies on improving the storage, quality difference [34], and functionality of kimchis have been conducted in different ways. It is known that different health functionalities are presented according to ingredients used in kimchis. Although some reports on both the differences in nutritional and functional ingredients [35] and the quality characteristics of olgari-baechu kimchi have been presented, there are few comparative studies on the quality and sensory characteristics of the olgari-baechu kimchi according to agricultural practices. As the production and consumption of safe foods has emerged as an important issue under the idea of health protection, it is important and is required to analyze and determine the differences in the quality and sensory characteristics of environmentally friendly agricultural products.

Thus, in this study the physochemical and sensory characteristics of the kimchis made of organically and conventionally cultivated olgari-baechu were investigated, while the kimchis were stored for over 24 days in order to determine the effects of cultivation methods on the quality and sensory characteristics of these kimchis.

2. Materials and methods

2.1. Materials and cultivation

Cabbages (Chinese cabbage, B. pekinensis RUP; olgari-baechu) for experiment were directly planted in a plastic greenhouse (5 m × 60 m) belonging to Agricultural Soyowon, Co., Ltd. located in Jeongwon-Li, Imsil-eup, Imsil-gun, Jeonbuk. It was cultivated for 2 months, from April 5 to June 4. The cabbages were divided into two groups; fertilization and control groups. The fertilization group used two fertilizers for cultivating olgari-baechu organically; eco-developed fertilizer (livestock excreta fermentation fertilizer, YC-FNC; CTCF2 Yoyo Korea Inc., Jeongeup, Korea) and commercial organic compost (YC-GC; functional stevia fertilizer, livestock excreta high-grade fertilizer, Korean stevia; Jeongeup). The control group (YC-Control) represents the general olgari-baechu cultivated using a chemical fertilizer (No. 14, Dongbu Farm Hannong, Seoul, Korea) in which three different fertilizers were prescribed. The fertilizer prescription followed the standard proposed by the National Academy of Agricultural Science (Good Agricultural Practices program; National Academy of Agricultural Science 2010 [36]). The eco-developed fertilizer (YC-FNC) treated group was processed by mixing the eco-developed fertilizer (560 kg/10a) with the mixed organic fertilizer (150 kg/10a, Green N-P-K 4-1-3; Biogreentech Inc., Kyoungki, Korea). The organic compost treated group (YC-GC) was processed by 560 kg/10a, and the control group with the chemical fertilizer (YC-Control) was processed by the basal fertilizer (urea, 12 kg/10a; phosphatic fertilizer, 18 kg/10a; and potassium chloride, 12 kg/10a) + additional fertilizer (urea, 42 kg/10a; potassium chloride, 18 kg/10a). These fertilizers were applied to the cultivation for 2 months (Fig. 1).

2.2. Nutritional composition analysis

2.2.1. Proximate analysis

The samples were fabricated by cutting the olgari-baechu with a size of 3 cm × 3 cm (Fig. 1) after removing foreign materials. The cuts were then packed in a plastic bag and lyophilized (IlShin Biobase, Korea) and pulverized (Hanil, Incheon, Korea). A proximate analysis was implemented by the AOAC method [37]. The moisture content was determined using an air-oven heating method at 105°C; the content of crude proteins was determined using the Micro Kjeldahl method; the content of crude fats was determined using an ether extraction method; the content of crude ashes was determined using a dry ashing method; and the content of crude dietary fibers was determined using the Prosky method [37].

2.2.2. Determination of mineral compositions

The contents of the main (P, K, Ca, and Mg) and trace (Fe, Zn, and Mn) minerals were determined in the freeze-dried sprouts samples. Briefly, 1 g was refluxed in a digestion system (Velp DK 42P) for 2 hours with 6 mL of 65% HNO3 under different temperatures (30 minutes at 50°C; 30 minutes at 80°C; 30 minutes at 150°C; and 30 minutes at 165°C) and for 3 hours with 4 mL of 70% HClO4 (30 minutes at 165°C; 60 minutes at 180°C; 60 minutes at 190°C; and 30 minutes at 200°C). After cooling, 10 mL of ultrapure water was added to each sample, which was left to stand for 60 minutes at 120°C. Final volumes were adjusted to 50 mL with ultrapure water. K, Ca, Mg, Fe, Zn, and Se were determined in the digested solutions by flame-atomic absorption spectrometry (Analyt 200; Perkin Elmer Waltham, MA, USA), while P content was determined according to the 4500-P B. The vitamin C composition was analyzed using the ascorbic acid standard method [38] in a UV/VIS spectrophotometer at 670 nm.
2.3. Preparation and fermentation of kimchi

The subingredients used to produce kimchi, such as red pepper, garlic, ginger, leek, and glutinous rice flour, were purchased from a large discount store on the day prior to preparation. The composition ratios of the ingredients used in the kimchis are presented in Table 1. The first process of producing the kimchis was selecting fresh olgari-baechu with similar size and shape and then washing the whole body (stem + leaf). Then, the washed olgari-baechu was preserved with a 7% sun-dried salt solution (80–90% of NaCl, Sinan sun-dried salt; Sinan-gun, Korea) for 1 hour. The next process is washing the preserved olgari-baechu three times and dewatering it for 30 minutes before applying the kimchi producing process. Garlic and ginger were prepared by cleaning and crushing (MR 4050 CA; Braun, Madrid, Spain). In the production process of the olgari-baechu kimchis, the composition ratios of the ingredients were determined as follows: the preserved olgari-baechu, 100 g, was mixed with 3.7 g of garlic, 1.5 g of ginger, 5.1 g of green onion, 4.8 g of red pepper powder, 6.2 g of liquid salted anchovy (Daesang Co., Ltd.), and 80 g of starch (glutinous rice:water = 1:9) [34]. The kimchis were stored at 5°C for 24 days. The experiments were implemented using the stored kimchi samples with a specific storage of 0 days (the day of storage), 7 days, and 24 days.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Ingredients in olgari-baechu kimchi.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients</td>
<td>Weight (g)</td>
</tr>
<tr>
<td>Young Chinese cabbage</td>
<td>100</td>
</tr>
<tr>
<td>Garlic</td>
<td>3.7</td>
</tr>
<tr>
<td>Ginger</td>
<td>1.5</td>
</tr>
<tr>
<td>Red pepper powder</td>
<td>4.8</td>
</tr>
<tr>
<td>Green onion</td>
<td>5.1</td>
</tr>
<tr>
<td>Anchovy juice</td>
<td>6.2</td>
</tr>
<tr>
<td>Thick salt</td>
<td>—</td>
</tr>
<tr>
<td>Glutinous rice</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Fig. 1. Three different types of young Chinese cabbage and Olgari-baechu kimchi cultivated using different of fertilizers.

2.4. pH and acidity

Each kimchi sample (100 g) was crushed (MR 4050 CA) for 3 minutes and was diluted five times using 10 g of distilled water. Then, the pH of the kimchi samples was measured (PP-15; Sartorius Co., Elk Grove Village, IL, USA) and the titratable acidity was determined by titrating with 0.1N NaOH to an end point of pH 8.3 [37].

2.5. Reducing sugar contents

The reducing sugar content in kimchi was measured by Yang et al’s [39] colorimetry using dinitrosalicylic acid. Dinitrosalicylic acid reagent was added to the dilute solution of kimchi, the mixture was stirred thoroughly, left 5 minutes for reaction, and cooled down. For the solution with developed color, we measured absorbance at 546 nm (UV-1,650PC; Shimadzu Co., Kyoto, Japan) and converted the result into glucose concentration for presentation.

2.6. Microbiological analysis

The total number of bacteria was measured using 10 g of the kimchi sample; 90 mL of 0.1% sterilized peptone water was added to the sample and the mixture was homogenized using a bag mixer (400 Model W STOMACHER; Korea Scientific Co., Daejeon, Korea) and the supernatant diluted with 0.1% peptone. The viable bacteria were counted using MRS and phenylethanol agars (Difco; Becton, Dickinson and Company, Franklin Lakes, NJ, USA) with 2% sucrose (PES [39]). Each sample was serially diluted with 0.85% (w/v) physiological saline. The total number of lactic acid bacteria was determined by spread-plating onto the MRS agar and incubating at 371°C for 48 hours, and the Leuconostoc genus population was counted by spread-plating onto the PES agar after incubation at 20°C for 48 hours [13]. In counting the number of lactobacilli, the number of colonies was counted (colony-forming units/mL) by
incubating the sample at 37 ± 1°C for 48 hours after solidifying it using MRS agar (Lactobacilli MRS agar; Becton, Dickinson and Company) with a 0.05% BCP indicator and overlapping PCA agars in order to avoid diffusion colonies.

2.7. Total polyphenol and flavonoid contents

2.7.1. Sample preprocessing

A microwave sample extraction device (Mars; CEM, Matthews, NC, USA) was used to prepare the sample by mixing 10 g of each sample with 50 mL of 70% methanol was added to the sample. The extraction was implemented at 90°C for 1 hour and 100 mL of each extraction was applied to the experiment.

2.7.2. Total polyphenol assay

The total polyphenol contents of the sample were measured using the Folin–Denis method [40]. That is, the sample solution, 0.1 mL, was mixed with 6 mL of distilled water and 0.5 mL of the Folin–Denis reagent and the mixture was laid at room temperature for 3 minutes.

2.7.3. Total flavonoid assay

The analysis of the total flavonoid contents was performed on 10 g of the kimchi sample by adding 20 mL of 90% ethanol. Then, it was centrifuged at 3,000 rpm for 10 minutes and the supernatant collected. Three more extractions were implemented three times by adding 8 mL of 80% ethanol to the residue. The total mixture was made up to 50 mL by missing the previous extracts with 80% of ethanol and was kept at room temperature for 40 minutes. Then, the absorbance was measured at 765 nm (UV 1,601; Shimadzu) with gallic acid (Sigma–Aldrich Co., St Louis, MO, USA) as a standard solution.

2.8. Sensory characteristics

The produced kimchis were stored at 5°C in a refrigerator and evaluations of the kimchis were performed at 0 days (the day of storage), 7 days, and 24 days after storage. In the sensory evaluation, the kimchi sample was prepared with about 15 g in a dish for each test group. A deep breath of the odor was taken for 4–5 seconds for appreciating it and the taste and texture were evaluated by chewing the sample without swallowing it. To avoid the effects of residual tastes on other kimchi samples, some boiled rice and water were provided to the evaluator. The sensory evaluation was performed by appearance. The odor evaluation consisted of four items: acidic odor, moldy odor, fresh cabbage odor, and fresh acidic odor. The taste evaluation consisted of acidic taste, moldy taste, and fresh acidic odor and fresh soursness taste. The texture evaluation consisted of fracture ability and chewiness. Then, the general taste was also evaluated. The levels for each evaluation were presented by a 5-point rating scale (5, very good; 4, good; 3, acceptable; 2, poor; and 1, very poor).

2.9. Statistical analysis

Data obtained from the study are presented as mean ± standard deviation and the differences between samples and growth conditions were tested by one-way analysis of variance followed by post hoc Duncan’s multiple range comparison tests, using SPSS version 18.0 software (SPSS Inc., Chicago, IL, USA) for Windows. Statistical significance was defined as p < 0.05. The correlation between the physiochemical characteristics of the test cultivation soil and the olgari-baechu after harvesting was verified using Pearson’s correlation coefficient.

3. Results

3.1. Proximate and nutrients contents

The results of the analyses of general nutritional contents in the organic olgari-baechu (YC-FNC, YC-GC) and the control group, general olgari-baechu (YC-Control: chemical fertilizer), are presented in Table 2. The YC-Control represents high contents of moisture, crude fat, and crude protein and YC-FNC and YC-GC had high contents of total dietary fibers and vitamin C. In the case of inorganic matters, P, Ca, Mg, and Fe, YC-FNC and YC-GC showed higher contents than YC-Control. YC-Control had significant (p < 0.01) N, K, Cu, Mn, and Zn contents compared to YC-FNC and YC-GC.

3.2. Correlation between the physiochemical characteristics of the test cultivation soil and the cabbage after harvesting

The results of the analyses of the correlation between the physiochemical characteristics of the test cultivation soil and the cabbage after harvesting are presented in Table 3. The correlation between the pH value in the test cultivation soil and the moisture (p < 0.049) and crude protein (p < 0.031) showed a negative figure but the correlation between the vitamin C content (p < 0.032) and the total polyphenol content (p < 0.025) represented a positive figure. Also, the correlation between the P2O5 content of phosphoric acid in the soil and the K (p < 0.009) and crude fiber (p < 0.017) contents of the cabbage showed a positive figure. The correlation between the K content in the soil and the moisture and protein contents of the cabbage showed a positive figure but the correlation between the vitamin C content (p < 0.026) and the total polyphenol (p < 0.031) content showed a negative figure.

3.3. pH and acidity

Changes in the acidity and pH according to storage periods in the kimchi made of olgari-baechu cultivated by varying fertilizer prescriptions are presented in Table 4. The pH in all types of olgari-baechu kimchi was 5.51 on the day of preparing the kimchi. The pH values after 7 days and 24 days of storage were 5.0 and 4.5, respectively. There was a tendency of the pH value to decrease significantly according to the length of time of storage (p < 0.001). The acidity on Day 0 was about 0.29–0.30% and the values after 7 days and 24 days of storage were 0.32–0.36 and 0.36–0.40%, respectively. The acidity increased significantly according to ripening period (p < 0.001).

3.4. Reducing sugar

Changes in reducing sugars of the olgari-baechu kimchi during storage are presented in Fig 2. There were no significant differences in reducing sugar contents between YC-Control and YC-FNC and YC-GC kimchi groups. Also, the reducing sugar contents were generally decreased after 24 days of storage (p < 0.002) compared to the early stage of the storage.

3.5. Microbiological aspects

Changes in the total number of Lactobacillus and other bacteria in the olgari-baechu kimchi according to storage periods are presented in Table 5. The total number of Lactobacillus sp. in both YC-FNC and YC-GC kimchi and YC-Control kimchi started to increase after 7 days and was further increased after 24 days significantly compared to that of Day 0 (p < 0.001).
Table 2
Proximate composition, mineral and vitamin contents of olgari-baechu kimchi.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Moisture (g/100 g)</th>
<th>Lipid (g/100 g)</th>
<th>Protein (g/100 g)</th>
<th>Ash (g/100 g)</th>
<th>Fiber (g/100 g)</th>
<th>Vitamin C (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YC-Control†</td>
<td>17.3 ± 0.1³</td>
<td>2.33 ± 1.1</td>
<td>17.9 ± 0.4³</td>
<td>14.8 ± 0.4³</td>
<td>31.3 ± 0.4³</td>
<td>19.3 ± 0.9³</td>
</tr>
<tr>
<td>YC-FNC</td>
<td>8.08 ± 1.1³</td>
<td>1.70 ± 1.1</td>
<td>11.8 ± 1.1²</td>
<td>15.0 ± 0.3³</td>
<td>36.7 ± 1.7³</td>
<td>350.2 ± 1.7³</td>
</tr>
<tr>
<td>YC-GC</td>
<td>7.50 ± 0.5³</td>
<td>1.45 ± 1.1</td>
<td>12.1 ± 1.4</td>
<td>16.7 ± 0.5³</td>
<td>40.5 ± 1.3³</td>
<td>377.7 ± 13.1³</td>
</tr>
<tr>
<td>p</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.002</td>
<td>0.004</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 3
Correlation coefficients between physical properties of soil after harvesting that affects the composition of olgari-baechu.

<table>
<thead>
<tr>
<th>Soil</th>
<th>pH (soil)</th>
<th>Total N</th>
<th>P₂O₅</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0.866 (0.333)</td>
<td>0.919 (0.257)</td>
<td>1.000 (0.000)</td>
<td>0.994 (0.671)</td>
<td>0.958 (0.186)</td>
<td></td>
</tr>
<tr>
<td>Young Chinese</td>
<td>N</td>
<td>-0.867 (0.322)</td>
<td>-0.502 (0.655)</td>
<td>-0.993 (0.075)</td>
<td>0.872 (0.326)</td>
<td>0.861 (0.339)</td>
</tr>
<tr>
<td>P</td>
<td>0.913 (0.267)</td>
<td>0.588 (0.600)</td>
<td>1.000 (0.000)</td>
<td>0.936 (0.241)</td>
<td>0.805 (0.402)</td>
<td>0.992 (0.081)</td>
</tr>
<tr>
<td>K</td>
<td>-0.135 (0.783)</td>
<td>-0.761 (0.499)</td>
<td>0.063 (0.960)</td>
<td>0.326 (0.789)</td>
<td>0.654 (0.546)</td>
<td>0.050 (0.968)</td>
</tr>
<tr>
<td>Ca</td>
<td>0.963 (0.174)</td>
<td>0.698 (0.508)</td>
<td>0.992 (0.083)</td>
<td>-0.965 (0.168)</td>
<td>-0.711 (0.407)</td>
<td>-1.000 (0.011)</td>
</tr>
<tr>
<td>Mg</td>
<td>0.778 (0.433)</td>
<td>0.359 (0.768)</td>
<td>0.962 (0.175)</td>
<td>-0.784 (0.427)</td>
<td>-0.931 (0.238)</td>
<td>-0.926 (0.247)</td>
</tr>
<tr>
<td>Cu</td>
<td>-0.305 (0.802)</td>
<td>-0.771 (0.440)</td>
<td>-0.963 (0.175)</td>
<td>0.184 (0.882)</td>
<td>-0.969 (0.160)</td>
<td>-0.197 (0.874)</td>
</tr>
<tr>
<td>Lipid</td>
<td>-0.970 (0.156)</td>
<td>-0.718 (0.492)</td>
<td>-0.987 (0.101)</td>
<td>0.972 (0.150)</td>
<td>0.691 (0.515)</td>
<td>0.999 (0.029)</td>
</tr>
<tr>
<td>Protein</td>
<td>-0.999 (0.031)</td>
<td>-0.889 (0.303)</td>
<td>-0.899 (0.288)</td>
<td>0.998 (0.037)</td>
<td>0.452 (0.702)</td>
<td>0.943 (0.216)</td>
</tr>
<tr>
<td>Ash</td>
<td>0.587 (0.601)</td>
<td>0.104 (0.934)</td>
<td>0.858 (0.343)</td>
<td>-0.595 (0.595)</td>
<td>-0.994 (0.071)</td>
<td>-0.795 (0.415)</td>
</tr>
<tr>
<td>Fiber</td>
<td>0.909 (0.274)</td>
<td>0.579 (0.607)</td>
<td>1.000 (0.017)</td>
<td>-0.913 (0.268)</td>
<td>-0.811 (0.397)</td>
<td>-0.990 (0.088)</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>0.999 (0.022)</td>
<td>0.885 (0.308)</td>
<td>0.903 (0.282)</td>
<td>0.999 (0.031)</td>
<td>0.459 (0.696)</td>
<td>0.946 (0.211)</td>
</tr>
<tr>
<td>Total polyphenol</td>
<td>0.999 (0.025)</td>
<td>0.885 (0.308)</td>
<td>0.903 (0.282)</td>
<td>0.999 (0.031)</td>
<td>0.459 (0.696)</td>
<td>0.946 (0.211)</td>
</tr>
<tr>
<td>Total flavonoid</td>
<td>0.627 (0.568)</td>
<td>0.154 (0.902)</td>
<td>0.883 (0.311)</td>
<td>-0.635 (0.562)</td>
<td>-0.987 (0.103)</td>
<td>-0.825 (0.383)</td>
</tr>
</tbody>
</table>

Significance as determined by Pearson's correlation coefficient.
† p < 0.05.
‡ p < 0.01.

Table 4
Changes in pH and acidity (% citric acid) of the Olgari Baechu kimchi with fermentation time.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Fermentation time (d)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>pH</td>
<td>YC-Control†</td>
<td>5.51 ± 0.3³</td>
</tr>
<tr>
<td></td>
<td>YC-FNC</td>
<td>5.31 ± 0.03³</td>
</tr>
<tr>
<td></td>
<td>YC-GC²</td>
<td>5.58 ± 0.03³</td>
</tr>
<tr>
<td>Acidity</td>
<td>YC-Control†</td>
<td>0.31 ± 0.03³</td>
</tr>
<tr>
<td></td>
<td>YC-FNC</td>
<td>0.29 ± 0.03³</td>
</tr>
<tr>
<td></td>
<td>YC-GC²</td>
<td>0.28 ± 0.02³</td>
</tr>
</tbody>
</table>

Significance as determined by Pearson's correlation coefficient.
† p < 0.05.
‡ p < 0.01.
³ Mean in the bars are significantly different at p < 0.05 by Duncan's multiple range test.

Fig. 2. Changes in reducing sugar contents of baechu kimchi during its fermentation at 5°C for 24 days. YC-Control, young Chinese cabbage commonly cultivated using chemical fertilizers; YC-FNC, young Chinese cabbage commonly cultivated using nature friendly composts; YC-GC, young Chinese cabbage commonly cultivated using general composts.
3.6. Total polyphenol and flavonoid contents in the *olgari-baechu kimchi* with fermentation time.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Fermentation time (d)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Total polyphenol</td>
<td>YC-Control</td>
<td>57.9 ± 2.50</td>
</tr>
<tr>
<td>(mg/GAE/100g)</td>
<td>YC-FNC</td>
<td>83.2 ± 1.37</td>
</tr>
<tr>
<td>extract</td>
<td>YC-GC</td>
<td>63.2 ± 2.11</td>
</tr>
<tr>
<td>Total flavonoid</td>
<td>YC-Control</td>
<td>4.1 ± 0.17</td>
</tr>
<tr>
<td>(mg/QE/g)</td>
<td>YC-FNC</td>
<td>6.5 ± 1.85</td>
</tr>
<tr>
<td>extract</td>
<td>YC-GC</td>
<td>5.2 ± 0.28</td>
</tr>
</tbody>
</table>

VC-Control, young Chinese cabbage commonly cultivated using chemical fertilizers; YC-FNC, young Chinese cabbage commonly cultivated using nature friendly composts; YC-GC, young Chinese cabbage commonly cultivated using general composts. * Young-Chinese cabbage commonly cultivated using chemical fertilizers. 1 Young-Chinese cabbage commonly cultivated using nature friendly composts. 2 Young-Chinese cabbage commonly cultivated using general composts.

**a-c** Mean in the bars are significantly different at p <0.05 by Duncan’s multiple range test.

3.7. Sensory characteristics

The results of the sensory evaluation, such as external appearance, odor, taste, fractural taste (texture), and total appearance, during its storage periods in the *olgari-baechu kimchi* produced by varying agricultural applications are presented in Table 7. The *olgari-baechu kimchi* generally represented decreases in fresh cabbage odor and fresh cabbage taste according to passage of storage compared to the days just after producing it and acidic odor, moldy odor, moldy taste, and fresh sourness taste were significantly increased (p < 0.001). YC-Control kimchi showed increases in moldy odor (p < 0.004) and moldy taste (p < 0.001), and fresh sourness taste (p < 0.014) after 7 days from the storage compared to YC-FNC and YC-GC kimchis but represented decreases in fresh cabbage odor (p < 0.008) and fresh acidic odor (p < 0.002). Also, YC-FNC and YC-GC kimchi showed improvement in overall appearance during storage periods compared to YC-Control kimchi (p < 0.05).

4. Discussion

In this study, the nature-friendly compost-based *olgari-baechu* (YC-FNC) *kimchi*, the two types of organic compost-based *olgari-baechu* (YC-GC) *kimchi*, and the conventional farming *chemical fertilizers*-based general *olgari-baechu* (YC-Control) *kimchi* were produced by varying agricultural applications and these different *kimchis* were stored at 5°C. Then, the quality, sensory, and functional characteristics of the *kimchis* were analyzed according to storage periods; 0 days, 7 days, and 24 days. YC-Control showed high contents of moisture, crude protein, and crude fat and YC-GC and YC-VC had high contents of dietary fiber, vitamin C, and total bioactive substances. Seong et al. [35] showed similar results that organic cabbage represent lower moisture contents than general cabbage and showed 5 times higher total dietary fiber content than general cabbage (2.0% of organic cabbage vs. 1.1% of general cabbage). Also, organic cabbage have 2.5 times higher vitamin C content than general cabbage (47.4 mg of organic cabbage vs. 19.2 mg of general cabbage). In this study, it was verified that YC-FNC and YC-GC...
fermentation process are varied according to ingredients of substrates, storage temperature, storage salinity, etc. [4,34]. The reducing sugar in the Salicornia herbacea powder added young radish water kimchi showed the maximum value after 13 days from its fermentation and then the value is decreased [49]. In this study the reducing sugar content in the olgari-baechu kimchi approaches its optimum ripening time after 7 days from the fermentation and is significantly decreased after 24 days from the fermentation. This shows that the reducing sugar contents vary according to materials used in kimchis.

It was verified that changes in the total number of bacteria in YC-FNC and YC-GC kimchis approached the maximum value after 7 days of fermentation and the value was maintained after 24 days from the fermentation. YR-Control showed increases in the total number of bacteria in the initial stage (Day 0) of the fermentation and showed decreases in the level after 24 days of fermentation. This shows that tendencies in changing the total number of bacteria are different according to agricultural applications. The number of microbes is rapidly increased according to processes of the fermentation in kimchis. Then, as the number of lactobacilli approaches its maximum level, it represents the unique tastes of piquancy and aroma in kimchis. As the kimchi approaches its optimum ripening time, the number of Leuconostoc mesenteroides approaches its maximum value and the number of Lactobacillus plantarum, which causes acidification, is increased as the time of decreasing the number of microorganisms. L. mesenteroides [45]. YC-FNC and YC-GC kimchis had very high contents of bioactive substances compared to YR-Control kimchi: the total polyphenol and flavonoid contents were about 1.3–2 times higher than YR-Control from the initial stage (Day 0) of its fermentation and were slightly increased during fermentation. In the fermentation process of kimchis, lactobacilli generate organic acids and fermentation products through the sugar included in cabbages and that increases tastes and healthy functionalities. In addition, fermentation creates antibiotics such as bacteriocin for inhibiting harmful bacteria, which represents unique flavors in kimchis. Factors in increasing bioactive substances of kimchis are different according to materials, fermentation conditions, pH, oxygen contents, temperature, and preservative agents [45].

Kong et al [46] reported that the young radish cultivated by sulfur treatments shows 2.5 times higher sulfur similar substance, which is a type of phytochemical, contents than that of cultivating it in general types of soil, which represents high effects of inhibiting the growth of AGS cancer cells [11,46]. In addition, organic tomatoes showed two times higher flavonoid contents than general tomatoes [50]. Similarly, in this study the organic olgari-baechu kimchi represented higher bioactive substances than the general olgari-baechu kimchi. In particular, the contents of the nutritional and bioactive substances in agricultural products are influenced by uses of fertilizers [51], soil microorganisms [52], attacks of harmful insects [53], harvest time [54], and other different factors [12,55]. Although the large differences in the bioactive substance contents is believed to be the effects of applying chemical fertilizers and attacks of harmful insects on the generation of the substance while the process and fermentation condition in the kimchi are not different, more specific reasons need to be investigated even though there are agricultural differences.

The YC-FNC and YC-GC kimchis had high scores for preference such as general tastes and odors. In general, the best taste in cabbage kimchis is presented by the total acid contents of 0.6–0.8% and the sourness taste and acidic odor are dramatically increased after 2 weeks from the ripening [56]. In the case of the general olgari-baechu kimchi in this study, the preference of the best taste was presented after 14 days from the ripening and the preference in the organic olgari-baechu kimchi showed a high level after 24 days from fermentation. It is considered that the organic olgari-baechu kimchi
has small and high amounts of moisture and fibers, respectively, which leads to slowing of fermentation. In addition, the optimum fermentation in kimchi is different from the time that affects the sourness taste and acidic odor according to materials and nutritional ingredients. The YC-FNC and YC-GC kimchis had very high bioactive substances contents in the raw material itself compared to the YC-Control kimchi and significantly improved in taste during fermentation. Therefore, it is expected that taking the organic oligo-baechu kimchi represents good tastes and allows getting large bioactive substances. Thus, the products obtained by processing livestock excrement using a batch processing technology (nature-friendly compost) are considered as a quality organic compost resource in environmentally friendly farming. This study proposes that organic oligo-baechu kimchi represents a high possibility for use as a healthy functional element for protecting and treating habitual diseases.

**Conflicts of interest**

All authors have no conflicts of interest to declare.

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