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Original article

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

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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.

1. Introduction

Although agricultural productivity in recent years has been greatly increased by increases in using chemical fertilizers and agrichemicals and improvements in cultivation techniques, this causes environmental pollution and leads to increases in anxieties about the safety of agricultural products. Recently, consumers want environmental protection and healthy foods; following social trends in pursuing health has led to sudden increases in the production and consumption of environmentally friendly agricultural products [1]. The reason that consumers are interested in organic agricultural products is mainly due to environmental protection, improvements in livestock welfare, increases in tastes, and

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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 and is used as a major ingredient of *kimchi* [22]. *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 (*bomdaong 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, thiocyanates, 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], anti-atherogenic [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 kimchis* 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 and environmental 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 physiochemical 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* RUPR; *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 soil 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% HNO_3 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% $HClO_4$ (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 (Analyst 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.