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Effect of *Wasabi* (*Wasabia japonica* Matsum) Stalk on the Fermentation of *Baechukimchi*

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Abstract The effects of *wasabi* stalk on the taste and storage characteristics of *baechukimchi* were assessed in the final product. *Wasabi* stalk was added in different ratios: 0, 1, 3, 5, or 7%(w/v) of Chinese cabbage. As the fermentation progressed, the pH of the product dropped. Total acidity increased in all treatments during fermentation. The total vitamin C content increased during the first 8 to 13 days of fermentation. Reducing sugar decreased in all treatment as fermentation continued. The numbers of total cells and lactic acid bacteria increased until they peaked, and then began decreasing as fermentation continued. With regard to acceptability characteristics, the 3% treatment was most favored. With simple regard to the quantitative level of *wasabi* stalk addition, the 3% treatment was most appropriate under all testing conditions. In conclusion, stalk seems to be an economical and natural additive which has effects on extension of the shelf life of *baechukimchi*.

Keywords: *baechukimchi*, *wasabi*, *wasabi* stalk

Introduction

Kimchi is a traditional fermented vegetable that Koreans have enjoyed for generations; it is a nutritious and delicious preserved food prepared with seasonings (1). Among the various *kimchi* preparations, *baechukimchi* uses Chinese cabbages as the major raw material, and pepper, garlic, ginger, green onion, fermented fish, and other spices are added to the cabbage and fermented (2). *Kimchi* undergoes fermentation even after reaching a delicious state and becomes very sour or soft; hence, efforts have been continuously made to prolong the edible period. Recently, because of the health-conscious demands of consumers, studies are researched at developing substitute preservatives that improve the taste and storage of *kimchi* is required (3,4).

The root and stalk of *wasabi* (*Wasabia Japonica* Matsum), a cruciferous perennial plant, are used primarily as an uncooked food; the entire plant is mixed with mustard and food colors, processed, and eaten. The taste and aroma of the *wasabi* stalk is inferior to the root, and thus its usage level as uncooked food is lower. In Japanese homes, the *wasabi* stalk is often pickled and eaten, and in Korea, it has reportedly been prepared as *kimchi* (5). *Wasabi* contains the volatile compound allylisothiocyanate that is not hot; however, as the plant tissues are damaged by cutting or grounding, it becomes hot due to the release of myrosinase, an enzyme contained within the plant's tissues (6). Allylisothiocyanate has been shown to have a strong preservative property, improve the taste of food, and have appetite-stimulating effects and aid in digestion, as well as antioxidant activity and anticancer activity (7). In Korea, numerous studies on *wasabi*'s antibacterial effect (7-10) and the quality effects of its addition to food (6,11-13) have been reported; nevertheless, these studies have primarily involved the root in most cases, and studies on the stalk are almost nonexistent. Jang and Park (6) and Na and Park (14) have reported that when *wasabi*, which has strong antibacterial activity is added to the seasoning of *dongchimi* and *kimchi*, the storage period of *kimchi* could be prolonged. In addition, *wasabi* has a refreshing taste and a greenish note; therefore, it is anticipated that even when added to Chinese cabbage, the tastes will match well, and the quality will also improve. Within *wasabi*, the root, which is consumed more than other parts of the plant, contains a high level of allylisothiocyanate. When added to *baechukimchi*, therefore, high antibacterial activity is anticipated. However, as its price is high, commercialization may raise the unit price. On the other hand, the *wasabi* stalk is approximately 77 times more economical than the root (the stalk is 1,300 won/kg, the root is 100,000 won/kg, 15), and it is harvested abundantly. Hence, it is convenient to use. Therefore, in our study, the *wasabi* stalk, which is economical and contains antibiotic activity that is anticipated to suppress over-ripening, was added to *baechukimchi*, and the effects of its addition on the physicochemical, microbiological, and sensory characteristics were examined. As such, the possibility of its use as a natural additive that could prolong the shelf life of *baechukimchi* was assessed, and the value of the use of the *wasabi* stalk for the commercial production of *baechukimchi* was investigated.

Materials and Methods

Materials The Chinese cabbage for *baechukimchi*, green onions and ginger were purchased at the local market in Seoul on the day of the test, while anchovy extracts, red pepper powder, garlic, and salt (sun-dried salt, over 80% purity) were purchased previously and stored. The *wasabi* stalk, 9 months old and approximately 40 cm in length, was provided by the *Wasabi* Korea Co., Ltd. (Jinan, Korea), in fresh condition. The main components of the Chinese cabbage include: 95.2% water, 1.4% crude protein, 0.1%

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Table 1. Recipe for *baechukimchi* prepared with different levels of *wasabi* stalk

Ingredient	%[1)]
Raw Chinese cabbage	100
Red pepper powder	3
Garlic	2
Green onion	1.5
Ginger	0.5
Anchovy extracts	0.75
Wasabi stalk[2)]	0
	1
	3
	5
	7

[1)]Based on raw Chinese cabbage.
[2)]One of these 5 additions was chosen for each treatment.

crude fat, 0.5% crude ash, and 28 mg% vitamin C. *Wasabi* stalk consists of: 92.6% water, 0.9% crude protein, 0.2% crude fat, 0.7% crude ash, 53 mg% vitamin C, and 16.6 mg% reducing sugar.

Handling the materials Raw *baechu* heads with the outer leaves were trimmed. After washing, the *baechu* was cut into 3.0×3.0 cm pieces. The *wasabi* stalk was prepared by washing well and grinding in a mixer (MR 4050 CA; Philips, Spain). Garlic and ginger were peeled, washed with distilled water and ground finely in a mixer (MR 4050 CA; Philips). Three cm of the white portion of the green onion was thinly sliced and prepared.

Preparing the *baechukimchi* and conditions for fermentation The cut *baechukimchi* was salted and soaked in twice the volume ratio of 15%(w/v) brine for 2 hr. They were then washed with tap water 3 times and with distilled water once. After draining for 30 min, the salted Chinese cabbages were mixed well with the other ingredients. The composition of *baechukimchi* materials are shown in Table 1. Fresh *wasabi* stalk was added in different ratios: 0 (control), 1, 3, 5, and 7%(w/v) per weight of Chinese cabbage in *baechukimchi*. Prepared *baechukimchi* was packed in polyethylene film and fermented for 25 days at 10°C after sealing.

pH One-hundred g of *baechukimchi* was blended with a blender (MR 4050 CA; Philips) and filtered with cheese cloths. The pH was measured at room temperature using a pH meter (420A; Orion Research Inc., Beverly, MA, USA).

Total acidity Liquid (10 mL) used for measuring pH was neutralized to pH 8.3 using 0.1 N NaOH, and the amount of 0.1 N NaOH used (in mL) was converted into total lactic acid content to determine the acidity (%, w/v).

Total vitamin C Total vitamin C content of the *baechukimchi* was determined through the 2,4-dinitro phenyl hydrazine method (16) using the filtrate of 25 g *kimchi*.

Reducing sugars Liquid was diluted to bring the sugar content within the standard curve, and the amount of reducing sugars was measured using the dinitrosalicylic acid (DNS) method (17).

Total cell number and lactic acid bacteria cell number A portion of the *baechukimchi* was squeezed with a sterilized cheese cloth. One mL of *kimchi* liquid was sampled and serially diluted in 0.85% sterile saline solution. One mL of the diluted *kimchi* liquid was then poured onto Plate Count agar (PCA, Becton, Dickinson and Co., Sparks, MN, USA) and *Lactobacillus* MRS agar (MRS agar, Becton, Dickinson and Co.), each. Plates were incubated at 30±1 and 37±1°C for 48 hr, respectively. The number of colonies that formed in each culture was presented as colony forming units (CFU/mL) (18).

Sensory evaluation Sensory evaluation of color, smell, overall taste, sour taste, hot taste, texture, and overall acceptance were performed by 30 trained students from Dankook University using the hedonic scale, with the best quality scored as 9 points and the worst as 1 point (19).

Statistical analysis The results of the physicochemical characteristic measurements and sensory evaluations were analyzed using the analysis of aniva (ANOVA) and Duncan's multiple test to determine a 5% significant difference among samples.

Results and Discussion

pH The pH changes in *baechukimchi* are shown in Fig. 3. Immediately after preparation, the pH of *baechukimchi* was 5.19-5.25; as the amount of the added *wasabi* stalk increased, the pH was slightly higher. In the initial phases of fermentation, pH increased temporarily; from 2 to 8 days of fermentation, with the progression of fermentation, it tended to decrease rapidly in all treatments. After 8 days of fermentation, all groups exhibited a slow decrease in pH.

From 2 to 8 days of fermentation with increasing amounts of added *wasabi* stalk, the pH decreased, and from 10 to 31 days, the pH increased. Nevertheless, after 31 days of fermentation, most treatments maintained a pH level comparable to previous levels, and pH decreased slowly; however, in the 7% treatment, a rapid reduction of pH was observed. Until the end of the fermentation period, the pH of the 3 and 5% treatments were 3.98 and 4.03, respectively. Compared to the other treatments, these maintained a high pH and decreased slowly, indicating that the addition of *wasabi* stalk delayed the fermentation from the optimal ripening period to the end of the fermentation period. Based on the results of the examination of the edible period of *baechukimchi* that predicted the optimum edible period of *kimchi* as that in which the pH ranged from 4.2-4.4 (20), the control was optimized at 8th day, the 1% treatment up to 10 days, the 3 and 5% treatment up to 13 days, and the 7% treatment up to 16 days. In comparison to the control, then, the optimum edible period of the 3 and 5% treatment was prolonged by 5 days.

The results of our study revealed a trend similar to that of Park *et al.* (21) who reported that when the fermentation period increased, the pH of the resulting *kimchi* decreased.

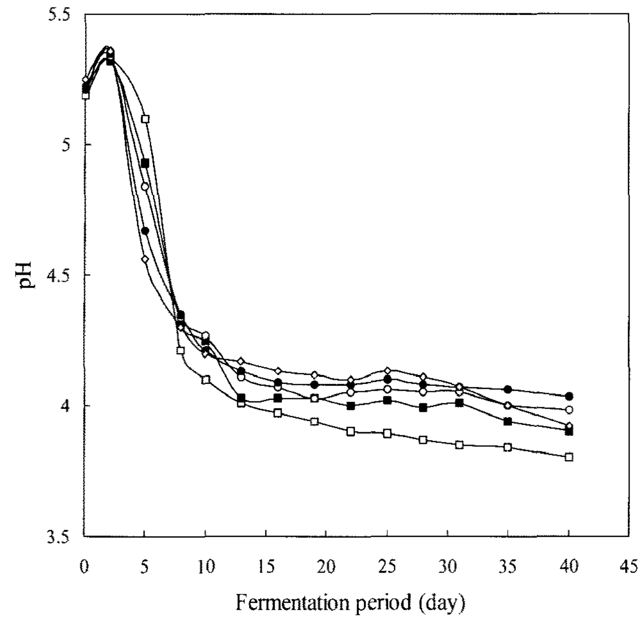

Fig. 1. Changes in pH of *baechukimchi* prepared with different levels of *wasabi* stalk during fermentation at 10°C for 40 days. -□- 0%; -■- 1%; -■- 3%; -●- 5%; -◇- 7%. Values represent mean from triple experiments.

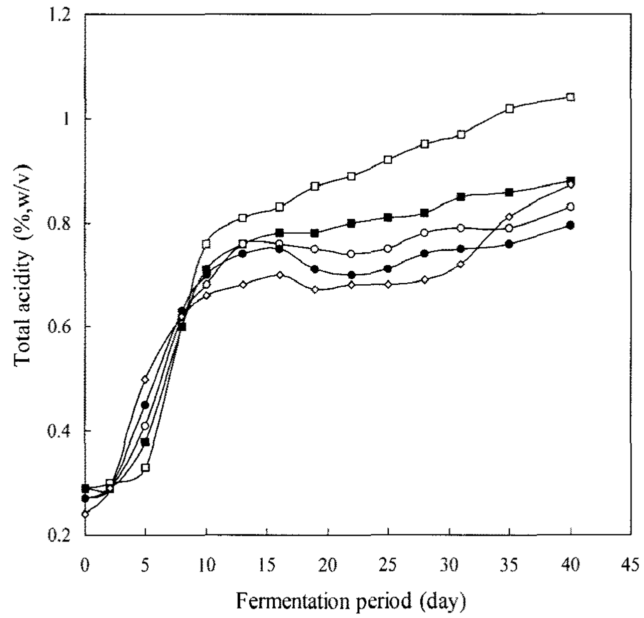

Fig. 2. Changes in total acidity of *baechukimchi* prepared with different levels of *wasabi* stalk during fermentation at 10°C for 40 days. -□- 0%; -■- 1%; -■- 3%; -●- 5%; -◇- 7%. Values represent mean from triple experiments.

Total acidity Changes in total acidity are shown in Fig. 2. Immediately after preparation, no major differences were observed among the treatment groups. Prior to 8 days of fermentation with increasing amounts of *wasabi* stalk added, high total acidity was detected compared to the control. From the 10th day of fermentation, the total acidity of the control rapidly elevated and maintained this high acidity. In the 1, 3, or 5% treatment groups, no large differences were observed among the treatment groups from the 10th day of fermentation, and from the 16th day, low total acidity was detected in 1>3>5%; however, the difference between 3 and 5% was not significant. From the 10th day of fermentation, the 7% treatment group continuously showed the lowest total acidity, and after 31 days, a rapid elevation was observed.

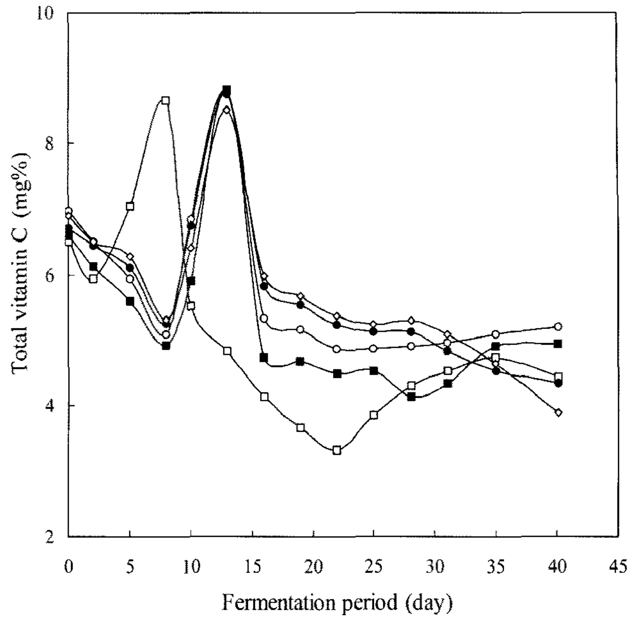

Fig. 3. Changes in total vitamin C content of *baechukimchi* prepared with different levels of *wasabi* stalk during fermentation at 10°C for 40 days. -□- 0%; -■- 1%; -■- 3%; -●- 5%; -◇- 7%. Values represent mean from triple experiments.

Based on the results of the examination of the edible period of *baechukimchi* that predicted the edible period of *kimchi* as that in which the total acidity ranged from 0.4-0.75% (20), the control was edible until 10 days, the 1% treatment up to 13 days, the 3% treatment up to 25 days, and the 5 and 7% treatment up to 31 days. In comparison to the control, then, the edible period of the 3% treatment was prolonged by 15 days.

Kim and Rhee (22) have reported that the elevation of the total acidity content during the fermentation of *kimchi* was due to the production and increase of organic acids and that organic acids produced during that time influenced the taste of *kimchi*.

Total vitamin C The changes in total vitamin C content of *baechukimchi* are shown in Fig. 3. Immediately after preparation, the order of the vitamin C content was 0>1>3>5>7% treatments. In both the control and in the groups treated with *wasabi* stalk, from preparation to 2 days of fermentation, the total vitamin C content decreased; from 8 days of fermentation, the content increased rapidly until it reached its maximal value, and then subsequently decreased.

The temporary increase of vitamin C during the fermentation period is due to enzymes contained in the raw materials. Under the aerobic environment of fermentation, pectin contained in the Chinese cabbage is degraded by galacturonase secreted by yeasts and fungi (23), and the galacturonic acid produced at that time subsequently becomes a substance that accelerates the biosynthesis of vitamin C (23). In addition, the maximal vitamin C content

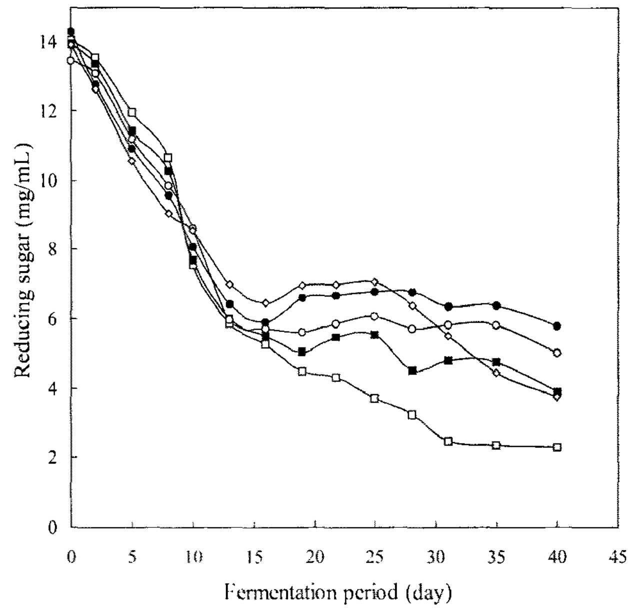

Fig. 4. Changes in reducing sugar content of *baechukimchi* prepared with different levels of *wasabi* stalk during fermentation at 10°C for 40 days. -□- 0%; -■- 1%; -■- 3%; -●- 5%; -◇- 7%. Values represent mean from triple experiments.

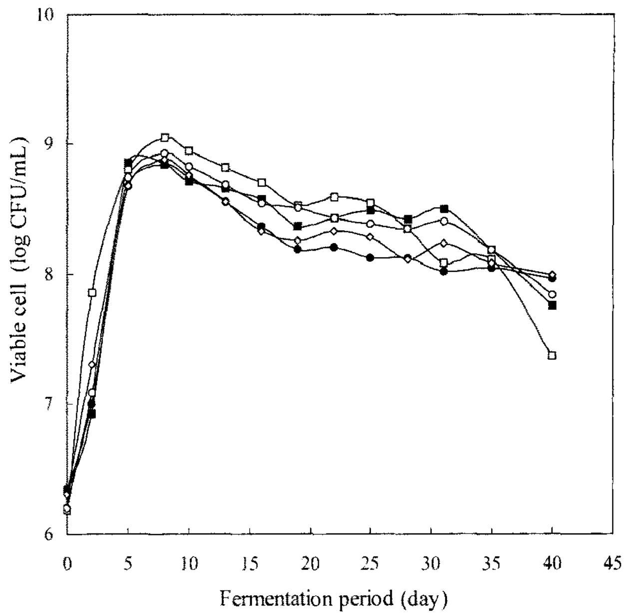

Fig. 5. Changes in total bacterial cell number of *baechukimchi* prepared with different levels of *wasabi* stalk during fermentation at 10°C for 40 days. -□- 0%; -■- 1%; -■- 3%; -●- 5%; -◇- 7%. Values represent mean from triple experiments.

of the control group and the *wasabi* stalk-treated group occurred at different times, which is probably due to the difference of the fermentation rate among the treatments (24). Generally, as the amount of *wasabi* stalk increased, the total vitamin C content also increased; these results from the 80 mg% of total vitamin C contained in the *wasabi* stalk (25), which in turn increases the vitamin C content of *baechukimchi*. The results of this experiment are in agreement with the previous report showing that the vitamin C content, which decreased during the initial period of fermentation, increased markedly during the optimal fermentation period, although only temporarily (23).

Reducing sugars The changes observed in the levels of reducing sugars in liquid during the fermentation of *baechukimchi* are shown in Fig. 4. As fermentation progressed in all treatments, the reducing sugars decreased, and the reducing sugar content showed a slight difference among the treatments. During the initial period of fermentation, the content of reducing sugars was highest in the control, and with increasing amounts of *wasabi* stalk added, the content of reducing sugars became lower. Nevertheless, from 10 days of fermentation in the control, this content decreased rapidly, and at the end of fermentation, its content of reducing sugars was lowest compared to the other treatments. For this reason, fermentation progressed most rapidly under these conditions. From the 10th day of fermentation in the 7% treatment, the content of reducing sugars was the highest; from the 25th day of fermentation, the content of reducing sugars decreased rapidly, and thus fermentation progressed rapidly. The groups with 3 and 5% added *wasabi* stalk showed a constantly high reducing sugar content. This agrees with the results of Park *et al.* (26) and Ahn *et al.* (27), who added safflower seed powder and young antlers to prolong the storage of *baechukimchi* and found that the content of reducing sugars in the treatment groups was low. In the end, the reducing sugars were maintained at the highest level in the 3 and 5% treatments.

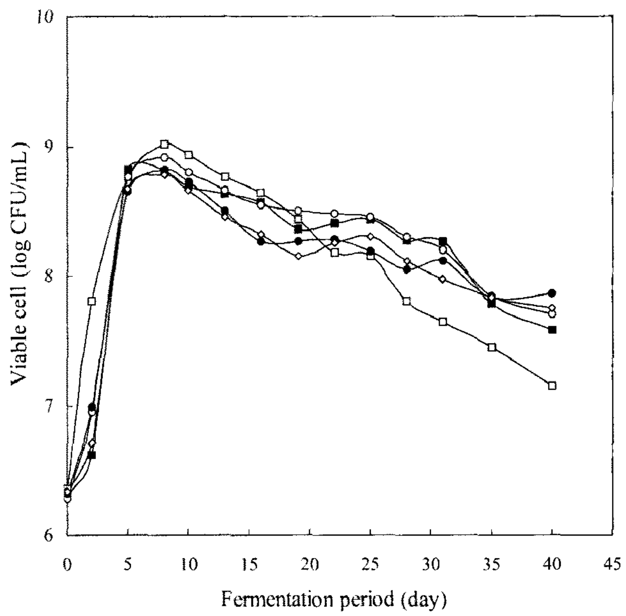

Fig. 6. Changes in lactic acid bacteria cell number of *baechukimchi* prepared with different levels of *wasabi* stalk during fermentation at 10°C for 40 days. -□- 0%; -■- 1%; -■- 3%; -●- 5%; -◇- 7%. Values represent mean from triple experiments.

Total cell number and lactic acid bacteria cell number Changes in total cell number and lactic acid bacteria cell number are shown in Fig. 5 and 6. The numbers of total cells and lactic acid bacteria increased rapidly until they peaked and then began a decreasing trend as fermentation continued. Until the 8th day of fermentation, the number of total bacteria and lactic acid bacteria was highest in the control, while the groups treated with *wasabi* stalk showed a lower number of total bacteria and lactic acid bacteria in comparison. However, among the treatments, no great differences were observed. After the 8th day of fermentation, differences in total bacteria, as well as lactic acid bacteria, were detected. The number of total bacteria in the control was continuously the highest value, while in comparison with the rest treatments, the total bacteria in the 5 and 7% treatments decreased substantially to the end of the fermentation period as fermentation progressed. After the 25th day of fermentation, the number of total bacteria in the control began to be decrease rapidly, and the 1 and 3% treatment groups displayed a slow increase and then a decrease after the 30th day of fermentation. On the other hand, in regard to the number of lactic acid bacteria, the control tended to decrease rapidly from the 8th day of fermentation until the end of the fermentation period. In the other treatment groups, lactic acid bacteria decreased slowly up to the 30th day of fermentation, and after the 31st day of fermentation, the number of lactic acid bacteria in the *wasabi* stalk treatments decreased rapidly. The 3% treatment showed the most static fluctuation in lactic acid counts during the fermentation.

Our results regarding the number of total bacteria and the number of lactic acid bacteria showed a trend similar to that of Moon and Chang (28), Moon *et al.* (3), and Park *et al.* (26) in that the number of total bacteria increased dramatically in the early fermentation period and subsequently decreased slowly.

Sensory evaluation Table 2 shows the results of the sensory evaluation of color, smell, overall taste, sour taste, hot taste, texture, and overall acceptance of *baechukimchi* fermented at 10°C for 40 days. In sensory evaluation characteristics, the color was significantly different throughout all fermentation days except the 19th and the 22nd day of fermentation ($p<0.05$). In the early fermentation period, the score of the control and the 3% treatment was high, and the preference level of the control and 1% treatment was gradually reduced after the 10th day of fermentation. On the other hand, the score of 3% treatment remained continuously high until the late fermentation period. Smell, overall taste, sour taste, hot taste, and overall acceptance were also

Table 2. Sensory evaluations of *baechukimchi* prepared with different levels of *wasabi* stalk during fermentation at 10°C for 40 days

Sensory characteristics	Day	*Wasabi* stalk (%)				
		0	1	3	5	7
Color	0	7.0±0.7$^{a,1)}$	6.5±0.4^{a}	6.8±0.9^{a}	6.0±0.4^{b}	5.5±0.4^{c}
	2	7.5±0.5^{a}	7.0±0.7^{b}	7.1±0.4^{ab}	5.6±0.6^{c}	5.2±0.4^{c}
	5	7.5±0.5^{a}	7.0±0.0^{b}	7.5±0.4^{a}	6.5±0.7	6.0±0.6^{d}
	8	8.0±0.6^{a}	7.3±0.5^{b}	7.8±0.3^{a}	7.0±0.7^{b}	6.3±0.5^{c}
	10	8.1±0.4^{a}	8.0±0.4^{a}	7.9±0.7^{a}	7.2±0.8^{b}	6.5±0.6^{c}
	13	8.0±0.3^{a}	7.8±0.5^{a}	8.0±0.1^{a}	7.0±0.8^{b}	6.4±0.4^{c}
	16	7.5±0.5^{abc}	7.7±0.5^{ab}	7.8±0.4^{a}	7.3±0.3^{bc}	7.4±0.4^{c}
	19	7.1±0.6^{a}	6.8±0.8^{a}	7.0±0.7^{a}	7.1±0.7^{a}	6.8±0.6^{a}
	22	6.5±0.4^{a}	6.6±0.5^{a}	6.6±0.4^{a}	6.4±0.5^{a}	6.7±0.7^{a}
	25	5.4±0.7^{b}	6.0±0.4^{a}	6.5±0.5^{a}	6.2±0.8^{a}	6.6±0.9^{a}
	28	5.0±0.7^{c}	5.8±0.3^{b}	6.0±0.7^{ab}	6.1±0.8^{ab}	6.5±0.5^{a}
	31	5.3±0.5^{c}	5.8±0.3^{ab}	6.2±0.4^{a}	6.0±0.7^{a}	5.5±0.7^{bc}
	35	5.5±0.5^{b}	5.7±0.5^{b}	6.5±0.5^{a}	6.3±0.5^{a}	5.4±0.8^{b}
	40	5.4±0.7^{b}	5.7±0.5^{b}	6.3±0.7^{a}	6.5±0.4^{a}	5.5±0.7^{b}
Smell	0	4.6±0.7^{a}	5.0±0.0^{a}	4.7±0.8^{ab}	4.3±0.5^{b}	4.2±0.5^{b}
	2	5.6±0.6^{ab}	6.5±0.5^{a}	5.8±0.8^{b}	5.3±0.5^{bc}	5.0±0.7^{c}
	5	7.5±0.4^{a}	7.0±0.6^{a}	6.2±0.8^{b}	5.5±0.5^{c}	4.9±0.9^{d}
	8	8.0±0.0^{a}	8.0±0.6^{a}	7.6±1.3^{a}	6.5±0.5^{b}	5.3±0.8^{c}
	10	7.1±0.7^{b}	8.2±0.7^{a}	8.5±0.3^{a}	6.9±0.6^{b}	6.0±0.7^{c}
	13	6.5±0.7^{c}	7.8±0.3^{b}	8.5±0.5^{a}	7.5±0.5^{b}	6.3±0.7^{c}
	16	6.1±0.7^{c}	7.0±0.6^{b}	7.7±0.5^{a}	8.0±0.4^{a}	6.9±0.8^{b}
	19	5.5±0.5^{c}	6.0±0.9^{c}	7.5±0.5^{a}	7.3±0.3^{ab}	6.8±0.8^{b}
	22	4.6±0.8^{d}	5.8±0.8^{c}	7.2±0.8^{a}	7.5±0.4^{a}	6.5±0.7^{b}
	25	4.0±0.7^{c}	5.5±0.7^{b}	7.0±0.4^{a}	6.8±0.3^{a}	5.9±0.7^{b}
	28	3.8±0.8^{c}	5.2±0.6^{b}	6.2±0.7^{a}	6.7±0.7^{a}	5.5±0.7^{b}
	31	3.5±0.7^{e}	5.5±0.5^{c}	6.0±0.4^{b}	6.5±0.4^{a}	4.5±0.5^{d}
	35	3.7±0.6^{d}	5.0±0.7^{b}	5.9±0.4^{a}	5.5±0.9^{ab}	4.4±0.4^{c}
	40	3.5±0.9^{c}	4.2±0.6^{b}	5.5±0.7^{a}	5.0±0.6^{a}	3.8±0.3^{bc}

significantly different throughout all fermentation days ($p<0.05$); the 3% treatment received significantly higher scores than the other groups, and the high score was maintained continuously until the end. In regard to smell and taste, the 7% treatment that contained the largest amount of *wasabi* stalk received the lowest score throughout all fermentation days. However, treatments that contained less than 5% *wasabi* stalk received higher scores than the control. We hypothesize that, when *wasabi* stalk is added at optimal levels, the hot taste of *wasabi* accelerates the release of saliva, and thus improves the appetite. It also received a high score because of the particularly refreshing and clean taste of *wasabi*. The 7% treatment received a low score in sour taste during the fermentation period, except on the 28th day of fermentation. Reviewing total acidity to determine the optimal fermentation period compared to the other treatments, the sour taste of 7% treatment, even at that point, was not high. Hence, it is important to suppress

Table 2. Continued

Sensory characteristics	Day	*Wasabi* stalk (%)				
		0	1	3	5	7
Taste	0	5.2 ± 0.8^{a}	5.1 ± 0.2^{a}	5.0 ± 0.7^{a}	3.1 ± 0.6^{b}	2.7 ± 0.7^{b}
	2	5.0 ± 0.7^{a}	4.1 ± 0.6^{b}	5.5 ± 0.5^{a}	3.5 ± 0.7^{c}	3.0 ± 0.7^{c}
	5	7.0 ± 0.9^{a}	7.5 ± 0.9^{a}	6.8 ± 0.8^{a}	5.5 ± 0.5	4.0 ± 0.7^{c}
	8	7.6 ± 0.9^{ab}	8.0 ± 0.7^{a}	7.2 ± 0.8^{bc}	7.0 ± 0.7^{bc}	6.6 ± 0.6^{c}
	10	7.0 ± 0.7^{bc}	7.5 ± 0.4^{ab}	8.0 ± 0.8^{a}	6.7 ± 0.7^{c}	6.0 ± 0.7^{d}
	13	6.0 ± 0.8^{d}	8.0 ± 0.6	8.5 ± 0.5^{a}	7.0 ± 0.4^{c}	6.3 ± 0.5^{d}
	16	5.5 ± 0.7^{b}	7.3 ± 0.3^{a}	7.5 ± 0.4^{a}	7.1 ± 0.7^{a}	5.0 ± 0.7^{b}
	19	5.0 ± 0.7^{b}	6.1 ± 0.7^{a}	6.7 ± 0.7^{a}	6.5 ± 0.4^{a}	5.2 ± 0.9^{b}
	22	5.2 ± 0.5^{c}	6.0 ± 0.8^{b}	7.0 ± 0.7^{a}	6.5 ± 0.5^{ab}	6.1 ± 1.0^{b}
	25	4.4 ± 0.4^{c}	5.4 ± 0.7^{b}	6.5 ± 0.4^{a}	5.5 ± 0.9	5.0 ± 0.7^{c}
	28	3.8 ± 0.5^{c}	4.6 ± 0.7^{b}	5.5 ± 0.5^{a}	5.5 ± 0.4^{a}	4.5 ± 0.7^{b}
	31	3.5 ± 0.4^{c}	4.5 ± 0.5^{b}	5.0 ± 0.4^{a}	4.9 ± 0.4^{a}	3.2 ± 0.5^{c}
	35	3.7 ± 0.7^{b}	4.2 ± 0.6^{b}	5.1 ± 0.7^{a}	4.8 ± 0.6^{a}	3.0 ± 0.6^{c}
	40	3.1 ± 0.2^{c}	4.3 ± 0.5^{b}	5.0 ± 0.4^{a}	4.7 ± 0.5^{a}	2.5 ± 0.5^{d}
Sour taste	0	2.0 ± 0.7^{ab}	1.6 ± 0.9^{bc}	2.5 ± 0.5^{a}	1.4 ± 0.6^{bc}	1.5 ± 0.5^{c}
	2	2.3 ± 0.5^{b}	1.7 ± 0.7^{c}	3.1 ± 0.7^{a}	1.6 ± 0.6^{c}	1.5 ± 0.4^{c}
	5	6.0 ± 0.7^{bc}	6.5 ± 0.8^{ab}	6.7 ± 0.5^{a}	5.5 ± 0.7^{c}	4.0 ± 0.3^{d}
	8	8.0 ± 0.6^{a}	8.2 ± 0.8^{ab}	7.6 ± 1.4^{bc}	7.2 ± 0.6^{cd}	6.7 ± 0.7^{d}
	10	7.9 ± 0.7^{a}	8.0 ± 0.4^{a}	7.8 ± 0.6^{a}	7.7 ± 0.3^{a}	6.7 ± 0.3^{b}
	13	6.2 ± 0.6^{c}	7.7 ± 0.7^{a}	8.2 ± 0.3^{a}	7.9 ± 0.4^{a}	7.1 ± 0.7^{b}
	16	6.0 ± 0.7^{c}	6.9 ± 0.7^{b}	7.6 ± 0.6^{a}	7.4 ± 0.6^{ab}	7.0 ± 0.7^{b}
	19	5.7 ± 1.0^{b}	6.0 ± 0.7^{ab}	6.7 ± 0.9^{a}	6.6 ± 0.7^{a}	5.0 ± 0.7^{c}
	22	4.2 ± 0.9^{c}	5.5 ± 0.5^{b}	6.4 ± 0.7^{a}	6.4 ± 0.4^{a}	6.0 ± 0.4^{ab}
	25	3.5 ± 0.6^{c}	5.0 ± 0.7^{b}	6.3 ± 0.6^{a}	6.5 ± 0.7^{a}	5.2 ± 0.8^{b}
	28	3.0 ± 0.7^{c}	4.4 ± 0.6^{b}	6.0 ± 0.8^{a}	5.9 ± 1.1^{a}	5.5 ± 0.7^{a}
	31	3.4 ± 0.6^{c}	4.2 ± 0.5^{b}	5.7 ± 0.3^{a}	5.5 ± 0.5^{a}	3.8 ± 0.6^{bc}
	35	3.5 ± 0.5^{c}	4.3 ± 0.5^{b}	5.0 ± 0.4^{a}	4.7 ± 0.5^{a}	3.2 ± 0.3^{c}
	40	3.1 ± 0.7^{c}	3.8 ± 0.8^{b}	4.7 ± 0.8^{a}	4.5 ± 0.4^{a}	2.8 ± 0.8^{c}
Hot taste	0	4.4 ± 0.6^{a}	4.2 ± 0.8^{a}	4.0 ± 0.6^{a}	2.5 ± 0.7^{b}	2.0 ± 0.7^{b}
	2	5.0 ± 0.7^{ab}	4.8 ± 0.8^{b}	5.5 ± 0.7^{a}	3.0 ± 0.7^{c}	2.5 ± 0.5^{c}
	5	6.2 ± 0.8^{a}	5.8 ± 0.9^{a}	5.7 ± 0.6^{a}	4.8 ± 1.3^{b}	4.0 ± 1.2^{b}
	8	7.4 ± 0.9^{ab}	8.0 ± 0.6^{a}	7.1 ± 0.6^{b}	5.9 ± 0.7^{c}	4.5 ± 0.7^{d}
	10	7.7 ± 0.7^{a}	7.8 ± 0.5^{a}	7.7 ± 0.6^{a}	5.5 ± 0.9^{b}	4.7 ± 1.0^{d}
	13	6.8 ± 0.8^{b}	7.7 ± 0.5^{a}	7.2 ± 0.8^{ab}	5.8 ± 0.5^{c}	5.0 ± 0.9^{c}
	16	6.5 ± 0.5^{b}	7.5 ± 0.9^{a}	7.6 ± 0.4^{a}	5.7 ± 0.5^{c}	4.8 ± 0.6^{d}
	19	6.8 ± 0.6^{a}	7.1 ± 0.4^{a}	7.3 ± 0.8^{a}	5.5 ± 0.5^{b}	4.5 ± 0.6^{c}
	22	6.5 ± 0.4^{b}	7.2 ± 0.5^{a}	7.5 ± 0.5^{a}	5.7 ± 0.5^{c}	4.6 ± 0.4^{d}
	25	5.7 ± 0.7^{b}	6.8 ± 0.8^{a}	7.0 ± 0.4^{a}	5.6 ± 1.0^{b}	4.1 ± 0.7^{c}
	28	5.5 ± 0.8^{c}	6.5 ± 0.5^{ab}	7.1 ± 0.7^{a}	5.9 ± 0.9^{bc}	4.5 ± 1.0^{d}
	31	6.1 ± 0.7^{b}	6.4 ± 0.6^{b}	7.0 ± 0.4^{a}	5.6 ± 0.4^{c}	4.6 ± 0.7^{d}
	35	6.3 ± 0.7^{bc}	6.7 ± 1.0^{ab}	6.9 ± 0.2^{a}	5.8 ± 0.6^{c}	4.8 ± 0.3^{d}
	40	5.6 ± 0.6^{b}	6.2 ± 0.6^{a}	6.3 ± 0.3^{a}	6.0 ± 0.6^{ab}	4.7 ± 0.8^{c}

Table 2. Continued

Sensory characteristics	Day	*Wasabi* stalk (%)				
		0	1	3	5	7
Texture	0	6.5±0.5[a]	6.6±0.4[a]	6.5±0.5[a]	6.6±0.5[a]	6.6±0.4[a]
	2	6.8±0.8[a]	6.7±0.8[a]	6.5±0.4[a]	6.6±0.7[a]	6.7±0.7[a]
	5	7.0±0.8[a]	7.2±0.6[a]	7.1±0.7[a]	6.8±0.8[a]	6.7±0.5[a]
	8	7.8±0.8[a]	8.0±0.7[a]	7.2±0.3[b]	6.8±0.8[bc]	6.6±0.6[bc]
	10	7.4±0.6[a]	7.8±0.6[a]	7.8±0.6[a]	6.8±0.3[b]	6.6±0.4[b]
	13	6.6±0.6[c]	7.5±0.4[b]	8.0±0.5[a]	7.0±0.4[c]	6.8±0.6[c]
	16	6.5±0.6[c]	7.3±0.8[ab]	7.8±0.5[a]	7.1±0.7[bc]	7.0±0.7[bc]
	19	5.7±1.0[b]	6.7±0.7[a]	7.2±0.8[a]	7.3±0.6[a]	7.3±0.5[a]
	22	5.5±0.6[d]	6.5±0.5[b]	6.9±0.2[bc]	7.2±0.5[ab]	7.5±0.5[a]
	25	4.8±0.8[c]	6.5±0.4[b]	6.8±0.8[ab]	6.7±0.5[b]	7.3±0.6[a]
	28	4.5±0.7[c]	6.0±0.8[b]	6.5±0.4[ab]	6.4±0.4[ab]	6.8±0.6[a]
	31	4.4±0.6[c]	5.9±0.6[a]	6.1±0.4[a]	6.0±0.4[a]	5.0±0.0[b]
	35	4.0±0.6[c]	5.4±0.7[b]	6.0±0.4[a]	5.8±0.3[ab]	4.4±0.4[c]
	40	4.0±0.8[b]	5.3±0.5[a]	5.8±0.8[a]	5.7±0.8[a]	3.8±0.6[b]
Overall acceptability	0	4.3±0.7[a]	4.1±0.7[a]	3.8±0.8[a]	2.8±0.6[b]	2.2±0.5[c]
	2	5.1±0.7[a]	5.0±0.6[a]	5.0±0.4[a]	4.0±0.7[b]	2.7±0.7[c]
	5	6.3±0.7[a]	6.0±0.7[a]	6.5±0.5[a]	5.4±0.6[b]	4.0±0.7[c]
	8	7.5±0.6[ab]	7.9±0.7[a]	7.3±0.6[b]	6.4±0.8[c]	5.3±0.5[d]
	10	7.8±0.6[a]	8.0±0.6[a]	7.8±0.3[a]	6.3±0.3[b]	5.7±0.6[c]
	13	7.0±0.7[c]	7.5±0.4[b]	8.3±0.3[a]	7.3±0.6[bc]	6.0±0.7[d]
	16	6.8±0.5[bc]	7.3±0.3[ab]	7.5±0.5[a]	7.0±0.7[c]	5.8±0.5[d]
	19	6.5±0.5[a]	6.9±0.6[b]	7.0±0.7[b]	6.7±0.5[b]	5.4±0.6[c]
	22	6.0±0.6[b]	6.2±0.8[b]	6.9±0.7[a]	6.5±0.8[ab]	5.3±0.5[c]
	25	5.5±0.6[bc]	6.0±0.5[ab]	6.5±0.4[a]	6.4±0.7[a]	5.4±0.8[c]
	28	5.2±0.5[c]	5.7±0.8[b]	6.3±0.3[a]	6.2±0.3[a]	5.3±0.6[bc]
	31	4.5±0.5[c]	5.8±0.5[b]	6.3±0.6[a]	6.2±0.3[a]	4.3±0.3[c]
	35	4.7±0.8[b]	5.2±0.8[b]	6.0±0.5[a]	5.9±0.6[a]	3.3±0.8[c]
	40	3.9±0.9[c]	4.7±0.3[b]	5.7±1.0[a]	5.5±0.7[a]	3.6±0.4[c]

[1)]Means designated with different letters are significantly different from each other within a row at $\alpha=0.05$ as determined by Duncan's multiple range test

the sour taste of *baechukimchi* to prevent over-fermentation; however, excess reduction of the sour taste did not receive a high score in preference. There were no significant differences in texture up to the 5[th] day of fermentation. Subsequently, however, a significant difference was detected ($p<0.05$) throughout the remainder of the fermentation period. Among the groups, the 3% treatment most consistently received a high score. The most favored treatment for *baechukimchi* in terms of sensory qualities (color, smell, overall taste, sour taste, hot taste, texture, and overall acceptability) was the 3%(w/v) addition of *wasabi* stalk per weight of Chinese cabbage in *baechukimchi* and the subsequent fermentation at 10°C. With simple regard to the quantitative level of *wasabi* stalk addition, a 3% treatment was most appropriate under all testing conditions, while added amounts of more than 7% could bring counter-results.

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