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Analysis of Microbiological Contamination in Kimchi and Its Ingredients

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ABSTRACT - Although Kimchi has health benefits, food poisoning associated with consumption of Kimchi has been frequently reported. Accordingly, microbiological properties of Kimchi (100 samples) and washing effects on microbial reduction against its ingredients (200 samples) were examined. Total aerobic bacteria, coliforms, *Escherichia coli, Bacillus cereus*, and *Clostridium perfringens* were quantified. In addition, *B. cereus*, *Salmonella* spp., Enterohemorrhagic *E. coli, C. perfringens, Campylobacter jejuni/coli, Staphylococcus aureus, Vibrio parahaemolyticus, Listeria monocytogenes,* and *Yersinia enterocolitica* were analysed qualitatively. Total aerobic bacteria count was approximately 1.4-9.0 log CFU/g, which were highest in ginger (8.8 log CFU/g), and Chonggak Kimchi (9.0 log CFU/g). The range of coliform counts detected in all raw materials was 0.5-7.3 log CFU/g and ginger showed the greatest number 7.3 log CFU/g among others. Contamination was decreased to 0.2-3.2, 0.3-2.7, and 1.0-3.9 log CFU/g for total aerobic bacteria, coliforms, and *B. cereus*, respectively, after washing. Minimising microbial contamination in Kimchi ingredients is necessary to ensure the safety of Kimchi. These results indicate that washing is a useful method to reduce bacterial contamination in Kimchi.

Key words: Food safety, Kimchi, Food quality, Food borne pathogen

Kimchi is a traditional fermented food, in Korea, Various vegetables, including Kimchi cabbage (*Brassica pekinensis*), a main ingredient, are brined and mixed with raw materials, including garlic, radish, ginger, green onion, and red pepper powder, followed by fermentation at a low temperature. Kimchi activates various immune functions that are otherwise not activated owing to modern dietary habits. It enhances immunity, promotes digestion by lactic acid fermentation, prevents adult diseases, such as colon cancer, sclerosis, and anaemia, influences the regulation of the circadian rhythm, and affects disease recovery[4]. However, Kimchi is processed from main ingredients (i.e., vegetables) typically harvested from natural soils and is fermented by microorganisms; accordingly, there is a risk of microorganismal contamination[3,18]. In addition, since agricultural products are often mixed with contaminants from their surrounding environments and are ingested in a raw state without thermal processing, contamination by microorganisms and their enrichment in optimal environments can be harmful to human health. For example, red pepper powder, which is used extensively in Korean diets, is not sterilized during the traditional drying process after harvest, and many seasoned foods are eaten directly, without thermal processing. In addition, red pepper powder is typically used as a mixed spice. Hence, *E. coli* contamination and subsequent food poisoning are possible. In one study, 2.8-2.9×10^2 coliforms were detected in red pepper powder[23]; however, few additional studies have investigated coliform contamination on red pepper powder. To investigate the microbiological safety of Kimchi, Yoon[34] examined the contamination level of intestinal bacteria in Kimchi raw materials, and found an unexpectedly high level of intestinal bacteria in the early stage of mashing, including pathogens or food-borne pathogens, such as *E. coli*, *Serratiamarcescens,* and *Salmonella gallinarum*. After forced contamination at 10°C, these microorganisms exhibited survival for 10 days, suggesting a hygienic problem in Kimchi immediately after mashing[34]. Despite a report indicating a low bio hazard risk for baechu Kimchi[30], another study detected pathogenic microorganisms, such as *E. coli*, *Salmonella* spp., and *Staphylococcus aureus*, in packaged Kimchi products, and these microorganisms decreased as storage time increased and after lactic acid bacteria reached an optimum[30].

Since Kimchi is manufactured as a non-thermal food, there are limited methods by which to control hazardous microorganisms. Few studies have examined sterilization

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methods and their effects on food hygiene during manufacturing, despite the important implications for food safety. Even fewer microbiological studies have examined the safety of kimchi because hazardous microorganisms perish during fermentation, even at the early stage of manufacturing, or are insufficient to cause harm when eaten; additionally, it is impossible to sterilize Kimchi in harsh conditions owing to the manufacturing procedure[18]. However, consumers increasingly prefer unfermented Kimchi, such as Geotjeori, and food distributors have gradually supplied greater quantities of unfermented kimchi. If the consumption of fresh Baechu Kimchi continues to increase, it is absolutely necessary to establish safety management measures for Baechu Kimchi manufacturing, for which raw vegetables are the main ingredients.

Kimchi is an uncooked processed food. It is difficult to effectively control hazardous microorganisms at the early unfermented stage of manufacturing. Accordingly, it is necessary to develop an appropriate control measure for microorganisms, e.g., heat treatment[13], additives[22,29], radiation[25], preservatives[24], buffers that suppress changes in pH[8,15], and the addition of a salt solution[16]. However, these methods have not been applied commercially owing to consumer safety concerns or decreases in the organoleptic quality of Kimchi. As such, previous studies have focused on fermentation suppression to enhance storability, and few studies have examined the sanitation of ingredients.

Thus, in this study, the effects of thorough ingredient washing during kimchi manufacturing and the sanitary state of Kimchi, a non-thermalfood, were examined to establish an efficient method for microorganism all control. Specifically, the raw materials of kimchi distributed in Korea were analysed in a comparative frame work before and after washing, and the sanitation states of commercialized Kimchi products were also examined.

Materials and Methods

Sample collection

From April 2014 to December 2015, 200 Kimchi ingredients were purchased from the Gwangju agricultural and marine products market, large grocery stores, and online shopping malls, including 30 Kimchi cabbages, 40 brined baechu cabbages, 35 radishes, 20 garlics, 24 gingers, 20 green onions, 8 onions, 14 red pepper powder samples, and 9 anchovy sauces. Non-edible parts were removed and the samples were then cut into optimal sizes for analyses. In addition, 100 Kimchi products available on the market were purchased from large grocery stores, department stores, and online shopping malls during the same period, including 40 Baechu Kimchi, 13 Mat Kimchi, 14 Yeolmu kimchi, 18 Kakdugi, and 15 Chonggak Kimchi. These samples were used to count microorganisms.

After they were purchased, all samples were kept at a cold temperature (< 4°C) and subjected to experiments within 24 hr.

Washing process for kimchi raw materials

After the removal of non-edible parts, raw materials for Kimchi were washed with flowing tap water for 3 min, air-dried, and then examined for bacteria. Each sample was kept in a refrigerator (4°C) during tests.

Analysis of bacteria as a sanitation indicator

After the careful pretreatment of Kimchi raw materials, a microorganism analysis was performed to monitor the numbers of aerobic bacteria and coliforms in each ingredient and in the completed Kimchi product. Analysis of total aerobic bacterial, *E. coli*, and coliforms were performed as described previously[17]. Results for each sample were multiplied by the dilution factor to calculate bacterial counts, and are expressed as colony forming units per gram of sample (CFU/g).

Analyses of nine pathogenic microbial species

In kimchi raw materials and completed product samples, *Bacillus cereus* and *Clostridium perfringens* were qualitatively and quantitatively analyzed, and *Staphylococcus aureus,* Enterohemorrhagic *E. coli, Campylobacter jejuni/coli, Yersinia enterocolitica, Salmonella* spp., *Vibrio parahaemolyticus,* and *Listeria monocytogenes* were analyzed qualitatively. Methods complied with the Korean Food Standards Codex.

Qualitative analysis of food-borne pathogens

A qualitative analysis was performed using the real-time RT-PCR system (Applied Biosystems, Foster City, CA, USA). For *Campylobacter jejuni* and *C. coli*, 25 g each of raw materials and Kimchi samples were homogenized with 225 mL of Bolton broth (Oxoid, Cambridge, UK) using a stomacher for 1 min, followed by un-aerobic enrichment at 42°C for 24 h. For *C. perfringens*, 25 g each of raw materials and Kimchi samples were mixed with 225 mL of 0.85% sterilized physiological saline for stomaching, and 1 mL of the homogenized diluted solution was added to Cooked Meat Media (Difco, Franklin Lakes, NJ, USA), followed by anaerobic culture at 37°C for 24 hr for enrichment. For *L. monocytogenes*, 25 g of samples mixed with 225 mL of *Listeria* Enrichment Broth (LEB; Difco) were subjected to stomaching for 1 min, followed by enrichment at 35°C for 48 hr. For *V. parahaemolyticus*, the same amount of sample was subjected to stomaching with 225 mL of Tryptic Soy Broth (TSB; Difco) mixed with 5% NaCl, followed by enrichment at 37°C for 24 h. For enterohemorrhagic *E. coli*,

S. aureus, Y. enterocolitica, B. cereus, and *Salmonella* spp., samples were mixed with 225 mL of Tryptic Soy Broth (Difco), followed by stomaching for 1 min and enrichment at 35°C for 24 h. DNA was extracted from each enriched culture medium using the QIAamp® DNA Mini QIAcubeKit (Qiagen, Hilden, Germany) following the manufacturer's instructions.

For lysis, 200 μL of enriched culture medium for each sample was mixed with 200 μL of Buffer AVL and vortexed for 15 sec. The mixed solution was centrifuged at 12,000 rpm for 3 min, and then 300 μL of the supernatant was applied to an Automated Centrifugal DNA/RNA Extractor (QIAcube; Qiagen, Valencia, CA, USA) for DNA extraction. The extracted DNA was used as a PCR template and was stored in an Ultra-low Temperature Freezer (−80°C) until RT-PCR amplification.

PCR was performed using the Power Check™ Pathogen Multiplex Real-Time PCR Kit (Kogene Biotech, Seoul, Korea), which contained primers for the detection of nine pathogenic microorganisms. Each primer set was designed to amplify DNAs of different lengths, so that DNA fragments corresponding to pathogenic microorganisms can be detected by PCR[11]. PCR mixtures (20 μL) consisted of PCR Premix containing primers in the kit, 5 μL of the probe, 10 μL of Master Mix, and 5 μL of template DNA isolated from raw materials and Kimchi samples. The PCR mixtures were incubated at 50°C for 2 min and at 95°C for 10 min for denaturation, followed by 40 cycles of 95°C for 15 s and 60°C for 1 min. To ensure the reliability of experimental results, DNAs of food-borne pathogens and sterilized distilled water were used as positive and negative controls, respectively, and PCR were repeated for each sample.

Quantitative analysis of food-borne pathogens

Quantitative analysis of *B. cereus* and *C. perfringens* were performed as described previously[17]. For the colonies exceeding the standard number, at least 5 typical colonies were selected from the plate and inoculated on a nutrient agar plate for Gram stainingand biochemical experiments. Finally, the colony numbers were multiplied by the dilution factor to calculate bacterial counts.

Biochemical analysis

Positive colonies in qualitative and quantitative analysis of food-borne pathogens were selected, inoculated on a nutrient agar plate for culture, and purified. They were then applied to a BD Phoenix™ Automated Microbiology System (BD Diagnostic Systems, Le Pont de Claix, France) for identification.

Measurement of salinity

The salinity of brined samples was measured using the Mohr method with 3 replications[5]. Approximately 1 g of sample, after grinding to a paste with a blender, was diluted 100-fold and filtered (Toyo No. 1). Then, 10 mL of the filtered solution was mixed with 1 mL of 2% potassium chromate for adjustment to 0.02 N $AgNO_3$ solution. An independent blank test with distilled water was also performed, and then the salinity was calculated according to the following formula:

Salinity (%) =
{0.02N $AgNO_3$ (mL) × 0.00117 × $AgNO_3$ factor × dilution rate / Sample (g)} × 100

Measurement of pH and total acidity

For pH measurements, samples were ground using a blender, and the pH was repeatedly measured using a pH meter (Thermo, Beverly, MA, USA). Mean values were calculated. To determine the optimal acidity, 1 g of sample after grinding to a pasteusing a blender was diluted 100-fold diluted and filtered (Toyo No. 1). Then, 20 mL of the filtered solution was adjusted to pH 8.3 with a 0.01 N NaOH solution, and the amount of NaOH solution consumed was calculated and converted to lactic acid (%, w/w).

Titratable acidity (%) =
{0.1N NaOH (mL) × 0.1N NaOH factor × 0.009 / Sample (g)} × 100

Statistical analysis

Measurements of the pH, optimal acidity, and salinity of kimchi samples were repeated 3 times, and data are expressed as means ± SD. All parameter estimates were analysed using the Statistical Package for the Society Science (SPSS, Windows ver. 8.2; SPSS Institute Inc., Cary, NC, USA), and significant differences between samples were determined by ANOVA, followed by post-hoc Duncan's multiple range tests, with a significance threshold of $p < 0.05$.

Results and Discussion

Changes in microbial abundance depending on the washing process for Kimchi raw materials

Agricultural products that are in contact with soil are directly or indirectly contaminated with various pathogenic and spoilage microorganisms during cultivation or distribution after harvest. In general, agricultural products have 10^4-10^9 CFU/g total aerobic bacteria, 10^3-10^5 CFU/g coliforms, and 10^3 CFU/g yeast[20].

Red pepper powder is not subjected to sterilization process

during drying in a dryer or using sunlight after harvest, and Baechu Kimchi is directly ingested without cooking after it is mixed withred pepper powder. Accordingly, *E. Coli* contamination is possible in baechu kimchi, and this could lead to food poisoning. Red pepper powder had 4.2-8.0 log CFU/g total aerobic bacteria and 0-4.2 log CFU/g coliforms. According to a previous report[23], the difference in microbial counts may be explained by differences in the place of origin and distribution route; therefore, it is necessary to minimise contamination with washing process of raw materials. For food-borne pathogens in raw materials, the remaining eight food-borne pathogens, except *B. cereus*, were undetectable. *B. cereus* was detected at the highest level in ginger (4.0 log CFU/g) among minor ingredients, followed by green onion (3.9 log CFU/g) and brined baechu cabbage (3.9 and 3.4 log CFU/g). For fresh-cut chicory, hand washing using water reduced the total aerobic bacteria counts by 1.4 log CFU/g and coliform counts by 0.9 log CFU/g, while machine washing using water reduced the counts by 1.8 log CFU/g and 1.2 log CFU/g, respectively[21]. For fresh-cutcarrots, a single wash with chlorinated water results in a greater reduction than washing with water (by 0.39 log CFU/g) and washing with ozonated water (by 0.04 log CFU/g) for 20 min[12], indicating that greater reductions in microbial abundance can be achieved using chlorinated water than ozonated water. Nevertheless, chlorinated water and ozonated water did not result in substantial reductions; accordingly, simply washing with water was a sufficient cost-effective method to reduce microorganisms. The use of electrolyzed water has recently been examined extensively. For example, lettuce with electrolyzed water exhibits reductions of 2.5 log CFU/g for total aerobic bacteria, 2.8 log CFU/g for coliforms, and 2.9 log CFU/g for *Salmonella* spp. compared to lettuce washed with water[7].

The changes in microbial counts after washing raw Kimchi materials are summarised in Fig. 1. For Kimchi cabbage, a main ingredient, the aerobic bacterial count in the control group before washing was 6.5 log CFU/g, and was 5.1 log CFU/g after washing, corresponding to a reduction of approximately 1.4 log CFU/g. The *E. Coli* and coliform counts were 2.9 log CFU/g before washing and 1.4 log CFU/g after washing, indicating a reduction of approximately 1.5 log CFU/g. For brined baechu cabbage, total aerobic bacteria and coliform counts decreased by 1.0 and 2.6 log CFU/g after washing, respectively, indicating that washing reduced microbial counts. With respect to the minor ingredients, washing decreased the aerobic bacterial counts for radish, onion, ginger, garlic, and green onion by 3.0, 1.8, 2.6, 1.2, and 3.2 log CFU/g, respectively, and coliform counts in ginger and green onion by 2.8 and 2.7 log CFU/g, respectively; these were the greatest reductions

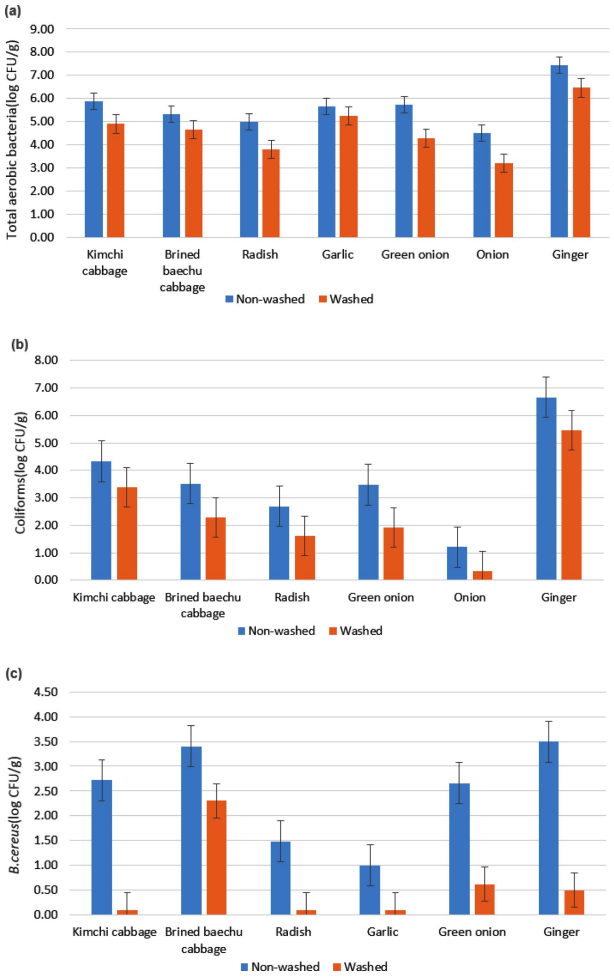

Fig. 1. Comparison of microbial contamination of raw materials of kimchi including; a) Total aerobic bacteria, b) Coliforms, c) *Bacillus cereus*.

observed among the raw materials.

Our findings are consistent with the previous reports[14,19] indicating total aerobic bacteria and coliform counts were lower in raw vegetables after washing than before washing. The food-borne pathogen *B. cereus* was undetectable in green onions after washing, but was detected at 3.9 log CFU/g before washing, corresponding to a reduction of approximately 3.9 log CFU/g. Additionally, Kimchi cabbage and ginger exhibited decreases in *B. cereus* of 2.7 and 3.2 log CFU/g after washing, respectively, indicating that washing effectively reduces *B. cereus*. The remaining eight food-borne pathogens were undetected both before and after washing.

In summary, the washing of Kimchi raw materials, which differed with respect to their initial microbial properties, substantially decreased microbial counts. These findings confirmed that washing could contribute to improvements in the sanitation and storability of kimchi ingredients, though

Table 1. Microbiological contamination of raw materials used for kimchi manufacturing

Sample	No. of samples	Range of microbial count (log CFU/g)					
		Total aerobic bacteria	Coliforms	*E. coli*	*B. cereus*	*L. monocytogenes*	*S. aureus*
Kimchi cabbage	30	4.90-8.28	0-5.49	0	0-2.72	N.D*	N.D
Brined baechu cabbage	40	4.04-7.74	0-4.81	0	0-3.40	N.D	N.D
Radish	35	4.04-8.04	0-4.20	0	0-2.34	N.D	N.D
Garlic	20	5.32-7.69	0-3.23	0	0-1.48	N.D	N.D
Green onion	20	4.89-7.04	0-6.62	0	0-3.88	N.D	N.D
Onion	8	1.36-5.86	0-1.30	0	0	N.D	N.D
Ginger	24	5.30-8.83	2.80-7.30	0	0-4.04	N.D	N.D
Red pepper powder	14	4.15-8.04	0-4.18	0	0-2.79	N.D	N.D
Anchovy sauce	9	0-1.77	0	0	0	N.D	N.D

*ND: Not detected (Detection limit: < 1 CFU/g).

Table 2. pH, acidity, and salinity of five commercial Kimchi products

Sample	No. of samples	pH	Acidity	Salinity
Baechu kimchi	40	$5.00 \pm 0.77^{a*}$	0.61 ± 0.30^{a}	1.94 ± 0.28^{a}
Sliced cabbage kimchi (or mat kimchi)	13	5.08 ± 0.81^{a}	0.61 ± 0.29^{a}	1.97 ± 0.15^{a}
Yeolmu kimchi	14	5.07 ± 0.84^{a}	0.61 ± 0.28^{a}	1.81 ± 0.39^{a}
Kakdugi	18	5.49 ± 0.91^{a}	0.31 ± 0.23^{b}	1.74 ± 0.38^{a}
Chonggak kimchi	15	5.42 ± 0.91^{a}	0.50 ± 0.26^{a}	1.80 ± 0.31^{a}

*Values with the same letters within a column are not different at $p < 0.05$ based on Duncan's multiple range tests.

Table 3. Range of microbial counts in five commercial Kimchi products

Sample	No. of samples	Range of microbial count (log CFU/g)						
		Total aerobic bacteria	Coliforms	*E. coli*	*B. cereus*	*L. monocytogenes*	*C. perfringens*	*S. aureus*
Baechu kimchi	40	$4.74\text{-}8.64^{ab*}$	$0\text{-}3.93^{a}$	0	$0\text{-}2.00^{ab}$	N.D**	N.D	N.D
Sliced cabbage kimchi (or mat kimchi)	13	$5.04\text{-}8.89^{a}$	$0\text{-}3.49^{a}$	0	$0\text{-}1.85^{b}$	N.D	N.D	N.D
Yeolmu kimchi	14	$5.77\text{-}8.71^{a}$	$0\text{-}4.26^{a}$	0	$0\text{-}2.45^{a}$	N.D	N.D	N.D
Kakdugi	18	$5.41\text{-}8.83^{b}$	$0\text{-}3.82^{a}$	0	$0\text{-}1.68^{ab}$	N.D	N.D	N.D
Chonggak kimchi	15	$5.51\text{-}8.96^{a}$	$0\text{-}4.83^{a}$	0	$0\text{-}1.60^{ab}$	N.D	N.D	N.D

*Values with the same letters within a column are not different ($p < 0.05$).
**ND: Not detected (Detection limit: < 1 CFU/g).

the extent of these reductions differed amon ginger ingredients.

Distribution of microbiological hygiene indicators and food-borne pathogens in commercial Kimchi products

The pH, acidity, and salinity of 100 commercial Kimchi products were analyzed, as summarized in Table 2. These products had different expiration dates and raw materials, and were not representative of all Kimchi products; thus, general conclusions regarding the safety of Kimchi could not be drawn. However, similar to previous studies, the pH and acidity of the commercial Kimchi products were obtained, and comparisons were made among products with similar values to identify patterns of hazardous microorganisms with respect to acidity[26,31]. Chonggak Kimchi had the highest number of total aerobic bacteria, 5.5-9.0 log CFU/g, followed by Mat Kimchi (5.0-9.0 log CFU/g), and Kakdugi (5.4-8.8 log CFU/g). Coliform counts, similar to aerobic bacterial counts, were highest in Chonggak Kimchi at 4.8 log CFU/g. Our results were consistent with previous international analyses of microorganisms in brined foods,

which have reported aerobic bacterial counts of approximately 8 log CFU/g for brined cabbage (0.5% and 1.5% NaCl)[28], 10^4-10^6 CFU/g for pickled cucumber[6], and approximately 10^4-10^5 CFU/g for sauerkraut[2,27]. Consistent with previous studies, our analysis also indicated a rapid reduction of coliforms as the storage time and acidity increased, and coliforms perished when the acidity of Kimchi reached around 0.7% (based on the lactic acid content)[9]. However, the initial coliform counts for the two products with the lowest acidity at the time of purchase were substantially different (1.7 log CFU/g and 3.5 log CFU/g), suggesting that hygiene management strategies to ensure the cleanliness of raw materials and working environments at the initial mashing stage should differ depending on the personal hygiene.

To determine the sanitary state of commercial Kimchi, total aerobic count, coliforms, *E. coli*, and food-borne pathogens were analyzed in 100 commercial Kimchi products, as summarized in Table 3. Among food-borne pathogens, *B. cereus* was detected in 41 out of 100 Kimchi product samples, and was most abundant in Yeolmu Kimchi. Total *B. cereus* in Kimchi products was 1.5 log CFU/g, including 1.6 log CFU/g for Baechu Kimchi, 1.6 log CFU/g for Yeolmu kimchi, 1.4 log CFU/g for Kakdugi, and 1.3 log CFU/g for Chonggak Kimchi. These counts were below 10,000 complying with general standards and specifications for foods in the Korean Food Standards Codex. All other food-borne pathogens, including *C. perfringens*, were undetected in all Kimchi samples, and current commercial Kimchi products demonstrated appropriate control, within the specifications for microorganisms according to the Korean Food Standards Codex.

Other brined foods, such as sauerkraut, are similar to Korean Kimchi. Argyri et al.[1] reported that brined olive shows a reduction of *L. monocytogenes* of approximately 3 log CFU/g for some storage periods, and Xiong et al.[32] reported that sauerkraut (8% NaCl) shows coliform reductions of about 4 log CFU/g after 5 days of storage following fermentation. In addition, intestinal bacteria in Chinese paocai declined by about 1.3 log CFU/g after 5 days of storage[33]. These previous studies showed that microbiological indicators of hygiene and food-borne pathogens in brined foods, like Kimchi, decline as the storage period for fermentation increases.

To evaluate the safety of Kimchi, 200 Kimchi raw materials and 100 kimchi products that are manufactured and sold in Korea were subjected to a comprehensive microbiological analysis, including the detection of food-borne pathogens, physical and chemical analyses, and analyses of the effects of washing on Kimchi microbes. The levels of microbiological indicators of hygiene were comparable to those observed in previous studies. Although the food-borne pathogen *B. cereus* was detected, the levels were within a safe range, i.e., below 10,000/g, in compliance with the standards and specifications for Kimchi products in the current Korean Food Standards Codex. Low levels of microorganisms were detected in raw materials used in kimchi and Kimchi products, indicating that current manufacturing and distribution of processes are safe. However, soil-borne contaminants can be introduced to raw materials; therefore, a thorough sanitary control process, such as washing, is required to ensure the safety of Kimchi products. In addition, careful attention should be paid to temperature control and the reuse of brines.

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국문요약

본 연구에서는 김치 제조시 철저한 재료 세척의 필요성을 확인하고, 더불어 비가열 식품인 김치의 위생 안전성 실태를 파악하여 효율적 미생물 저감화 방안을 마련하고자 국내에서 유통되는 김치 원·부재료 200건의 세척 전과 후의 비교분석과 시판 김치 100건에 대하여 미생물 분석을 실시하였다. 김치 원·부재료 및 완제품에 대하여 일반세균수, 대장균 및 대장균군을 모니터링 하였으며, 병원성 미생물 9종(*Bacillus cereus, Clostridium perfringens* 정성·정량, *Staphylococcus aureus,* Enterohemorrhagic *Escherichia coli, Campylobacter jejuni/coli, Yersinia enterocolitica, Salmonella* spp., *Vibrio parahaemolyticus, Listeria monocytogenes* 정성)을 분석 하였다. 모니터링 결과, 김치 원·부재료 및 완제품에서 일반세균은 1.4~9.0 log CFU/g 수준으로 확인되었으며, 원·부재료 중 생강에서 8.8 log CFU/g, 완제품 중 총각김치에서 9.0 log CFU/g으로 일반세균이 가장 높게 나타났다. 대장균군은 0.5~7.3 log CFU/g으로 확인되었으며, 생강에서 7.3 log CFU/g으로 가장 높게 나타났고, 병원성 미생물 9종의 분석결과, *Bacillus cereus*를 제외한 나머지 8종의 식중독균은 모든 시료에서 검출되지 않았다. 김치 제조 시 사용되는 김치 원·부재료들의 세척 공정 후 미생물 수는 일반세균수 0.2~3.2 log CFU/g, 대장균군 0.3~2.7 log CFU/g, *Bacillus cereus* 1.0~3.9 log CFU/g 감소하였다. 따라서, 김치 원·부재료의 세척 공정으로 미생물 오염도를 감소 시켰으며, 이 결과를 통하여 김치 완제품의 위생 및 저장성 증진에 기여 할 수 있을 것으로 확인되었다.

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