Analysis for change in microbial contents in five mixed Kimchi starter culture and commercial lactic acid bacterial-fermented sausages and biological hazard in manufacturing facilities

Seung Yun Lee¹ · Da Young Lee¹ · On You Kim¹ · Sun Jin Hur¹

Received: 5 September 2018 / Revised: 17 October 2018 / Accepted: 11 November 2018 / Published online: 22 November 2018
© The Korean Society of Food Science and Technology and Springer Science+Business Media B.V., part of Springer Nature 2018

Abstract The purpose of this study was to compare change in microbial contents between sausages with five mixed Kimchi starter culture (T1) and commercial lactic acid bacterial (LAB) (T2) during fermentation, and to screen manufacturing facilities for microbial condition. For T1 and T2, pH levels decreased at 7 days and increased at 14 days. For color, the lightness of T1 decreased at 7 days (36.50 ± 6.04) and slightly increased at 14 days (38.40 ± 4.35). In addition, T1 and T2 were observed decrement of redness and increment of yellowness during ripening. Mold, yeast, and LAB were detected, whereas pathogenic bacteria were not detected in both sausages (T1 and T2) and screening manufacturing facilities. Taken together, five mixed Kimchi starter culture fermented sausage was similar to commercial LAB-fermented sausage, and this study could be used to information as basic data biological hazard for HACCP system in fermented sausage.

Keywords Microorganisms · Kimchi · Fermented sausage · Hygiene of manufacturing facility

Introduction

Fermented sausages are not heated before the manufacturing process or intake, and are meant to be stored for long periods without refrigeration. The ripening of sausages

includes chemical, physical, microbiological, and enzymatic changes, which are occurred factor until the final product (Ahn et al., 2018; Benno, 2003; Choi et al., 2018; Emre and Halil, 2018; Jung et al., 2018). These changes can determine microbial characteristics and food hygiene, which is related stability and safety of food affecting food quality. Therefore, starter cultures are very important to ensure product stability and quality.

Kimchi is a famous Korean fermented vegetable food, which has baechu cabbage, salt, various herb and spices (Cheigh et al., 1994). Kimchi is fermented by numerous microorganisms such as *Weissella*, *Lactobacillus*, *Leuconostoc*, and *Pediococcus* species (at a concentration of 10^7 – 10^9 CFU/g) (Chang and Chang, 2010; Choi et al., 2002; Kang et al., 2012). Lactic acid bacteria (LAB), used to make Kimchi, have been found to have anticancer, antimicrobial, and antipathogenic activities (Kwak et al., 2014; Lee, 1997; Rhee et al., 2011). *Weissella kimchii* (*W. kimchii*) and *Weissella koreensis* (*W. koreensis*) which are isolated Kimchi have been proposed as probiotic to prevent vaginal infections as well as inhibit the germination of target microorganisms spores during food fermentation and exhibits and anti-obesity effect (Abriouel et al., 2015; Choi et al., 2012). Previous studies observed that *Lactobacillus*, *Leuconostoc* and *Weissella* have reflecting the increasing importance of these bacteria as starter culture and these would contributed improve the quality and safety of fermented dry sausage (Ammor et al., 2007; Colins et al., 1993). Thus, fermented Kimchi could be a good starter culture for fermented sausage. The microbial ingredients for meat starter cultures commonly include yeast (*Debaryomyces hansenii*, *Candida famata*), fungi (*Penicillium chrysogenum*, *Penicillium nalgiovense*), and bacteria (LAB, micrococci, staphylococci, actinomycetes, and enterobacteria) (Fernández-López et al., 2008). Flores et al.

✉ Sun Jin Hur
hursj@cau.ac.kr

¹ Department of Animal Science and Technology, Chung-Ang University, 4726 Seodong-daero, Daedeok-myeon, Anseong-si, Gyeonggi 17546, Republic of Korea

(2004) reported that *Debaryomyces* spp. can have important effects on volatile compounds during the ripening of fermented sausages, by inhibiting the formation of lipid oxidation products and inducing the generation of ethyl esters. These processes are responsible for the development of typical sausage aroma. Similarly, fungal starter cultures also have an important role in generating the aroma and taste of fermented meat products (Ba et al., 2018; Cook, 1995; Lücke, 1998). Bacteria used as starter culture, such as *Micrococcaceae* and LAB, are responsible for lipolytic activity, proteolysis, color formation, and altering chemical reactions (Ordóñez et al., 1999). However, pathogenic microorganisms can also grow during the fermentation of sausages. *Listeria*, *Enterobacteriaceae*, and *Staphylococcus aureus* (*S. aureus*) have been responsible for food poisoning incidents in fermented sausages (Colak et al., 2007; Pecanac et al., 2015; Sameshima et al., 1998). Among the aforementioned pathogens, *Escherichia coli* (*E. coli*) and *Listeria monocytogenes* (*L. monocytogenes*) are cold-tolerant organisms, which survive fermentation. Especially, *L. monocytogenes* can contaminate meat and is unaffected by pH changes and low water activity (Lahti et al., 2001; Muthukumarasamy and Holley, 2007).

Since meat is perishable, poor handling of fermented sausage can be detrimental to public health and meat production industries. Therefore, Hazard Analysis and Critical Control Point (HACCP) systems must be established for fermented sausage or Kimchi fermented sausage. This study was conducted to determine changes in pH, color, and microbial growth in five mixed Kimchi starter culture fermented sausage compared to those of LAB-fermented sausage. Furthermore, the evaluation of microbiological hazards in manufacturing facilities was performed to assess HACCP system for Kimchi fermented sausage.

Materials and methods

Sample database in manufacturing facility

This study was conducted using data from a manufacturing facility. The data were classified processing sites. The sampling sites were: (1) boning room (conveyor belt, surface of chopping board, and deboner), (2) process room (surface of chopping board, grinder, silent cutter machine, knife of silent cutter, sausage stuffer, sausage clipper), (3) storage room, (4) freezer room, (5) ripening room, (6) refrigerator room, and (7) food equipment (surface of chopping board, knife, container, and rice paddle).

Fermented sausage formulation and processing

For the preparation of the used Kimchi, the average composition of the various raw materials and ingredients are as follows: 83% baechu cabbage, 7% radish, 1.8% garlic, 1% ginger, 2% green onion, 3% red pepper, and trace ingredients such as salted shrimp, fish sauce (aekjoet) etc. added < 3%; the final salt content is calculated at 2.5% (w/w). Kimchi was fermented for 14 days and ground by using a grinder.

LAB were isolated from fermented Kimchi, and each LAB were identified using by 16S rRNA genes were amplified by PCR using the universal primer. Sequence analyses confirmed that five microorganisms such as *Lactobacillus* spp., *Leuconostoc* spp., *Lactococcus* spp., *Pediococcus* spp., and *Weissella* spp., were found in the fermented Kimchi. Thus, the confirmed LAB of fermented Kimchi was used as starter culture for making Kimchi-fermented sausage. Another starter culture for making commercial fermented sausages were *Lactobacillus acidophilus*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Bifidobacterium bifidum*, and *Lactobacillus lactis* purchased from Nutribiotech Inc. (Icheon, Gyeonggi, Korea). Fermented sausages were inoculated with above mentioned starter cultures at levels of 6–7 log CFU/g. The pork meat and pork back fat was chopped and mixed with prepared ingredient according to formulation. The pork meat was trimmed to eliminate fat and connective tissue. The trimmed pork (90%) and pork back fat (10%) was mince twice through a 3-mm plate in a grinder (SMC-12; Techinkorea, Cheongju-si, Chungbuk, Korea). The minced pork meat was cured with salt (1%), sugar (0.1%), ascorbic acid (0.045%) and nitrite (0.02%). After then, the mixture was mixed using a mixer for 20 min, and then cured for 24 h at 4 °C. The cured meat was placed in a bowl cutter along with black pepper (0.15%), white pepper (0.1%), ground Kimchi or lactic acid bacteria combined powder (2%) according to the experimental design. The sausages were stuffed in natural casings 30 cm in length and 3 cm in diameter, and dried and ripened at 4 °C for 7 days at a relative humidity of 75–80%. The period of second ripening was set at 12 °C for 30 days at a relative humidity of 65–75% (Fig. 1). Analyses of microorganism level, salt content, pH and color value were conducted at 0, 7, and 14 days of ripening.

Microbiological analysis

To assess microorganism content, samples were ten fold diluted with 0.85% sterile saline in a bag filter after homogenization with a stomacher (Bagmixer 400, Interscience, Co., Saint Nom, France) for 3 min. In addition, we assessed hygiene of manufacturing facilities at before

Fig. 1 Photographs of the two types of fermented sausages during fermentation of 14 days

working operation through performance of microorganisms using by swab standard methods (Ismail et al., 2013). This method conducted as follow. The moistened swabs rub lightly surface of samples or test area (10×10 cm), after then, the collected swab placed into sterile water in tube. This study was conducted extraction of microorganism in swab using by vortexing step, after then tested for microorganisms. At the same time, the samples were inoculated with 1 mL of each dilution in the center of the plate. The total plate count (TPC) was performed using Petrifilm (3 M, Minnesota, USA) and TPC values were obtained by enumerating the red colonies. Coliform and *E. coli* enumerations were performed using Petrifilm and, blue colonies with bubbles were counted as *E. coli*, and red colonies with bubbles were counted as coliforms. *S. aureus* enumerations were performed using Petrifilm, and determined by the presence of purple colonies. Evaluation of *Salmonella* and *L. monocytogenes* were performed with an Easy stamp using the chromogenic method. Moreover, greenish-blue and black centers were counted as *Salmonella typhimurium*, and blue colonies with white a halo were counted as *Listeria*. The above mentioned microorganisms were incubated for 48 h at 37 °C. Evaluation of yeast and mold were also performed using Petrifilm and incubated for 4 days at 25 °C (Fernández-López et al., 2008; Jayawardana et al., 2015).

pH

To assess the pH values of fermented sausages, 10 g of sausage and 90 mL of distilled water were mixed, and filtered with 4 layer sterilized gauze. pH values were measured using a pH meter (Five Easy Plus pH, Mettler Toledo, Greifensee, Switzerland) following the fermentation period.

Color value

Color values of fermented sausages were measured as Hunter values of lightness (L^*), redness (a^*), and yellowness (b^*) using a colorimeter (Color reader, CR-13, Minolta Co, Tokyo, Japan) following the fermentation period. The total color difference was described by the color value E . L^* , a^* , b^* Hunter values of the standard plate were $L^* = 96.40$, $a^* = 0.00$, and $b^* = 1.50$.

Statistical analysis

All statistical analysis was performed using the one-way analysis of variance (ANOVA) procedure of SPSS 20.0 (SPSS, Inc., Chicago, IL, USA). A Tukey's multiple comparison test was used to determine significant differences between mean values, and significance was considered at $P < 0.05$.

Results and discussion

This study examined changes in pH and color in two types of fermented sausages [five mixed Kimchi starter culture fermented sausage (T1) and commercial LAB-fermented sausage (T2)] during the fermentation period (Table 1). The pH of both groups (T1 and T2) was significantly decreased at 7 days ($p < 0.05$). However, the pH of T1 and T2 increased at the end of fermentation. It is well known that the increase of pH was affected by proteolytic activity with formation of peptides, ammonia and amino acids during sausage ripening (Demeyer and Vandekerckhove, 1979; Dierick et al., 1974). In general, the pH of fermented sausages is affected by LAB growth during fermentation. Decreasing pH results in a decline in the water holding

Table 1 Change in pH and color (Hunter's L*, a* and b*) of sausage following fermentation

Storage (days)	pH		Color					
			L*		a*		b*	
	T1	T2	T1	T2	T1	T2	T1	T2
0	4.01 ± 0.01 ^b	4.12 ± 0.00 ^b	49.00 ± 5.49 ^a	44.20 ± 6.90 ^a	10.65 ± 1.08 ^a	7.95 ± 1.00 ^a	6.07 ± 1.29 ^b	3.85 ± 2.20 ^c
7	3.91 ± 0.01 ^c	3.64 ± 0.00 ^c	36.50 ± 6.04 ^b	37.70 ± 7.00 ^a	8.63 ± 1.78 ^b	8.21 ± 1.29 ^a	7.74 ± 1.42 ^a	6.70 ± 0.70 ^b
14	5.45 ± 0.01 ^a	4.93 ± 0.01 ^a	38.40 ± 4.35 ^b	38.40 ± 6.70 ^a	5.82 ± 2.58 ^c	3.78 ± 1.20 ^b	7.55 ± 1.20 ^a	11.95 ± 3.47 ^a

T1, fermented sausage with kimchi; T2, fermented sausage with lactic acid bacteria

^{a-c}Mean values with different superscript are significantly different ($p < 0.05$) different within same column

capacity, which controls the growth of pathogenic bacteria such as *E. coli* O517:H7 and *S. aureus* (Glass et al., 1992; Samelis et al., 1994). In this study, we found that changes in pH were similar between five mixed Kimchi starter culture fermented (T1) and commercial fermented sausage (T2). The microflora present during fermentation by Kimchi could inhibit the growth of pathogenic bacteria due to a decline in pH, similar to that of commercial fermented sausage. However, there was no change in salt content during the fermentation period in both sausages (Data not shown). This result is in agreement with previous report (Papamanoli et al., 2003) which was conducted in fermented sausage. Thus, it seems that pH of fermented sausages was not affected by salt content.

Color is a critical sensory characteristic of sausages. Table 1 shows the effect on color parameters including lightness (L*), redness (a*), and yellowness (b*) for both groups of fermented sausages (T1 and T2). The L* values for both groups (T1 and T2) showed a tendency to gradually decrease, but were not significant different between T1 and T2, during the fermentation period. The L* values significantly decreased at 7 days, but slightly increased at 14 days for both types of sausages (T1 and T2). The decrease in L* value was accompanied by the formation of dark color due to the browning reaction. Similarly, Bozkurt and Bayram (2006) determined that L* values generally decrease during the ripening of fermented sausages. In this study, a* (redness) values of T1 significantly decreased during fermentation periods, whereas b* (yellowness) of T1 slightly increased at 7 days. In addition, a* (redness) values of T2 significantly decreased at 14 days, whereas b* (yellowness) of T2 significantly increased during fermentation periods. However, there was no significant difference in a* or b* levels between T1 and T2 during the fermentation period. Bozkurt and Bayram (2006) observed that nitrogenous compounds present in meat combined with myoglobin having a red color, thereby increasing a* values. Subsequently, the decline of a* values might be due to the partial denaturation of nitrosomyoglobin by release of

lactic acid. In addition, at 7 days, a* values decreased with decreasing pH in the fermented sausages. This result was similar to that of a previous study, which suggested that another possible reason for decreasing a* values is denaturation of nitrosomyoglobin due to the production of lactic acid (Pérez-Alvarez et al., 1999). The b* value of both sausages (T1 and T2) increased after 7 days. This result can be explained by a previous studies suggesting that increasing b* values might be due to an increase lipid peroxidation by the microbial lipases generated by the starter culture and the during processing (Kim et al., 2015; Suckow et al., 2016). In this study, we found that changes in color were influenced by altered myoglobin and pH; furthermore, five mixed Kimchi starter culture fermented sausage (T1) and commercial-LAB starter culture fermented sausage (T2) showed similar results. Therefore, LAB in these two sausage types could be assumed to be similar, as pH and color characteristics of both groups (T1 and T2), which are influenced by LAB, were almost identical. Figure 2 shows changes in TPC, yeast, mold, and LAB during the fermentation period of both sausages (T1 and T2). The TPC increased during the fermentation period; after 14 days, maximum values for T1 and T2 were 7.43 and 8.32 log CFU/mL, respectively. Our results showed that the addition of various Kimchi starter culture and commercial LAB starter culture did not significantly affect the TPCs. The number of yeast and mold colonies increased during the first 7 days, and then decreased slightly towards the end of fermentation on both sausages (T1 and T2). LAB was not detected at first, but gradually increased up to 7 days, after which a slight decrease was observed at 14 days. Probiotic microorganisms previously identified in Kimchi included *Lactobacillus* spp., *Leuconostoc* spp., *Pediococcus* spp. (such as *Lactobacillus brevis*, *L. casei*, *Leuconostoc mesenteroides*, *Leuconostoc citreum*, and *Pediococcus cerevisiae*), and novel strains (such as *Leuconostoc kimchi* and *Lactobacillus kimchi*) (Chang and Chang, 2010; Lee et al., 2006; Oh et al., 2004). These studies suggested that probiotic microorganisms

Fig. 2 Changes in microorganism content of fermented sausages during the fermentation period. * $p < 0.05$ when comparing the two different fermented sausage groups (T1 and T2)

from Kimchi play an important role in regulating immune responses related to anticancer activities, prevention of pathogen infection, and antimutagenic activity (Choi et al., 2015; Park et al., 2014; Park and Rhee, 2001).

Herein, the rapid growth of LAB at 7 days resulted in a decrease in the pH of fermented sausages. Silins (2014) also showed that exponential LAB growth stops on the seventh day of ripening (Silins, 2014). Furthermore, low pH, induced by lactic acid bacteria, can inhibit pathogenic bacteria; therefore, pathogenic bacteria such as *Salmonella*, *Listeria*, *E. coli*, and *S. aureus* were not detected in either

sausage group (T1 and T2) during fermentation. Even if these samples were infected to pathogenic bacteria such as *Salmonella*, *Listeria*, *E. coli*, and *S. aureus*, LAB growth during fermentation can inhibit these pathogenic bacteria. Therefore, pathogenic bacteria was not detected in this study. In accordance with the conclusions of Greer and Dilts (1995). The bactericidal effects of lactic acid are via the breakdown of the bacterial cell membrane through the penetrability of the undissociated acid. According to previous reports, lactic acid production by LAB and reduction of pH affect inhibition of various pathogenic bacteria such

as *Listeria* and *E. coli* strains (Daeschel, 1989; Maragkoudakis et al., 2009; Petrova et al., 2009). In addition, the LAB produces various antimicrobial substances, such as hydrogen peroxide, carbon dioxide, diacetyl, and bacteriocins, can antagonize against spoilage and pathogenic bacteria (Ammor et al., 2006). Therefore, optimal conditions of LAB growth are important during the production of fermented sausages. Furthermore, decreasing pH might enhance the stability and hygiene of sausages. As indicated, starter cultures used in this study were able to decrease the pH through LAB growth, which could inhibit pathogenic bacteria; thus, the selection of a starter culture is very important for fermented sausage quality. Furthermore, we measured biogenic amines (histamine and tyramine) of fermented sausages (Data not shown) and found that the tyramine was the only biogenic amine found in the fermented sausages. However, the concentration was very low level (13.0–84.9 mg/kg sausage). Moreover, among various starter cultures, the tyramine concentration of fermented sausage with LAB (*L. plantarum*) decreased approximately 84.6% than that of fermented sausage with *Staphylococcus carnosus* and *Lactobacillus sakei*. Therefore, based on similar results for both groups (T1 and T2), bacteria from fermented Kimchi could be used as a starter culture and as probiotics.

Considering increasing trends for the consumption of meat products in Korea, proper hygiene and safety policies are essential for public health (Lee et al., 2010; Nam et al., 2007). As shown in Table 2, we studied the hygiene of manufacturing facilities through enumerating microorganisms from swab samples. Lehto et al. (2011) determined the surface hygiene guidelines for TPC, Enterobacteria, yeast, and mold on food processing surfaces. The microbiological criteria suggesting undesirable food hygiene conditions are > 10 CFU/cm² for TPC, > 5 CFU/cm² for yeast, a score of “+++” (heavy) for mold, and > 1.1 CFU/cm² for enterobacteria (Lehto et al., 2011). In the boning room, the log TPC, yeast, and mold values ranged from 1.00 to 2.26 per cm². In the process room, the log TPC, yeast, and mold values ranged from 1.00 to 4.78 per cm², and the log coliform count was detected to be 1.88 on the surface of the chopping board. Overall, TPC, yeast, and mold counts from the storage room were the highest. However, *S. aureus*, *E. coli*, *Salmonella*, and *Listeria* were not detected in the manufacturing facility. Overall, this result indicated that the hygiene conditions of the boning room and refrigerator room were more desirable than that of the storage room. This suggests that growth of microorganisms was inhibited by low temperatures. Moreover, this study can provide the following recommendations according to results from the manufacturing facility refer to previous studies (Humphrey et al., 1988; Mead and Thomas, 1973; Tompkin, 1994). First, sanitising

Table 2 Microorganism counts from surfaces of manufacturing facility

Sampling test	TPC ^a	Coliform ^a	Yeast ^a	Mold ^a
Boning room				
Conveyor belt	1.70	ND	1.00	1.70
Surface of chopping board	2.26	ND	1.00	2.30
Deboner	1.70	ND	2.00	2.30
Process room				
Surface of chopping board	2.02	1.88	1.00	2.43
Grinder	3.65	ND	1.40	3.49
Silent cutter machine	3.55	ND	1.18	2.15
Knife of silent cutter	3.34	ND	1.18	1.40
Sausage stuffer	4.78	ND	1.00	4.28
Sausage clipper	4.18	ND	2.40	4.60
Storage room	9.23	ND	4.78	9.25
Freezer room	4.11	ND	2.88	6.09
Ripening room	2.48	ND	1.30	2.40
Refrigerator room	2.08	ND	1.00	2.64
Food equipment				
Surface of chopping board	2.08	ND	1.95	2.62
Knife	4.37	ND	2.36	3.55
Container	5.21	ND	1.88	5.99
Rice paddle	1.00	ND	1.00	2.43

ND not detected

^aUnit: log CFU/cm²

and cleaning of all products and machines related to the meat processing line should be performed before use and as separate process. The cleaning steps provide detail followed as: (1) pre-clean: scrape and the contamination substance of surface and rinse with water, (2) wash: use hot water with detergent to remove the remainder oil (grease) and food residue. (3) sanitise: use sanitizer (hypochlorites; < 200 ppm, chlorine dioxide with 100 ppm at 10 min, peroxyacetic acid; 100–200 ppm) (4) final rinse: clear away the sanitizer if necessary (5) dry: use towels and materials to remove water. Second, cross-contamination, which is the physical movement or transfer of harmful bacteria from one person, material, or place to another, should be carefully avoided for prevention of serious problems including foodborne illness. Especially, the introduction of pathogenic bacteria such as *S. aureus* should be prevented by avoiding inadequate hand washing or injury, soiled clothing or aprons. In addition, raw meats and cooked foods should be separated, and then, store food and nonfood products away from walls and at least 15 cm. Mead and Thomas (1973) suggested that the addition of chlorine as chilling water (30–50 ppm) in most processors could be reduce cross contamination (Mead and Thomas, 1973). Humphrey et al. (1988) reported that many

treatments (6% phosphate in water at 60–90 °C, 5% sodium chloride in water at 18 °C, 5% lactic acid in water at 60–72 °C) removed or destroyed salmonellas at the end of processing for preventing cross-contamination. Third, humidity and temperature need to be controlled to inhibit the growth of pathogenic bacteria. Examples, the temperature of major processing and packaging room should be controlled at < 5 °C, the whole packaging room need to be worked on aseptic condition and humidity should be controlled < 60% in manufacturing facilities. These conditions allow to inhibit the growth of pathogenic bacteria. Therefore, it is important to establish the Critical Control Point for inhibition of contamination during the manufacturing process through evaluation of biological hazard analysis and these data could provide information for determination of biological hazard analysis.

The present study revealed that the pH, color, and microbial growth between five mixed Kimchi starter culture fermented sausage (T1) and commercial-fermented sausage (T2) are not significantly different. Pathogenic microorganisms were not detected during fermentation of both sausage types (T1 and T2). Moreover, the manufacturing facilities for Kimchi starter culture fermented sausage and commercial-fermented sausage did not contain pathogenic microorganisms. These results indicate that fermented Kimchi can be used as starter culture for fermented sausage without risk of contamination by pathogenic microorganisms. Probiotics in Kimchi-fermented sausage could be beneficial, as these probiotics are familiar to Korean consumers. In addition, the pattern of microbial contamination in manufacturing facilities identified in this study could be used to establish the CCP (biological hazard) in a HACCP system for fermented sausage. Furthermore, regulation of food facilities is beneficial for public health.

Acknowledgements This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry and Fisheries (IPET) through High Value-added Food Technology Development Program and was funded by Ministry of Agriculture, Food and Rural Affairs (MAFRA) (116034-03-1-HD020). This research was supported by the Chung-Ang University.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

References

- Abriouel H, Lerma LL, Casado Muñoz MdC, Montoro BP, Kabisch J, Pichner R, Cho GS, Neve H, Fusco V, Franz CMAP, Gálvez A, Benomar N. The controversial nature of the *Weissella* genus: technological and functional aspects versus whole genome analysis-based pathogenic potential for their application in food and health. *Front. Microbiol.* 6: 1197 (2015)
- Ahn KI, Shim JY, Kim TK, Choi JH, Kim HW, Song DH, Kim YB, Jeon KH, Choi YS. Effects of replacing pork with tuna levels on the quality characteristics of frankfurters. *Korean J. Food Sci. Anim. Resour.* 38: 718–726 (2018)
- Ammor S, Tauveron G, Dufour E, Chevallier I. Antibacterial activity of lactic acid bacteria against spoilage and pathogenic bacteria isolated from the same meat small-scale facility: 1—screening and characterization of the antibacterial compounds. *Food Control* 17: 454–461 (2006)
- Ammor MS, Flórez AB, Mayo B. Antibiotic resistance in non-enterococcal lactic acid bacteria and bifidobacteria. *Food Microbiol.* 24: 559–570 (2007)
- Ba HV, Seo HW, Seong PN, Kang SM, Kim YS, Cho SH, Park BY, Ham JS, Kim JH. *Lactobacillus plantarum* (KACC 92189) as a potential probiotic starter culture for quality improvement of fermented sausages. *Korean J. Food Sci. Anim. Resour.* 38: 189–202 (2018)
- Benno K. Production and microbiological characteristics of fermented sausages. *Korean J. Food Sci. Anim. Resour.* 23: 361–375 (2003)
- Bozkurt H, Bayram M. Colour and textural attributes of sucuk during ripening. *Meat Sci.* 73: 344–350 (2006)
- Chang JY, Chang HC. Improvements in the quality and shelf life of Kimchi by fermentation with the induced bacteriocin-producing strain, *Leuconostoc citreum* GJ7 as a Starter. *J. Food Sci.* 75: M103–M110 (2010)
- Cheigh HS, Park KY, Lee CY. Biochemical, microbiological, and nutritional aspects of kimchi (Korean fermented vegetable products). *Crit. Rev. Food Sci. Nutr.* 34: 175–203 (1994)
- Choi HJ, Cheigh CI, Kim SB, Lee JC, Lee DW, Choi SW, Park JM, Pyun YR. *Weissella kimchii* sp. nov., a novel lactic acid bacterium from kimchi. *Int. J. Syst. Evol. Microbiol.* 52: 507–511 (2002)
- Choi H, Kim YW, Hwang I, Kim J, Yoon S. Evaluation of *Leuconostoc citreum* HO12 and *Weissella koreensis* HO20 isolated from kimchi as a starter culture for whole wheat sourdough. *Food Chem.* 134: 2208–2216 (2012)
- Choi HJ, Lee NK, Paik HD. Health benefits of lactic acid bacteria isolated from kimchi, with respect to immunomodulatory effects. *Food Sci. Biotechnol.* 24: 783–789 (2015)
- Choi YS, Ku SK, Kim TK, Park JD, Kim YC, Kim HJ, Kim YB. Distribution of microorganisms in *Cheongyang* red pepper sausage and effect of central temperature on quality characteristics of sausage. *Korean J. Food Sci. Anim. Resour.* 38: 749–758 (2018)
- Colak H, Hampikyan H, Ulusoy B, Bingol EB. Presence of *Listeria monocytogenes* in Turkish style fermented sausage (sucuk). *Food Control* 18: 30–32 (2007)
- Colins MD, Samelis J, Metasopoulos, Wallbanks W. Taxonomic studies on some leuconostoc-like organisms from fermented sausages: description of a new genus *Weissella* for the *Leuconostoc paramesenteroides* group of species. *J. Appl. Bacteriol.* 75: 595–603 (1993)
- Cook PE. Fungal ripened meats and meat products, pp. 110–129. In: *Fermented meats*. Campbell-Platt G, Cook PE (eds). Springer, Boston, MA (1995)
- Daeschel MA. Antimicrobial substances from lactic acid bacteria for use food preservatives. *Food Technol.* 43: 164–167 (1989)
- Demeyer DI, Vandekerckhove P. Compounds determining pH in dry sausage. *Meat Sci.* 34: 351–362 (1979)
- Dierick N, Vandekerckhove P, Demeyer D. Changes in nonprotein nitrogen compounds during dry sausage ripening. *J. Food Sci.* 39: 301 (1974)
- Emre H, Halil V. New approaches to production of turkish-type dry-cured meat product “Pastirma”: salt reduction and different

- drying techniques. Korean J. Food Sci. Anim. Resour. 38: 224–239 (2018)
- Fernández-López J, Sendra E, Sayas-Barberá E, Navarro C, Pérez-Alvarez JA. Physico-chemical and microbiological profiles of “salchichón” (Spanish dry-fermented sausage) enriched with orange fiber. Meat Sci. 80: 410–417 (2008)
- Flores M, Durá MA, Marco A, Toldrá F. Effect of *Debaryomyces* spp. on aroma formation and sensory quality of dry-fermented sausages. Meat Sci. 68: 439–446 (2004)
- Glass KA, Loeffelholz JM, Ford JP, Doyle MP. Fate of *Escherichia coli* O157:H7 as affected by pH or sodium chloride and in fermented, dry sausage. Appl. Environ. Microbiol. 58: 2513–2516 (1992)
- Greer GG, Dilts BD. Lactic acid inhibition of the growth of spoilage bacteria and cold tolerant pathogens on pork. Int. J. Food Microbiol. 25: 141–151 (1995)
- Humphrey TJ, Mead GC, Rowe B. Poultry meat as a source of human salmonellosis in England and Wales. Epidemiol. Infect. 100: 175–184 (1988)
- Ismail R, Aviat F, Michel V, Le Bayon I, Gay-Perret P, Kutnik M, Fédérighi M. Methods for recovering microorganisms from solid surfaces used in the food industry: a review of the literature. Int. J. Environ. Res. Public Health. 10: 6169–6183 (2013)
- Jayawardana BC, Liyanage R, Lalantha N, Iddamalgoda S, Weththasinghe P. Antioxidant and antimicrobial activity of drumstick (*Moringa oleifera*) leaves in herbal chicken sausages. LWT Food Sci. Technol. 64: 1204–1208 (2015)
- Jung JT, Lee JK, Choi YS, Lee JH, Choi JS, Choi YI, Chung YK. Effect of rice bran and wheat fibers on microbiological and physicochemical properties of fermented sausages during ripening and storage. Korean J. Food Sci. Anim. Resour. 38: 302–314 (2018)
- Kang SM, Kim TS, Cho SH, Park BY, Lee SK. Comparison of microbial and physico-chemical quality characteristics in Kimchi-fermented sausages with sodium nitrite and green tea extract. J. Anim. Sci. Technol. 54: 299–305 (2012)
- Kim JH, Hong GE, Pyun CW, Park W, Lee CH. Enhancement of physicochemical, microbiological and sensory properties of fermented loin by using processed sulfur-fed pigs. Anim. Prod. Sci. 56: 1936–1945 (2015)
- Kwak SH, Cho YM, Noh GM, Om AS. Cancer preventive potential of kimchi lactic acid bacteria (*Weissella cibaria*, *Lactobacillus plantarum*). J. Cancer Prev. 19: 253–258 (2014)
- Lahti E, Johansson T, Honkanen-Buzalski T, Hill P, Nurmi E. Survival and detection of *Escherichia coli* O157:H7 and *Listeria monocytogenes* during the manufacture of dry sausage using two different starter cultures. Food Microbiol. 18: 75–85 (2001)
- Lee JY, Kim CJ, Kunz B. Identification of lactic acid bacteria isolated from kimchi and studies on their suitability for application as starter culture in the production of fermented sausages. Meat Sci. 72: 437–445 (2006)
- Lee JY, Paik JK, Hwang HS, Lee JE, Shin WS, Kim HW, Paik HD, Hong WS. Survey of hygienic condition and management of meat markets in Seoul and Gyeong-Gi area, Korea-HACCP-certified and non certified. Korean J. Food Sci. Anim. Resour. 30:336–344 (2010)
- Lee CH. Lactic acid fermented foods and their benefits in Asia. Food Control 8: 259–269 (1997)
- Lehto M, Kuisma R, Määtä J, Kymäläinen HR, Mäki M. Hygienic level and surface contamination in fresh-cut vegetable production plants. Food Control 22: 469–475 (2011)
- Lücke FK. Fermented sausages, pp. 441–483. In: Microbiology of fermented foods. B. J. B. Wood. (1998)
- Maragkoudakis PA, Mountzouris KC, Psyrras D, Cremonese S, Fischer J, Cantor MD, Tsakalidou E. Functional properties of novel protective lactic acid bacteria and application in raw chicken meat against *Listeria monocytogenes* and *Salmonella enteritidis*. Int. J. Food Microbiol. 130: 219–226 (2009)
- Mead GG, Thomas NL. Factors affecting the use of chlorine in the spin-chilling of eviscerated poultry. Br. Poult. Sci. 14: 99–117 (1973)
- Muthukumarasamy P, Holley RA. Survival of *Escherichia coli* O157:H7 in dry fermented sausages containing micro-encapsulated probiotic lactic acid bacteria. Food Microbiol. 24: 82–88 (2007)
- Nam BR, Nam JO, Park JM, Lee RM, Gu HJ, Kim MH, Chang UJ, Suh HJ, Kim JM. Survey of the status of country-of-origin labels and hygiene on the meat markets of 4 regions in Korea. Korean J. Food Sci. Anim. Resour. 27: 122–126 (2007)
- Oh CK, Oh MC, Kim SH. The depletion of sodium nitrite by lactic acid bacteria isolated from kimchi. J. Med. Food. 7: 38–44 (2004)
- Ordóñez JA, Hierro EM, Bruna JM, Hoz LDL. Changes in the components of dry-fermented sausages during ripening. Crit. Rev. Food Sci. Nutr. 39: 329–367 (1999)
- Papamanoli E, Tzanetakis N, Litopoulou-Tzanetaki E, Kotzekidou P. Characterization of lactic acid bacteria isolated from a Greek dry-fermented sausage in respect of their technological and probiotic properties. Meat Sci. 65: 859–867 (2003)
- Park KY, Jeong JK, Lee YE, Daily III JW. Health benefits of kimchi (Korean fermented vegetables) as a probiotic food. J Med. Food. 17: 6–20 (2014)
- Park HD, Rhee CH. Antimutagenic activity of *Lactobacillus plantarum* KLAB21 isolated from kimchi Korean fermented vegetables. Biotechnol. Lett. 23: 1583–1589 (2001)
- Pecanac B, Djordjevic J, Baltic MZ, Djordjevic V, Nedic DN, Starcevic M, Dojcinovic S, Baltic T. Comparison of bacteriological status during ripening of traditional fermented sausages filled into different diameter artificial casings. Proc. Food Sci. 5: 223–226 (2015)
- Pérez-Alvarez JA, Sayas-Barberá MAE, Fernández-López J, Aranda-Catalá V. Physicochemical characteristics of Spanish-type dry-cured sausage. Food Res. Int. 32: 599–607 (1999)
- Petrova M, Georgieva R, Dojchinovska L, Kirilov N, Iliev I, Antonova S, Hadjieva N, Ivanova I, Danova S. Lactic acid bacteria against pathogenic microbes. Trakia J. Sci. 7: 33–39 (2009)
- Rhee SJ, Lee JE, Lee CH. Importance of lactic acid bacteria in Asian fermented foods. Microb. Cell Fact. 10: 1–13 (2011)
- Samelis J, Stavropoulos S, Kakouri A, Metaxopoulos J. Quantification and characterization of microbial populations associated with naturally fermented Greek dry salami. Food Microbiol. 11: 447–460 (1994)
- Sameshima T, Magome C, Takeshita K, Arihara K, Itoh M, Kondo Y. Effect of intestinal *Lactobacillus* starter cultures on the behaviour of *Staphylococcus aureus* in fermented sausage. Int. J. Food Microbiol. 41: 1–7 (1998)
- Silins I. (2014). The effects of pH, aW, and lactic acid bacteria on *Listeria monocytogenes* in fermented sausages. Paper presented at the 9th Baltic Conference on Food Science and Technology” Food for Consumer Well-Being” FOODBALT 2014, Jelgava, Latvia, 8–9 May, 2014
- Suckow KS, Denielski GM, Borges TD, Macedo REF de. Effect of salt and fat reduction on the physical chemical changes during the manufacture of probiotic dry fermented sausage. International Technical Symposium (2016).
- Tompkin R. HACCP in the meat and poultry industry. Food Control 5: 153–161 (1994)