Research Note

Microbial levels for food contact and environmental surfaces in meat processing plants and retail shops

Jung-Hyun Kim and Dong-Gyun Yim^{1,*}

Department of Public Health, Graduate School of Public Health, Seoul National University, Seoul 08826, Korea

¹Department of Health Administration and Food Hygiene, Jinju Health College, Jinju, Gyeongnam 52655, Korea

Received September 23, 2016
Revised November 15, 2016
Accepted November 15, 2016
Published online February 28, 2017

*Corresponding Author
Tel: +82-55-740-1814
Fax: +82-55-743-3010
E-mail: tousa0994@naver.com

pISSN 1226-7708
eISSN 2092-6456

© KoSFoST and Springer 2017

Abstract The microbial contamination levels for food contact and environmental surfaces in meat processing plants and retail shops were assessed. Sixty-eight samples from meat processing plants and 44 from retail shops were collected. Samples were tested for total aerobic plate count (APC). Via monthly evaluation of samples from plants, the highest APC values were obtained in January as well as December and the second highest in April, May, and February ($p < 0.005$). The highest APC values of samples from plants were obtained from boots, followed by aprons, cutting machines, and knives ($p < 0.001$). Interestingly, the APC value of samples from shops in January was highest ($p < 0.001$). The contamination of cotton gloves, knives, boots, and wristlets was relatively higher even in shops ($p < 0.001$). In addition, there was a positive correlation between the APC and specimen ($r = 0.231$). For monitoring, the microbial sampling should consider testing the food contact and environmental surfaces along with raw meats.

Keywords: food contact and environmental surfaces, meat processing plants, retail shops, microbial contamination

Introduction

In recent years, there has been a growing concern regarding meat and meat products transmitting food-borne pathogens, including bacteria, despite efforts for the improvement of meat hygiene (1). Foods originating from animals showed as a major cause of infections with pathogenic microorganisms (2). Considering the increasing trends in the consumption of meat in Korea, proper hygiene management for protecting public health and strengthening consumer confidence is required. In particular, it is vital to manage the processing and distribution stages after the slaughter process to provide safe meat and meat products (3).

The currently employed procedures in the food industry for developing HACCP systems are based on subjective assessments of the actions taken to control microbiological contamination in production processes (4). Therefore, HACCP systems are based on microbiological data with estimates of the number of indicator organisms on products at various stages of processing (5). Aerobic plate count (APC) provides an estimate of total bacterial counts, and a higher APC is an indication of poorer quality and a reduced shelf life (6).

Microbial contamination can occur by exposure to the environment (7). When analyzing the microbial quality of meat samples, various

environmental factors during the slaughtering process have been observed in previous studies (1). However, meat products may be cross-contaminated by different pathogenic microorganisms during slaughtering processes such as chilling, cutting, and slicing (8). Therefore, the stages from processing line to retail outlets are vital factors affecting microbiological quality. Most of the contamination can take place during processing such as by exposure to meat facility equipment (e.g., saws and grinders), contact with meat handlers (e.g., cotton gloves and knives), and other environmental items (e.g., cutting table) (6). The cleanliness of meat contact surfaces has to be maintained and under control to reduce contamination by bacteria (9). The microbiological quality of meat can also be affected by the effect of the type of retail outlet sampled and the season at which the meat was analyzed (10). However, data on seasonal and monthly variations in microbiological examinations of meat contact surfaces in different processing plants and retail shops are limited. In particular, various meat contact surfaces and environmental factors of microbial contamination prepared in HACCP-implementing processing plants and retail shops have not been extensively studied. Therefore, this study aimed to investigate the level of microbial contamination in food contact surfaces and environmental impacts from meat processing line to retail shops in order to evaluate the microbiological hygiene after implementation of the HACCP system.

Materials and Methods

Sample collection A total of 112 food contact and environmental surface samples (68 from meat processing line and 44 from retail shops) were collected from randomly selected plants and retail shops located in three administrative regions in Korea (Gyeonggi, Gyeongsang, and Chungchong) over a one-year period. The selection of the plants was based on their capacities to process large amounts of meat (approximately 30 tons of meat per day) and their variety of processing lines (beef and pork). Collection was dependent on the cooperation of the owners. Experienced technicians or quality control staff at the plants and shops performed the microbiological sampling. The HACCP system, including sanitation procedures, was adopted in all plants and retail shops. A 12-month microbial survey of the plants and retail shops was conducted and during visits in this period, surface swab samples were collected. After collection, the swab samples were kept at 4–5°C in a portable incubator. The samples were transported to the laboratory and analyzed for APC. The surface swabs from the food equipment were always taken from the same sites, directly exposed to the processed raw material, and were collected within 2 h after standard sanitation of the equipment. For food contact and environmental surfaces, a surface swab technique was used as described in the Compendium of Methods for the Microbiological Examination of Foods (11). A sterile polypropylene template was used to sample each 10 cm² surface area. Before sampling, the sterile swabs were kept in 10 mL sterile peptone water in suitable conditions. After the sampling of the 10 cm² area, the swabs were placed aseptically back into peptone water. Immediately after sampling, the tubes containing the swabs was placed in a mobile incubator and maintained at 4°C. When the samples arrived at the laboratory, each tube containing the swab was vortexed for 10 s to assure mixture of the sample.

Microbiological analysis Samples were analyzed to determine the APC, which serves as a hygiene indicator, as described in the corresponding microbiological guidelines to the method specified in Process Criteria and Ingredient Standard of Livestock Products (12). Homogenized microbial extracts were serially diluted in 0.1% buffered peptone water. Each diluted 1 mL sample was plated individually and spread thoroughly. The APC was determined using plate count agar (Difco Laboratories, Detroit, MI, USA) incubated at 37±1°C for 48 h. All analyses were performed in triplicate. The counted colonies were expressed as the CFU/cm² of the food contact surface or as the CFU/equipment if the surface was small. In all cases, plate counts were determined and converted to log₁₀ CFU values using standardized plate count rules (11).

Statistical analysis STATA version 12.0 was used for the statistical analysis. ANOVA test was used for the comparison of the month and specimen with the APC of samples from meat processing plants and retail shops, respectively, and results were presented as mean and

standard errors. The Pearson correlation analyses were performed to evaluate the relationship between the specimen and APC. All values were mean and standard errors. *p*-Values less than 0.05 were considered significant.

Result and Discussion

Sixty-eight samples from meat processing plants and 44 from retail shops were examined and categorized by month and specimen (not presented in Table). By month, the highest number of samples was collected in August (23.5%), followed by November (19.1%). By specimen, the hands and knives account for 25% of the samples in meat processing plants, followed by the chopping board (22.1%). The knives (29.5%) were ranked the highest in retail shops, followed by hands (25%) and then chopping boards (15.9%).

The APC at meat packaging plants is shown in Table 1. The samples are categorized by month and specimen. By month, the highest APC was found in January as well as December, followed by April, May, and February in descending order (*p*<0.005). The high values of APC in January and December might be attributed to neglecting or failure in temperature management (<15°C) in plants because temperature drops in winter in comparison with summer. By specimen data, the APCs for food contact and environmental surfaces were highest in boots, followed by apron, cutting machine, and knives (*p*<0.001). Handling the meat using multiple knives was identified as risk factors for high contamination of boots and apron (13). APC counts for samples at meat processing plants were between 1.69 and 3.87 CFU/cm². High contamination of food contact and environmental surfaces is because of improper and ineffective cleaning and disinfection (13). Visual observation can be completely false when assessing the cleanliness of a surface (13). Eisel *et al.* (14) observed that APC counts for food contact surfaces at a meat processing plant ranged from 2.2–3.7 CFU/cm². Cetin *et al.* (15) observed that APC counts for food contact surfaces were between 2.23 and 3.0 CFU/cm². Eisel *et al.* (14) also reported that if pathogenic microorganisms are present on food contact surfaces, then this can threaten food safety. Choi *et al.* (16) noted that vectors of microbial contamination during processing include meat contact with the hands and clothes of workers, knives, and contaminated surfaces of processing equipment such as saws and boning tables. The results show that the high values of food contact and environmental surfaces came from boots and aprons on the processing line.

Table 1 shows the level of APC in samples from retail shops. The samples were categorized by month and specimen. By month, the APCs in samples were highest in January, followed by April, February, and August (*p*<0.001). Interestingly, the level of APC of samples from retail shops in winter was generally higher than those of samples in summer. Basically, microbial contamination of the cutting board and cotton gloves was the highest in summer and lowest in winter (17). The high contamination levels in January might be the result of poor

Table 1. General characteristics and aerobic plate count (APC) in samples from meat processing plants and retail shops

Plants (n=112)							
Meat processing plants (n=68)				Meat retail shops (n=44)			
		Frequency (%)	Mean±SE	F/p-value	Frequency (%)	Mean±SE	F/p-value
Month	January	4 (5.9) ^e	2.95±0.82 ^A	2.938/0.005	2 (4.5) ^f	3.15±1.06 ^A	6.621/<0.001
	February	7 (10.3) ^c	2.55±0.29 ^D		4 (9.1) ^d	2.56±0.35 ^C	
	March	1 (1.5) ^g	1.95±0.00 ^I		0 (0.0) ^g	-	
	April	7 (10.3) ^c	2.84±1.02 ^B		7 (15.9) ^c	2.90±0.98 ^B	
	May	5 (7.4) ^d	2.77±0.27 ^C		0 (0.0) ^g	-	
	June	4 (5.9) ^e	2.20±1.38 ^E		3 (6.8) ^e	1.00±0.67 ^I	
	July	3 (4.4) ^f	2.00±0.53 ^H		2 (4.5) ^f	1.90±0.71 ^E	
	August	16 (23.5) ^a	2.12±0.45 ^F		13 (29.5) ^a	2.03±0.45 ^D	
	September	3 (4.4) ^f	1.48±0.00 ^K		3 (6.8) ^e	1.48±0.00 ^F	
	October	5 (7.4) ^d	2.01±0.56 ^G		2 (4.5) ^f	1.40±0.00 ^H	
	November	13 (19.1) ^b	1.72±0.63 ^J		8 (18.2) ^b	1.42±0.07 ^G	
	December	0 (0.0) ^h	2.95±0.82 ^A		0 (0.0) ^g	-	
Specimen	Chopping boards	15 (22.1) ^b	2.17±0.56 ^E	6.335/<0.001	7 (15.9) ^c	1.90±0.66 ^F	4.401/<0.001
	Hand	17 (25.0) ^a	1.76±0.47 ^H		12 (27.3) ^b	1.64±0.48 ^H	
	Apron	3 (4.4) ^d	3.38±0.69 ^B		2 (4.5) ^e	1.58±1.56 ^I	
	Cutting machine	4 (5.9) ^c	2.46±0.12 ^C		0 (0.0) ^f	1.94±0.65 ^E	
	Worktable	3 (4.4) ^d	2.12±0.56 ^F		2 (4.5) ^e	1.68±0.11 ^G	
	Cotton gloves	3 (4.4) ^d	1.69±0.08 ^I		2 (4.5) ^e	3.87±0.00 ^A	
	Boots	3 (4.4) ^d	3.87±0.00 ^A		3 (6.8) ^d	2.08±0.76 ^C	
	Knives	17 (25.0) ^a	2.30±0.80 ^D		13 (29.5) ^a	2.19±0.20 ^B	
	Wristlets	3 (4.4) ^d	2.06±0.10 ^G		3 (6.8) ^d	2.01±0.80 ^D	

Results are shown as frequencies (%) and mean±standard errors (SE). Means with different letters indicate a statistically significant difference ($p<0.05$) by Duncan's multiple range test. p -values were calculated by ANOVA (unit: log CFU/cm²). Logarithmic transformations were used for the APC.

^{a-h}Frequencies and ^{A-K}means with different superscripts in the same column are significantly different ($p<0.05$).

Table 2. Correlation between APC and specimens (unit: log CFU/cm²)

Sample	Mean±SE	Correlations	
		APC	Specimens
APC	2.13±0.77 ^B		0.231***
Specimen	4.15±2.94 ^A	0.231***	

^{A-B}Means with different superscripts in the same column are significantly different ($p<0.05$).

*** $p<0.001$.

hygiene practices during processing and abuse temperatures ($>15^{\circ}\text{C}$) in winter. By specimen data, the highest APC was found in cotton gloves, knives, boots, wristlets, and cutting machines in descending order ($p<0.001$). APC counts for food contact and environmental surfaces at retail shops were between 1.58 and 3.87 CFU/cm². Jeon *et al.* (18) evaluated that APC counts ranged from 0 to 2.2×10^6 CFU/cm² for utensils and equipment and from 1×10^2 to 2.7×10^8 CFU/cm² for cotton gloves. If stored meat comes in contact with other contaminated meat or equipment, cross-contamination is very likely to occur (13). Moreover, some forms of preparation, such as cutting and tray prior to selling, may highly increase the likelihood of blood or meat juice to outflow on the tables, knives, and chopping boards in retail shops (13). These findings indicated that the high values of surfaces came from gloves and knives on the retail packaging line and these may be potential risks related to hazardous organisms.

Table 2 represents the correlation between the APC and specimen. The mean values of APC and specimen were found to be 2.13 and 4.15 CFU/cm², respectively. We analyzed the correlation between the APC and specimen. As a result, a positive correlation was found between the two factor ($r=0.231***$).

The microbiological quality of the food contact and environmental surfaces was analyzed. The results from this study show that APC prevalence in samples at meat processing plants and retail shops was highest in January. The contamination of boots, aprons, cutting machines, and knives was relatively higher in meat processing plants. Moreover, the contamination of cotton gloves, knives, boots, and wristlets was relatively higher in retail shops. Our data explain how bacterial loads are affected by food contact and environmental surfaces related to meat processing plants or retail shops. Meat handlers should avoid improper handling of products and ensure proper implementation of disinfection plans (19). The present study provides useful information about the hygienic levels at meat processing plants and retail shops by the assessment of microbiological data.

Acknowledgments This study was financially supported by the research funds of Jinju Health College.

Disclosure The authors declare no conflict of interest.

References

1. Bae YY, Choi YM, Kim MJ, Kim KH, Kim BC, Rhee MS. Application of supercritical carbon dioxide for microorganism reductions in fresh pork. *J. Food Safety* 31: 511-517 (2011)
2. Hwang WM, Lee SM, Hwang HS, Han JH. Survey on the contamination of microorganisms in chicken meat from slaughterhouse in Incheon area. *Korean J. Vet. Public Health* 28: 59-65 (2004)
3. 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. *Korean J. Food Sci. An.* 30: 336-344 (2010)
4. Corlett Jr. DA. HACCP User's Manual. Springer US, New York City, NY, USA. pp. 1-474 (1998)
5. Gill CO, Bryant J, McGinnis JC. Microbial effects of the carcass washing operations at three beef packing plants. *Fleischwirtschaft* 3: 46-48 (2000)
6. Jay JM. Modern Food Microbiology. Van Nostrand Reinhold, New York, NY, USA. pp. 251-254 (1992)
7. Koutsoumanis K, Sofos J. Microbial contamination of carcasses and cuts. In: *Encyclopedia of Meat Sciences*. Jensen WK, Devine C, Dikeman M (eds). Elsevier Academic Press, Cambridge, MA, USA. pp. 727-737 (2004)
8. Duffy E, Belk K, Sofos J, Bellinger G, Pape A, Smith G. Extent of microbial contamination in United States pork retail products. *J. Food Protect.* 64: 172-178 (2001)
9. Butterworth S, Heinemann R. The Science of Food. 4th ed. Reed educational and professional publishing Ltd., London, UK. pp. 110-112 (2000)
10. Kammenou M, Metaxopoulos J, Drosinos EH. Microbiological quality of minced beef from butcher shops and supermarkets. *Ital. J. Food Sci.* 15: 95-104 (2003)
11. Vanderzant C, Splittstoesser DF. Compendium of methods for the microbial examination of foods. 3rd ed. American Public Health Association, Washington, DC, USA. pp. 75-94 (1992)
12. Quarantine and Inspection Agency. Livestock processing standards and ingredient specifications No. 2012-118. Animal Plant and Fisheries Quarantine and Inspection Agency, Republic of Korea (2013)
13. Upadhyaya M, Poosaran N, Fries R. Prevalence and predictors of *Salmonella* spp. in retail meat shops in Kathmandu. *J. Agric. Sci. Technol.* 2: 1094-1106 (2012)
14. Eisel WG, Linton RH, Muriana PM. A survey of microbial levels for incoming raw beef, environmental sources, and ground beef in a red meat processing plant. *Food Microbiol.* 14: 273-282 (1997)
15. Cetin O, Kahraman T, Buyukunal SK. Microbiological evaluation of food contact surfaces at red meat processing plants in Istanbul, Turkey. *Ital. J. Anim. Sci.* 5: 277-283 (2006)
16. Choi YM, Park HJ, Jang HI, Kim SA, Imm JY, Hwang IG, Rhee MS. Changes in microbial contamination levels of porcine carcasses and fresh pork in slaughterhouses, processing lines, retail outlets, and local markets by commercial distribution. *Res. Vet. Sci.* 94: 413-418 (2013)
17. Oh YS, Lee SH. Hygienic quality of beef and distribution of pathogens during cut-meat processing. *J. Food Hyg. Saf.* 16: 96-102 (2001)
18. Jeon HC, Kim JE, Son JW, Chae HS, Jin KS, Oh JH, Shin BW, Lee JH. Evaluation of the microbial contamination status and sanitation practice level in butcher's shops in Seoul. *Korean J. Vet. Serv.* 34: 409-416 (2011)
19. Kim JH, Yim DG. Assessment of the microbial level for livestock products in retail meat shops implementing HACCP system. *Korean J. Food Sci. An.* 36: 588-594 (2016)