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Bacteriological Survey for Food/Food Contacting Surfaces in Large Grocery Stores in Korea

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A bacteriological survey for 20 large grocery stores (M1 to M20) in Korea was investigated for one year. The average detection rate of *Esherichia coli* was 22% (166/763) for 7 kinds of ready-to-eat food through the year, where each grocery store and each type of food showed different detection rates. Eleven grocery stores showed lower detection rates, while 9 grocery stores showed a higher than average rate. Especially, M3 showed a rate that was twice as high as the average and one which was 7 times higher than M14, which had the lowest rate of 6% *E. coli* detection. The detection rate for each type of food was: 38% (41/109) for *Kimbop*, 31% (34/109) for vegetable salad, 19% (21/109) for bean-curd, 18% (20/109) for the cooked materials used in making *Kimbop*, 17% (19/109) for *Hoe* (sliced raw fish) and *Sushi* (Japanese vinegared rice delicacies), and 11% (12/109) for cooked pork hock. During the summer, the *E. coli* detection rate averaged 43% (71/166), which was twice as high as other seasons. Most (89/100) of the food contacting surfaces contained more than the critical limit (1.3 $\log_{10}$ CFU/10 cm^2) of aerobic viable cell counts (AVC). The $\log_{10}$ AVC and $\log_{10}$ coliform count (CC) of 218 meat samples (beef, pork, and chicken) ranged between 4.6-7.1 CFU/g and 1.9-6.4 CFU/g, except for 41 meat samples (19%) which were found to contain no coliform. There was a definite correlation between the $\log_{10}$ AVC and $\log_{10}$ CC, and the values of $\log_{10}$ CC made a more accurate straight than the $\log_{10}$ AVC, which are variable. From these results, it is suggested that a detection rating of less than 2.1 CFU/g of $\log_{10}$ CC (correspond to 5.0 CFU/g of $\log_{10}$ AVC) is the critical point of freshness, and a rating of more than 6.3 CFU/g of $\log_{10}$ CC (correspond to 7.0 CFU/g of $\log_{10}$ AVC) can be considered an initial spoilage point.

Key words: Bacteriological survey, AVC (aerobic viable cell count), CC (coliform count), *Esherichia coli*, Critical point, Spoilage point

Introduction

Recently, the food market industry has become more and more complex, and the number of large grocery stores has increased significantly in the last decade in Korea. The larger the scale of grocery stores, the more difficult it becomes to manage safety. Thus, it is not always possible to supervise food safety. Therefore, there is always a danger of food poisoning accidents. The number of food poisoning accidents has not decreased and the number of patients per an accident has increased each year, even though environmental conditions surrounding food have improved. It has been reported that food poisoning accidents were mainly caused by cooked food such as *Kimbop* and lunch packages, meat, fish, shellfish and their by-products (Kwak and Park, 1986; Kye et al., 1988; Hong and Lee, 1990; Kwak and Kim, 1996; Maguire et al., 2000; Ser et al., 2000; Choi et al., 2001; Lee et al., 2001). Food can often be contaminated by environmental microorganisms and by workers during handling. Kwak and Kim (1996) reported that take-out packaged meals (Dosirak) showed from 4.1 to 4.6 CFU/g of $\log_{10}$ AVC (aerobic viable cell count), from 0.8 to 2.2 CFU/g of $\log_{10}$ CC (coliform count), and from 0.1 to 1.5 CFU/g of $\log_{10}$ *E. coli* count (ECC). Meat can be contaminated after slaughtering, and especially ground beef due to an increased surface area and mixing during the

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grinding operation (Ayres, 1995; Eisel et al., 1997). Safe high quality products rely on reduction of microbial contamination during slaughtering operations, and effective cleaning and sanitation programs and safe handling procedures. Eisel et al. (1997) reported that the average $\log_{10}$ AVC for beef products ranged from 3 CFU/g for retail cuts to nearly 7 CFU/g for boxed beef and beef carcasses. Hatha et al. (1998) reported that the $\log_{10}$ AVC ranged from 2.0-6.6 CFU/mg in frozen raw shrimp (*Penaeus monodon*) and 2.0-5.8 CFU/mg in frozen cooked shrimp. The above reports indicate that there is a significant difference of microbial quality in food based on handling methods. The growth of microorganisms in or on food can cause food deterioration during display and food poisoning accidents. Therefore, microbial surveys are quite important to identify and monitor potential hazards in food (Notermans et al., 1993; Brown et al., 2000; Hoornstra and Notermans, 2001; Kvenberg and Schwalm, 2000). The present study surveyed the bacteriological sanitary conditions of food and food contacting surfaces for 20 grocery stores in Korea for a year.

Materials and Methods

Sample collection

Food samples were randomly taken from 20 grocery stores (M1 to M20) in Korea from October 2000 to September 2001. Samples were collected aseptically with a sterile knife, scissors, spoon and bottle. Food contacting surfaces were sampled using a one-site swabbing method wherein a 100 cm^2 rectangular area was examined, and the results were shown in $\log_{10}$ CFU/100 cm^2. Electric meat saws, cutting boards for meat butchering and cutting raw fish, and knives were swabbed with a sterilized cotton plug and, the swab sample was put into a sterilized bottle. Collected samples were placed in a portable cooler (4°) and transported back to the laboratory within 4 hrs. Bacteriological examination samples were aseptically trimmed and 30 g of the samples were stomached (Seward, London, England) for 2 minutes with 270 mL of phosphate buffer to achieve 10 times dilution. The bottles with swab samples were filled with 20 mL of phosphate buffer and shaken vigorously for 2 minutes. An aerobic viable cell count (AVC) was conducted with a pour plate method according to official methods instructed by the FDA (AOAC, 1992). Both, the coliform count (CC) and the *E. coli* count (ECC) were enumerated using a pour plate method with an Coli ID medium (bioMerieux, Marcy l'Etoile, France). The Coli ID medium contains two chromogenic substrates: one for β-D-glucu- ronidase which gives a red color for E. coli colonies and one for β-galactosidase which shows blue colonies for the other coliforms (Sueiro et al., 2001; Park et al., 2002; Park et al., 2003). The rest of the media used in this study were Difco (Maryland, USA) commercial products.

Statistical analysis

Bacteriological counts were transformed in to log CFU/g before performing statistical analysis. Data was analyzed using an analysis of variance (ANOVA) with SAS® software to determine if there were statistically significant ($P \leq 0.05$) correlations between microbial levels and food contacting surfaces by kinds of food (SAS institute, 1989). Any significant differences were analyzed by the multiple comparison procedure of Duncan's Multiple Range test, using a level of significance of alpha=0.05.

Results and Discussion

E. coli detection from ready-to-eat foods

To examine the sanitary condition of food in Korean grocery stores, *E. coli*, one of the representative sanitary indicators was examined in 7 kinds of ready-to-eat food such as *Kimbop*, vegetable salad, cooked pork hock, bean curd, cooked materials for *Kimbop*, *Hoe* (sliced raw fish), and *Sushi*. The average detection rate of *E. coli* was 22% (166/763) through the year, and each grocery stores and each food showed different detection rates. Eleven of the 20 grocery stores showed lower detection rates, while the remaining grocery stores were higher than the average detection rate. Especially, M3 showed a rate that was twice as high as the average and one which was 7 times higher than M14, which had the lowest rate of 6% *E. coli* detection. (Table 1). The *E. coli* detection rate was quite significantly different from other foods: 38% (41/109) for *Kimbop*, 31% (34/109) for vegetable salad, 19% (21/109) for bean-curd, 18% (20/109) for cooked materials for *Kimbop*, 17% (19/109) for both *Hoe* and *Sushi*, and 11% (12/109) for cooked pork hock (Table 2). The results of this study show that *Kimbop* and salad had a continuously high monthly detection for a year. It is worker's hands which are the principal factor in the secondary microbial contamination of food. *Kimbop* and salad are very moist and their preparation requires a great deal of contact

Table 1. The detection of *Esherichia coli* from 7 kinds of ready-to-eat food for one year

	Sampling times*	Number of samples per month	Total number of samples	Number of *E. coli* detections	Detection rates (%)
M1	7	7	49	10	20
M2	5	7	35	7	20
M3	5	7	35	14	40
M4	5	7	35	10	29
M5	7	7	49	7	14
M6	5	7	35	11	31
M7	6	7	42	15	36
M8	5	7	35	3	8.6
M9	4	7	28	8	29
M10	5	7	35	6	17
M11	4	7	28	5	18
M12	5	7	35	4	11
M13	7	7	49	10	20
M14	5	7	35	2	6
M15	6	7	42	5	12
M16	6	7	42	10	24
M17	5	7	35	3	8.6
M18	6	7	42	12	2.9
M19	7	7	49	15	31
M20	5	7	28	9	32
Total			763	166	22

*Samples were usually collected bimonthly from January at some grocery stores and from February at the others.

Table 2. Detection rate of *Esherichia coli* by food collected from 20 grocery stores for one year

	Winter			Spring			Summer			Autumn			Detection times	Number of samples	Detection rate (%)
	12	1	2	3	4	5	6	7	8	9	10	11			
Kimbop	3	2	3	0	3	5[a]	7	5	1	6	1	5	41	109	38
Vegetable salad	2	3	4[a]	2	4[a]	2	6	4	2	1	2	2	34	109	31
Bean-curd	2	0	0	0	4	1	4	4	2	1	3	0	21	109	19
Cooked materials for *Kimbop*	0	0	0	1	0	1	2	6	2	3	2	3	20	109	18
Hoe	2	0	2	0	0	1[b]	8	5[b]	1	0	0	0	19	109	17
Sushi	1	0	1	1	1	2	3	1	4	2	2	1	19	109	17
Cooked pork hock	0	0	0[a]	0	2	2	1	2	1	3	1	0	12	109	11
Total	10	5	10	4	14	14	31	27	13	16	11	11	166	763	22
Detection rate (%)	15 (25/166)			19 (32/166)			43 (71/166)			23 (38/166)					

During the study, *Staphylococcus aureus* (shown with a) was deteced once from *Kimbop*, twice from salad, once from cooked pork hock, and *Salmenella* spp. (shown with b) was detected twice from *Hoe.*

with worker's hands. In the present study, *Kimbop* showed an *E. coli* detection rate which was twice as high as the cooked materials used to make it. This result indicates that worker's hands contaminated the food during handling. During the summer (from June to August), the detection rate was 43%, which was twice as high as other seasons. *Staphylococcus aureus* was detected once in *Kimbop* in May, once from salad in February and again in April and once from cooked pork hock in April. *Salmonella* spp. was detected once from *Hoe* in May and once again in August (data not shown). Park et al. (2003) reported that *Kimbop* showed the highest detection rate of 32% (8/25) and *E. coli* was even detected during winter in s sanitary survey of 4 large grocery markets in Busan. Their results are in accord with the present study.

Aerobic viable cell count from food contacting surfaces

Unsanitary food contacting surfaces can contaminate food during preparation. Therefore, it is important to patiently survey bacteriological populations on food contacting surfaces. Table 3 shows the statistical analysis (P=0.05) of $\log_{10}$ AVC detected from food contacting surfaces in 20 grocery stores. In the analysis results using SAS®, cutting boards and knives for fish were cleaner than other utensils, while knives and electric saws for meat had higher bacterial numbers. It is thought that the utensils used for preparing fish are cleaner because they are washed often to eliminate fish guts on the cutting board. Solberg et al. (1990) suggested that less than 1.1 CFU/10 cm^2 of $\log_{10}$ AVC was acceptable as an allowable level on food contacting surfaces, and more than 1.3 of $\log_{10}$ CFU/10 cm^2 as a bacteriological critical limit for utensils during handling, but a 0.8 CFU/10 cm^2 represents a bacteriological critical limit after disinfection. In the present study, most (89/100) of the food contacting surfaces sampled showed more bacterial numbers than the critical limit (1.3 CFU/10 cm^2). These results indicate poor sanitary conditions on food contacting surfaces in large grocery stores. However, coliforms and pathogenic bacteria were not detected from any utensils in the present study. Coliforms and *E. coli*, sanitary indicative bacteria, are not present in high numbers in washed and dried utensils. Therefore, it is not easy to detect them after cleaning and disinfection, while *E. coli* can not be effectively eliminated with cleaning (1997). Park et al. (2003) reported that most utensils contained higher bacterial population than the critical limit, but did not show *E. coli*, any other coliforms, and pathogenic bacteria in 4 large markets in Busan. Our results are in accord with Park et al. (2003).

The relationship between aerobic viable cell counts and coliform counts in meat

The detection of pathogenic organisms in food is very important, but involves relatively complex procedures. Therefore, testing for indicator organism (*E. coli* and coliform organisms) has been introduced as a simpler means of controlling the hygienic status of foods and helps to ensure the production of safe food. In the present study, the AVC and CC of 218 meat samples (67 samples of beef, 91 samples of pork, 60 samples of chicken) were examined. The detection rate of coliform was 100% (60/60) for chicken, 79% (72/91) for pork, and 67% (45/67) for beef. The detected coliforms were mostly *Enterobacteria* sp., *Citrobacter* sp., *Klebsiella* sp., *Proteus* sp., and *Aeromonas* sp. (data not shown). The CC

Table 3. Aerobic viable cell counts of food contacting surfaces by each mart

Grocery stores	Cutting board (CFU/10 cm^2)		Knife (CFU/10 cm^2)		Electric saw (CFU/10 cm^2)
	For salad bar	For fish	For fish	For meat	For meat
M1	$2.28±1.68^{abc}$	$0.50±1.00^{b}$	$1.49±1.31^{b}$	$3.76±1.93^{ab}$	$2.32±1.28^{ab}$
M2	$1.73±1.08^{abc}$	$1.73±0.37^{b}$	$1.84±1.51^{ab}$	$3.20±1.53^{ab}$	$2.53±0.81^{ab}$
M3	$1.98±0.42^{abc}$	$2.07±0.66^{b}$	$1.97±0.69^{ab}$	$3.25±1.25^{ab}$	$3.71±0.74^{a}$
M4	$3.06±2.23^{abc}$	$1.80±1.57^{b}$	$2.27±1.75^{ab}$	$2.73±0.82^{ab}$	$2.65±1.08^{ab}$
M5	$3.02±0.89^{abc}$	$1.00±1.48^{b}$	$2.87±1.16^{ab}$	$3.69±0.83^{ab}$	$1.95±1.44^{ab}$
M6	$2.53±1.10^{abc}$	$1.25±0.86^{b}$	$1.80±0.32^{b}$	$1.56±1.80^{b}$	$3.20±1.28^{ab}$
M7	$3.13±0.99^{ab}$	$2,84±0.56^{b}$	$1.01±1.17^{b}$	$3.93±2.13^{ab}$	$2.90±1.88^{ab}$
M8	$0.84±0.97^{c}$	$0.81±0.98^{b}$	$1.82±1.70^{ab}$	$2.46±1.26^{ab}$	$2.56±0.68^{ab}$
M9	$1.70±1.24^{abc}$	$1.60±1.13^{b}$	$1.76±1.50^{ab}$	$2.33±0.98^{ab}$	$2.96±0.34^{ab}$
M10	$2.23±1.15^{abc}$	$2.06±1.50^{b}$	$2.22±0.63^{ab}$	$3.56±0.78^{ab}$	$1.99±0.67^{ab}$
M11	$2.57±1.82^{abc}$	$2.63±1.82^{b}$	$2.46±1.09^{ab}$	$4.07±2.76^{ab}$	$3.34±0.90^{ab}$
M12	$1.77±1.34^{abc}$	$2.02±2.79^{b}$	$2.01±1.27^{ab}$	$3.37±1.47^{ab}$	$2.57±1.79^{ab}$
M13	$1.71±0.54^{abc}$	$1.43±1.66^{b}$	$1.35±1.79^{b}$	$2.08±0.73^{ab}$	$1.82±0.95^{ab}$
M14	$2.25±1.88^{abc}$	$1.58±1.83^{b}$	$1.86±1.73^{ab}$	$2.95±2.20^{ab}$	$2.70±1.96^{ab}$
M15	$3.53±1.37^{a}$	$2.08±0.74^{b}$	$1.95±1.65^{ab}$	$3.23±0.93^{ab}$	$3.14±0.42^{ab}$
M16	$2.92±0.77^{abc}$	$2.95±2.17^{b}$	$3.24±1.45^{ab}$	$3.78±1.08^{ab}$	$3.46±0.72^{ab}$
M17	$2.16±0.86^{abc}$	$0.87±1.03^{b}$	$2.96±0.90^{ab}$	$2.75±1.50^{ab}$	$1.52±1.14^{b}$
M18	$1.67±1.49^{abc}$	$5.08±0.88^{a}$	$3.00±2.67^{ab}$	$3.96±1.04^{ab}$	$2.66±1.70^{ab}$
M19	$2.97±1.23^{abc}$	$1.23±1.16^{b}$	$4.00±1.74^{a}$	$2.72±2.19^{ab}$	$3.01±0.40^{ab}$
M20	$1.17±1.39^{bc}$	$1.17±0.88^{b}$	$1.20±0.93^{b}$	$4.27±0.94^{a}$	$2.14±1.71^{ab}$

Table 4. The aerobic viable cell and coliform counts detected from 218 meat samples

Grouping of CC by the range (log CFU/g)	Number of samples	Mean value of AVC (log CFU/g)	Mean value of CC (log CFU/g)
0	41	4.5	0
$10^1 \leq r < 10^2$	3	4.6	1.9
$10^2 \leq r < 10^3$	32	5.4	2.7
$10^3 \leq r < 10^4$	59	5.7	3.6
$10^4 \leq r < 10^5$	63	6.6	4.7
$10^5 \leq r < 10^6$	17	6.8	5.5
$10^6 \leq r < 10^7$	3	7.1	6.4

AVC (aerobic viable cell count) and CC (coliform count) were examined with 218 meat samples - beef (67), pork (91), and chicken (60). Bacteriological counts were transformed into log CFU/g. The CC was grouped by 10 times, and AVC and CC were averaged in each group.
r, the range of coliform count.

was divided into groups of 10, and the bacterial counts were averaged with log cell numbers in each group (Table 4). The 218 meat samples ranged between 4.5-7.1 CFU/g of $\log_{10}$ AVC and 1.9-6.4 CFU/g of $\log_{10}$ CC. Forty one samples (19%) showed no coliform, when they showed 4.5 CFU/g of $\log_{10}$ AVC. Three meat samples showed 7.1 CFU/g of log 10 AVC and 6.4 CFU/g of $\log_{10}$ CC. Eisel et al. (1997) reported that beef samples ranged between 3.0-6.9 CFU/g of $\log_{10}$ AVC, 1.4-3.2 CFU/g of $\log_{10}$ CC, and below 2 CFU/g of $\log_{10}$ ECC in a meat processing plant. In the present study, the $\log_{10}$ CC was much higher than in Eisel et al. (1997), while the $\log_{10}$ AVC were in accord with Eisel et al. (1997). The logarithmic counts of the AVC and CC were plotted (Fig. 1). The AVC and CC showed linear graphs, and especially, the log10CC showed a more accurate slope (R^2=0.9983) than AVC (R^2=0.8949). Generally, a 5.0 $\log_{10}$ AVC/cm^2 can be suggested as the population for fresh food, a 6.0-7.0 as an initial spoilage point, and above a 7.0 as obviously spoiled, where off-odors and slime are noticeable (Ayres et al., 1950; Ayres, 1960). In Fig. 1, the 5.0 $\log_{10}$ AVC/g corresponds to 2.1 $\log_{10}$ CC/g and the 7.0 $\log_{10}$ AVC/g corresponds to 6.3 $\log_{10}$ CC/g. From these results, it is suggested that less than 2.1 $\log_{10}$ CC/g can be acceptable as a critical limit for freshness and more than 6.3 $\log_{10}$ CC/g as the initial spoilage point. Eisel et al. (1997) reported that high AVC did not necessarily correlate with high CC and ECC. They reported that some meat samples had relatively higher AVC and relatively lower CC and ECC, while others had relatively lower AVC and relatively higher CC and ECC. And they suggested 3 $\log_{10}$ CFU/g as a CC limit and 2 $\log_{10}$ CFU/g as an ECC limit. Our results are not in accord with Eisel et al. (1997). Until recently, however, it is unclear whether the relationship between CC and ECC affects product safety and quality. In the present study, there was a definite correlation between AVC and CC in the analytic results of 218 meat samples, and the $\log_{10}$ CC made a more accurate beeline than the $\log_{10}$ AVC. Then, it is suggested that less than a 2.1 $\log_{10}$ CFU/g of CC can be acceptable as a critical limit for freshness and more than a $\log_{10}$ 6.3 $\log_{10}$ CFU/g as the initial spoilage point.

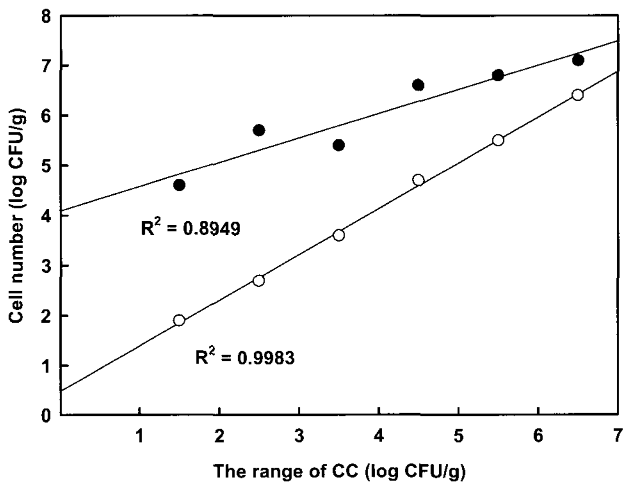

Fig. 1. Linear graph showing the increase of aerobic viable cell counts and coliform counts. In total, 218 meat samples were examined and grouped by 10 times with coliform counts. AVC (aerobic viable cell count) and CC (coliform count) were averaged in each group. •, AVC; , CC.

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