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ARTICLE

Consumer Hygiene Practices Regarding the Use of Home Refrigerators to Store Meat in the Capital Area of Korea

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Abstract

Food hygiene practices must be maintained from farm to table in order to prevent contamination by microorganisms. This study was conducted to investigate consumer hygiene practices related to the refrigerator storage of meat, including a microbial analysis, monitoring of refrigerator temperatures and consumer surveys of female homeowners in the capital area of Korea. Home refrigerator temperatures were maintained above 5°C in 26 (19.7%) of the 132 houses investigated. The percentage of the refrigerators with a total microbial count over 10^2 CFU/100 cm^2 was 14.4%. No *E. coli*, *Salmonella* spp. or *Listeria monocytogenes* microbes were detected. However, *Staphylococcus aureus* was detected in 14 houses (10.6%). The only statistically significant difference in hygiene practices between the non-contamination group and contamination group was in the last time of refrigerator cleaning ($p<0.01$), as determined by the consumer survey. To improve food hygiene when using a refrigerator, raw materials must be packaged, meat should be stored only on a designated shelf, and cooked foods must be contained to prevent cross-contamination. The refrigerator should be cleaned regularly, at least once a month, and refrigerator thermometers should be monitored below 5°C in order to keep food safe.

Key words: foodborne pathogens, refrigerator, hygiene, temperature, raw-meat storage

Introduction

The demand for meat products is increasing continuously in Korea, due to the increased incomes and corresponding higher dietary expectations of food consumers. However, changes in the global market, the occurrence of BSE (mad cow disease), foot-and-mouth disease, and food poisoning outbreaks related to meat consumption have increased meat safety concerns. These concerns have led consumers to consider the freshness of the meat, its place of origin, its safety, and its taste, rather than its price (Cha, 2007).

Staphylococcus aureus infections originate mainly from humans and livestock. Transmission from employees during the handling of carcasses is considered as the major route of *S. aureus* contamination (Kim *et al.*, 2009; Kitai *et al*., 2005). Several previous studies in Korea have examined the contamination of raw meat by various foodborne pathogens, such as *Campylobacter* spp. in poultry (Kang *et al*., 2006; Han *et al*., 2007; Hong *et al*., 2007), *Salmonella* spp. in livestock products (Chang, 2000), pathogenic *E. coli* in rawmeat (Jo *et al*., 2004; Kim *et al*., 2006; Lee *et al*., 2009), *Listeria monocytogenes* in processed livestock products (Baek *et al*., 2000; Choi *et al*., 2001) and *S. aureus* in animal sources (Moon et al., 2007). Leakage from packages containing rawmeat in the refrigerator presents a risk of contamination of the refrigerator. Therefore, it is necessary to investigate refrigerator hygiene practices and recommend the most appropriate practices for consumers. In this study, we examined refrigerator temperature and the microbial analysis of various foodborne pathogens in the home refrigerators of food consumers in the capital region of Korea; in addition, a consumer survey was used to investigate the home refrigerator hygiene practices of the study participants.

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Materials and Methods

Selection of the refrigerators

In the capital area of Korea, 132 homes of consumers who were randomly sampled were visited and swab sam-

ples were collected from the consumers' refrigerators from January 18 to March 26 in 2010. A cooler with an ice pack was carried to store the swab samples at the appropriate temperature until microbial analysis.

Refrigerator temperature monitoring

The storage temperatures of the selected refrigerators were monitored using a data logger (Thermo Recorder Model TR-525, T&D Corporation, Nagano, Japan). The data logger was placed in the raw-meat storage area for 24 h, and the temperature was read at 10 min intervals. The average temperature recorded over 24 h was determined and used for further analyses.

Sampling for the microbial test

A 10×10 cm area in the middle of the rawmeat storage area of each refrigerator was swabbed using a 3M E-Swab kit (3M China Ltd., Shanghai, China). The microbial analysis was conducted in the laboratory within 2 h of sample collection.

Microbial enumeration

The microbial sample was serially diluted. To quantify the total aerobic count, each diluted 1 mL sample was plated on a plate count agar (PCA, Difco, USA) and incubated at 30°C for 72 h. The diluted 1 mL samples were also plated on 3M Petrifilm (3M) to count coliforms and *E. coli*. The Petrifilm was incubated at 30°C for 48 h. Blue colonies with bubbles were counted as *E. coli*, and the red colonies with bubbles were counted as coliforms.

Standard strains

L. monocytogenes KCCM 40407, *S. aureus* ATCC 12600, and *S.* Typhimurium KCCM 11863 were purchased from the Korea Food Research Institute and the Korea Culture Center for Microorganisms. The microbial examination methods used to compare the isolated colonies are described below.

***Listeria monocytogenes* detection**

A 1-mL sample of the swabbed solution was inoculated into 10 mL of UVM-Listeria selective enrichment broth (modified, Merck, Germany) and incubated at 30°C for 24 h for the 1st enrichment. The enrichment broth was subsequently inoculated into 10 mL of Fraser Listeria selective enrichment broth (Merck) and incubated at 30°C for 24 h for the 2nd enrichment. The enriched culture was streaked onto Listeria selective agar (Oxford formulation, Oxoid, UK) and incubated at 30°C for 48 h. Typical black colonies were inoculated into Tryptic Soy Agar plates (TSA, Difco) and incubated at 30°C for 24 h. The colonies on the TSA were biochemically tested using an API Listeria kit (bioMérieux, France) for final identification.

***Salmonella* spp. detection**

A 1-mL diluted swab sample was inoculated into 10 mL of Bacto Peptone Water (BPW, Difco) and incubated at 35°C for 24 h. An enrichment culture sample of 0.1 mL was inoculated into 10 mL of Rappaport-Vassiliadis broth (Difco) and incubated at 42°C for 24 h. The enrichment sample was plated onto Salmonella-Shigella agar (Difco) and incubated at 35°C for 24 h. Typical *Salmonella* spp. colonies were streaked onto TSA and incubated at 30°C. The colonies on the TSA were identified biochemically with an API 20E kit (bioMérieux).

***Staphylococcus aureus* detection**

A 1-mL swab sample was inoculated into 10 mL of Tryptic Soy Broth (TSB, Difco) containing 10% NaCl and incubated at 35°C for 24 h. The enrichment culture was streaked onto Mannitol Salt Agar plates (MSA, Difco) and incubated at 35°C for 24 h. Typical opaque yellow colonies were picked, streaked onto TSA, and incubated at 30°C for 24 h. The colonies on the TSA were tested using an API Staph kit (bioMérieux) for final confirmation.

Consumer hygiene survey for home refrigerator practices

The consumers who were selected for refrigerator temperature and microbial analysis (n=132) were also given a survey of consumer hygiene practices related to meat refrigeration. The questions were focused on the cleaning frequency, cleaning method and food storage methods for the home refrigerator.

Statistical analysis

The correlation between the microbial contamination level and the hygiene practices of the refrigerator users was analyzed using SPSS WIN 17.0 (SPSS Inc., Chicago, IL, USA); descriptive analyses, ANOVA, χ^2-tests, and correlation analyses were conducted.

Results

Average temperatures and microbial levels in the raw-meat storage area in the refrigerator

Home refrigerator temperatures were maintained below

5°C in the monitored refrigerators (83.3%) (Table 1). The current study showed that 2 out of 132 houses maintained their refrigerators at a temperature above 10°C. The total microbial counts from the raw-meat storage areas in the refrigerator showed that 55 houses (41.7%) were relatively clean with a microbial number below 10 CFU/10^2 cm^2. The average total microbial count was 2.5 Log CFU/100 cm^2; however, a swab sample from one refrigerator showed a high total plate number of 5 Log CFU/100 cm^2 (Table 2). Coliforms were detected in samples from 5 refrigerators (3.8%) at 1-2 Log CFU/100 cm^2, and *E. coli* was not detected in any sample (Tables 2 and 3).

Table 1. Average temperatures of the raw-meat storage area of consumers' refrigerators

Temperature (°C)	Home refrigerator (N)	Percentage (%)
-4.0 ~ -3.1	2	1.5
-3.0 ~ -2.1	0	0.0
-2.0 ~ -1.1	0	0.0
-1.0 ~ -0.1	4	3.0
0.0 ~ 0.9	7	5.3
1.0 ~ 1.9	25	18.9
2.0 ~ 2.9	30	22.7
3.0 ~ 3.9	26	19.7
4.0 ~ 4.9	12	9.1
5.0 ~ 5.9	10	7.6
6.0 ~ 6.9	5	3.8
7.0 ~ 7.9	9	6.8
8.0 ~ 8.9	0	0.0
9.0 ~ 9.9	0	0.0
10.0 ~ 10.9	1	0.8
11.0 ~ 11.9	0	0.0
12.0 ~ 12.9	0	0.0
13.0 ~ 13.9	0	0.0
14.0 ~ 14.9	1	0.8
Total	132	100.0

Foodborne pathogen detection

Listeria spp. was detected in 5 rawmeat storage areas. The strains were identified as *Listeria welshimeri*, *Listeria grayi*, *Listeria seeligeri*, and *Listeria ivanovii*. However, no *Listeria monocytogenes* or *Salmonella* spp. were detected in this study. The colonies that grew on the Salmonella-Shigella agar were identified as *Pantoea* spp., *Enterobacter* spp., *Klebsiella* spp., *Citrobacter* spp., and *Serratia* spp. Meanwhile, 14 swab samples (10.6%) from the 132 refrigerator swab samples tested positive for *Staphylococcus aureus* (Table 3).

The relationship between cunsumer hygiene practices and microbial levels

The correlation between the microbial contamination level and the hygiene practices of refrigerator users was also analyzed. Among the 132 homes in which microorganism contamination was tested, the group with contamination and the group without contamination were divided and compared to understand better the food safety perceptions of each group of consumers. Refrigerators with sufficiently high total microbial plate counts or in which coliforms or *S. aureus* were detected were categorized as contaminated, while refrigerators in which none of those factors was observed were categorized as non-contaminated. The contamination group (n=81) and non-contamination group (n=51) were compared to investigate the effects of home refrigerator hygiene practices (Table 4). The methods used to clean the refrigerator were similar in both groups. However, the non-contamination group cleaned the refrigerator more often (once a month on average) than the contamination group (once every two to three months on average). Furthermore, the most recent cleaning was more recent in the non-contamination

Table 2. The total plate count numbers, coliforms, and *E. coli* in consumers' refrigerators

(CFU/100 cm^2)	Total plate count (%)	Coliforms (%)	*E. coli* (%)
ND[1)]	55 (41.7%)	127 (96.2%)	132 (100%)
1 Log ≤ x < 2 Log	26 (19.7%)	5 (3.8%)	-
2 Log ≤ x < 3 Log	32 (24.2%)	-	-
3 Log ≤ x < 4 Log	12 (9.1%)	-	-
4 Log ≤ x < 5 Log	5 (3.8%)	-	-
x ≥ 5 Log	2 (1.5%)		
Total	132 (100%)	132 (100%)	132 (100%)

[1)] ND: not detected

Table 3. The detection of foodborne pathogens in consumers' refrigerators

Pathogen detection (CFU/100 cm^2)	*Salmonella* spp. (%)	*L. monocytogenes* (%)	*S. aureus* (%)
Negative	132 (100%)	132 (100%)	118 (89.4%)
Positive	-	-	14 (10.6%)
Total	132 (100%)	132 (100%)	132 (100%)

Table 4. Hygiene practices and microbial contamination of refrigerators in the non-contamination group (n=51) and the contamination group (n=81)

Item		Non-contamination group	Contamination group	χ^2-value
Refrigerator cleaning method	Water	13 (25.5)	16 (20.3)	7.993
	Detergent	21 (41.2)	39 (49.4)	
	Water and vinegar	11 (21.6)	9 (11.4)	
	Vinegar	0 (0.0)	1 (1.3)	
	Refrigerator detergent	2 (3.9)	8 (10.1)	
	Bleaching agent	0 (0.0)	3 (3.8)	
	Others	4 (7.8)	3 (3.8)	
	Subtotal	51 (100.0)	79 (100.0)	
Cleaning frequency	Once per week	2 (3.9)	3 (3.8)	12.120
	Every other week	3 (5.9)	7 (8.8)	
	Once per month	20 (39.2)	19 (23.8)	
	Every other month	16 (31.4)	33 (41.3)	
	Twice per year	5 (9.8)	13 (16.3)	
	Once per year	1 (2.0)	5 (6.3)	
	Never	2 (3.9)	0 (0.0)	
	Others	2 (3.9)	0 (0.0)	
	Subtotal	51 (100.0)	80 (100.0)	
The last time of refrigerator cleaning	Within one week	12 (23.5)	19 (23.5)	25.567**
	Two weeks ago	8 (15.7)	9 (11.1)	
	Three weeks ago	3 (5.9)	3 (3.7)	
	One month ago	21 (41.2)	13 (16.0)	
	Two months ago	1 (2.0)	22 (27.2)	
	Three months ago	4 (7.8)	15 (18.5)	
	Others	2 (3.9)	0 (0.0)	
	Subtotal	51 (100.0)	81 (100.0)	

**$p<0.01$

group than in the contamination group (1 month vs. 2 months); this difference was statistically significant ($p<0.01$). Therefore, the regular and frequent cleaning of the refrigerator is important to reduce bacterial contamination.

Most consumers replied that they package and preserve rawmeat. On average, consumers filled nearly 70% of the volume of their refrigerators with food; however, a portion of consumers (30.9% in the contamination group and 23.5% in the non-contamination group) reported that they fill more than 80% of the volume of their refrigerator with food.

Discussion

This study aims to investigate consumer hygiene practices regarding to the refrigerator storage of meat by experiments and consumer surveys of female homeowners in the capital region of Korea. In this study, 19.8% (26) of the refrigerators of 132 houses were kept over 5°C. According to a study by Lagendijk *et al*. (2008), only 37% of consumers were positive that their refrigerator was kept below 4°C. Therefore, it has been recommended that consumers close their refrigerator doors tightly and check the door gaskets to ensure the maintenance of safe temperatures. Marklinder *et al*. (2004) tracked food shoppers and monitored the refrigerator temperature one day after they had stored the food in the refrigerator. The average storage temperature for minced meat was 6.2°C and that of ready-to-eat salad was 7.4°C with a maximum temperature of 18.2°C for food storage. These authors recommended that consumers should use a thermometer to monitor their refrigerator temperature regularly.

To investigate contamination of foodborne pathogens, microbial analysis for the refrigerator shelf was conducted. Although no *E. coli*, *Salmonella* spp. or *Listeria monocytogenes* microbes were detected, *Staphylococcus aureus* was detected in 14 refrigerators (10.6%) out of 132 home. Jackson *et al*. (2007) emphasized that some foodborne pathogens, such as *S. aureus*, *L. monocytogenes*, and *Y. enterocolitica*, were detected in refrigerators in the UK and Ireland and warned that there is a risk of cross-contamination of ready-to-eat foods by the foodborne pathogens, implying that refrigerator temperature control is important to prevent the growth of the psychrophilic bacteria.

After acquiring the test data of the 132 homes of microorganism contamination, the group with contamination and the group without contamination were divided to compare the hygienic practices of each group of consumers by the consumer survey. There was a statistically significant difference ($p<0.01$) in the last time of refrigerator cleaning rather than cleaning method among these groups between the non-contamination group and contamination group.

Our study showed that the temperature control of the refrigerator is important to prevent the growth of harmful bacteria. Additionally, consumers should be careful to package cooked food properly to prevent cross-contamination in the refrigerator. Finally, the total microbial plate count was correlated with the time of the last cleaning. Therefore, frequent and regular cleanings of the refrigerator are important to keep the food safe and free from contamination. To maintain a low refrigerator temperature, the food in the refrigerator should leave enough space to allow the cool air to circulate, and no more than 70% of the refrigerator space should be filled with food. In addition, to prevent cross-contamination in the refrigerator, consumers should practice frequent hand washing; *S. aureus* has also been detected on the refrigerator handles (Gorman *et al*., 2002). A study from Spain also emphasized that hygiene practices in the kitchen with information, temperature control and proper cleaning (Garayoa *et al*., 2011).

The results of this study will be used to guide the preparation of educational materials to help consumers understand food safety better.

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