Journal of Food Protection, Vol. 83, No. 2, 2020, Pages 305–314
https://doi.org/10.4315/0362-028X.JFP-19-202

Research Paper

Monitoring of Hygiene in Institutional Kitchens in Belgium

E. DUTHOO,[1] S. KRINGS,[2] G. DAUBE,[2] F. LEROY,[3] B. TAMINIAU,[2] M. HEYNDRICKX,[1,4] AND K. DE REU[1]*

[1]*Technology and Food Science Unit, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), 9090 Melle, Belgium;* [2]*Department of Food Science—Microbiology, FARAH Center, University of Liège, Quartier Vallée 2 (B43b), Avenue de Cureghem 10, B-4000 Liège, Belgium;* [3]*Research Group of Industrial Microbiology and Food Biotechnology (IMDO), Department of Applied Biological Sciences and Engineering, Vrije Universiteit Brussel, Brussels, Belgium; and* [4]*Department of Pathology, Bacteriology and Avian Diseases, Ghent University, B-9820 Merelbeke, Belgium*

MS 19-202: Received 26 April 2019/Accepted 4 November 2019/Published Online 21 January 2020

ABSTRACT

Microbiological contamination of food during preparation and storage is a risk factor in institutional kitchens. In this Belgian study, hygiene practices in 40 institutional kitchens from four public sectors (10 hospitals, 10 schools, 10 retirement homes, and 10 child care centers) were evaluated to determine whether differences in these practices exist between these sectors. Contamination levels were also analyzed at several critical contact points. A data collection instrument and microbiological analysis of hand contact surfaces, food contact surfaces, and kitchen utensils were used. Hand washing resulted in only a slight reduction in total aerobic bacteria counts (TACs), and all microorganisms evaluated except *E. coli* were still present at countable levels. *Enterobacteriaceae* were found on one-third of the cleaned cutting boards. Cleaned work surfaces had the highest average TAC of all cleaned surfaces. Only slight improvements in TACs and *Enterobacteriaceae* and *B. cereus* counts were observed between used and cleaned work surfaces. The results from the data collection instrument revealed that child care centers had the lowest hygiene scores, whereas the other three sectors were fairly similar, with hospitals scoring highest. The low hygiene score for the child care centers was verified by comparing the results for cleaned surfaces among the sectors. The average TAC on surfaces was highest for child care centers and lowest for hospitals. Child care centers also had the second highest total mean counts and the highest number of total surface samples positive for *Enterobacteriaceae*. The highest number of surface samples positive for *Staphylococcus aureus* was also found in child care centers. This study highlights some areas of concern for hygiene improvement in institutional kitchens, differences between public sectors, and similarities in conclusions about hygiene based on the scores from the survey instrument and the results of the microbiological analyses.

HIGHLIGHTS

- Hand washing resulted in only a slight reduction in TACs.
- *Enterobacteriaceae* were present on one-third of cleaned cutting boards.
- Slight improvements in microbial counts were found between used and cleaned surfaces.
- Child care centers had the lowest hygiene scores of the four public sectors evaluated.
- Microbiological results from the four sectors seem to verify the hygiene survey scores.

Key words: Kitchen hygiene; Microbiological food quality; Microbiological food safety

In institutional kitchens, foodstuffs are often handled several times before food is served. Good hygiene practices must therefore be followed at every step. In January 2006, European Commission *(9)* Regulation 852/2004 came into effect, whereby food business operators in European Union (EU) member states are required to safeguard food quality and safety by establishing, implementing, and maintaining permanent procedures based on hazard analysis and critical control point principles such as practices to guarantee hygienic conditions during food production and preparation, including proper storage and handling of raw foodstuffs and end products *(22–24)*.

* Author for correspondence. Tel: +3292723043; Fax: +3292723001; E-mail: koen.dereu@ilvo.vlaanderen.be.

Cross-contamination is an important factor in the occurrence of foodborne outbreaks. Microorganisms can be transferred onto food from hands, kitchen utensils, or kitchen surfaces during preparation *(4, 6, 17, 23, 37)*. Bacteria can survive for >4 h on cutting boards that have not been sanitized. Even after cleaning, knife-damaged cutting boards can harbor bacteria, resulting in cross-contamination *(1, 2, 37)*. Other reasons for the presence of pathogens in food are improper cooking conditions, such as not reaching adequate temperatures *(3, 17, 23)*. Biofilms formed by bacteria responsible for foodborne disease and spoilage can develop on food contact surfaces in industrial kitchens; such biofilms can ensure bacterial survival even after cleaning, which can affect food quality and safety *(5)*. Improper storage temperatures are also correlated with the microbiological quality of food *(16)*.

The European Food Safety Authority and the European Centre for Disease Prevention and Control *(10)* reported that in 2016 households were the most frequent place of exposure in foodborne outbreaks in EU member states. Among different types of institutional kitchens, 9.4% ($n = 49$) of foodborne outbreaks were located in schools or kindergartens, 3.5% ($n = 18$) were in residential institutions, and 1.2% ($n = 6$) were in hospitals or medical care facilities. Despite the smaller percentage of total outbreaks associated with institutional kitchens, such catering services target elderly people, children, pregnant women, and immunocompromised individuals, all of whom are more susceptible to foodborne illnesses *(5, 12)*. The large number of meals produced every day by these facilities can potentially affect hundreds of individuals simultaneously. Child care centers are particularly high risk because the caregivers prepare the food, serve the food, clean up after meals, and care for the infants and young children *(23, 32)*.

Current food hygiene in Belgium is monitored by the Federal Agency for the Safety of the Food Chain (FASFC) and certification bodies mainly based on visual inspection sometimes supplemented by sampling and microbiological analysis *(11)*. However, these two methods do not address the two most important risk factors regarding food preparation by heat treatment: food handling practices by the kitchen workers and the hygiene status of the food contact surfaces *(15)*. A microbiological analysis to evaluate the actual hygiene conditions of the institutional kitchens in combination with a checklist-based assessment of food handling practices could address both of the most important risk factors *(7)*.

The aim of this study was to evaluate the hygiene practices in institutional kitchens in Belgium. The study was performed in 10 school kitchens, 10 child care center kitchens, 10 hospital kitchens, and 10 kitchens in residential homes in Belgium. Our aim was to obtain data on the hygiene status of these public sectors using both a data collection instrument and microbiological analysis of hand contact surfaces and food contact surfaces. For 94% of the selected kitchen surfaces, both those just used and those that had been cleaned were sampled to monitor the effectiveness of the in-house cleaning procedures. Indicator organisms (e.g., *Enterobacteriaceae*) and pathogens (e.g., *Bacillus cereus*) were chosen for the microbial analysis to allow a quantitative comparison of routine hygiene practices. Another objective of the study was to pinpoint the most contaminated critical contact points in these kitchens.

MATERIALS AND METHODS

Institutional kitchens selected. This study was funded by the Belgian Federal Public Service for Health, Food Chain Safety, and the Environment, who requested a sample survey of 40 geographically dispersed institutional kitchens (10 school kitchens, 10 child care center kitchens, 10 retirement home kitchens, and 10 hospital kitchens) in Belgium. Seventy percent of the kitchens, equally distributed over the four types of kitchens, were randomly selected from an FASFC list of 899 kitchens that had more comments on hygiene practices during routine visits. Other kitchens were selected based on their location and were contacted by telephone or e-mail and asked for permission to visit. Volunteer kitchens were visited once. A maximum of 16 surface samples for microbiological analysis were taken in each kitchen, and a data collection instrument was used for observations and interviews.

Data collection instrument. A data collection instrument was developed to evaluate food handlers' practices and sanitation and hygiene conditions in each kitchen. The items on the instrument were based on the questionnaire used during FASFC inspections *(11)* and additional published checklists *(13, 26, 34)*. The data collection instrument comprised 36 items (Table 1) divided into six categories: food handler's hands, food handler's uniform, environmental conditions, cleaning methods, temperature control, and types of surfaces. The instrument data were collected during on-site observations and personal interviews with kitchen supervisors. Two doctoral researchers, both of whom were comfortable in the local language, conducted the visits, and the results were verified by deliberations between the two researchers. Both researchers had received training in the form of visual observation of audits performed by the FASFC and independent auditors. The majority of the instrument's items could be answered as "yes," "no," or "not applicable." These responses were scored as 1 (compliant) or 0 (noncompliant) or were excluded from scoring (not applicable). For observational data, a 0 was given when at least one of the food handlers present did not comply with the recommended practice. When a nonapplicable answer was given, the total scoring was recalculated based on 36 items. A maximum of five nonapplicable answers were allowed per kitchen. Some items were semiquantitative, for which the scoring was recalculated to obtain a score between 0 and 1. All scores were added to obtain a total hygiene score per kitchen. Kitchens were labeled noncompliant (Table 1) for a certain item when the obtained score was 0 for that item.

Sample collection. The types of surfaces that were sampled are listed in Table 2. Each surface type was sampled once per kitchen. Gloves were worn during sampling; between samples, hands were disinfected, and new gloves were put on. Surface samples were collected with a premoistened sterile cotton pad in a stomacher bag containing 25 mL of maximum recovery diluent (MRD; Oxoid, Basingstoke, UK). The moistened cotton pad was removed from the bag with disinfected tweezers. After swabbing the surface, the pad was returned to the bag; the same place was then swabbed with a sterile dry cotton pad, which was also added to the original bag. The target size of the sampled surface area was approximately 625 cm^2. However, the sampled areas ranged from 10 to 1,500 cm^2 depending on the surface type. After sampling, swab samples were stored and transported in a cooler with cooling blocks.

Microbiological analysis. Samples were analyzed on the day they were collected. After making appropriate further dilutions in MRD, the following microbiological assays were performed: total mesophilic aerobic bacteria counts (TACs) and counts of *Enterobacteriaceae, B. cereus, Staphylococcus aureus,* and *Escherichia coli*. *S. aureus* was included in the analysis as an indicator of food handler personal hygiene, *E. coli* was included as an indicator of fecal contamination, and *Enterobacteriaceae* and *B. cereus* were included as indicators of good hygiene practices during food production. Plate count agar (PCA; Oxoid) plates incubated at 30°C for 72 h were used for TACs. Violet red bile glucose agar (VRBG; Bio Rad, Marnes-la-Coquette, France) plates incubated at 37°C for 24 h were used for enumeration of *Enterobacteriaceae*. Mannitol egg yolk polymyxin agar (MYP; Oxoid) plates incubated at 30°C for 48 h were used for

TABLE 1. *Noncompliance with recommended practices in institutional kitchens*[a]

Survey item	No./total no. (%) of noncompliant kitchens				
	Hospitals	Schools	Retirement homes	Child care centers	Total
Food handler's hands					
Hands are washed between preparation of different foods	0/10 (0)	1/10 (10)	1/9 (11)	4/10 (40)	6/39 (15)
Hands are washed after every visit to the toilet	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)	0/40 (0)
Hands are dried or cleaned on apron during food handling	1/10 (10)	0/10 (0)	0/10 (0)	1/9 (11)	2/39 (5)
No wounds on the hands	0/10 (0)	1/10 (10)	0/10 (0)	0/10 (0)	1/40 (2.5)
Fingernails are clean	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)	0/40 (0)
Food handler's uniform					
Apron is clean	1/10 (10)	2/10 (20)	1/10 (10)	3/9 (33)	7/39 (18)
Apron is replaced at least once per day	1/10 (10)	2/9 (22)	3/8 (37.5)	4/7 (57)	10/34 (29)
Hairnets are worn	0/10 (0)	1/10 (10)	1/10 (10)	8/10 (80)	10/40 (25)
Environment					
Environment is in a good state and is clean	0/10 (0)	0/10 (0)	1/10 (10)	1/10 (10)	2/40 (5)
Environment is easily cleaned	0/10 (0)	0/10 (0)	1/10 (10)	0/10 (0)	1/40 (2.5)
No spoiled food or food unsuitable for human consumption is in the vicinity	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)	0/40 (0)
The sink for washing the food is clean	2/10 (20)	1/10 (10)	1/10 (10)	0/10 (0)	4/40 (10)
Trash has adequate disposal and does not come into contact with food	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)
Leftovers are thrown away (not used again)	3/10 (30)	3/10 (30)	0/10 (0)	1/10 (10)	7/40 (17.5)
All water is suitable for human consumption	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)	0/40 (0)
Sinks are available close to preparation areas	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)	0/40 (0)
Only one person works per surface	2/10 (20)	3/10 (30)	2/10 (20)	0/10 (0)	7/40 (17.5)
Activities for possibly contaminated foods are separated	1/10 (10)	0/10 (0)	5/9 (56)	8/9 (89)	14/38 (37)
Meat and vegetable preparation are spatially separated	4/9 (44)	1/9 (11)	7/9 (78)	7/7 (100)	19/34 (56)
Raw and prepared foods are spatially separated in the refrigerator	0/10 (0)	1/9 (11)	7/9 (78)	7/8 (88)	15/36 (42)
Cleaning					
Used surfaces get cleaned more than once per day	7/10 (70)	6/10 (60)	3/10 (30)	5/10 (50)	21/40 (52.5)
Cutlery used is clean	0/10 (0)	1/10 (10)	0/10 (0)	0/10 (0)	1/40 (2.5)
Cutlery gets cleaned after each use	1/10 (10)	2/10 (20)	1/10 (10)	1/10 (10)	5/40 (12.5)
Surfaces and cutlery get disinfected	0/10 (0)	2/10 (20)	1/10 (10)	4/10 (40)	7/40 (17.5)
Dishwasher is clean	0/10 (0)	1/10 (10)	0/10 (0)	2/8 (25)	3/38 (8)
Dish cloths are clean	2/10 (20)	0/10 (0)	0/10 (0)	0/10 (0)	2/40 (5)
Dish cloths get replaced daily[b]	1/6 (17)	1/10 (10)	0/10 (0)	2/10 (20)	4/36 (11)
Cleaning events are recorded	1/10 (10)	2/10 (20)	2/10 (20)	3/10 (30)	8/40 (20)
Temp control					
Refrigerator temp is correct	0/10 (0)	0/10 (0)	0/10 (0)	4/10 (40)	4/40 (10)
Freezer temp is correct	0/10 (0)	1/10 (10)	0/10 (0)	2/10 (20)	3/40 (7.5)
Frozen foods are defrosted either in the refrigerator or in the microwave	0/6 (0)	2/10 (20)	1/10 (10)	0/10 (0)	3/36 (8)
Hot foods are kept heated at no less than 60°C	3/10 (30)	2/10 (20)	1/9 (11)	NA[c]	5/28 (18)
Types of surfaces					
Food contact surfaces are smooth	0/10 (0)	1/10 (10)	0/10 (0)	0/10 (0)	1/40 (2.5)
Food contact surfaces are easy to clean	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)	0/40 (0)
Food contact surfaces are intact	0/10 (0)	0/10 (0)	0/10 (0)	0/10 (0)	0/40 (0)
Cutting board is made of stainless steel or polypropylene	0/10 (0)	0/10 (0)	0/10 (0)	3/10 (30)	3/40 (7.5)
Mean (%)	8.6	10.1	11.4	22.4	12.9

[a] Kitchens labeled as noncompliant had a score of 0 for that item.
[b] This question was included later in the project when 4 of the 10 hospitals had already been sampled.
[c] NA, not applicable.

TABLE 2. *Values for total mesophilic aerobic bacterial counts (TACs) and counts of* Enterobacteriaceae, B. cereus, E. coli, *and* S. aureus *from swab samples collected during preparation of food in 40 institutional kitchens*

	TAC				*Enterobacteriaceae*				*B. cereus*				*E. coli*				*S. aureus*			
			Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)	
Sample type[a]	*n*	No. (%) positive	Mean LLE[b]	Count[c]	*n*	No. (%) positive	Mean LLE	Count	*n*	No. (%) positive	Mean LLE	Count	*n*	No. (%) positive	Mean LLE	Count	*n*	No. (%) positive	Mean LLE	Count
Hands BW	40	40 (100)	−0.2	3.4 ± 1.0	40	14 (43)	−0.2	1.0, 1.4, 2.2	40	8 (20)	0.3	0.8, 1.0, 1.3	34	1 (3)	−0.2	0.9	40	6 (15)	−0.2	0.1, 0.4, 1.2
Hands AW	40	40 (100)	−0.2	2.9 ± 1.1	40	11 (28)	−0.2	0.1, 0.4, 1.7	40	4 (10)	0.3	0.6, 0.9, 1.4	34	0	−0.2		40	2 (5)	−0.2	0.7, 1.3
Sink	40	40 (100)	−0.4	4.0 ± 1.5	40	34 (85)	−0.4	2.3 ± 1.3	40	11 (28)	0.1	0.6, 1.0, 1.6	34	9 (26)	−0.4	0.7, 1.2, 2.0	40	5 (13)	−0.4	0.2, 0.2, 0.5
Used knife	39	37 (95)	0.6	2.3, 4.0, 5.0	39	16 (41)	0.6	2.0, 2.7, 3.4	39	5 (13)	1.2	1.3, 1.7, 3.3	33	1 (3)	0.6	0.7	39	2 (5)	0.6	1.7, 2.0
Cleaned knife	40	33 (83)	0.7	1.5, 2.4, 3.3[d]	40	5 (13)	0.7	0.7, 0.7, 3.1	40	2 (5)	1.2	1.4, 1.4	34	0	0.7		40	1 (3)	0.7	0.9
Used cutting board	31	31 (100)	−0.4	2.5, 3.8, 5.2	31	16 (52)	−0.4	2.0, 2.7, 4.3	31	14 (45)	0.1	0.5, 1.7, 1.8	26	2 (8)	−0.4	0.5, 0.9	31	10 (32)	−0.4	−0.1, 0.1, 0.6
Cleaned cutting board	38	38 (100)	−0.4	1.7, 2.1, 3.6	39	13 (33)	−0.4	−0.1, 1.6, 2.2	39	9 (23)	0.1	0.9, 1.0, 1.8	33	0	−0.4		39	2 (5)	−0.4	−0.1, 0.2
Used ladle	38	33 (87)	0.05	1.5, 2.1, 2.7[d]	38	5 (13)	0.05	1.4, 1.5, 1.7	38	4 (11)	0.6	1.1, 1.1, 1.4	33	0	0.05		38	0	0.05	
Cleaned ladle	37	36 (97)	0.009	1.4, 2.2, 3.0	38	7 (18)	0.009	0.8, 2.0, 2.7	38	6 (16)	0.5	0.8, 0.8, 0.8	33	1 (3)	0.009	1.5	38	1 (3)	0.009	0.6
Used work surface	39	39 (100)	−0.4	2.0, 3.3, 4.3	40	20 (50)	−0.4	1.2 ± 1.5	40	8 (20)	0.1	0.4, 1.0, 1.4	34	1 (3)	−0.4	−0.1	40	4 (10)	−0.4	0.1, 0.4, 0.7
Cleaned work surface	39	36 (92)	−0.4	2.3, 3.0, 3.7[d]	40	18 (45)	−0.4	1.3 ± 1.3	40	10 (25)	0.1	0.5, 0.8, 1.6	34	0	−0.4		40	1 (3)	−0.4	−0.1
Apron	30	29 (97)	−0.4	2.5 ± 0.9	30	13 (43)	−0.4	0.5 ± 0.8	30	7 (23)	0.1	0.4, 0.4, 0.4	24	0	−0.4		30	3 (10)	−0.4	1.1, 1.2, 1.5
Used tray	31	29 (94)	−0.4	1.8, 2.2, 2.8	31	8 (32)	−0.4	0.1, 1.6, 2.7[d]	31	1 (3)	0.1	1.5	25	0	−0.4		31	3 (10)	−0.4	0.1, 0.4, 0.9
Cleaned tray	34	34 (100)	−0.4	1.6, 2.1, 2.6[d]	34	8 (24)	−0.4	−0.1, 0.6, 1.1	34	3 (9)	0.2	0.4, 0.4, 1.6	28	0	−0.4		34	1 (3)	−0.4	−0.1
Used extra	35	31 (89)	0.4	1.9, 3.0, 5.2	35	9 (26)	0.4	0.9, 1.1, 2.9	35	1 (3)	0.8	0.4	30	2 (7)	0.4	1.0, 1.1	35	1 (3)	0.4	−0.1
Cleaned extra	39	38 (78)	0.4	1.7, 2.5, 3.4[d]	40	11 (28)	0.4	0.5, 1.9, 2.4	39	1 (3)	0.9	1.5	34	0	0.4		40	3 (8)	0.4	0.3, 0.6, 0.7

[a] BW, before washing; AW, after washing. Extra: whisks, strainers, cutting machines, or blenders.
[b] Lower limit of enumeration.
[c] For counts that are normally distributed, means ± standard deviations are shown. For counts that did not follow a normal distribution, first quartile (Q1), median (Q2), and third quartile (Q3) values are shown or individual results are shown when fewer than three results were obtained.
[d] Counts were normally distributed, but Q1, Q2, and Q3 are given to allow comparison of results between samples that were used and those that were cleaned.

enumeration of *B. cereus,* and identification was confirmed by growth on blood agar base (Oxoid) with 7% defibrinated sheep blood (E&O Labs, Bonnybridge, Scotland) incubated at 30°C for 24 h. Baird Parker agar with rabbit plasma fibrinogen (BP+RPF; bioMérieux, Marcy l'Étoile, France) incubated at 37°C for 48 h was used for enumeration of *S. aureus*. RAPID'*E. coli* 2 agar (Bio Rad) incubated at 44°C for 24 h was used for enumeration of *E. coli*. For PCA, VRBG, RAPID'*E. coli,* and BP+RPF cultures, the suspension was plated using the pour plate technique. Further dilutions were plated using a spiral plater (Eddy-Jet, IUL instruments, Barcelona, Spain). All results were recalculated to a standardized surface area of 20 cm^2. The lower limits for enumeration for these plates were –0.4 to 1.4 log CFU/20 cm^2, depending on the type of surface area. For the MYP plates, the suspension was plated using the spread plate technique. Further dilutions were plated using a spiral plater. The lower limits for enumeration for MYP plates were 0.1 to 1.9 log CFU/20 cm^2, depending on the type of surface area.

Statistical analysis. All statistical analyses of the microbiological results were performed using RStudio (version 9.4; https://docs.rstudio.com/connect/1.5.2/admin/index.html). For the data collection instrument results, the first quartile (Q1), median (Q2), and third quartile (Q3) values of the obtained hygiene scores were calculated per type of kitchen. An analysis of variance (95% confidence interval) was used to compare data collection instrument results for the four types of kitchens. Evaluation of the log-transformed values for each microbiological parameter was based on the histogram and a quantile-quantile plot. For enumeration values that were normally distributed, mean and standard deviation were recorded. For enumeration values that did not follow a normal distribution, the Q1, Q2, and Q3 values were recorded. In certain cases, Q1, Q2, and Q3 were recorded even though the enumeration values were normally distributed. These values were important in situations in which one of the data sets for the samples from used or cleaned surfaces did not follow a normal distribution. The three values would allow comparison of samples from used versus cleaned for each surface type.

RESULTS

Data collection instrument. The data collection instrument comprised 36 items, which allowed a maximum hygiene score of 36. The mean (±SD) score for the 40 sampled kitchens was 30.9 ± 3.2, with a low score of 23.8 and a high score of 36. The Q1, Q2, and Q3 scores for the kitchens in each of the four public sectors are listed in Table 3. The lowest median (28.5) was obtained for the child care centers, and the median values for the other sectors were 31.2 to 32.6. Results for the child care centers were significantly different from those for the hospitals. The level of noncompliance in the kitchens for each surveyed group is shown in Table 1.

Microbiological analysis. A total of 598 surface samples were collected from the 40 kitchens (Table 2). For TACs, 9.8% of the swab samples produced cultures that were not countable; 5.2% were below the lower enumeration limit and 4.6% were overgrown. For *Enterobacteriaceae,* 64.4% of the samples were below the lower enumeration limit and 0.7% were overgrown. These overgrown samples all came from used surfaces located in various kitchens. For *B. cereus,* 83.9% of the samples were below the lower enumeration limit and 0.3% were overgrown. The overgrown samples came from a cleaned cutting board and a cleaned whisk from the same kitchen. For *E. coli,* 96.6% of the samples were below the enumeration limit and 0.2% were overgrown; this overgrown sample came from a sink. *E. coli* was not often found on the sampled surfaces. The highest occurrence of *E. coli* was found in the sinks, for which 26% of the samples were countable, and the median value was 1.2 log CFU/20 cm^2. *E. coli* was found on only one cleaned surface: a cleaned ladle at 1.5 log CFU/20 cm^2. For *S. aureus,* 92.5% of the samples were below the lower enumeration limit.

TABLE 3. *Hygiene scoring of institutional kitchens per public sector based on the data collection instrument*

Sector	*n*	Hygiene score		
		Minimum	Quartiles[a]	Maximum
Hospitals	10	29.1	30.7, 32.7, 34.0	36.0
Schools	10	26.5	30.3, 31.7, 34.2	34.8
Retirement homes	10	24.9	30.3, 31.2, 33.1	35.5
Child care centers	10	23.8	26.6, 28.5, 30.0	33.8

[a] First quartile (Q1), median (Q2), third quartile (Q3).

Comparison of microbiological analysis on cleaned surfaces per sector. *Enterobacteriaceae* and *B. cereus* counts for samples of cleaned surfaces collected from kitchens in the four public sectors are shown in Tables 4 and 5, respectively. The highest *Enterobacteriaceae* and *B. cereus* counts were found in retirement homes and schools (both 1.4 log CFU/20 cm^2), respectively. TACs for samples of cleaned surfaces collected from kitchens in the four sectors are shown in Supplemental Table S1. Child care centers had the highest mean TAC for all cleaned surfaces (2.9 log CFU/20 cm^2), and hospitals had the lowest (2.3 log CFU/20 cm^2).

DISCUSSION

Data collection instrument. Table 1 demonstrates that the main problems found in the kitchens were no separation between meat and vegetable preparation (56% of kitchens), surfaces cleaned not more than once per day (52.5%), no clear separation between raw and prepared food in the refrigerator (42%), no separation between contamination activities (e.g., no clear spatial separation for preparation of hot meals, sandwiches, and salads; 37%), and aprons replaced less than once per day (29%). Garayoa et al. *(13)* found that samples from more than half of the aprons exceeded the established TAC limit, and *Enterobacteriaceae* were present on 71.4% of the sampled aprons. This prevalence could be related to infrequent change of aprons and personal hygiene practices. These results indicate that aprons can be a hygiene risk. Yoon et al. *(37)* found that hygiene could be improved by replacing aprons more than once per day. The possible number of times an apron can be changed is subject to practical limitations.

TABLE 4. Enterobacteriaceae *counts for swab samples collected from cleaned surfaces during preparation of food in 10 institutional kitchens in each of four public sectors*

	Hospitals				Schools				Retirement homes				Child care centers			
			Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)	
Sample type[a]	*n*	No. (%) positive	Mean LLE[b]	Count[c]	*n*	No. (%) positive	Mean LLE	Count	*n*	No. (%) positive	Mean LLE	Count	*n*	No. (%) positive	Mean LLE	Count
Hands AW	10	1 (10)	−0.2	0.1	10	2 (20)	−0.2	0.1, 2.2	10	3 (30)	−0.2	0.5, 1.0, 2.3	10	5 (50)	−0.2	0.1, 0.4, 1.3
Cleaned knife	10	3 (30)	0.7	0.7, 0.7, 1.9	10	1 (10)	0.7	4.1	10	1 (10)	0.7	0.7	10	0	0.7	
Cleaned cutting board	10	2 (10)	−0.4	−0.2, 1.0	10	4 (40)	−0.4	1.2, 1.9, 2.4	10	3 (30)	−0.4	−0.1, −0.1, 0.7	9	4 (44)	−0.4	2.2 ± 0.7
Cleaned ladle	9	0	0.009		9	1 (11)	0.009	0.6	10	2 (20)	0.009	3.0, 3.7	10	4 (40)	0.009	0.8, **1.5**, 2.1
Cleaned work surface	10	4 (40)	−0.4	1.8, 3.0, 3.6	10	4 (40)	−0.4	−0.4, 0.6, 1.5	10	4 (40)	−0.4	0.7, 1.5, 1.9	10	5 (50)	−0.4	1.1 ± 0.7
Cleaned tray	10	1 (10)	−0.4	1.1	9	2 (22)	−0.4	−1.1, 0.2	10	3 (30)	−0.4	−0.2, 0.6, 0.9	5	2 (40)	−0.4	0.5, 1.8
Cleaned extra	10	2 (20)	0.4	−0.1, 2.1	10	2 (20)	0.4	−0.1, 1.5	10	3 (30)	0.4	2.1, 2.2, 2.5	10	4 (40)	0.4	0.7, 1.8, 2.7
Mean	69	13 (19)	−0.4–0.7	0.1, 1.0, 2.5	68	16 (24)	−0.4–0.7	−0.1, 1.0, 1.9	70	20 (29)	−0.4–0.7	1.4 ± 1.3	64	26 (38)	−0.4–0.7	0.6, 1.3, 2.1

[a] AW, after washing. Extra: whisks, strainers, cutting machines, or blenders.
[b] Lower limit of enumeration.
[c] For counts that are normally distributed, means ± standard deviations are shown. For counts that did not follow a normal distribution, first quartile (Q1), median (Q2), and third quartile (Q3) values are shown or individual results are shown when fewer than three results were obtained.

TABLE 5. B. cereus *counts for swab samples collected from cleaned surfaces during preparation of food in 10 institutional kitchens in each of four public sectors*

	Hospitals				Schools				Retirement homes				Child care centers			
			Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)				Level (log CFU/20 cm^2)	
Sample type[a]	*n*	No. (%) positive	Mean LLE[b]	Count[c]	*n*	No. (%) positive	Mean LLE	Count	*n*	No. (%) positive	Mean LLE	Count	*n*	No. (%) positive	Mean LLE	Count
Hands AW	10	0	0.3		10	2 (20)	0.3	0.6, 2.1	10	1 (10)	0.3	1.1	10	1 (10)	0.3	0.6
Cleaned knife	10	0	1.2		10	2 (20)	1.2	1.4, 1.5	10	0	1.2		10	0	1.2	
Cleaned cutting board	10	2 (20)	0.1	0.4, 1.8	10	4 (40)	0.1	1.3, 1.6, 3.3	10	1 (10)	0.1	0.9	9	2 (22)	0.1	0.4, 1.0
Cleaned ladle	9	4 (44)	0.5	0.7, 0.8, 0.9	9	1 (11)	0.5	0.8	10	0	0.5		10	1 (10)	0.5	0.8
Cleaned work surface	10	2 (20)	0.1	0.7, 1.9	10	2 (20)	0.1	0.4, 1.7	10	3 (30)	0.1	0.6, 0.7, 1.3	10	3 (30)	0.1	0.7, 0.9, 1.1
Cleaned tray	10	2 (20)	0.2	0.4, 2.7	9	1 (11)	0.2	0.4	10	0	0.2		5	0	0.2	
Cleaned extra	10	0	0.9		9	0	0.9		10	1 (10)	0.9	1.5	10	0	0.9	
Mean	69	10 (14)	0.1–1.2	0.5, 0.8, 1.7	67	11 (16)	0.1–1.2	0.8, 1.4, 1.7	70	6 (9)	0.1–1.2	0.8, 1.0, 1.4	64	7 (11)	0.1–1.2	0.5, 0.8, 1.0

[a] AW, after washing. Extra: whisks, strainers, cutting machines, or blenders.
[b] Lower limit of enumeration.
[c] For counts that are normally distributed, means ± standard deviations are shown. For counts that did not follow a normal distribution, first quartile (Q1), median (Q2), and third quartile (Q3) values are shown or individual results are shown when fewer than three results were obtained.

Child care centers had the lowest median hygiene score, and the level of noncompliance often deviated greatly from the overall total noncompliance for each surveyed item (Table 1). For example, 89% of child care centers did not separate possible contamination activities, and 88% did not separate raw foods and prepared foods in the refrigerator. These practices could result in cross-contamination because foods served raw can contain high populations of microorganisms *(28)*. The spatial separation of areas for meat and vegetable preparation did not necessarily cause problems because child care centers normally do not serve raw vegetables, but these surfaces could be used to prepare any raw food, such as a fruit puree. Among the child care centers, 80% had food handlers who did not use hairnets when preparing food, and 40% had refrigerators with a temperature >5°C. The survey question concerning the temperature at which the food was kept after preparation was considered not applicable for child care centers because they prepare the food immediately before it is consumed, and small children cannot tolerate food served at high temperatures.

Although hospitals had the lowest overall percentage of noncompliance according to the data collection instrument, they scored less well than other sectors regarding the cleanliness of dish cloths; 20% of the hospital kitchens used dirty dish cloths, a practice not observed in the other sectors. Infrequently disinfected dish cloths can be heavily contaminated and thus a source of cross-contamination *(20, 30)*. Hospitals also had 17% noncompliance regarding daily replacement of dish cloths. A small number of kitchens used disposable towels instead of dish cloths. In these cases, a score of 1 was given for both questions regarding the dish cloths because this practice conforms to hygiene regulations.

Microbiological analysis. In general, TACs were lower on cleaned surfaces than on used surfaces, as expected. However, the median TACs for cleaned and used ladles were not significantly different (difference of 0.1 log CFU/20 cm^2). The number of samples positive for all microorganisms was higher for cleaned ladles than for used ladles. The median *B. cereus* count was only slightly reduced after cleaning, and for *Enterobacteriaceae,* cleaning actually increased levels by 0.5 log CFU/20 cm^2. For both the trays and work surfaces, TACs were only slightly reduced for the cleaned versus used samples. These observations could be explained by the fact that trays and ladles were mostly used with heated food products containing a low bacterial load. These items were cleaned relatively quickly after use, which probably prevented further microbial growth. The cleaning of trays resulted in a notable reduction in *Enterobacteriaceae* counts but only a slight reduction in the number of positive samples. For *B. cereus,* the percentage of positive tray samples increased from 3 to 9% after cleaning.

Of the cleaned surfaces, the work surfaces had the highest mean TAC. Only a slight reduction in TAC was observed after cleaning, whereas cleaning resulted in a slight increase in *Enterobacteriaceae* counts and only a slight reduction in *B. cereus* counts. These findings suggest that work tables should be cleaned more thoroughly and more frequently. The use of dirty dish cloths and towels is probably one of the causes for the high counts on cleaned surfaces. Forty-five percent of work surfaces still tested positive for *Enterobacteriaceae* after cleaning, and *B. cereus* prevalence was higher for cleaned work surfaces than for used ones (25 and 20%, respectively). *B. cereus* can produce diverse enterotoxins, possible causing diarrhea or emesis when present in food at more than 10^5 CFU/g *(35)*. Although the levels of *B. cereus* in these kitchens were not high enough to pose an immediate risk, the slight reduction in this pathogen on work surfaces highlights the importance of good hygiene practices because this spore-forming bacterium can survive some heat treatments. Between 2007 and 2012, *B. cereus* was identified as the causative agent for two to eight foodborne outbreaks per year in Belgium, resulting in 147 cases of emetic illness and one death *(8)*.

The highest TACs were found in the sink, on the used knife, and on the used cutting board, probably because these items are primarily used with raw products. A large reduction in all assayed microorganisms was achieved by cleaning. However, among the cutting board samples, 33% tested positive for *Enterobacteriaceae* and 23% tested positive for *B. cereus* after cleaning. Thorough cleaning of cutting boards is important because of their direct contact with food products. Surfaces of cutting boards can be damaged through contact with knife edges *(27, 38),* and the resulting crevices and irregular surfaces can allow the persistence of microorganisms, which makes cleaning and disinfection more challenging *(12)*. The material composition of the cutting board can also influence the microbial load. Montville and Schaffner *(21)* determined that plastic surfaces often have higher microbial levels. Pathogens from contaminated meat can be transferred onto plastic cutting board surfaces after contact for only 5 to 10 s. These cutting boards can then cross-contaminate subsequent food products, specifically when these products are not subsequently thoroughly heated *(7, 31, 36)*.

The sink samples mostly had the highest microbial counts and the highest percentage of positive samples. For *Enterobacteriaceae,* 85% of sink samples produced countable levels. Sinks also had the second-highest mean *Enterobacteriaceae* count, at 2.3 ± 1.3 log CFU/20 cm^2. Counts on sinks were surpassed only by those on used knives and used cutting boards, which both had a median level of 2.7 log CFU/20 cm^2. Sink drains are one of the most common areas of contamination *(37)*. Microbial growth in drains in facilitated by the high moisture levels and accumulation of stagnant water *(31)*. Rodríguez et al. *(25)* reported that faucets and cutting boards were the food contact surfaces with the highest microbial loads.

Hand washing resulted in only a 0.5-log reduction in TACs, and all hand samples yielded countable bacterial levels. Samples collected for food handlers' hands were positive for all assayed microorganisms except *E. coli,* although a reduction in counts was found after hand washing. Foodborne outbreaks can be caused by pathogens

transmitted from hands to food via food contact surfaces *(14, 37)*. Todd et al. *(31)* reported that washing of bare hands was not sufficient to lower the risk of food contamination. Gloves can prevent transfer of microorganisms when the gloves are washed at the same frequency as the hands or if the gloves are replaced regularly. Soiled gloves can present the same risk for cross-contamination as unwashed hands *(13, 26, 37)*. However, wearing gloves can give the food handler a false sense of protection. Personnel should be thoroughly informed of the possibility of microorganisms adhering to the surfaces of gloves and the likelihood of contamination of both the inside and outside of the gloves when hands are not properly washed before putting gloves on. Body heat increases the temperature and moisture inside the gloves and can encourage rapid multiplication of any microorganisms present *(3, 13, 19)*.

Comparison of microbiological analysis on cleaned surfaces per sector. The total mean TAC for all cleaned surfaces was highest for child care centers and lowest for hospitals (Table S1). These results seem consistent with the hygiene scores from the data collection instrument (Table 3). Child care centers also had the highest TACs for three types of surfaces: hands, cutting boards, and work surfaces. Schools had the highest counts for three other types of surfaces: knives, ladles, and trays. Retirement homes had the highest TACs for the extra sampling points (whisks, strainers, cutting machines, or blenders).

Retirement homes had the highest mean *Enterobacteriaceae* counts on cleaned surfaces (Table 4), whereas child care centers had a comparable total mean but also the highest total number of positive samples for all cleaned surfaces (38%) and for nearly all of the individual surfaces. Only the cleaned knives in hospitals had a higher number of positive samples for *Enterobacteriaceae* compared with the other three sectors. This finding is of particular concern for children <5 years of age because they suffer high rates of enteric bacterial infections caused by *Enterobacteriaceae (29). Enterobacteriaceae* are indicators of sanitation and are sensitive to antimicrobial sanitizers *(26, 33)*. These results for child care centers therefore suggest that either the method of cleaning and/or the use of sanitizers should be updated in these centers and/or more food hygiene training should be conducted for those food handlers. Lee *(18)* used an ATP bioluminescence meter to compare the microbial quality of food handlers' hands and kitchen utensils in child care centers before and after food hygiene training. After training, ATP levels decreased significantly, and hygiene practices by the food workers also improved.

Schools had the highest mean *B. cereus* count (1.4 log CFU/20 cm^2) and the highest percentage of positive samples (16%) for all cleaned surfaces among the four sectors (Table 5). They also had the highest number of positive samples for three types of individual surfaces: hands, knives, and cutting boards.

Only one swab sample taken from cleaned surfaces was positive for *E. coli*; this sample from a cleaned ladle in a retirement home had 1.5 log CFU/20 cm^2. In hospitals, schools, retirement homes, and child care centers, 0, 5.9, 2.9, and 7.7% of the swab samples were positive for *S. aureus,* respectively, at levels of –0.1 to 1.3 log CFU/20 cm^2. Of the four sectors, child care centers had the highest number of positive samples.

In this study, 70% of the kitchens evaluated had previously been deemed unsatisfactory by the FASFC for one or more hygiene practices during routine visits. The microbiological results seemed to verify the trends in the hygiene scores obtained with the data collection instrument. TACs and *B. cereus* counts were the only parameters for which the total number of positive samples was not highest in child care centers, but these centers still had the highest total number of samples positive for TACs. Hospitals had the highest hygiene scores according to the data collection instrument, a finding confirmed by the microbiological results. For TACs on cleaned surfaces, hospitals had the lowest counts and lowest prevalence of positive samples. For *Enterobacteriaceae,* hospitals also had the lowest prevalence of positive samples and shared the lowest counts with the schools for total cleaned surfaces. *E. coli* and *S. aureus* were never found on cleaned surfaces in hospitals.

Possible limitations of this study are the small number of kitchens included per sector and the fact that each kitchen was visited only once. Thus, comparisons between the four sectors should be interpreted with caution, although both microbiological results and data collection instrument results indicate less than adequate hygiene practices in child care centers. Another limitation could be the use of a different surface sampling method, limiting possible comparisons with results of studies in which agar contact plate hygiene monitoring was used. However, our surface sampling method is much more sensitive than the contact plate method and has the advantage that small and irregular surfaces can be sampled. The use of indicator organisms provides only a general reflection of hygiene status. However, indicator organisms were analyzed because the presence of pathogens is expected to be too low to reliably identify critical contact points and differences in hygiene status among the four sectors. Because we focused on kitchens with generally lower hygiene scores, our findings do not provide a general view of the hygiene issues in institutional kitchens but mainly indicate where improvements could more easily be made.

In summary, these findings indicate that hygiene in institutional kitchens needs improvement. Hand washing resulted in only a slight reduction in TACs, and all microorganisms except *E. coli* were still countable after washing. One-third of cleaned cutting boards still harbored *Enterobacteriaceae*; thus, the effects of crevices caused by contact with knife blades should be considered. Work tables should be cleaned more frequently and more thoroughly. Among the four public sectors, child care centers had the lowest hygiene scores, whereas the scores for the other three sectors were similar; hospitals had the highest scores. A comparison of microbiological results from cleaned surfaces across sectors suggest that lower hygiene scores can be indicative of higher levels of contamination, specifically for child care centers. For example, the total mean TAC was highest for child care centers and lowest for hospitals. The

total mean *Enterobacteriaceae* count was second highest for child care centers, and these centers had the highest total number of positive samples. Child care centers also had the highest number of samples positive for *S. aureus*.

ACKNOWLEDGMENTS

We thank Eline Dumoleijn, Sjarlotte Willems, Elly Engels, Sofie De Vlam, and Ann Van De Walle for technical assistance. We also thank all the kitchens that agreed to participate in this study. We thank the Belgian Federal Public Service for Health, Safety of the Food Chain, and the Environment (project 5057) for funding this research.

SUPPLEMENTAL MATERIAL

Supplemental material associated with this article can be found online at: https://doi.org/10.4315/0362-028X.JFP-19-202.s1

REFERENCES

1. Ak, N. O., D. O. Cliver, and C. W. Kaspar. 1994. Cutting boards of plastic and wood contaminated experimentally with bacteria. *J. Food Prot*. 57:16–22. https://doi.org/10.4315/0362-028X-57.1.16
2. Ak, N. O., D. O. Cliver, and C. W. Kaspar. 1994. Decontamination of plastic and wooden cutting boards for kitchen use. *J. Food Prot*. 57:23–30. https://doi.org/10.4315/0362-028X-57.1.23
3. Ayçiçek, H., B. Sarimehmetoğlu, and S. Çakiroğlu. 2004. Assessment of the microbiological quality of meals sampled at the meal serving units of a military hospital in Ankara, Turkey. *Food Control* 15:379–384. https://doi.org/10.1016/S0956-7135(03)00101-4
4. Bean, N. H., and P. M. Griffin. 1990. Foodborne disease outbreaks in the United States, 1973–1987: pathogens, vehicles, and trends. *J. Food Prot*. 53:804–817. https://doi.org/10.4315/0362-028X-53.9.804
5. Biranjia-Hurdoyal, S., and M. C. Latouche. 2016. Factors affecting microbial load and profile of potential pathogens and food spoilage bacteria from household kitchen tables. *Can. J. Infect. Dis. Med. Microbiol.* https://doi.org/10.1155/2016/3574149
6. Chen, Y., K. M. Jackson, F. P. Chea, and D. W. Schaffner. 2001. Quantification and variability analysis of bacterial cross-contamination rates in common food service tasks. *J. Food Prot*. 64:72–80. https://doi.org/10.4315/0362-028X-64.1.72
7. da Vitória, A. G., J. de Souza Couto Oliveira, C. P. de Faria, and J. F. B. de São José. 2018. Good practices and microbiological quality of food contact surfaces in public school kitchens. *J. Food Saf.* 38. https://doi.org/10.1111/jfs.12486
8. Delbrassinne, L., N. Botteldoorn, M. Andjelkovic, K. Dierick, and S. Denayer. 2015. An emetic *Bacillus cereus* outbreak in a kindergarten: detection and quantification of critical levels of cereulide toxin. *Foodborne Pathog. Dis*. 12:84–87. https://doi.org/10.1089/fpd.2014.1788
9. European Commission. 2004. Regulation (EC) No 852/2004 of the European Parliament and the Council of 29 April 2004 on the hygiene of foodstuffs. *Off. J. Eur. Union* L 139(47):1–54. Available at: eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:139:0001:0054:en:PDF. Accessed 7 November 2018.
10. European Food Safety Authority and European Centre for Disease Prevention and Control. 2017. The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2016. *EFSA J*. 15:5077–5305. https://doi.org/10.2903/j.efsa.2017.5077
11. Federaal Agentschap voor de Veiligheid van de Voedselketen (FASFC). 2017. DIS 3198. Grootkeukens (bereiding + distributie): infrastuctuur, inrichting en hygiene [3198] v3 [Industrial kitchens (preparation + distribution): infrastructure, devices and hygiene]. Federaal Agentschap voor de Veiligheid van de Voedselketen, Brussels.
12. Garayoa, R., C. Abundancia, M. Díez-Leturia, and A. I. Vitas. 2017. Essential tools for food safety surveillance in catering services: on-site inspections and control of high risk cross-contamination surfaces. *Food Control* 75:48–54. https://doi.org/10.1016/j.foodcont.2016.12.032
13. Garayoa, R., N. Yánez, M. Díez-Leturia, M. Bes-Rastrollo, and A. I. Vitas. 2016. Evaluation of prerequisite programs implementation and hygiene practices at social food services through audits and microbiological surveillance. *J. Food Sci*. 81:921–927. https://doi.org/10.1111/1750-3841.13258
14. Guzewich, J., and M. P. Ross. 1999. Evaluation of risks related to microbiological contamination of ready-to-eat food by food preparation workers and the effectiveness of interventions to minimize those risks. U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition. Available at: http://www.cfsan.fda.gov/~ear/rterisk.html. Accessed 7 December 2018.
15. Illés, C. B., A. J. Tóth, A. Dunay, J. Lehota, and A. Bittsánszky. 2018. Evaluation of food safety knowledge and microbial status of food contact surfaces in schools. *J. Food Saf.* 38. https://doi.org/10.1111/jfs.12480
16. Jang, H. G., N. H. Kim, Y. M. Choi, and M. S. Rhee. 2013 Microbiological quality and risk factors related to sandwiches served in bakeries, cafés, and sandwich bars in South Korea. *J. Food Prot*. 76:231–238.
17. Kusumaningrum, H. D., G. Riboldi, W. C. Hazeleger, and R. R. Beumer. 2003. Survival of foodborne pathogens on stainless steel surfaces and cross-contamination to foods. *Int. J. Food Microbiol*. 85:227–236. https://doi.org/10.1016/S0168-1605(02)00540-8
18. Lee, J. H. 2018. An investigation of factors that influence hygiene practices at a small day care center. *J. Food Prot*. 81:158–164. https://doi.org/10.4315/0362-028X.JFP-17-163
19. Lues, J. F. R., and I. Van Tonder. 2007. The occurrence of indicator bacteria on hands and aprons of food handlers in the delicatessen sections of a retail group. *Food Control* 18:326–332. https://doi.org/10.1016/j.foodcont.2005.10.010
20. Mattick, K., K. Durham, M. Hendrix, J. Slade, C. Griffith, M. Sen, and T. Humphrey. 2003. The microbiological quality of washing-up water and the environment in domestic and commercial kitchens. *J. Appl. Microbiol*. 94:842–848. https://doi.org/10.1046/j.1365-2672.2003.01904.x
21. Montville, R., and D. W. Schaffner. 2004. Statistical distributions describing microbial quality of surfaces and foods in foodservice operations. *J. Food Prot*. 67:162–167. https://doi.org/10.4315/0362-028x-67.1.162
22. Osimani, A., L. Aquilanti, S. Tavoletti, and F. Clementi. 2013. Microbiological monitoring of air quality in a university canteen: an 11-year report. *Environ. Monit. Assess*. 185:4765–4774. https://doi.org/10.1007/s10661-012-2903-7
23. Osimani, A., L. Aquilanti, S. Tavoletti, and F. Clementi. 2013. Evaluation of the HACCP system in a university canteen: microbiological monitoring and internal auditing as verification tools. *Int. J. Environ. Res. Public Health* 10:1572–1585. https://doi.org/10.3390/ijerph10041572
24. Petruzzelli, A., A. Osimani, S. Tavoletti, F. Clementi, V. Vetrano, S. Di Lullo, F. Paolini, M. Foglini, E. Micci, N. Orazietti, T. Luchetti, and F. Tonucci. 2018. Microbiological quality assessment of meals and work surfaces in a school-deferred catering system. *Int. J. Hosp. Manag*. 68:105–114. https://doi.org/10.1016/j.ijhm.2017.10.003
25. Rodríguez, M., A. Valero, G. D. Posada-Izquirdo, E. Carrasco, and G. Zurera. 2011. Evaluation of food handler practices and microbiological status of ready-to-eat foods in long-term care facilities in the Andalusia region of Spain. *J. Food Prot*. 74:1504–1512. https://doi.org/10.4315/0362-028x.jfp-10-468
26. Rodríguez-Caturla, M. Y., A. Valero, E. Carrasco, G. D. Posada, R. M. García-Gimeno, and G. Zurera. 2012. Evaluation of hygiene practices and microbiological status of ready-to-eat vegetable salads in Spanish school canteens. *J. Sci. Food Agric*. 92:2332–2340. https://doi.org/10.1002/jsfa.5634
27. Rossi, E. M., L. Beilke, and J. F. Barreto. 2018. Microbial contamination and good manufacturing practices in school kitchen. *J. Food Saf.* 38. https://doi.org/10.1111/jfs.12417
28. Ryu, J., J. Ko, H. Park, S. Yang, and H. Kim. 2011. Microbial examination of nonheated foods served in feeding programs of

elementary schools, Iksan City, Jeonbuk Province, Korea. *J. Food Prot*. 74:1564–1568. https://doi.org/10.4315/0362-028x.jfp-11-009
29. Staskel, D. M., M. E. Briley, L. H. Field, and S. S. Barth. 2007. Microbial evaluation of foodservice surfaces in Texas child-care centers. *J. Am. Diet. Assoc*. 107:854–859. https://doi.org/10.1016/j.jada.2007.02.013
30. Tebbutt, G. M. 1988. Laboratory evaluation of disposable and reusable disinfectant cloths for cleaning food contact surfaces. *Epidemiol. Infect*. 101:367–375. https://doi.org/10.1017/S0950268800054315
31. Todd, E. C. D., J. D. Greig, C. A. Bartleson, and B. S. Michaels. 2009. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 6. Transmission and survival of pathogens in the food processing and preparation environment. *J. Food Prot*. 72:202–219. https://doi.org/10.4315/0362-028X-72.1.202
32. Todd, E. C. D., B. S. Michaels, J. D. Greig, D. Smith, J. Holah, and C. A. Bartleson. 2007. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 2. Description of outbreaks by size, severity, and settings. *J. Food Prot*. 70:1975–1993. https://doi.org/10.1109/IConAC.2015.7313992
33. Tortorello, M. L. 2003. Indicator organisms for safety and quality—uses and methods for detection: minireview. *J. AOAC Int*. 86:1208–1217. https://doi.org/10.1111/j.1745-3984.1971.tb00907.x
34. Tóth, A. J., and A. Bittsánszky. 2014. A comparison of hygiene standards of serving and cooking kitchens in schools in Hungary. *Food Control* 46:520–524. https://doi.org/10.1016/j.foodcont.2014.06.019
35. Uyttendaele, M., A. De Loy-Hendrickx, A. Vermeulen, L. Jackxens, J. Debevere, and F. Devlieghere. 2018. Microbiological guidelines: support for interpretation of microbiological test results of foods. die Keure, Brugge, Belgium.
36. Wachtel, M. R., J. L. McEvoy, Y. Luo, A. M. Williams-Campbell, and M. B. Solomon. 2003. Cross-contamination of lettuce (*Lactuca sativa* L.) with *Escherichia coli* O157:H7 via contaminated ground beef. *J. Food Prot*. 66:1176–1183. https://doi.org/10.4315/0362-028X-66.7.1176
37. Yoon, Y., S. R. Kim, D. H. Kang, W. B. Shim, E. Seo, and D. H. Chung. 2008. Microbial assessment in school foodservices and recommendations for food safety improvement. *J. Food Sci*. 73:304–313. https://doi.org/10.1111/j.1750-3841.2008.00828.x
38. Zhao, P., T. Zhao, M. P. Doyle, J. R. Rubino, and J. Meng. 1998. Development of a model for evaluation of microbial cross-contamination in the kitchen. *J. Food Prot*. 61:960–963. https://doi.org/10.4315/0362-028X-61.8.960