ORIGINAL ARTICLE
UDC: 614.3:614.446]:579.6
DOI: https://doi.org/10.2298/VSP200521050P

Hygiene status of food contact surfaces in public school canteens in the city of Novi Sad, Serbia

Higijenski status kontaktnih površina pri rukovanju hranom u kantinama državnih škola grada Novog Sada, Srbija

Milka Popović*†, Milan Ž. Baltić‡, Vera Gusman*†, Radivoje Andjelković§, Radmila Velicki*†, Jelena Bjelanović*†, Radmila Mitrović‖, Jelena Janjić‡

***University of Novi Sad, Faculty of Medicine, Novi Sad, Serbia; †Institute of Public Health of Vojvodina, Novi Sad, Serbia; ‡University of Belgrade, Faculty of Veterinary Medicine, Belgrade, Serbia; §Ministry of Defence of the Republic of Serbia, Military Health Department, Belgrade, Serbia; ‖Institute of Meat Hygiene and Technology, Belgrade, Serbia**

Abstract

Background/Aim. Establishing a food safety control system is extremely important in preventing diseases associated with foodborne pathogens. The aim of this study was to examine the hygiene status of food contact surfaces and the application of good hygiene practices by food handlers in school canteens. **Methods.** A total of 10,366 swabs were taken from food contact surfaces, including food handler's hands from public school canteens in Novi Sad, Serbia, over ten years (2008–2017), covering voluntary good hygiene practices and obligatory Hazard Analysis Critical Control Points (HACCP) implementation periods. **Results.** Statistically significant differences ($p < 0.05$) in aerobic colony counts (ACCs) on surfaces between two examined periods were found. A general positive trend regarding the reduction of microbial contamination of food contact surfaces was observed. The percentage of surfaces swabs with ACCs above 2.48 log CFU/cm^2 significantly decreased ($R^2 = 0.453$) during the study period, and the percentage of coagulase-positive *Staphylococcus* in the swabs also decreased, but not significantly ($R^2 = 0.264$), and average annual *Enterobacteriaceae* counts above the established limit values on surfaces significantly decreased ($R^2 = 0.442$) over the years. A significantly higher ($p < 0.05$) percentage of workers' hands harbored ACCs, coagulase-positive *Staphylococcus,* and *Enterobacteriaceae* above the established limits than the equipment or work surfaces. **Conclusion.** The results obtained showed the proper implementation of good hygiene practices concerning food contact surfaces, but the implementation of good personal hygiene practices needs enhanced supervision.

Key words:
enterobacteriae; hygiene; public health; school; serbia; surface properties; staphylococcus.

Apstrakt

Uvod/Cilj. Uspostavljanje sistema kontrole bezbednosti je izuzetno važno u prevenciji bolesti povezanih sa patogenima koje se prenose hranom. Cilj ovog istraživanja bio je da se utvrdi higijenski status kontaktnih površina i primena dobre higijenske prakse pri rukovanju hranom u školskim kantinama. **Metode.** Ukupno 10 366 briseva uzeto je sa površina koje dolaze u kontakt s hranom i ruku osoblja zaposlenog u školskim kantinama u Novom Sadu u desetogodišnjem periodu (2008–2017). Istraživanje je uključivalo dva perioda: a) dobrovoljnu primenu dobre higijenske prakse i b) obaveznu implementaciju sistema *Hazard Analysis Critical Control Points* (HACCP). **Rezultati.** Statistički značajna razlika ($p < 0,05$) utvrđena je u ukupnom broju aerobnih bakterija (*aerobic colony counts* -ACCs) na površinama. Primećen je opšti pozitivni trend u pogledu smanjenja mikrobiološke kontaminacije površina koje dolaze u kontakt s namirnicama. Učestalost nalaza briseva sa utvrđenim ukupnim ACCs iznad 2,48 log CFU/cm^2 smanjivala se statistički značajno ($R^2 = 0,453$) tokom perioda ispitivanja; učestalost prisustva koagulaza pozitivnih stafilokoka se takođe smanjivala, ali ne statistički značajno ($R^2 = 0,264$), dok se prosečan broj enterobakterija iznad utvrđenih graničnih vrednosti na površinama statistički značajno smanjio tokom godina ($R^2 = 0,442$). Na brisevima ruku ispitanog osoblja utvrđena je statistički značajno viša ($p < 0,05$) učestalost prisustva ukupnog ACCs, koagulaza pozitivnih stafilokoka i enterobakterija iznad utvrđenih granica u odnosu na briseve uzete sa opreme ili radnih površina. **Zaključak.** Dobijeni rezultati pokazuju pravilnu primenu dobre higijenske prakse kada su u pitanju površine koje dolaze u kontakt s hranom, dok implementacija prakse dobre lične higijene zaposlenih zahteva pojačan nadzor.

Ključne reči:
enterobacteriae; higijena; zdravstvena zaštita; škola; srbija; površina, svojstva; staphylococcus.

Correspondence to: Jelena Janjić, University of Belgrade, Faculty of Veterinary Medicine, Bulevar oslobođenja 18, 11 000 Belgrade, Serbia. E-mail: jeckonbg@gmail.com

Introduction

Food safety is one of the main public health challenges. Establishing a food safety control system is essential in preventing diseases associated with foodborne pathogens [1–2]. Along with the elderly and immunocompromised, young children fall in the population groups that are very susceptible to foodborne diseases [3]. School canteens must provide a high level of food safety and personal hygiene to ensure that all food is safe to eat. That implies that all food handlers must practice a high level of personal and food hygiene, including efficient hygiene of all food contact surfaces (FCS), knowing how to store foods at suitable and safe temperatures, and how to maintain cleanliness and prevent cross-contamination [4–5]. Food safety in canteens can be achieved through the application of good hygiene practice (GHP) during food preparation and distribution or the implementation of the Hazard Analysis Critical Control Points (HACCP) system [6–7].

Pathogenic microorganisms, which have the potential to cause food spoilage and food poisoning, are always present in food handling environments. Microorganisms are usually introduced into the food environment through raw materials, water, and employees [1, 8]. Sometimes, the application of good sanitation practices can prevent the growth of these organisms. However, if contamination levels are high or sanitation procedures are inadequate, transient microorganisms can become established, multiply, and become resident [2, 9–10].

The modern approach to food safety also includes complete control of the production process along the entire production chain, from farm to fork [11]. Food safety and quality policy is a set of regulations designed to result in food that will not endanger the health of consumers due to the presence of biological, chemical, or physical hazards above prescribed levels (for some of them, there is zero tolerance) [12, 13]. Numerous bacterial pathogens, such as *Escherichia (E) coli*, *Clostridium difficile*, and *Shigella* spp., can survive for months on dry surfaces and even longer on wet surfaces [14]. There is no doubt that standardization of food products facilitates food trade, and that applies to national and regional specialties, as well as to ready-to-eat foods. However, the fact is that all food intended for human consumption must be safe for human health [4].

Microbial analyses are an essential part of food safety practice and a tool to verify correct system function. Microbiological analysis of FCSs and estimation of the overall number of bacteria are essential in assessing and monitoring general hygiene.

A good food safety monitoring system in public school facilities (including preschool facilities) has been established in the City of Novi Sad, Serbia. Over the past decade, only one foodborne outbreak was recorded in a public kindergarten in Novi Sad. This outbreak was of histamine intoxication from fish and fish products [15].

The aim of this study was to examine the hygiene status of FCSs and to follow the trend in the change of an unacceptable number of the examined group of bacteria in ten years in public school canteens in the City of Novi Sad, Serbia, covering voluntary GHP and obligatory HACCP implementation periods.

Methods

Sampling

There is an annual food safety monitoring program in school canteens adopted and implemented by the Institute of Public Health of Vojvodina, Novi Sad, Serbia. The program provides microbiological testing of FCSs by taking swabs from equipment, surfaces, and hands of the kitchen staff from more than 100 public school food premises that prepare and/or distribute food, during a ten-year period, in the city of Novi Sad, Serbia.

Sampling was performed by trained personnel who completed the swab sampling training program. Each swab was moistened with sterile 1% buffered peptone water (10 mL in a tube), then leaned on the wall of the tube to drain excess liquid. Swabs were swiped on the surfaces delineated by a sterile template (10 × 10 cm), left to right and right to left, five times, and up and down five times. The swabs were returned to the tube aseptically, breaking the stick, and were transported to the laboratory in a cooler box at a maximum temperature of 4 °C. In order to check the hygiene status of FCSs and the implementation of GHP by food handlers over time, a total of 10,366 swabs were taken.

Microbiological methods

To verify the level of contamination, 4–5 samples were taken from each selected canteen twice a year, using the swab technique according to the International System for Standardization (ISO) 18593 standard [16]. For each facility, representative swab samples were taken from different FCSs and classified into three categories: equipment, countertops/working surfaces, and hands. Microbiological analyses included aerobic colony count (ACC), *Enterobacteriaceae* count, and counts of coagulase-positive *Staphylococcus*. All microbial analyses were conducted in an ISO/International Electrotechnical Commission (IEC) 17025:2005 accredited laboratory (Institute of Public Health of Vojvodina, Center for Hygiene and Human Ecology/Department for Sanitary Bacteriology, Novi Sad, Serbia).

Two periods were covered during the ten-year investigation period – before and after mandatory HACCP implementation (effective from May 31, 2011, with practical application started in 2012). Different methods were used for the microbiological analysis of swabs in these two periods. Until 2012 (the first period of investigation), swabs were analyzed referring to an internal guidance document adopted by the Institute of Public Health of Vojvodina, with established ACC limit values based on achieved GHP performed on the premises over a long period. From 2012 and on, after obligatory HACCP implementation, all swabs were analyzed according to ISO for ACC [17], *Enterobacteriaceae* [18–19], and coagulase-positive *Staphylococcus* counts [20, 21]. After appropriate storage and transport, a microbiological analysis should start as soon as possible, no later than four hours after sampling. Bacterial counts recovered from swabs taken from surfaces of defined size enclosed by templates were expressed as colony forming unit (CFU)/cm^2, while counts recovered from indeterminate surfaces (small parts of machines and apparatus used in food preparation, curved surfaces, hands, etc.) were expressed as CFU/mL. All bacterial counts were transformed into logarithms. The microbiological criteria specific to the type of FCS were identical before and after HACCP implementation. The unacceptable number of ACCs on smooth surfaces – fine porcelain, glass, stainless steel, and metal is > 1 log CFU/cm^2; for other wooden, plastic, and stone surfaces > 1.48 log CFU/cm^2; for equipment and dishes – cutlery, plates, pots, etc. > 2 log CFU/cm^2; for bottles and other containers for liquid products > 0.3 log CFU/cm^2. The microbiological criterion for an unacceptable number of ACCs for food handlers' hands is > 2.30 log CFU/cm^2. Limit value for *Enterobacteriaceae* count, for all types of FCSs, is > 0.3 log CFU/cm^2 [22].

To assess the effectiveness of applied hygiene practices in school kitchen canteens, we divided the established number of ACC into four classes: Class I (≤ 2.10 log CFU/cm^2 or CFU/mL); Class II (results between 2.11 and 2.30 log CFU/cm^2 or CFU/mL); Class III (results between 2.31 and 2.48 log CFU/cm^2 or CFU/mL); and Class IV (> 2.48 log CFU/cm^2 or CFU/mL). Class I indicates a good standard of applied GHP, Classes II and III correspond to the satisfactory application of GHP, and Class IV represents unsatisfactory hygiene practice.

Statistical analysis

The data were first analyzed using descriptive statistics and presented as frequency and percentage (%) for categorical data. For numerical data, bacterial counts were expressed as mean ± standard error (SE). For statistical analysis, all bacterial counts were transformed into logarithms. Statistical analysis of the results was conducted using Microsoft Excel 2010 and GraphPad Prism software, version 7.00 for Windows (GraphPad Software, San Diego, California, USA, www.graphpad.com). The average total ACC was compared to the average ACC for each year individually by one-factor analysis of variance (ANOVA), while Student's t-test was performed to compare the average colony count separately. Statistical significance was at the level of $p < 0.05$. The coefficient of determination (R^2) was used to evaluate the significance of the bacterial count trends for ACC, coagulase-positive *Staphylococcus*, and *Enterobacteriaceae* above the established limits between 2008 and 2017 (Microsoft Office, Excel, 2010). Trends with R^2 values exceeding 0.30 were considered significant [23]. The χ^2 test was used to compare the percentages of incidence of ACC, coagulase-positive *Staphylococcus*, and *Enterobacteriaceae* on the examined surfaces.

Results

The total number of swabs in the four ACC classes over ten years is shown in Table 1. Table 1 shows the period before and after the implementation of HACCP. The incidence of Class IV findings was 10.86% in the first study period and 7.24% in the second. In all observed ACC classes, the prevalence of this type of bacteria was higher in the first study period.

Table 2 shows that the highest average ACC during the

Table 1

Number (percentage) of surfaces from school food preparation facilities with ACCs categorized in four classes, before and after mandatory HACCP implementation

Class	Obligatory HACCP (years)					Mandatory HACCP (years)						
	2008	2009	2010	2011	Σ	2012	2013	2014	2015	2016	2017	Σ
I	508 (80.95)	1,003 (81.55)	981 (79.78)	1,049 (84.62)	3,541 (81.83)	1,067 (87.46)	1,007 (82.54)	734 (74.83)	885 (95.99)	873 (97.43)	786 (98.20)	5,352 (88.63)
II	33 (5.29)	44 (3.54)	80 (6.47)	40 (3.26)	197 (4.55)	35 (2.89)	45 (3.68)	55 (5.61)	15 (1.63)	7 (0.78)	6 (0.77)	163 (2.70)
III	7 (1.06)	38 (3.10)	53 (4.32)	21 (1.72)	119 (2.75)	12 (0.96)	18 (1.50)	30 (3.06)	11 (1.19)	10 (1.12)	5 (0.64)	86 (1.43)
IV	80 (12.70)	145 (11.81)	116 (9.43)	129 (10.40)	470 (10.86)	106 (8.69)	150 (12.28)	161 (16.41)	11 (1.19)	6 (0.67)	3 (0.39)	437 (7.24)
Total (n)	628	1,230	1,230	1,239	4,327	1,220	1,220	980	922	896	800	6,038

Class I (≤ 2.10 log CFU/cm^2 or CFU/mL); Class II (results between 2.11 and 2.30 log CFU/cm^2 or CFU/mL); Class III (results between 2.31 and 2.48 log CFU/cm^2 or CFU/mL) and Class IV (> 2.49 log CFU/cm^2 or CFU/mL).
ACC – aerobic colony count; HACCP – Hazard Analysis Critical Control Points; CFU – colony forming units.
Values are expressed as number (percentages).

Table 2

Average aerobic colony count (log CFU/cm^2) determined on surfaces in school facilities for preparation and distribution of food, before and after mandatory HACCP implementation

Mandatory HACCP implementation	n	Mean values	SE
Before			
2008	627	1.42 ^{A}	0.051
2009	1,230	1.48 $^{A, a}$	0.041
2010	1,230	1.40 ^{A}	0.039
2011	1,240	1.06 $^{B, a}$	0.039
Σ	4,327	1.29 ^{b}	0.022
After			
2012	1,220	1.13 $^{A, a}$	0.030
2013	1,220	1.09 ^{A}	0.034
2014	981	1.22 $^{A, a}$	0.037
2015	922	0.64 $^{B, a}$	0.021
2016	896	0.26 $^{C, a}$	0.018
2017	800	0.75 $^{D, a}$	0.022
Σ	6,039	1.03 ^{b}	0.012

Different letters (A, B, C, D) indicate statistically significant differences ($p < 0.05$) between annual colony counts separately; different letters (a, b) indicate statistically significant differences ($p < 0.05$) only between the average aerobic colony count (Σ) and annual colony count separately.
CFU – colony forming unit; HACCP – Hazard Analysis Critical Control Points; SE – standard error.

examined period was 1.48 ± 0.041 log CFU/cm^2 in 2009, and the average ACC during all years was 1.13 ± 0.010 log CFU/cm^2. A comparison of average ACCs on surfaces in school facilities before HACCP implementation and the annual average count is shown in Table 2. There were significant differences between ACCs (log CFU/cm^2) of FCCs in school facilities that prepare and distribute food during the ten-year period. In the first trial period (2008, 2009, 2010, 2011), before the introduction of the HACCP system, the average ACCs in 2011 (1.06 ± 0.039 log CFU/cm^2) were significantly lower ($p < 0.05$) than the annual ACCs in previous years and the average ACCs for this period.

The average ACC in the first trial period before HACCP implementation (1.29 log CFU/cm^2) was significantly higher ($p < 0.05$) than the average ACC in the second period after HACCP implementation (1.03 log CFU/cm^2).

The ACCs, when calculated as annual percentages and categorized in the four classes, showed large variations in the examined years (Figure 1). The percentage of swabs with ACCs up to 2 log CFU/cm^2 increased significantly over the years. The percentage of Class I ACCs significantly increased ($R^2 = 0.493$) during the examined period (Figure 1a).

Trend analyses of the annual percentages of ACCs on surfaces from school facilities that indicated acceptable GHP from 2008 to 2017 are shown in Figures 1b and 1c. A significant percentage of surfaces was categorized as Class II ($R^2 = 0.502$) for the tested period from 2008–2018. During 2010 and 2014, more surfaces were categorized as Class II than in other examined years.

On the examined surfaces, the percentage of Class III ACCs decreased from 2008–2017. The highest annual percentages of Class III ACCs were found on surfaces in 2010 and 2014, but there was no significant decrease ($R^2 = 0.190$) of Class III ACCs during the years.

Importantly, the percentage of surfaces with ACCs above 2.48 log CFU/cm^2 (Class IV) significantly decreased ($R^2 = 0.453$) during the study period. The data obtained indicate that the application of HACCP has generally improved the microbiological status of surfaces in school facilities (Figure 1d).

The prevalence of coagulase-positive *Staphylococcus* in the swabs was highest in 2009 (1.30% of swabs were positive), but in the following years, this percentage decreased, although not significantly ($R^2 = 0.264$) (Figure 2).

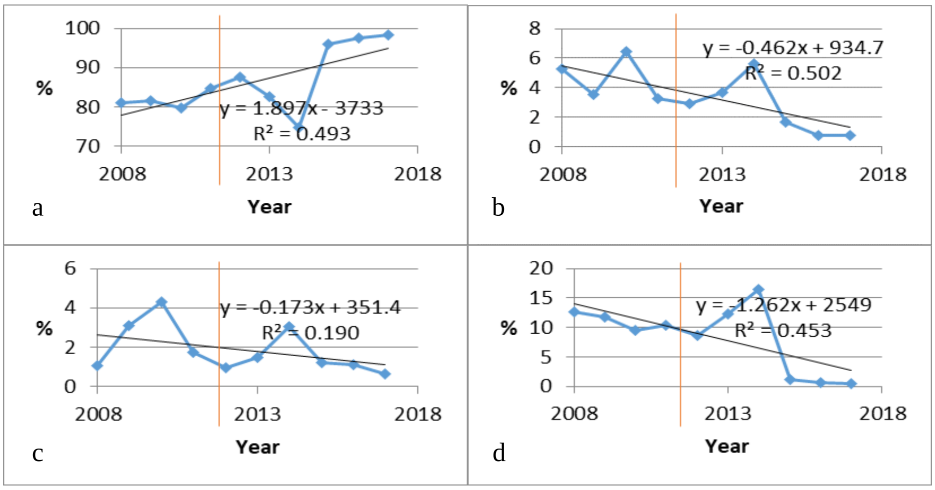

Fig. 1 – Annual percentage of four levels of aerobic colony counts isolated from surfaces in school facilities from 2008–2017.
Vertical red line represents separation of two periods.
a – Class I (up to 2.10 log CFU/cm^2); b – Class II (from 2.11 to 2.30 log CFU/cm^2); c – Class III (2.31–2.48 log CFU/cm^2); d – Class IV (over 2.48 log CFU/cm^2).
CFU – colony forming unit.

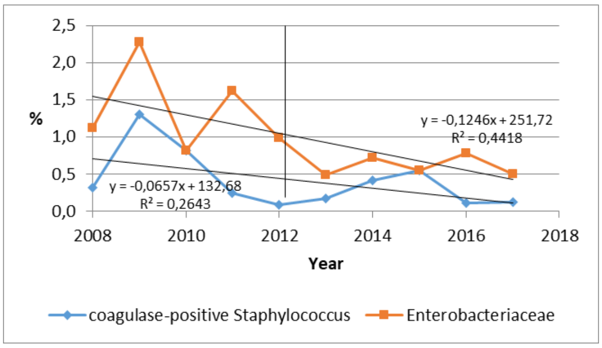

Fig. 2 – Annual percentage of surfaces in school facilities that contained coagulase-positive *Staphylococcus* and surfaces with *Enterobacteriaceae* counts above the established limit values.
The vertical black line represents the separation of two periods.

Average annual *Enterobacteriaceae* counts above the established limit values on surfaces significantly decreased ($R^2 = 0.442$) over the years and especially began to decline after the introduction of HACCP in 2012 (Figure 2).

Figure 3 shows the percentages of isolated bacteria above the established limits on three types of examined surfaces. A significantly higher ($p < 0.05$) percentage (10.53) of workers' hands harbored ACCs levels above the established limits than did work surfaces (6.21) or equipment (3.96). Moreover, a significantly lower ($p < 0.05$) percentage of sampled equipment harbored this group of bacteria than the work surfaces. A significantly higher ($p < 0.05$) percentage of swabs that harbored coagulase-positive *Staphylococcus* above the established limits were taken from workers' hands (3.60) than from equipment (0.17) or work surfaces (0.45). In addition, a significantly higher ($p < 0.05$) percentage of workers' hands (4.36) harbored *Enterobacteriaceae* above the established limits than the equipment (1.12).

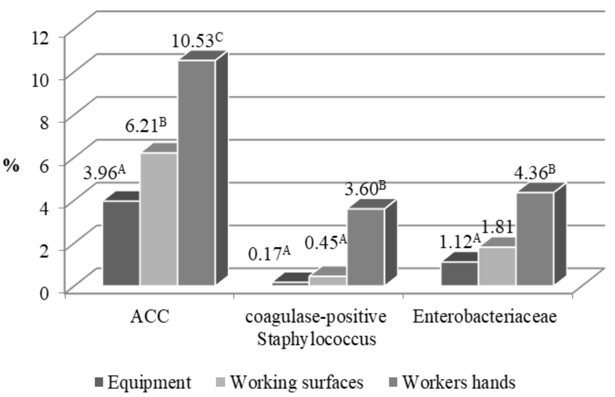

Fig. 3 – Total percentage of three surface types in school facilities that contained isolated aerobic colony count (ACC), coagulase-positive *Staphylococcus* and *Enterobacteriaceae* over the established limits during the 10-year study.
Different letters (A, B, C) indicate significant differences ($p < 0.05$) between the examined bacteria groups on the examined surfaces separately.

Discussion

Many authors defined different limits for satisfactory or unsatisfactory ACC [24–27]. In our case, ACCs were transformed from ACCs into log base 10, and all results were grouped based on the limit values of GHP. Table 1 shows the highest percentage of FCSs analyzed, throughout the entire test period, corresponding to the period when GHP was applied (Class I). Factors influencing the count of bacteria on FCSs are the season of the year, climate conditions, type of food contact material, etc. [27–30]. So far, the results are encouraging since the ACC of the largest percentage of FCSs in food preparation and distribution facilities in school institutions belonged to Class I, with low ACCs, indicating the good application of GHP. However, throughout the entire test period, the percentage of unsatisfactory ACCs was significant. That indicates that monitoring procedures, including microbial analyses, play a significant part in improving food hygiene and safety in the examined facilities [31].

Data from Table 2 indicate that general hygiene satisfied the strictest limit values (under 2 log CFU/cm^2) in all facilities. It can be concluded that the ACC levels decreased over the years, except in 2014, where the annual average ACC was significantly higher ($p < 0.05$) than the all-year average. That could be explained by the extremely high temperatures and humidity recorded in 2014. In Serbia, in the period from 1951 to 2017, 2014 was the rainiest and the hottest year in the history of temperature measurement [32]. Climate conditions have an impact on food safety, incidence, and prevalence of foodborne disease [30, 33–34]. Temperature and precipitation patterns are closely related to transport, survival, and growth of foodborne bacteria [35].

From the results shown, we can notice variations in the percentage of Class I ACCs, and variations occurred after the introduction of HACCP but generally, except for 2014, the percentage of Class I swabs increased year by year. That indicates a gradual improvement in hygiene and the appropriate application of GHP (Figure 1).

Low counts of coagulase-positive *Staphylococcus* were recorded in samples from food and work surfaces in a school catering system [36], and our data also agreed with low counts of this bacterium reported by Willis et al. [37]. A lack in temperature maintenance together with a high microbial number can lead to outbreaks of staphylococcal food poisoning [38], and could also explain some increased incidence of this pathogen in individual years of our study (Figure 2). Coagulase-positive *Staphylococcus* includes the pathogenic species *Staphylococcus aureus*, which is mostly associated with human skin and can be, thus, easily introduced into the food chain via improper food handling [39]. High levels of *Enterobacteriaceae* were ascribed by Garayoa et al. [25] to a lack of hygiene during processing. *E. coli*, a member of the family *Enterobacteriaceae*, normally lives in animal and human intestinal tracts from where it can directly spread to food, but it can also contaminate food by various other indirect pathways. Water used during food preparation and for cleaning surfaces can also be contaminated with this pathogen. The presence of *E. coli* on surfaces, such as those examined in the current study, indicates direct or indirect fecal contamination from the hands of food handlers or contaminated work surfaces or equipment [40].

Data from Figure 3 indicate the role of food handlers is truly significant in the transmission of foodborne diseases. Many authors emphasize the importance of maintaining and improving food handling practices [40–42].

Conclusion

In this ten-year study, surfaces in most school facilities had satisfactory ACCs, as measured by the surface swab technique. However, the microbiological status of workers' hands showed a need for much better practice of personal hygiene procedures. Considering all types of surfaces examined, school canteens in Novi Sad, Serbia, showed the satisfactory application of HACCP with regard to environmental hygiene and procedures. The significant improvement in the application of GHP after the introduction of HACCP in terms of *Enterobacteriaceae* and coagulase-positive *Staphylococcus* numbers attests to appropriate control measures and adequate knowledge of food hygiene principles by the food handlers. The effectiveness of the HACCP system was confirmed, and the general average improvement of hygiene conditions in the examined canteens was also demonstrated. However, for these types of facilities, the need for enhanced supervision to support the proper implementation of good personal hygiene practices should be seriously considered.

Acknowledgment

This paper was supported by the Ministry of Education, Science, and Technological Development of the Republic of Serbia, Project "Selected Biological Hazards to the Safety/Quality of Food of Animal Origin and the Control Measures from Farm to Consumer" (TR 31034) and Project "Production of hard cheese with added value from milk produced in organic and self-sustaining systems" (TR 31095).

The authors would like to express their sincere gratitude to Dr. Sheryl Avery and Professor Sava Bunčić for their assistance in the preparation of the paper.

R E F E R E N C E S

1. *Lee H, Abdul Halim H, Thong K, Chai, L.* Assessment of food safety knowledge, attitude, self-reported practices, and microbiological hand hygiene of food handlers. Int J Environ Res Public Health 2017; 14(1): 55.
2. *Zanin LM, da Cunha DT, de Rosso VV, Capriles VD, Stedefeldt E.* Knowledge, attitudes and practices of food handlers in food safety: An integrative review. Food Res Int 2017; 100 (Pt 1): 53–62.
3. *Odeyemi OA.* Public health implications of microbial food safety and foodborne diseases in developing countries. Food Nutr Res 2016; 60: 29819.
4. *Janjić J, Katić V, Ivanović J, Bošković M, Starčević M, Glamočlija N,* et al. Temperatures, cleanliness and food storage practices in domestic refrigerators in Serbia, Belgrade. Int J Consum Stud 2015; 40(3): 276–82.
5. *Husain NRN, Muda WMW, Jamil NIN, Hanafi NNN, Rahman RA.* Effect of food safety training on food handlers' knowledge and practices: A randomized controlled trial. Br Food J 2016; 118(4): 795–808.
6. *Vo TH, Le NH, Le ATN, Minh NNT, Nuorti JP.* Knowledge, attitudes, practices and training needs of food-handlers in large canteens in Southern Vietnam. Food Control 2015; 57: 190–4.
7. *Osimani A, Milanović V, Aquilanti L, Polverigiani S, Garofalo C, Clementi F.* Hygiene auditing in mass catering: a 4-year study in a university canteen. Public Health 2018; 159: 17–20.
8. *Ye K, Wang J, Han Y, Wang C, Qi C, Ge X.* Investigation on microbial contamination in the cold storage room of domestic refrigerators. Food Control 2019; 99: 64–7.
9. *Gusman V, Medić D, Jelesić Z, Mihajlović-Ukropina M, Milošević V, Považan A.* Listeria monocytogenes isolated in ready-to-eat food in South Bačka region of Vojvodina province, Serbia. Arch Biol Sci 2014; 66(1): 11–4.
10. *Tóth AJ, Koller Z, Illés CB, Bittsánszky A.* Development of conscious food handling in Hungarian school cafeterias. Food Control 2017; 73: 644–9.
11. *Aung MM, Chang YS.* Traceability in a food supply chain: Safety and quality perspectives. Food control 2014; 39: 172–84.
12. *Drew CA, Clydesdale FM.* New food safety law: effectiveness on the ground. Crit Rev Food Sci Nutr 2015; 55(5): 689–700.
13. *King T, Cole M, Farber JM, Eisenbrand G, Zabaras D, Fox EM,* et al. Food safety for food security: Relationship between global megatrends and developments in food safety. Trends Food Sci Technol 2017; 68: 160–75.
14. *Janjić J, Ćirić J, Bošković M, Šarčević D, Popović M, Baltić MŽ.* Consumer Responsibility for Food Safety. Res Agricul 2017; 3(1): 1.
15. *Petrović J, Babić J, Jakšić S, Kartalović B, Ljubojević D, Ćirković* M. Fish Product-Borne Histamine Intoxication Outbreak and Survey of Imported Fish and Fish Products in Serbia. J Food Prot 2016; 79(1): 90–4.
16. *International Organization for Standardization.* ISO 18593:2010. Microbiology of food and animal feeding stuffs – Horizontal methods for sampling techniques from surfaces using contact plates and swabs. Geneva: ISO; 2010.
17. *International Organization for Standardization.* ISO 4833:2003. Microbiology of food and animal feeding stuffs: horizontal method for the enumeration of microorganisms. Colony count technique at 30°C. Geneva: ISO; 2003.
18. *International Organization for Standardization.* ISO 21528–1:2004. Microbiology of food and animal feeding stuffs. Horizontal methods for the detection and enumeration of *Enterobacteriaceae*. Part 1: Detection and enumeration by MPN technique with pre-enrichment. Geneva: ISO; 2004.
19. *International Organization for Standardization.* ISO 21528–2:2004. Microbiology of food and animal feeding stuffs. Horizontal methods for the detection and enumeration of *Enterobacteriaceae*. Part 2: colony-count method. Geneva: ISO; 2004.
20. *International Organization for Standardization.* ISO 6888–1:1999. Microbiology of food and animal feeding stuffs – Horizontal method for the enumeration of coagulase-positive staphylococci (*Staphylococcus aureus* and other species) – Part 1: Technique using Baird-Parker agar medium. Geneva: ISO; 2004.
21. *Regulation.* Regulation on General and Specific Food Hygiene Requirements at any Stage of Production, Processing and Trade. ("Official Gazette RS" No 30/10.
22. *Regulation.* Guide for the Application of Microbiological Criteria for Food. Belgrade: Ministry of Agriculture, Forestry and Water Supply Trade; 2011. p. 1–63.
23. *Adamse P, Van der Fels-Klerx HJI, de Jong J.* Cadmium, lead, mercury and arsenic in animal feed and feed materials – trend analysis of monitoring results. Food Addit Contam Part A Chem Anal Control Expo Risk Assess 2017; 34(8): 1298–311.
24. *Doménech-Sánchez A, Laso E, Pérez MJ, Berrocal CI.* Microbiological levels of randomly selected food contact surfaces in hotels located in Spain during 2007–2009. Foodborne Pathog Dis 2011; 8(9): 1025–9.
25. *Garayoa R, Díez-Leturia M, Bes-Rastrollo M, García-Jalón I, Vitas AI.* Catering services and HACCP: temperature assessment and surface hygiene control before and after audits and a specific training session. Food Control 2014; 43: 193–8.
26. *De Oliveira ABA, da Cunha DT, Stedefeldt E, Capalonga R, Tondo EC, Cardoso MRI.* Hygiene and good practices in school meal services: Organic matter on surfaces, microorganisms and health risks. Food Control 2014; 40: 120–6.
27. *Djekić I, Kuzmanović J, Anđelković A, Saračević M, Stojanović MM, Tomašević I.* Effects of HACCP on process hygiene in different types of Serbian food establishments. Food Control 2016; 60: 131–7.

28. *Taché J, Carpentier B*. Hygiene in the home kitchen: changes in behaviour and impact of key microbiological hazard control measures. Food Control 2014; 35(1): 392–400.
29. *De la Cruz Garcia C, Moragas GS, Nordqvist D*. Food Contact Materials. In: *Motarjemi Y, Lelieveld H,* editors. Food Safety Management: A Practical Guide for the Food Industry. Amsterdam, Boston, Heidelberg, London, New York, Oxford, Paris, San Diego, San Francisco, Singapore, Sydney, Tokyo: Academic Press; 2014; p. 397–419.
30. *Djekić I, Kuzmanović J, Anđelković A, Saračević M, Stojanović MM, Tomašević I*. Relationships among hygiene indicators in takeaway foodservice establishments and the impact of climatic conditions. J Appl Microbiol 2016; 121(3): 863–72.
31. *Garayoa R, Yánez N, Díez-Leturia M, Bes-Rastrollo M, Vitas AI*. Evaluation of prerequisite programs implementation and hygiene practices at social food services through audits and microbiological surveillance. J Food Sci 2016; 81(4): M921–7.
32. The Republic of Serbia. Republic Hydrometeorological Service of Serbia. Seasonal Bulletin for Serbia. Climate Monitoring and Climate Monitoring Department, Sector of the National Center for Climate Change. Development of climate models and risk assessment of natural disasters. Climatological Data for 2014. Belgrade, Serbia: Republic Hydrometeorological Service of Serbia; 2014. (Serbian)
33. *Bezirtzoglou C, Dekas K, Charvalos E*. Climate changes, environment and infection: facts, scenarios and growing awareness from the public health community within Europe. Anaerobe 2011; 17 (6): 337–40.
34. *Holvoet K, Sampers I, Seynnaeve M, Uyttendaele M*. Relationships among hygiene indicators and enteric pathogens in irrigation water, soil and lettuce and the impact of climatic conditions on contamination in the lettuce primary production. Int J Food Microbiol 2014; 171: 21–31.
35. *Liu C, Hofstra N, Leemans R*. Preparing suitable climate scenario data to assess impacts on local food safety. Food Res Int 2015; 68: 31–40.
36. *Petruzzelli A, Osimani A, Tavoletti S, Clementi F, Vetrano V, Di Lullo S,* et al. Microbiological quality assessment of meals and work surfaces in a school-deferred catering system. Int J Hosp Manag 2018; 68: 105–14.
37. *Willis C, McLauchlin J, Amar C, Sadler-Reeves L, Elviss N, Aird H,* et al. Assessment of the microbiological safety of precut fruit from retail and catering premises in the United Kingdom. J Food Prot 2016; 79(4): 598–604.
38. *Mossong J, Decruyenaere F, Moris G, Ragimbeau C, Olinger CM, Johler S,* et al. Investigation of a staphylococcal food poisoning outbreak combining case-control, traditional typing and whole genome sequencing methods, Luxembourg, June 2014. Euro Surveill 2005; 20(45): doi: 10.2807/1560-7917.ES.2015.20.45.30059.
39. *Fetsch A, Contzen M, Hartelt K, Kleiser A, Maassen S, Rau J, Strommenger B. Staphylococcus aureus* food-poisoning outbreak associated with the consumption of ice-cream. Int J Food Microbiol 2014; 187: 1–6.
40. *Rosmawati N, Manan W, Izani N, Nurain N*. Evaluation of environmental hygiene and microbiological status of selected primary school canteens. Health and the Environment Journal 2014; 5(3): 110–27.
41. *Campos AKC, Cardonha ÂMS, Pinheiro LBG, Ferreira NR, de Azevedo PRM, Stamford TLM*. Assessment of personal hygiene and practices of food handlers in municipal public schools of Natal, Brazil. Food Control 2009; 20(9): 807–10.
42. *Park SH, Kwak TK, Chang HJ*. Evaluation of the food safety training for food handlers in restaurant operations. Nutr Res Pract 2010; 4(1): 58–68.

Received on May 21, 2020
Revised on March 4, 2021
Accepted on April 27, 2021
Online First May 2021