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Journal of Consumer Protection and Food Safety
Journal für Verbraucherschutz und Lebensmittelsicherheit

ISSN 1661-5751
Volume 15
Number 1

J Consum Prot Food Saf (2020) 15:73-82
DOI 10.1007/s00003-019-01241-5

Journal of Consumer Protection and Food Safety (2020) 15:73–82
https://doi.org/10.1007/s00003-019-01241-5

Journal of Consumer Protection and Food Safety
Journal für Verbraucherschutz und Lebensmittelsicherheit

RESEARCH ARTICLE

Exploring food safety risk factors in selected school foodservice establishments in Mexico

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Received: 22 January 2019 / Revised: 2 July 2019 / Accepted: 12 July 2019 / Published online: 20 July 2019

Abstract

The monitoring of good hygienic practices (GHP) in school foodservice establishments (SFS) ensures children's health and identifies the risk factors that threaten food safety. This study examined the hygienic-sanitary profile of selected Mexican SFS and identified safety risk factors. Seven SFS and their corresponding personnel were submitted for GHP inspection based on Mexican guidelines, WHO (World Health Organization) Five Keys to Safer Food, and demographic information. Additionally, 162 samples taken from surfaces, personnel's hands, food sources, tap water and meals were collected for microbial assessment (total coliforms, *Escherichia coli* and aerobic count, *Salmonella*, *Listeria monocytogenes*, *Staphylococcus aureus*). Personnel were literate women who received annual GHP training and achieved a satisfactory proficiency score ($74 \pm 4.2\%$) based primarily on their attitudes according to WHO questionnaires. SFS showed a satisfactory GHP compliance level ($74 \pm 5.4\%$) according to the Mexican guidelines, and a lack of GHP protocols was the main common risk factor. All SFS shared similar microbial rates across the sample categories: aerobic count (87.7%), *S. aureus* (56.2%), total coliforms (47.5%), *Salmonella* (16.0%), *E. coli* (9.3%) and *Listeria monocytogenes* (0%). Food sources and personnel were identified as risk factors in terms of microbial quality. GHP compliance level was a predictor of the microbial quality of SFS with respect to *S. aureus* rates ($r = -0.747$, $p = 0.050$) and coliform ($r = -0.774$, $p = 0.041$). The hygienic-sanitary profile of Mexican SFS was observed on the basis of empirical knowledge of the personnel, which justifies the implementation of standardized GHP protocols for improving personnel proficiency and maintaining sanitary controls.

Keywords Food safety · Hygiene · Pathogens · Schools

1 Introduction

One of the main public health concerns worldwide is foodborne disease (FBD), which impacts consumer health, economic development and social stability (Newell et al. 2010). The WHO has estimated that there are 600 m annual cases of FBD associated with pathogenic microorganisms or chemical substances, resulting in 420,000 deaths each year (WHO 2017). The largest morbidity (40%) and mortality (30%) rates derived from FBD correspond to children, and diarrhoea is considered the main clinical manifestation (WHO 2017). In Mexico, FBD rates are on the rise; the Minister of Epidemiology reports that annually, there are > 4,500,000 cases of diarrhoea and bacterial food poisoning nationwide (DGE 2017). Other notable diseases related to FBD in Mexico include Hepatitis A, Cholera, Typhoid, and Salmonellosis. Similarly, the main target population corresponds to children (DGE 2017).

The Minister of Health regulates food safety in Mexico under the Official Mexican Guideline "NOM-251-SSA1-2009" (DOF 2010). The guideline establishes criteria to implement good hygienic practices (GHP), standard operating procedures, hazard analysis critical control points and personnel training for the production of innocuous and

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healthful foods (DOF 2010), which is the basic model implemented in many countries (Walker et al. 2003; Djekic et al. 2014). Legal guidelines of "NOM-251-SSA1-2009" should be followed by any food establishment in Mexico (DOF 2010). In particular, school foodservice establishments (SFS) are considered an important concern for ensuring food safety, given that any incident can affect the health of children (Machado et al. 2014).

Ensuring the food safety of the meals produced by SFS has been complex and challenging. During the period of 2012–2019, News media reported several FBD outbreaks in SFS affecting approximately 800 children in Mexico (Reyes 2012; Rosas 2012; Martínez 2017; Morales 2018; Escamilla 2018; Tinoco 2019; Ladino 2019). The main ethological agents identified in these outbreaks were *Salmonella*, *Escherichia coli* and *Staphylococcus aureus,* which are some of the main FBD bacteria recognized worldwide (WHO 2017). Many of these bacteria are related to faecal–oral transmission, which may reflect the hygienic practices of food handlers (Todd et al. 2008). Castañeda-Ruelas and Jiménez-Edeza (2017) noted the practices of food handlers as a potential vehicle of enteric bacteria into the SFS in Mexico.

Several risk factors for food safety have been widely described: improper cooking procedures, time–temperature abuse during storage, cross-contamination in the foodservice setting, inadequacy of hygienic and sanitation programmes, and acquisition of unsafe food sources (WHO 2006; Abdul and Mohd 2013). Food handlers as pathogen carriers have also been reported as a related risk factor (Todd et al. 2008). Several studies have emphasized that knowledge of GHP and educational training of food handlers are integral components of their proficiency for producing innocuous food and minimizing the risk of FBD (Chapman et al. 2010; Webb and Morancie 2015). Additionally, microbial monitoring of foodservice establishments is useful to determine contamination sources and establish appropriate hygiene and sanitation programmes (Yoon et al. 2008).

The food safety compliance of SFS in Mexico and the associated risk factors need to be investigated to minimize FBD and strengthen GHP adherence. The aim of this study was to evaluate the compliance of the hygienic-sanitary practices of certain Mexican SFS and their personnel and to identify the food safety risk factors via an evaluation of Mexican GHP guidelines, personnel proficiency for preparing food safety and the microbiological assessment of SFS.

2 Materials and methods

2.1 Design of study

A cross-sectional study involving seven SFS in Mexico was carried out from September 2015 to February 2016. This study was conducted with the voluntary participation and mutual agreement of the SFS, which were identified with capital letters (A–G). The SFS were characterized by having similar infrastructures, operating on a full-time schedule (8 h) serving food for lunch, and adapting a kitchen and a canteen inside the school's facilities. The SFS had 5 ± 2 food handlers per kitchen (Fig. 1) that fed a range of 220–450 children under a weekly diet programme. The design of the study included three evaluations:

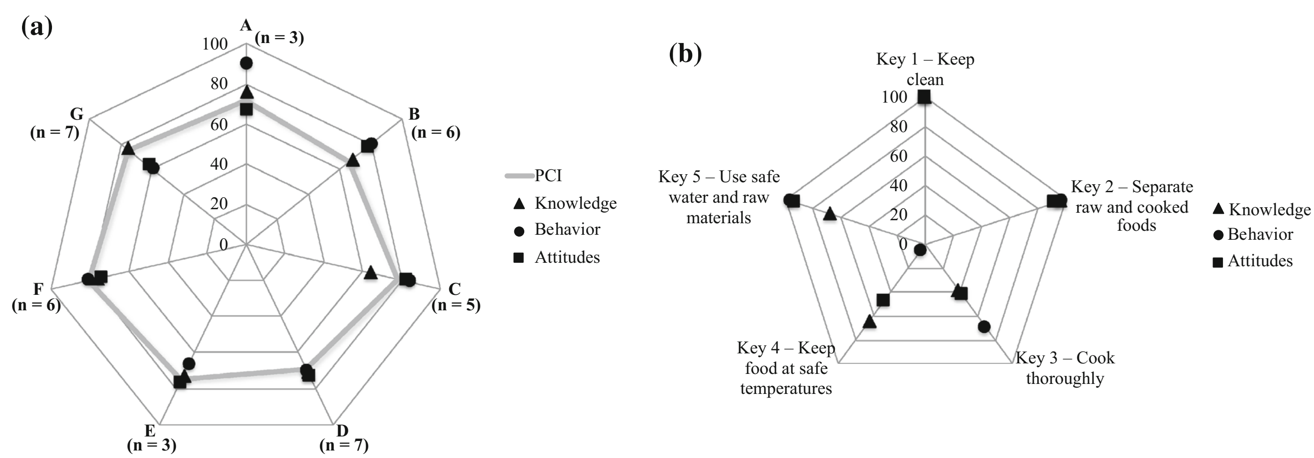

Fig. 1 Personnel proficiency score was calculated in the selected school foodservice establishments in Mexico. Scores of knowledge, attitudes, and behaviour exhibited by personnel belonging to selected school foodservice establishments (**a**). The value within the parenthesis indicates the number of food handlers evaluated. Overall scores were obtained by a section of the questionnaire designed by the WHO (**b**). The compliance scale for the personnel competence index (% PCI) was as follows: good (80–100%), satisfactory (60–79%), unsatisfactory (40–59%), and very unsatisfactory (1–39%)

(1) GHP compliance level of SFS via Official Mexican GHP Guideline (NOM-251-SSA1-2009) inspection;
(2) proficiency of food personnel throughout questionnaires of WHO five-keys for food safety and demographic information recording; and
(3) microbiological quality assessment of environmental, personnel and food served in SFS.

The personnel were not informed about the inspection day in order to avoid biases in the results.

2.2 Personnel proficiency score (PCI)

Face-to-face interviews were performed to record demographic information of food personnel belonging to the SFS (Table 1). Furthermore, a questionnaire designed by the WHO (2006) was applied to the measurement of personnel proficiency for the hygienic preparation of food by integrating the score of knowledge, attitudes and behaviour of personnel. The questionnaire included 31 questions categorized in sections of knowledge (n = 11), attitudes (n = 10) and behaviour (n = 10), and based on the five keys to safer food: keep clean (Key 1), separate raw and cooked food (Key 2); cook thoroughly (Key 3); keep food at safe temperatures (Key 4); and use safe water and raw materials (Key 5). The permissible answers for knowledge, attitudes and behaviour questionnaires were two (true or false), three (agree, not sure and disagree) and five (always, most of the time, sometimes, not often, and never), respectively. The questionnaire forms and responses are available at the WHO site (WHO 2006). The compliance scale assigned for PCI was based on the percentage value obtained from questions correctly answered: good (80–100%), satisfactory (60–79%), unsatisfactory (40–59%), and very unsatisfactory (1–39%). A total of 37 food handlers of SFS participated in the verbal interviews and completed the questionnaires.

Table 1 Demographic characteristics of the food handlers employed in selected schools in Mexico

Characteristics	n	%
Gender		
Females	37	100
Males	0	0
Age range		
25–35	14	38
36–55	21	57
> 56	2	5
Level of education		
Illiterate	0	0
Elementary school	4	11
Middle school	20	54
High school	8	22
College	5	14
Employment status		
Yes	18	49
No	19	51
GHP training course		
Yes	34	92
No	3	8
Ratio of students to food handlers		
220–300	1	14
301–380	4	57
381–450	2	29

2.3 Good hygienic practices compliance level (GHPI)

The SFS was evaluated via premise inspections using an audit form based on NOM-251-SSA1-2009 for defining the hygienic-sanitary profile of SFS. Figure 2 describes the main evaluated elements of Mexican GHP guidelines, and the criteria by element assessed could be reviewed in NOM-251-SSA1-2009. The inspection was performed from the beginning of the food preparation process up to the distribution of the meals to children. Each criterion of GHP was evaluated based on observation and assigned a compliance value (total = 1, partial = 0.5 and null = 0). The compliance good hygienic index (GHPI) formula and categorical scale are shown in Fig. 2.

2.4 Sampling plan

From the seven participating SFS, 162 samples were collected corresponding to contact surfaces (n = 60), food personnel (n = 21), tap water (n = 14), food sources (n = 46) and meals that were ready for consumption (n = 21). Table 2 shows the distribution of different categories of samples collected in each SFS. The difference in the type and number of food samples collected between the SFS was dependent on their menu and its availability during the assigned sampling day. A single sample was conducted in SFS on different days, and the collection of the samples was carried out randomly in aseptic conditions. The sampling of contact surfaces (400 cm^2) and personnel's hands (pair of hands) were performed by swabbing the surface with sterile sponges hydrated in buffer solution (Whirl–Pak® Bags), which were subsequently placed into tubes containing 10 mL of sterile buffer solution. Food samples ($\approx$ 500 g) and tap water (1 L) were collected in hermetic sterile bags and sterile plastic bottles containing 1% $Na_2S_2O_3$, respectively (APHA 2001). All samples were placed into cool boxes and transported immediately to the

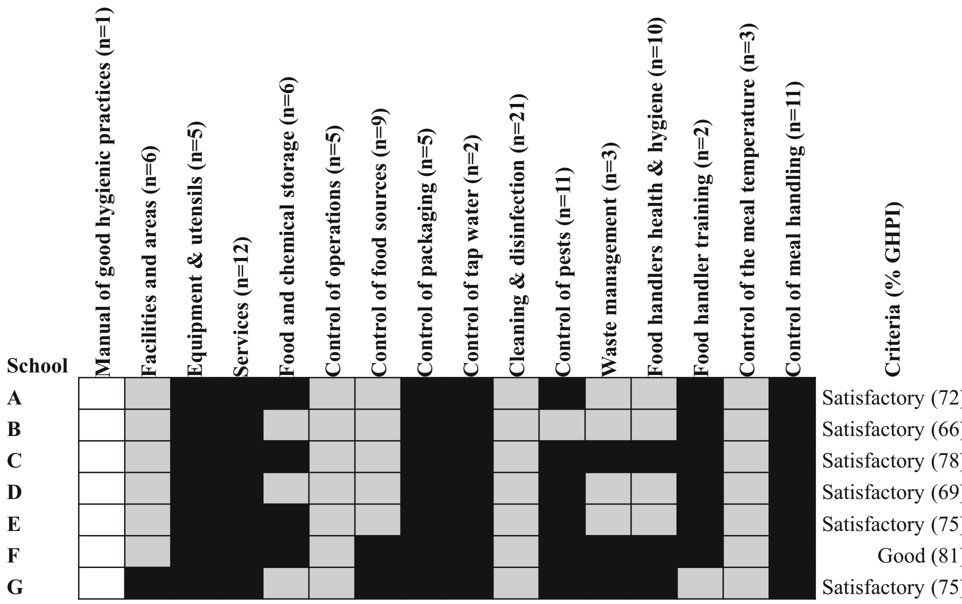

Fig. 2 Hygienic-sanitary profile of selected school foodservice establishments in Mexico via inspection of NOM-251-SSA1-2009 guidelines. The compliance scale for good hygiene practices index (% GHPI) ranged from good (80–100%), satisfactory (60–79%), unsatisfactory (40–59%), to very unsatisfactory (1–39%). The compliance good hygienic index (GHPI) was determined with the following formula: GHPI = [score obtained/maximum score achievable]. The value within the parenthesis indicates the number of questions evaluated by each element of the GHP based on NOM-251-SSA1-2009

Table 2 Total samples collected from school foodservice establishments in Mexico

Category	Type	No. of samples by school							Total samples
		A	B	C	D	E	F	G	
Surface	Table	3	3	3	3	3	3	3	21
	Cutting boards	3	3	3	3	3	3	3	21
	Refrigerator	3	3	3	3	0	3	3	18
Personal	Hands	3	3	3	3	3	3	3	21
Water	Tap	2	2	2	2	2	2	2	14
Food sources	Vegetables	2	9	3	7	4	5	3	33
	Dairy	1	0	0	0	0	0	0	1
	Poultry/beef	1	2	2	1	2	2	2	12
Meals	Cooked food	6	2	2	2	2	1	3	18
	Salads	0	0	0	0	1	1	1	3
Total		24	27	21	24	20	23	23	162

laboratory for microbial analysis within 2 h after collection.

2.5 Microbiological analysis

For *Salmonella*, the samples were pre-enriched with 1% peptone water in a 1:10 ratio and incubated for 24 h at 37 °C. Aliquots of 0.1 mL and 1 mL were homogenized with 10 mL of Rappaport–Vassiliadis broth and 9.0 mL of selenite cystine broth and incubated at 42 °C and 37 °C for 24 h, respectively. Cultures were seeded onto Hektoen agar and XLD agar and incubated for 24 h at 37 °C (Andrews et al. 2018). Confirmation of presumptive colonies was carried out by amplifying the 244 bp fragment of the *invA* gene (Chiu and Ou 1996).

L. monocytogenes was isolated following the protocol described by USDA–FSIS (2017). Samples were pre-enriched with UVM broth in a 1:10 ratio and incubated for 24 h at 30 °C. Aliquots of 0.1 mL from the culture were then homogenized with 10 mL of Fraser broth and incubated at 37 °C for 48 h. Positive cultures (black coloration) were plated in duplicate on modified Oxford agar and incubated for 48 h at 37 °C. The presumptive colonies were confirmed by biochemical tests.

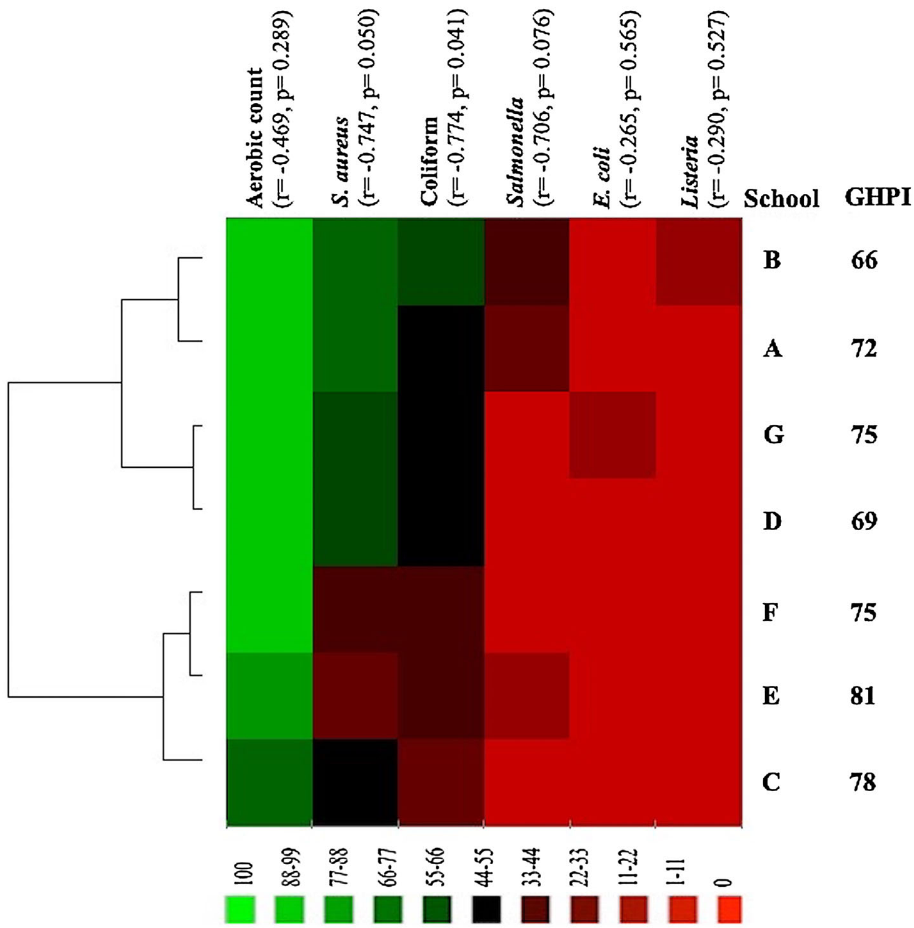

Fig. 3 Microbiological profiles of school foodservice establishments in Mexico. Column labels indicate school foodservice establishment IDs, GHPI (%), and the global microbial detection rate for each school foodservice establishment. The colour scale is represented by colour gammas from red to green through black. The tree on the left-hand side of the figure shows a hierarchical complete-linkage clustering of the profiles based on the Euclidean distance. The coefficient of correlation and significance is shown in parentheses for each microorganism (color figure online)

Specific 3 M™ Petrifilm™ Count Plates were used for quantification of *S. aureus* (Petrifilm™ Staph Express Count Plates), aerobic count (Petrifilm™ Aerobic Count Plates), *E. coli* and total coliforms (Petrifilm™ *E. coli*/coliforms Count Plates). For colony enumeration, 1 mL of sample and diluted sample (ten-fold serial dilution factor) were inoculated onto the centre of the bottom film in duplicate. All plates were incubated at 35 °C for 24 h (*S. aureus*) or 48 h (aerobic count, *E. coli* and total coliforms) by bacteria type. After incubation, colonies were counted according to the typical colonial morphology for *S. aureus* (red-violet colonies), aerobic count (red-violet colonies), *E. coli* (blue colonies with gas) and total coliforms (red and blue colonies with gas). Microbiological concentration was expressed according to the sample type: surface (CFU/cm^2), hands (CFU/hands), domestic water (UFC/100 mL) and food (UFC/g).

2.6 Statistical analysis

Cross-tabulation was carried out to examine the distribution and relationship of the variables using the MINITAB® programme. Bivariate correlation analyses were conducted to determine the correlation between GHPI and microbial rates and PCI. Additionally, a χ^2 test was performed between the categorical variables of the sample (type and SFS) and the detection of different microorganisms. A value of $p < 0.05$ was considered significant.

3 Results

3.1 Personnel proficiency score

Table 1 summarizes the profile of the participating personnel in the study. The 37 participants were all female with an age range of 25–65 years old and literate (mainly with a middle school education). If personnel had a maternal relationship with any of the students, their participation was voluntary (51%); otherwise, the workers were financially compensated (49%). The average length of employment of the personnel was approximately one year, during which time 92% of participants received at least one GHP training session. The results obtained during the evaluation of knowledge, attitudes,

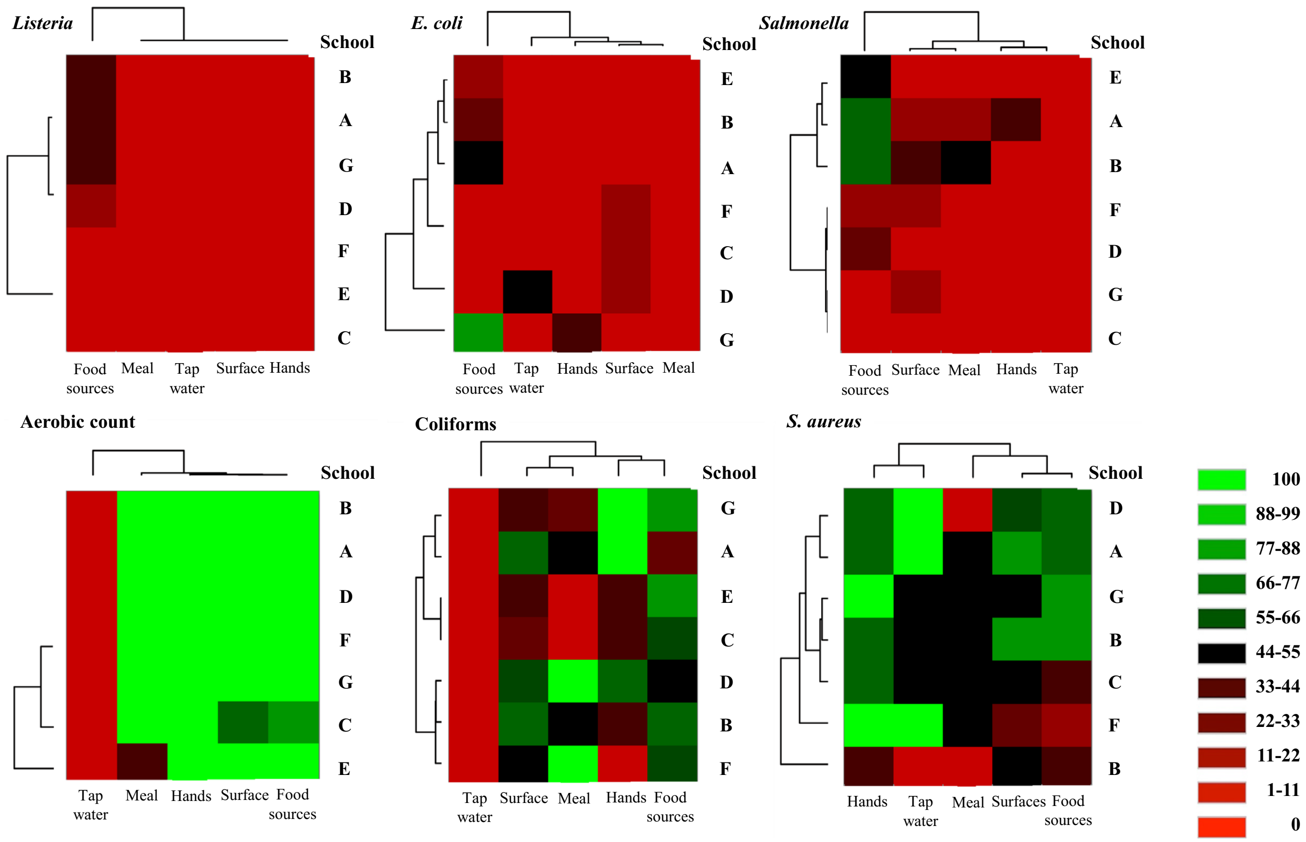

Fig. 4 Heatmap showing the distribution of microorganisms across the different sample categories collected from school foodservice establishments in Mexico. Column labels indicate school foodservice establishment IDs and the microbial detection rate for each sample category. The colour scale is represented by colour gammas from red to green through black. The tree on the left-hand and upper side of the figure shows a hierarchical complete-linkage clustering of the profiles based on the Euclidean distance (color figure online)

and behaviours of the personnel demonstrated an approval rate of 72 ± 9.08%, 73 ± 11.32%, and 75 ± 14.65%, respectively (Fig. 1). The PCI revealed a satisfactory personnel proficiency score (74 ± 4.16%) (Fig. 1), which was dependent on their attitudes (r = 0.959, $p = 0.001$). The main deficiency factors identified were the use of a safe temperature for cooking and food storage.

3.2 Good hygienic practices compliance level

Figure 2 describes the hygienic-sanitary profile obtained by each SFS in Mexico. The SFS presented an acceptable compliance to the GHPI; overall, 86% (6/7) were scored as satisfactory, and 14% (1/7) were scored as good. Among the risk factors identified were the lack of a GHP protocol and cleaning/disinfection protocols, deficiency in control actions, personnel health and hygiene. No statistically significant association was observed between PCI and GHPI (r = 0.233, $p = 0.615$), which implies the involvement of other risk factors in the GHPI.

3.3 Microbial assessment

All SFS were positive for at least one microorganism evaluated, and the incidences in the 162 collected samples were 56.2% *S. aureus*, 16.0% *Salmonella*, 9.3% *E. coli*, 47.5% total coliforms and 87.7% aerobic count. *L. monocytogenes* was not identified in any of the evaluated samples. However, *Listeria* spp. were detected in 5.6% of samples. Figure 3 shows the global detection rate of each microorganism by SFS, exhibiting a similar microbiological profile: high detection rates of total coliforms, aerobic count and *S. aureus*, and the sporadic presence of *Salmonella* and *E. coli*. The correlation analysis revealed a relationship between the GHPI compliance level and the reduction in the microbiological rates in the SFS; *S. aureus* (r = − 0.747, $p = 0.050$) and total coliforms (r = − 0.774, $p = 0.041$) rates were considered statistically significant (Fig. 3).

Figure 4 shows the heatmap of the microbial assessment of the sample categories collected from SFS in Mexico, and Table 3 organizes the microbial rates into categorical

Table 3 Overall microbial detection rates in categories of samples collected from Mexican SFS

Category	Type	Total samples (n = 162)	Microbial detection rates (%)*					
			AC	SA	TC	EC	SE	LS
Personal	Hands	21	100	71	52	5	5	0
Water	Tap	14	0	64	0	7	0	0
Surface	Table	21	95	71	57	14	5	0
	Cutting boards	21	86	33	29	5	5	0
	Refrigerator	18	94	56	50	6	22	0
Food sources	Vegetables	31	94	55	61	10	6	39
	Fruits	2	100	50	50	50	0	50
	Dairy	1	100	100	0	0	0	0
	Beef	7	86	86	71	14	71	14
	Poultry	4	100	50	75	0	50	75
	Ham	1	100	0	100	0	0	0
Meals	Beans with meat	1	100	0	0	0	0	0
	Chicken	4	100	25	0	0	0	0
	Enchiladas	1	100	100	0	0	100	0
	Meat	8	75	25	25	13	13	0
	Pasta	1	100	0	0	0	0	0
	Rice	2	100	100	0	0	0	0
	Tacos	1	100	0	0	0	0	0
	Salads	3	33	33	0	0	0	0

**AC* aerobic count, *SA S. aureus*, *TC* total coliforms, *EC E. coli*, *SE Salmonella*, and *LS Listeria*

samples, revealing the polymicrobial contamination of most samples. The schools shared similar microbial detection profiles across the sample categories for most of the microorganisms: *S. aureus* ($\chi^2 = 25.64$, $p = 0.000$), *Salmonella* ($\chi^2 = 37.46$, $p = 0.000$), aerobic count ($\chi^2 = 70.77$, $p = 0.000$), total coliforms ($\chi^2 = 51.79$, $p = 0.000$), and *Listeria* spp. ($\chi^2 = 36.00$, $p = 0.000$). The linkage clustering analysis revealed the food source as the most common food safety risk factor, followed by the hands of personnel and surfaces. Additionally, *Salmonella* was statistically associated with the SFS ($\chi^2 = 27.37$, $p = 0.000$), which could indicate sporadic pathogen colonization. The quantification of *S. aureus*, *E. coli*, total coliforms and aerobic counts by sample category is displayed in Table 4.

4 Discussion

Mexican schools have had to install foodservice establishments within their facilities, and they have incorporated students' mothers and personnel perform the associated functions. From this perspective, it is imperative to guarantee that personnel have the competence to exercise hygienic control of the factors that influence food safety. Although Mexican SFS achieved a satisfactory hygienic-sanitary profile, decreased scores were associated with attitudes of personnel and the lack of certain GHP requirements. The knowledge, behaviour and attitudes of personnel are critical to carry out all the actions associated with the proper functioning of the foodservice (Bucheri et al. 2010). Sociodemographic characteristics of personnel have also been described as risk factors for hygienic food handling (Firdaus et al. 2015).

According to the demographic characteristics and PCI (Table 1 and Fig. 1), it can be inferred that the hygienic handling of food is conducted according to empirical knowledge and based on the know-how of women aged > 35 years. Educational level does not necessarily influence GHP (Soares et al. 2012), but the lack of continuous training could be the root of the observed deficiencies in knowledge, behaviour and attitudes scores (Bucheri et al. 2010; Soares et al. 2012; Firdaus et al. 2015). As revealed on the WHO questionnaire, the management of storage and cooking temperatures were weak elements among the respondents, while the remaining keys seemed to be known topics. These results reflected the experience of personnel as housewives and their use of ingenuity to overcome the lack of control instruments (thermometers). Nee and Sani (2011) have indicated that female personnel are more concerned about GHP and consumers' health than male personnel, favouring the food safety process. Age, educational level, monthly income and working experience are described as positive predictors for maintaining GHP

Table 4 Categorization of the microbiological levels in sample categories collected from school foodservice establishments in Mexico

Microorganism	Category (no. samples)	Not detected % (n)	Frequency of UFC levels % (n)*		
			1 > UFC < 10	10 > UFC < 100	> 100 UFC
Aerobic count	Tap water (n = 14)	100 (14)	0	0	0
	Surfaces (n = 60)	5 (3)	20 (12)	18 (11)	57 (34)
	Hands (n = 21)	0	14 (3)	24 (5)	62 (13)
	Meals (n = 21)	10 (2)	28 (6)	5 (1)	57 (12)
	Food sources (n = 46)	2 (1)	13 (6)	17 (8)	68 (31)
Coliforms	Tap water (n = 14)	100 (14)	0	0	0
	Surfaces (n = 60)	54 (32)	8 (5)	38 (23)	0
	Hands (n = 21)	47 (10)	10 (2)	24 (5)	19 (4)
	Meals (n = 21)	57 (12)	10 (2)	19 (4)	14 (3)
	Food sources (n = 46)	37 (17)	11 (5)	9 (4)	43 (20)
E. coli	Tap water (n = 14)	93 (13)	7 (1)	0	0
	Surfaces (n = 60)	95(57)	0	5 (3)	0
	Hands (n = 21)	95 (20)	0	5 (1)	0
	Meals (n = 21)	100 (14)	0	0	0
	Food sources	78 (36)	0	22 (10)	0
S. aureus	Tap water (n = 14)	36 (5)	36 (5)	7 (1)	21 (3)
	Surfaces (n = 60)	47 (28)	13 (8)	18 (11)	22 (9)
	Hands (n = 21)	28 (6)	24 (5)	5 (1)	43 (9)
	Meals (n = 21)	62 (13)	5 (1)	14 (3)	19 (4)
	Food sources (n = 46)	41 (19)	2 (1)	16 (7)	41 (19)

*The microbiological concentration was expressed according to the sample categories: surface (CFU/cm^2), hands (CFU/hands), tap water (UFC/100 mL) and food (UFC/g)

control (Nee and Sani 2011; Soares et al. 2012; Lee et al. 2017).

The hygienic-sanitary profile of SFS revealed partial GHP compliance according to Mexican requirements (DOF 2010), which exposed risk factors for ensuring food safety (Fig. 2). SFS were distinguished by the adequate distribution of the food handling areas and optimal level of basic resources, which could contribute to minimizing microbial contamination and facilitating cleaning and disinfection operations. However, the lack of manuals and information on GHP were identified as the most common deficiency among SFS, and this was reflected in the high rates of spoilage microbes (Fig. 3). Most of the previous foodborne outbreaks have been the consequence of non-adherence of personnel to GHP (Todd et al. 2008; Kadariya et al. 2014).

The observed microbiological profile among the SFS (Fig. 3) showed a common behaviour of GHP application within the SFS and demonstrated that food sources followed by personnel and surfaces were the main vehicles for spreading microorganisms. Several studies have described the involvement of food sources, personnel, surfaces, water, and air as sources of spoilage microorganisms and pathogens contributing to the challenge of controlling microbial contamination (Gutiérrez et al. 2012; Lee et al. 2017). In particular, these SFS showed high contamination rates of *S. aureus*, total coliforms and aerobic count (Fig. 4), violating the guarantee to prepare harmless food and exhibiting the microbial sources that impact the total GPHI compliance. The use of microbial indicators as criteria for food safety has been previously described (National Research Council 1985). Aerobic counts have limited use for the inference of food safety, and only a high quantified microbial load may denote loss of stability in an environment or medium. However, the presence of *S. aureus* and *E. coli* could denote a potential health hazard and the occurrence of faecal contamination and possible faecal pathogens, respectively.

Personnel showed deficiencies in GHP when reporting the presence of different microorganisms (Fig. 4). *E. coli* and *Salmonella* detection indicates contamination of faecal origin, since these bacteria are part of the intestinal human microbiota (Castañeda-Ruelas and Jiménez-Edeza 2017). Moreover, *S. aureus* can grow and remain viable on the human skin for prolonged periods, favouring transfer of the bacterium to inert surfaces and food (Kadariya et al. 2014). Therefore, particular attention should be paid to the proper washing and disinfection of hands and the monitoring of personnel health (Byrd-Bredbenner et al. 2013).

Furthermore, it should be noted that personnel needed enforcement of the knowledge and attitudes towards GHP (Fig. 1). Chapman et al. (2010) have reported that the inclusion of food safety information sheets inside the foodservice setting positively influences adherence to GHP by personnel.

Microbiological monitoring of food contact surfaces (Fig. 4 and Table 3) revealed that the empirical cleaning and disinfection routines adopted by these establishments are not totally effective. Interestingly, School B (SFS-B) showed the presence of *Salmonella* in a refrigerator, on a table and in meals as a cross-contamination phenomenon. *Salmonella, L. monocytogenes, S. aureus, E. coli, Campylobacter* and other spoilage bacteria have been recognized for their biofilm-induced ability to adhere to inert surfaces, favouring food contamination and increasing the poisoning risk (Larsen et al. 2014). The biofilm capacity and resistance against antimicrobials and sanitizers have also been described as bacterial survival factors, promoting cross-contamination and hindering disinfection (Gutiérrez et al. 2012). Rotation of disinfection protocols can be an efficient strategy to minimize the microbial load (Carrasco et al. 2012).

This study identified food sources as vehicles of multiple spoilage and pathogenic bacteria (Fig. 4 and Table 3). Although the contamination of a food source could arise from its origin, it is the responsibility of personnel to take measures to reduce the contamination risk in the environment and in processed food (Soares et al. 2012). The main cause of the excessive microbial levels quantified (Table 4) could be in line with the unknown use of safe temperatures observed in the WHO questionnaires (Fig. 1). The lack of microbial control among food sources favours cross-contamination and increases the risk of contaminating prepared meals. The presence of *Salmonella*, *S. aureus* and *E. coli* observed in the prepared meals (Table 3) constitutes a serious public health problem that should not go unnoticed due to their connection with previous FBD outbreaks in Mexican SFS (Reyes 2012; Rosas 2012; Martínez 2017; Morales 2018; Escamilla 2018; Tinoco 2019; Ladino 2019). This study suggested the microbial monitoring of tap water and the implementation of in situ disinfection measures because this source is indispensable for food handling.

5 Conclusions

These results provide an initial overview of the food preparation quality in Mexican SFS. However, it is necessary to add the participation of a greater number of schools to categorize the hygienic-sanitary profiles of these foodservices in Mexico. The GHP adherence level was essentially based on the experience of the personnel, but the increase in microbial contamination was supported by a lack of safety of raw food. Additionally, certain unsafe practices in the temperatures used for food were exposed as a risk factor for controlling pathogens. Most importantly, the findings identified an opportunity for improvements in preparing food safely based on controlling the potential elements involved as microorganism vehicles and implementing educational strategies regarding current GHP guidelines. It is important that competent authorities reinforce the monitoring of the application of official standards and encourage the training of personnel in matters of GHP.

Acknowledgements The authors are grateful to Mrs. Maritza Castillo-Burgos, Mr. Guadalupe Castro-Anaya, Mrs. Lluvia Campos Lizárraga, Mrs. Johanna Parra Aragón, Mrs. Rosa Salazar Arriaga, Mrs. Ana López Valenzuela, Mr. Pablo Orona Soto, and Mrs. Wendy Melchor Sánchez for their technical support. Additionally, we thank the schools for their voluntary participation in this study.

Funding This work was financially supported by Consejo Nacional de Ciencia y Tecnología (SEP/SEB-CONACYT-2015/Project 264821).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The principals and personnel of the participating foodservice establishments were informed about the objectives of the study and signed written inform consent. The transcription, capture, analysis and presentation of the data were performed while maintaining the confidentiality of the data.

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