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Microbial Status and Sanitation level of Food Contact Surfaces (FCSs) of Three University Restaurant Kitchens for Three Public Universities at Central-Delta Region in Egypt

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Abstract: The microbiological safety of food is primarily influenced by hygienic practices during food handling and the sanitation of food contact surfaces (FCSs). Consequently, the safety of foods served in university restaurants can be assessed by evaluating the microbiological quality of FCSs. This research aims to evaluate the microbial quality (MQ) and sanitation level of FCSs in the kitchens of three university restaurant kitchens for three public universities in the Central-Delta region of Egypt. A total of 108 swabs were collected from surfaces related to food (preparation tables, dining tables, cutting boards), cooking utensils (pots, knives, trolley tanks, mobile tanks, scoops, colanders), and kitchen equipment (peeling machine, steam pots, bain-maries). The samples were examined for total aerobic colony count (TACC), total Coliform count (TCC), yeast and mold count, *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), *Bacillus cereus* (*B. cereus*), *Salmonella* and *Shigella* spp. The microbiological analysis revealed that the greatest compliance rates with good hygienic conditions were observed in the FCSs of the UNK-1 university restaurant kitchen. In contrast, the sanitation levels of FCSs in the UNK-2 and NUK-3 university restaurant kitchens were classified as "unsatisfactory." These findings highlight the need for improvements to enhance the sanitation levels of these university restaurants. Adopting and implementing effective sanitation programs, Good Manufacturing Practices (GMPs), and Hazard Analysis and Critical Control Points (HACCP) is essential to ensuring the safety of food served to students.

Keywords: Hygienic evaluation, food contact surfaces, pathogens, TACC, TCC, restaurant kitchens, Egypt.

1. Introduction

University restaurant kitchens play a vital role in providing food services to students, faculty members, and administrative staff. These kitchens must prioritize cleaning and disinfection procedures to comply with good manufacturing practices (FAO, 2011). Therefore, it is crucial for them to follow established and approved protocols.

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One of the leading risk factors for outbreaks of foodborne illnesses in food service operations is the use of contaminated equipment and food contact surfaces resulting from inadequate cleaning or disinfection because cleaning work surfaces, utensils, and equipment is crucial to preventing microorganism contamination that can subsequently multiply in prepared foods, reaching unacceptable levels (Possas and Pérez-Rodríguez, 2023). Therefore, implementing efficient cleaning and

disinfection procedures is essential to ensure the quality control and safety of food in university restaurant facilities, ensuring the provision of safe food to the public/students (Rufai and Wartu, 2023).

Food contact surfaces (FCSs) include any surfaces that directly contact food, such as utensils, workers' clothing, kitchen equipment, and facilities (Baghapour *et al*., 2015; Tenna *et al*., 2023). These surfaces can harbor pathogens and transfer them to food via cross-contamination. Mechanical processes such as slicing, trimming, milling, shredding, peeling, and mechanical abrasion can introduce contaminants from contaminated equipment (Bukhari *et al*., 2021). Contaminated kitchen utensils are responsible for 27% of food-borne pathogen outbreaks and infections (WHO, 2000; Soares *et al*., 2012). In 2008, a Canadian outbreak tied to ready-to-eat deli meat was attributed to contamination originating from the slicer machine (Simmons and Wiedmann, 2018). Based on the findings of Ismail *et al*. (2017), many foodborne illness outbreaks are linked to bacterial cross-contamination or recontamination on FCSs. A study on a foodborne illness outbreak in France in 1998 found that 40% of cases of contamination were linked to equipment contamination (Cappitelli *et al*., 2014). Common bacteria that cause food-borne outbreak include *Salmonella* spp., S*higella*, *E. coli* (members of the Enterobacteriaceae family), and *S. aureus* (Tenna *et al*., 2023). Nhalpo *et al*. (2014) assessed the cleanliness of FCSs used for meals served to students in central South Africa. The study's results showed that overall viable counts were high across the board. 20% of surfaces had unacceptable levels of *S. aureus* and *E. coli*, while 30% had unsatisfactory Coliform counts. Yeast and mold counts were unacceptable in 50% and 60% of preparation surfaces and aprons, respectively. Mohammed *et al*. (2018) studied the prevalence of *E. coli* and *S. aureus* on FCSs in Kaduna State University restaurants. The cleanliness of FCSs was evaluated at five chosen restaurants in Kaduna State University. Out of 50 samples tested, 13 (26%) were positive for *E. coli*, while none positive for *S. aureus*. Among the 13 *E. coli* positive samples, 8 (61.5%) came from plates, 3 (23.1%) from cutting boards, and 1 (7.7%) from each table and spoon.

Despite numerous studies on FCSs across various regions worldwide, there is limited information on their safety and microbial status in the study area (Oranusi *et al*., 2013; Lani *et al*., 2014; Zailani *et al*., 2015; Zulfakar *et al*., 2018; and Fahim *et al*., 2022). Additionally, Egypt lacks technical regulations or guidelines for microbiological control of surfaces.

The effectuality of cleaning and disinfection practices is usually monitored by reductions in bacteria such as *Salmonella* and *E. coli*, along with TACC and TCC. Proposed reference values for bacterial contamination in the food industry exhibit high variability compared to the sanitary sector (Giovinazzo *et al*., 2018). Consequently, food safety quality management systems and high standards of hygiene in the work environment covering surfaces, equipment, and utensils are fundamental for preventing microbial contaminations and ensuring that meals do not compromise public health (Carrascosa *et al*., 2012). The cleanliness of FCSs in a university restaurant can indicate its sanitation level (Zulfakar *et al*., 2018). Thus, evaluating hygiene standards in food-processing and serving establishments is essential for controlling and preventing foodborne illnesses. Microbiological assessments should extend beyond just analyzing food to include an examination of all food-contact surfaces and utensils utilized in food processing, preparation, and serving. (Bukhari *et al*., 2021). The cleanliness of FCSs can indicate a food premise's sanitation level (Zulfakar *et al*., 2018). Thus, microbiological analysis of these surfaces helps identify indicator bacteria of poor hygienic conditions, such as ACC, *S. aureus*, and *Enterobacteriaceae* (Da Vitória *et al*., 2018).

Hence, in our knowledge, there is insufficient data on the microbial ecology of food contact surfaces in university kitchens in Egypt. Therefore, our study aims to evaluate the hygiene conditions of FCSs in three restaurant kitchens located in three public universities in the Central-Delta region of Egypt. Microbiological quality assessed, including TACC, TCC, total yeast and mold count, and potential foodborne pathogens such as *E. coli*, *B. cereus*, *S. aureus*, *Salmonella* and *Shigella* spp., on twelve types of FCSs using the swabbing method, one of the most effective techniques for such investigations. Additionally, this study aims to fill a knowledge gap regarding the impact of hygienic

status on food contact surfaces, providing valuable data on hygiene practices and proper surface cleaning to prevent cross-contamination.

2. Materials and Methods

2.1. Study area and collection of samples

The study was performed in the three restaurant kitchens of three public universities in the Central-Delta region of Egypt. Sampling was conducted on inert FCSs that have contact with food, cooking utensils, and kitchen equipment's (Table 1) after preparing food and their cleaning (Rios-Castillo *et al*., 2021). The three major restaurant kitchens were chosen and coded UNK-1, UNK-2 and UNK-3. This sampling took place from October to December 2021, coincidental with the periods when the restaurants served students. Samples were collected once a month from FCSs on working days that had been cleaned and were ready for use during lunch time. The sampling involved swabbing a designated area (PHE, 2014).

Composite surface samples were taken from 12 various types of FCSs. The sampling was performed according to the methods outlined by APHA (2004) and Christison *et al*. (2008) with minor modifications. A pre-moistened sterile cotton swab with sterile buffered peptone water (BPW) was used to swab the test surfaces. After swabbing, each sample was Put into a sterile tube containing 9 ml of BPW.

For individual surface samples, a hundred and eight (108) swab samples were collected from food-associated surfaces (preparation tables, dining table cutting boards), cooking utensils (pots, preparation knives, trolley tanks, mobile tanks, scoops, colander), and kitchen equipment's (peeling machine, stem pots, bain-marie) following the guidelines outlined in ISO 18593:2018.

The collected swabs were correctly labeled and immediately placed in an iced cooler to inhibit bacterial growth. They were taken to the laboratory of microbiology on that same day and analyzed microbiologically as soon as they arrived.

Table 1. Distribution of swab samples examined for FCSs

No.	Sample type	Number of swabs
Food associated preparation surfaces (APSs)		
1	Preparation table	9
2	Dining table	9
3	Cutting boards	9
Cooking utensils		
4	Pots	9
5	Preparation knives	9
6	Trolley tanks	9
7	Mobile tanks	9
8	Scoops	9
9	Colander	9
Kitchen equipment's		
10	Peeling machine	9
11	Stem pots	9
12	Bain-marie	9
	Total	**108**

2.2. Sample processing and analysis

Swab samples in tubes were mixed thoroughly for 30 seconds using a vortex to prepare the initial dilutions. For each sample, serial dilutions of 1:10 were prepared using peptone water. Then,

serial dilutions were performed to 10^{-7} for each sample to achieve a suitable colony count, ranging from 30 to 300. The samples were analyzed for ACC, TCC, yeast and mold, *E. coli*, *B. cereus*, *S. aureus*, *Salmonella* and *Shigella* spp., following the procedures outlined in NTC 5230 217 (ICONTEC, 2017). The TACC was expressed in colony-forming units per square centimeter (CFU/cm²) for FCSs. Also, for the detection of *E. coli*, *Salmonella* and *Shigella* spp., the results were reported as presence or absence of these bacteria.

Surface hygiene was evaluated using microbiological analysis. To interpret our results, we took into account the criteria outlined by Losito *et al*. (2017). These authors classified the samples into three categories based on bacteria counts. Samples are considered compliant if their bacteria count is between 0 and 1.6 $\log_{10}$ CFU/cm², labeled as improvable if the count is between 1.6 and 2.69 $\log_{10}$ CFU/cm², and categorized as not compliant if it exceeds 2.70 $\log_{10}$ CFU/cm². These compliance criteria were chosen for their practicality, feasibility, and verifiability in assessing hygiene and sanitation programs related to surfaces in the food industry and distribution system. According to Colombian guidelines for microbiological sampling of surfaces, the efficacy of a cleaning and disinfection procedure is classified based on aerobic mesophilic counts, in which the areas are clean (2-10 CFU/cm²), acceptable (11-100 CFU/cm²), dirty (>100 CFU/cm²), and out of control (101-1000 CFU/cm²) (ICONTEC, 2017).

2.3. Statistical analysis

Data analyses were conducted using IBM SPSS Statistics version 29 (SPSS Inc., Chicago, Illinois, USA). A *P* value of less than 0.05 was considered significant.

3. Results and Discussion

Microbial quality (MQ), sanitation level and hygienic status of composite swab samples of FCSs in tested university restaurant kitchens.

In the current study, TACC, yeast, and mold counts were identified as quality indicators, while TCC and *S. aureus* were selected as hygiene indicators. Additionally, foodborne pathogens such as *E. coli*, *Salmonella* and *Shigella* spp. were assessed as safety indicators (Rane, 2011).

Results depicted in Table 2 showed that the microbial analysis of composite surface swab samples revealed that the mean levels of TACC, TCC, yeast and mold, *B. cereus*, and *S. aureus* varied across samples. Specifically, TACC ranged from 0 to 4.43±0.16 $\log_{10}$ CFU/cm², *S. aureus* from 0 to 2.33±0.10 $\log_{10}$ CFU/cm², *Enterobacteriaceae* from 0 to 2.12±0.13 $\log_{10}$ CFU/cm², and yeast and mold counts ranged from 0 to 3.60±0.18 $\log_{10}$ CFU/cm² (Table 2).

The results indicate that the composite swab sample from the FCSs of the UNK-1 university restaurant kitchen was free from any detected microorganisms (Table 2). Notably, the TACC was substantially higher in UNR-2 (4.43±0.16 $\log_{10}$ CFU/cm²) compared to FCS samples from UNK-3 (3.85±0.17 $\log_{10}$ CFU/cm²). Similarly, the TCC of surface swabs in UNR-2 (2.12±0.13 $\log_{10}$ CFU/cm²) was significantly greater than that of UNR-3 swab samples (1.74±0.12 $\log_{10}$ CFU/cm²). Additionally, levels of *B. cereus* and *S. aureus* were higher in FCS samples from UNK-2 (2.34±0.11 and 2.33±0.10 $\log_{10}$ CFU/cm², respectively) than in UNK-3 swab samples (2.11±0.10 and 1.80±0.06 $\log_{10}$ CFU/cm², respectively) (P>0.05) (Fig. 1). The examined surface swabs were also discovered to be contaminated with yeasts and molds, with a mean value of 3.60±0.18 $\log_{10}$ CFU/cm² in UNK-2, while counts in UNK-3 were lower at 2.98±0.15 $\log_{10}$ CFU/cm². Importantly, no *Shigella* and *Salmonella* spp. were found in any of the samples analyzed.

The Total Aerobic Colony Count (TACC) in food processing environments is used to evaluate the hygiene of the entire food production process (Touimi *et al*., 2019). According to a World Health Organization report (2007), while a high TACC does not inherently pose a risk to human health, it reflects the overall quality of production systems (Rahimi *et al*., 2019). Total Coliforms serve as

indicators of failures in cleaning and disinfection procedures, which can lead to cross-contamination and biofilm formation on surfaces. Moreover, Henroid *et al*. (2004) and Marzano and Balzaretti (2013) proposed that the standard for total bacterial count on cleaned and sanitized food contact surfaces (FCSs) should be less than 1.3 Log_{10} CFU/cm².

Table 2. Bacterial contamination and sanitation levels of composite swab samples for TACC, TCC, yeast and mold count, *B. cereus* and *S. aureus* found on FCSs of three university restaurants for three public universities at Central-Delta region in Egypt. Data presented as Mean log_{10} CFU/ cm^2 ± Standard deviation

Salmonella and *Shigella* spp. *were not detected in all examined FCSs samples.*
*According to Colombian regulation for the microbiological sampling of surfaces (ICONTEC, 2017). ** According to Legnani, *et al*. (2004).

University restaurant code	TACC	Sanitation level *	TCC	Hygienic status**	mold and yeast	*B. cereus*	*S. aureus*
	Log_{10} CFU/cm^2						
UNK-1	0.00^{c}±0.00	Clean	0.00^{c} ±0.00	Satisfactory	0.00^{c} ±0.00	0.00^{c} ±0.00	0.00^{c} ±0.00
UNK-2	4.43^{a}±0.16	Out of control	2.12^{a}±0.13	Unsatisfactory	3.60^{a}±0.18	2.34^{a}±0.11	2.33^{a}±0.10
UNK-3	3.85^{b}±0.17	Out of control	1.74^{b}±0.12	Unsatisfactory	2.98^{b}±0.15	2.11^{b}±0.10	1.80^{b}±0.06

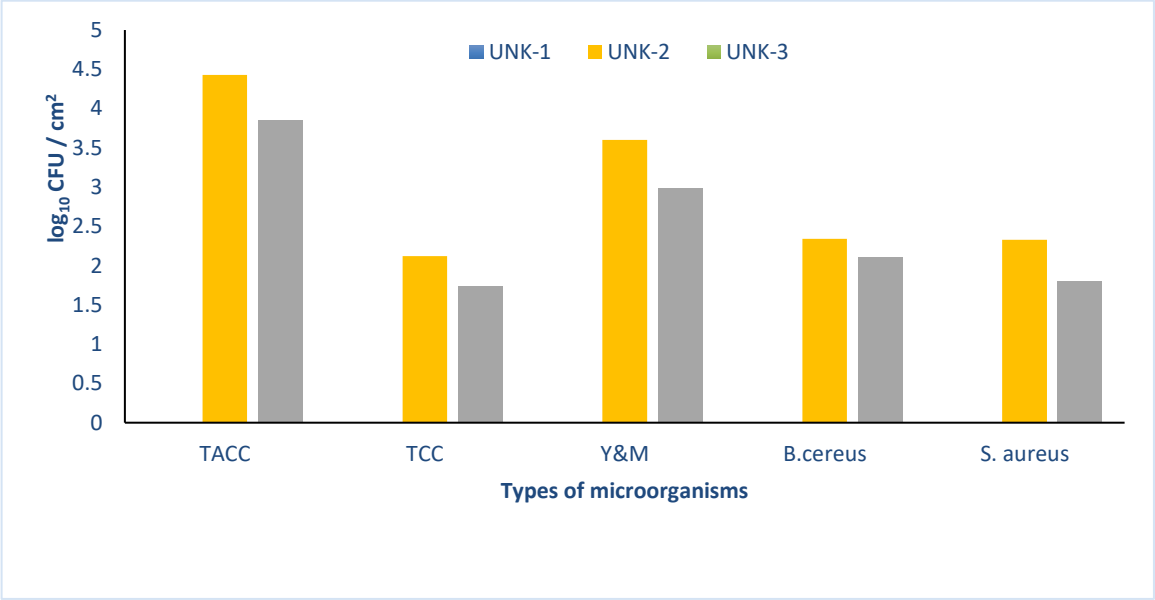


Figure 1 Microbial contamination of composite swab samples for TACC, TCC, yeast and mold count, *B. cereus* and *S. aureus* found on FCSs of three university restaurants for three public universities at Central-Delta region in Egypt.

The study utilized the Australian guidelines (NSW Government Food Authority, 2013) because, to date, no standardized guidelines for permissible microbiological levels for FCS are being implemented in Egypt. Global standards for total aerobic colony counts (TACCs) on FCSs include guidelines from the US Public Health Service, which recommend a maximum of 10 bacterial cells per cm² (Sagoo *et al*., 2009). Notably, two restaurant kitchens demonstrated significantly higher bacterial counts ($P < 0.05$) compared to these standards. Overall results (Table 2 and Fig. 1) indicated that two out of three university restaurant kitchens exceeded the Australian standard guideline of 1 log_{10} CFU/cm² for TACC on FCSs (NSW Government Food Authority, 2013).

The TACC observed in this study were above the recommended maximum limit of 10 CFU/cm² for aerobic plate counts, as established by the Guidelines for Environmental Infection Control

in Health-Care Facilities (2015), NSW (2013), and ICONTEC (2017). This suggests that the FCSs in the UNK-2 and UNK-3 restaurant kitchens were likely contaminated with bacteria, posing a risk for food contamination. The results indicate insufficient cleaning and poor hygiene practices on these surfaces, which could lead to both initial contamination and subsequent recontamination, as highlighted by Adekolurejo *et al*. (2016).

According to the Colombian guidelines (ICONTEC, 2017), the FCSs in the UNK-1 restaurant kitchen were free of all examined microorganisms (0 $\log_{10}$ CFU/cm²), categorizing them as clean. In contrast, the FCSs in both the UNK-2 and UNK-3 restaurant kitchens were found to be out of control. Legnani *et al*. (2004) noted that FCSs are considered hygienically satisfactory when TACC are below 50 CFU/cm². The surfaces assessed in this study had TACC exceeding this benchmark, indicating that the cleaning procedures in restaurant kitchens UNK-2 and UNK-3 were insufficient and that these surfaces became contaminated.

Microbial contamination of individually for each of FCSs which collected from university restaurant kitchens

The microbiological analysis of surface samples from three university restaurant kitchens for three public universities in the central Delta region of Egypt revealed variability in the mean levels of TACC, TCC, yeast and mold counts, as well as the presence of *B. cereus*, *S. aureus*, and *E. coli*. These differences were observed across the individual results obtained from each FCS, as detailed in Tables 3-5 and illustrated in Figures 2-3.

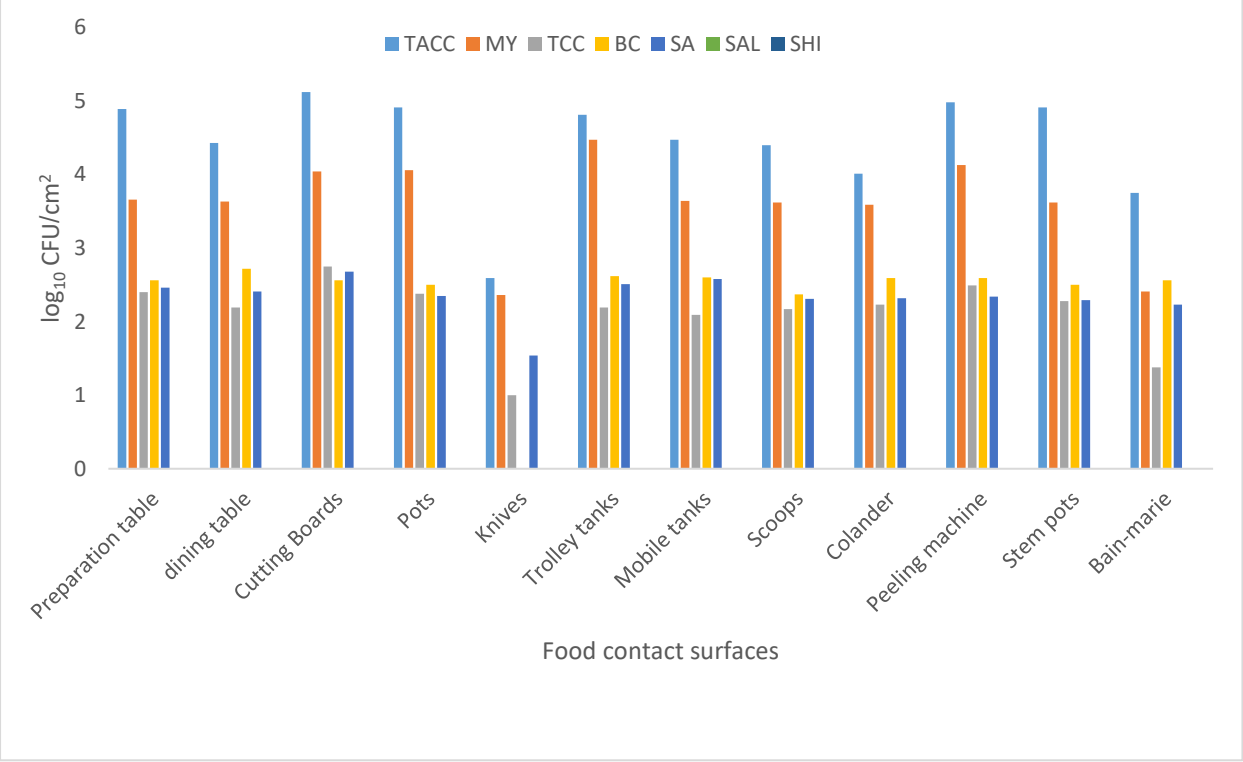
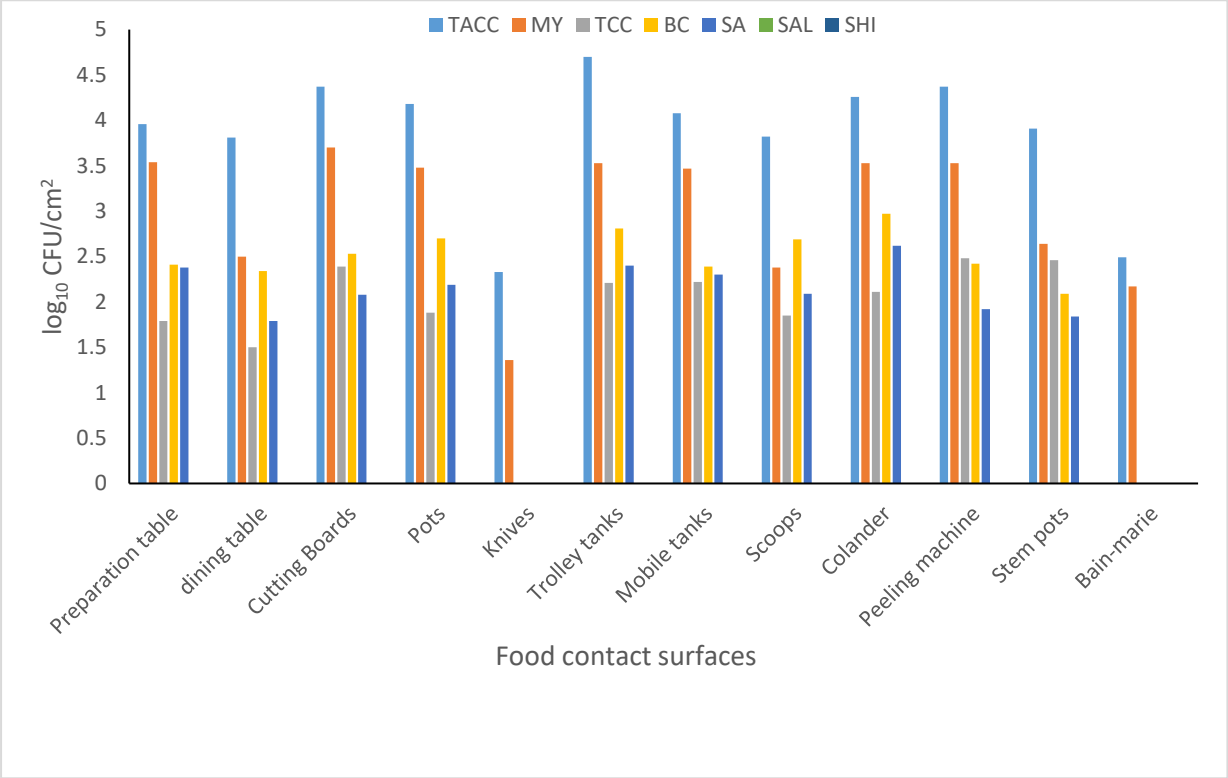


Figure 2. The Mean log CFU/cm² for TACC, mold and yeast (MY), TCC, *B. cereus* (BC), *S. aureus* (SA), *Salmonella* spp. (SAL) and *Shigella* spp. (SHI) on different type of food contact surfaces in UNK-2 restaurant kitchen.

The median comparison of microbial counts of FCSs in the tested restaurant kitchens is shown in Tables 3-5 and Figures 2-3. In the UNK-1 restaurant kitchen, none of the 12 examined microbial parameters were detected, indicating these surfaces were free from all tested microorganisms. However, in the UNK-2 and UNK-3 restaurant kitchens, FCSs were contaminated with these

microorganisms. The results revealed a statistically significant difference in the microbiological load of FCSs at UNK-2 and UNK-3 restaurant kitchens. Most FCSs in UNK-2 and UNK-3 showed microbial growth. In UNK-2, the median count of $\log_{10}$ ACC on FCSs ranged from 2.59±0.21 $\log_{10}$ CFU/cm² on preparation knives (cooking utensils) to 5.12±0.05 $\log_{10}$ CFU/cm² on cutting boards (APSs). In UNK-3, the median count of $\log_{10}$ ACC on FCSs ranged from 2.33±0.04 $\log_{10}$ CFU/cm² on preparation knives (cooking utensils) to 4.70±0.08 $\log_{10}$ CFU/cm² on trolley tanks (cooking utensils). The microbiological load exceeds the acceptable limits specified by the NSW (2013) and Colombian (2017) guidelines. According to Willis *et al*. (2013), TAAC on cleaned and ready-to-use surfaces should be below 10 CFU/cm², and the count for *Enterobacteriaceae* and other pathogenic bacteria should be below 1 CFU/cm².

Figure 3: The Mean log CFU/cm² for TACC, mold and yeast (MY), TCC, *B. cereus* (BC), *S. aureus* (SA), *Salmonella* spp. (SAL) and *Shigella* spp. (SHI) on different type of food contact surfaces in UNK-3 restaurant kitchen.



Total Coliform counts (TCCs) ranged from 0 (FCSs of UNK-1) to 2.75±0.04 $\log_{10}$ CFU/cm² (cutting boards of UNK-2) across all inert surfaces. The cutting boards (APSs of UNK-2) and the peeling machine (kitchen equipment's of UNK-3) exhibited the highest TCC, while the preparation knives and Bain-marie showed the lowest counts ($P < 0.05$). Additionally, *E. coli* was detected on preparation tables, cutting boards (APSs), trolley tanks, scoops, colanders (cooking utensils), and peeling machine (kitchen equipment's) in both FCSs for examined restaurant kitchens (Tables 3-5).

According to Legnani *et al*. (2004), inert surfaces in both UNK-2 and UNK-3 university restaurant kitchens were found to be unsatisfactory based on microbiological criteria (Tables 4-5), whereas FCSs in the UNK-1 restaurant kitchen were satisfactory (Table 3). Oliveira *et al*. (2014) reported similar findings, evaluating the hygienic condition of FCSs such as mixers, cutting boards, dishes, and countertops, and found aerobic mesophilic counts similar to this study, with FCSs in UNK-1 being below the reference value. Likewise, Janjić *et al.* (2015) discovered mesophilic counts exceeding 10 CFU/cm² on food preparation surfaces.

The results from this work indicate lower counts than those reported in other studies assessing the hygienic conditions of FCSs, including kitchen utensils (Al-Aejroosh *et al*., 2021). (TCCs are closely linked to the effectiveness of cleaning protocols. In the university restaurant kitchens of UNK-

2 and UNK-3, many inert surfaces exhibited Coliform counts that surpassed the regulatory standards set by this regulation, resulting in an unsatisfactory classification (Tables 4-5).

The current study found notably high levels of microbiological contamination on FCSs ($P<0.05$), with peeling machine and cutting boards exhibiting the poorest hygiene status. This aligns with the findings of Christison *et al*. (2008) and Sibanyoni and Tabit (2019). Additionally, no *Shigella* and *Salmonella* spp. were detected in any of the examined university restaurant kitchens.

Our findings indicate that cutting boards are the most contaminated surfaces, containing the highest bacterial counts, while preparation knives are the least contaminated (Figs. 2–3). This discrepancy can be attributed to cross-contamination from raw materials and inadequate hygiene practices. Consequently, the high rate of surface contamination poses a substantial risk to students., as raw food contamination is a well-established cause of food-borne outbreaks (Taulo *et al*., 2008; Dourou *et al*., 2011).

Although, there were visual differences in contamination levels among plates, pots, spoons, and tables, the microbial counts on these FCSs showed statistically significant differences ($P < 0.05$). According to Cunningham *et al*. (2011), FCSs samples with TCCs exceeding 1.0 $\log_{10}$ CFU/cm² failed the hygiene test. Our findings showed high TCC in some FCSs, while no counts were detected in some FCSs in UNK-1, knives, and the Bain-marie in UNK-3. This high occurrence of TCCs points to hygiene problems in these restaurants.

The conformity of samples to the standards outlined by Losito et al. (2017). showed variable microbiological compliance rates across different FCSs, as detailed in Tables 3-5. The poor hygiene levels observed on many surfaces can be attributed to cross-contamination between food items and surfaces, along with the subsequent growth of microbes in biofilms (Lee *et al*., 2016). Insufficient cleaning and sanitation procedures, coupled with overall inadequate sanitary conditions in food preparation areas, lead to the buildup of food debris and bacteria in biofilms. Additionally, the lack of HACCP program implementation may have adversely affected the hygienic conditions of FCSs, highlighting the necessity for immediate corrective measures.

The results obtained from that study indicate that implementing good hygienic practices (GHP), good manufacturing practices (GMP), and food safety systems (such as HACCP and ISO 22000) is mandatory for ensuring a safe food preparation environment (Attala and Kassem, 2011).

Table (3): Bacterial contamination levels for TACC, TCC, *B. cereus, S. aureus*, *Salmonella* and *Shigella* spp. found on FCSs of UNK-1 university restaurant kitchen.

Parameter	Assonated preparation Surfaces				Cooking utensils					Kitchen equipment's		
	Preparation table	dining table	Cutting Boards	Pots	Preparation Knives	Trolley tanks	Mobile tanks	Scoops	Colander	Peeling machine	Stem pots	Bain-marie
	Bacterial count, Log_{10} CFU/cm^2, (Mean ± SEM)											
TACC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
EC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SAL	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SHI|	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TACC: Total aerobic colony count, MY: mold and yeast, TCC: *Total coliform count*, EC*: Escherichia coli,* BC*: Bacillus cereus,* SA*: Staphylococcus aureus,* SAL: *Salmonella* spp.*,* SHI*: Shigella* spp.*,*
ND: no detected,
Each value is mean of three replicates. Means within a row marked with different superscript letters are significantly different at ($P < 0.05$).
Compliant: 0 to 1.6 log_{10}CFU/cm^2; Improvable: 1.6 and 2.69 log_{10}CFU/cm^2; Not compliant: 2.70 log_{10}CFU/cm^2.

Table (4): Bacterial contamination levels for TACC, TCC, *B. cereus, S. aureus*, *Salmonella* and *Shigella* spp. found on FCSs of UNK-2 university restaurant kitchen. Data presented as Mean log_{10} CFU/ cm^2 ± Standard error of mean (SEM)

Parameter	Assonated preparation Surfaces				Cooking utensils				Kitchen equipment's			
	Preparation table	dining table	Cutting Boards	Pots	Preparation knives	Trolley tanks	Mobile tanks	Scoops	Colander	Peeling machine	Stem pots	Bain-marie
	Bacterial count, Log_{10} CFU/cm^2, (Mean ± SEM)											
TACC	4.89^{a} ± 0.09	4.43^{b} ± 0.24	5.12^{a} ± 0.05	4.91^{a} ± 0.22	2.59^{d} ± 0.21	4.81^{a} ± 0.06	4.47^{b} ± 0.43	4.40^{b} ± 0.28	4.01^{c} ± 0.15	4.98^{a} ± 0.05	4.91^{a} ± 0.17	3.75^{c} ± 0.08
MY	3.66^{b} ± 0.08	3.63^{b} ± 0.07	4.04^{ab} ± 0.51	4.06^{ab} ± 0.44	2.36^{c} ± 0.09	4.47^{a} ± 0.12	3.64^{b} ± 0.03	3.62^{b} ± 0.12	3.59^{b} ± 0.06	4.13^{a} ± 0.44	3.62^{b} ± 0.03	2.41^{c} ± 0.25
TCC	2.40^{bc} ± 0.04	2.19^{bc} ± 0.12	2.75^{a} ± 0.04	2.38^{bc} ± 0.05	1.00^{e} ± 0.٣0	2.19^{bc} ± 0.32	2.09^{c} ± 0.17	2.17^{bc} ± 0.22	2.23^{bc} ± 0.03	2.49^{ab} ± 0.12	2.28^{bc} ± 0.03	1.38^{d} ± 0.21
EC	+ve	-ve	+ve	-ve	-ve	+ve	+ve	+ve	+ve	+ve	-ve	-ve
BC	2.56^{ab} ± 0.13	2.72^{a} ± 0.08	2.56^{ab} ± 0.29	2.50^{ab} ± 0.02	ND	2.62^{ab} ± 0.23	2.60^{ab} ± 0.03	2.37^{b} ± 0.04	2.59^{ab} ± 0.18	2.59^{ab} ± 0.19	2.50^{ab} ± 0.21	2.56^{ab} ± 0.03
SA	2.46^{abcd} ± 0.03	2.41^{bcd} ± 0.24	2.68^{a} ± 0.03	2.35^{bcd} ± 0.06	1.54^{e} ± 0.03	2.51^{ab} ± 0.15	2.58^{abc} ± 0.13	2.31^{cd} ± 0.03	2.32^{cd} ± 0.21	2.34^{cd} ± 0.15	2.29^{cd} ± 0.11	2.23^{d} ± 0.03
SAL	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SHI	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TACC: Total aerobic colony count, MY: mold and yeast, TCC: *Total coliform count*, EC*: Escherichia coli,* BC*: Bacillus cereus,* SA*: Staphylococcus aureus,* SAL: *Salmonella* spp.*,* SHI*: Shigella* spp.*,* ND: no detected; -ve negative, +ve positive.

Each value is mean of three replicates. Means within a row marked with different superscript letters are significantly different at ($P < 0.05$).

Compliant: 0 to 1.6 log_{10}CFU/cm^2; Improvable: 1.6 and 2.69 log_{10}CFU/cm^2; Not compliant: 2.70 log_{10}CFU/cm^2.

Table (5): Bacterial contamination levels for TACC, TCC, *B. cereus, S. aureus*, *Salmonella* and *Shigella* spp. found on FCSs of UNK-3 university restaurant kitchen. Data presented as Mean log_{10} CFU/ cm^2 ± Standard error of mean (SEM)

Parameter	Assonated preparation Surfaces				Cooking utensils					Kitchen equipment's		
	Preparation table	dining table	Cutting Boards	Pots	Preparation knives	Trolley tanks	Mobile tanks	Scoops	Colander	Peeling machine	Stem pots	Bain-marie
	Bacterial count, Log_{10} CFU/cm^2, (Mean ± SEM)											
TACC	3.96^{bc} ± 0.07	3.81^{c} ± 0.11	4.37^{ab}± 0.24	4.18^{bc} ± 0.04	2.33^{d} ± 0.04	4.70^{a} ± 0.08	4.08^{bc} ± 0.24	3.82^{c} ± 0.06	4.26^{ab} ± 0.19	4.37^{ab} ± 0.23	3.91^{bc} ± 0.73	2.49^{d} ± 0.05
MY	3.54^{a} ± 0.14	2.50^{b} ± 0.11	3.70^{a}± 0.07	3.48^{a} ± 0.10	1.36^{c} ± 0.09	3.53^{a} ± 0.09	3.47^{a} ± 0.08	2.38^{b} ± 0.12	3.53^{a} ± 0.04	3.53^{a} ± 0.06	2.64^{b} ± 0.83	2.17^{b} ± 0.17
TCC	1.79^{d} ± 0.25	1.50^{e} ± 0.33	2.39^{ab}± 0.09	1.88^{cd} ± 0.11	ND	2.21^{ab} ± 0.19	2.22^{ab} ± 0.06	1.85^{cd} ± 0.20	2.11^{bc} ± 0.24	2.48^{a} ± 0.03	2.46^{a} ± 0.03	ND
EC	+ve	-ve	+ve	-ve	-ve	+ve	+ve	-ve	-ve	+ve	-ve	-ve
BC	2.41^{cd} ± 0.09	2.34^{de} ± 0.20	2.53^{bc}± 0.06	2.70^{abc}± 0.03	ND	2.81^{ab} ± 0.07	2.39^{cde} ± 0.05	2.69^{abc}± 0.03	2.97^{a} ± 0.03	2.42^{cde} ± 0.12	2.09^{e} ± 0.55	ND
SA	2.38^{b} ± 0.03	1.79^{f} ± 0.10	2.08^{de}± 0.13	2.19^{cd} ± 0.06	ND	2.40^{b} ± 0.20	2.30^{bc} ± 0.19	2.09^{de} ± 0.03	2.62^{a} ± 0.03	1.92^{ef} ± 0.03	1.84^{f} ± 0.03	ND
SAL	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SHI	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TACC: Total aerobic colony count, MY: mold and yeast, TCC: *Total coliform count*, EC: *Escherichia coli*, BC: *Bacillus cereus*, SA: *Staphylococcus aureus*, SAL: *Salmonella* spp., SHI: *Shigella* spp., ND: no detected; -ve negative, +ve positive.

Each value is mean of three replicates. Means within a row marked with different superscript letters are significantly different at ($P < 0.05$).

Compliant: 0 to 1.6 log_{10}CFU/cm^2; Improvable: 1.6 and 2.69 log_{10}CFU/cm^2; Not compliant: 2.70 log_{10}CFU/cm^2.

Percentage of occurrence of isolated bacteria in the exanimated surfaces

The results of this study indicated that FCSs in there were contaminations of FCSs of restaurant kitchens in three public universities in the Central Delta region of Egypt were polluted with *E. coli*, *B. cereus*, and *S. aureus*. The prevalence for every species varied across different surfaces, as shown in Table 6 and Figures 4-5.

Table 6. Percentage of positive swab samples of *E. coli, B. cereus* and *S. aureus* on different type of FCSs.

Examined FCSs	No. of examined samples	*Incidence of Microorganisms in food contact Surfaces; N (%)*				
		E. coli	*B. cereus*	*S. aureus*	*Salmonella* spp.	*Shigella* spp.
Associated preparation surfaces (APSs)						
Preparation table	9	6(66.66)	6(66.66)	6(66.66)	-	-
dining table	9	0(0)	6(66.66)	6(66.66)	-	-
Cutting Boards	9	6(66.66)	6(66.66)	6(66.66)	-	-
Cooking utensils						
Pots	9	0(0)	6(66.66)	6(66.66)	-	-
Preparation Knives	9	0(0)	0(0)	3(33.33)	-	-
Trolley tanks	9	6(66.66)	6(66.66)	6(66.66)	-	-
Mobile tanks	9	6(66.66)	6(66.66)	6(66.66)	-	-
Scoops	9	3(33.33)	6(66.66)	6(66.66)	-	-
Colander	9	3(33.33)	6(66.66)	6(66.66)	-	-
Kitchen equipment's						
Peeling machine	9	6(66.66)	6(66.66)	6(66.66)	-	-
Stem pots	9	0(0)	6(66.66)	6(66.66)	-	-
Bain-marie	9	0(0)	3(33.33)	3(33.33)	-	-
Total	**108**	**36 (33.3)**	**63 (58.3)**	**66 (61.11)**	**-**	**-**

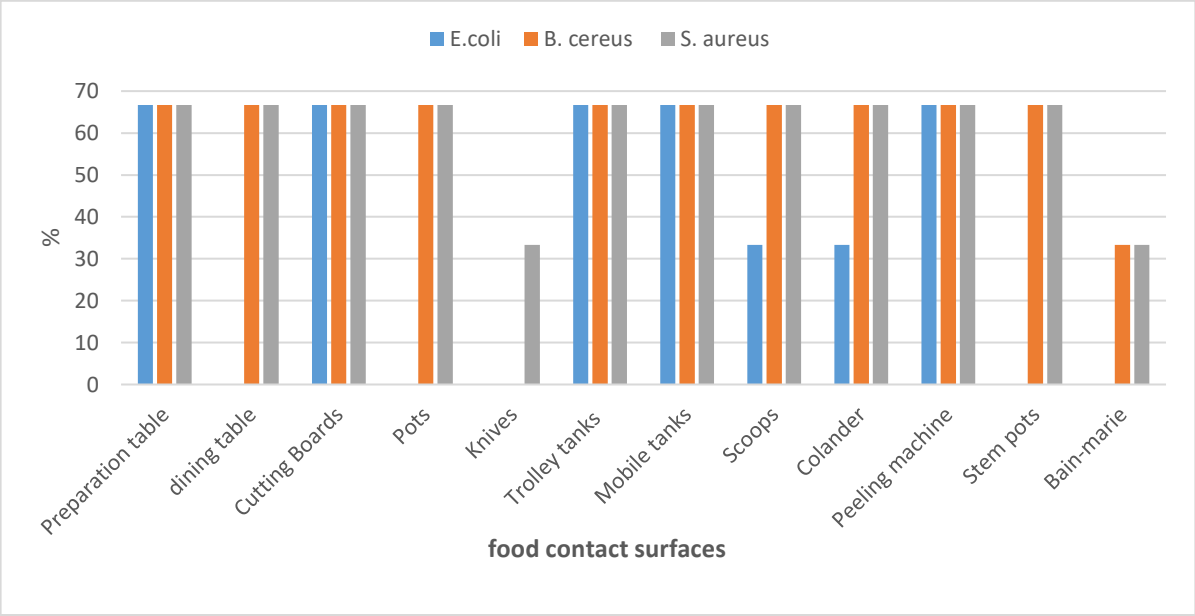


Fig. 4. Incidence of isolated pathogenic microorganisms found on 108 examined FCSs from 3 university restaurant kitchens in three public universities at Central-Delta region in Egypt.

The results in Table 6 and Figure 4 indicate that *S. aureus* had the highest prevalence at 61.11%, followed by *B. cereus* at 58.3%. *E. coli* exhibited the least prevalence at 33.3% (Table 6 and Figure 5). *S. aureus* was most frequently found in swab samples from various FCS, with a prevalence of 55.6%, followed by preparation knives and Bain-marie, each at 33.3%. Similarly, *B. cereus* was

predominantly detected in most examined FCS (66.7%), with Bain-marie also showing a prevalence of 33.3%. *E. coli* and *S. aureus* were least detected on dining tables, preparation knives, pots, stem pots, and Bain-marie, with rates of prevalence of 0.00% and 33.3%, respectively. In this study, *S. aureus*, *B. cereus*, and *E. coli* contaminant microorganisms were found in at most of all twelve types of analyzed FCSs (Fig. 4). Importantly, no *Salmonella* and *Shigella* spp. contamination was observed. The research revealed that preparation tables, cutting boards, trolley tanks, and mobile tanks were the most contaminated FCS, each at 66.6%, while Bain-marie and preparation knives had the least contamination rates of 22.2% and 7.41%, respectively (Figure 4). Additionally, the incidence of contaminated FCS varied among universities, with the greatest rate of 66.6% at UNR-2 and no contamination at UNR-1 (Figures 2-3).

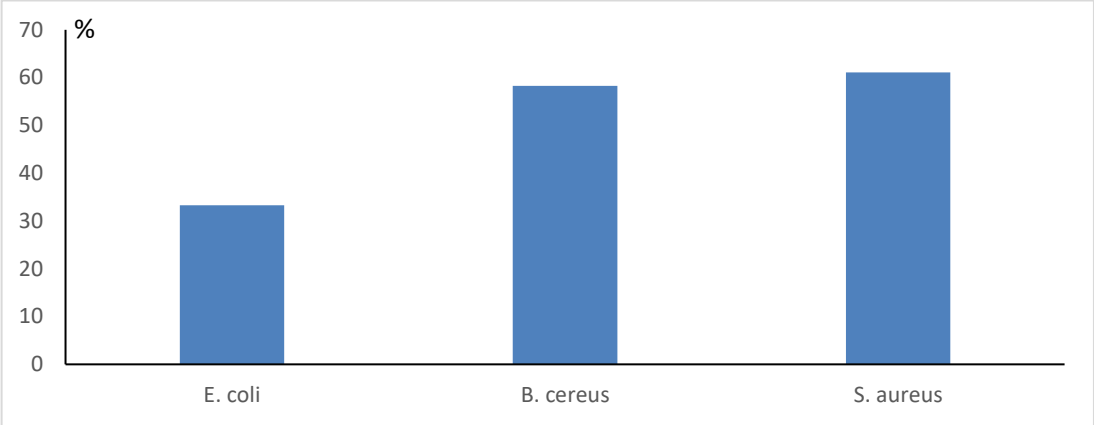


Fig 5: Incidence of contamination by each pathogenic microorganism species onto the 108 examined food contact surfaces

The results of this study align with several other studies. For instance, this study observed prevalence surpasses that of Sudheesh *et al*. (2013). In Oman, only one out of the five sampled restaurants did not detect *E. coli*, while all of them negative free for *S. aureus*. However, it is less than the prevalence reported by Zailani *et al*. (2013). Begani *et al*. (2012) found a 0% prevalence for *S. aureus*. In this study, among the 13 (26%) isolates positive for *E. coli*, plates were the most contaminated surfaces at 61.5%, followed by chopping boards at 23.1%, and tables and spoons each at 7.7%. These results are consistent with those from studies conducted in Italy (Losito *et al*., 2017), Spain (Garayoa *et al*., 2016), and South Africa (Sibanyoni and Tabit, 2019). The higher rates of contamination on these surfaces can be explained by the raw nature of the materials handled (such as raw meats) and the physical characteristics of the surfaces.

Many restaurants utilize primitive cleaning tools, such as worn-out sponges and subpar detergents, resulting in high rates of microbial contamination, as highlighted by this study. In contrast, accredited restaurants, like UNR- 1, adhere to rigorous quality control standards for cleaning, food processing, and storage. Several authors (Osimani *et al*., 2013; Garayoa *et al*., 2014) have asserted that implementing strict quality control system, conducting official inspections by relevant authorities, and mandating accreditation certificates are effective strategies to enhance sanitation levels in food-serving establishments.

Again, it is worth noting that Egypt currently lacks regulatory limits regarding general hygiene standards and the occurrence of foodborne pathogens on FCSs. Consequently, it is imperative that authorities carry out investigations and monitoring, implementing immediate corrective actions as necessary.

4. Conclusion

This study aimed to evaluate the microbiological quality (MQ) of 108 food contact surfaces (FCSs) samples in three restaurant kitchens for three public universities in the Central-Delta region of Egypt in order to provide new data on the hygienic conditions related to food preparation. This study constitutes the first assessment of the microbiological quality of FCSs in three public of Central Delta region universities, highlighting specific areas that require improvement. In light of our actual results, the elevated levels of bacterial counts on FCSs strongly suggest the necessity for enhanced hygiene protocols and the adoption of a HACCP system in this facility to guarantee the safety and quality of food served to students.

Competing Interests

The authors declare that they have no competing of interests in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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