ORIGINAL ARTICLE

Assessment of the Microbiological Quality of Food Contact Surfaces in Collective Catering in Central Morocco

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Abstract

Background: Food safety is a global concern due to the rise in foodborne diseases, with contamination of food contact surfaces being a significant factor. This study aimed to assess the hygienic conditions and bacteriological contamination levels on food contact surfaces in collective catering in Central Morocco.

Methods: A cross-sectional descriptive study was conducted across six restaurants. A total of 186 swab samples were taken from 17 types of food contact surfaces, including cutting boards, serving tables, knives, sinks, plates, and other utensils. The samples were taken according to ISO 18593:2018 and analyzed using selected culture media for aerobic mesophilic bacteria (AMC), *Enterobacteriaceae*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Pseudomonas spp,* as well as the presence of *Salmonella spp.* and *Listeria monocytogenes*. The surfaces were classified based on compliance with hygiene standards.

Results: Sixty-seven samples (36%) exhibited more than 2.70 $\log_{10}$CFU/cm², indicating non-compliance with hygiene standards. Raw meat cutting boards, sinks, and salad preparation containers were identified as the most contaminated food contact surfaces, with non-compliance rates of 83.3%, 58.3%, and 54.2%, respectively. In contrast, glasses, plates, and baking worktops were the least contaminated, with compliance rates of 77.8%, 72.8%, and 66.7%, respectively. The isolated bacteria were Coagulase-negative staphylococci (28.5%), *Escherichia coli* (18,8%), *S. aureus* (7.5%), *Klebsiella pneumoniae* (4.8%), *Pseudomonas aeruginosa* (1.6%), *E. faecalis* (1.6%), *Proteus mirabilis* (1%), and *Salmonella spp.* (0.5%). No *Listeria spp.* contamination was detected. The mean levels of aerobic mesophilic bacteria, *S. aureus*, and *Enterobacteriaceae* ranged from 1.59 $\log_{10}$CFU/cm² to 3.93 $\log_{10}$CFU/cm², 0 $\log_{10}$CFU/cm² to 1.49 $\log_{10}$CFU/cm², and between 1.55 and 4.34 $\log_{10}$CFU/cm², respectively.

Conclusion: This initial assessment of collective restaurants in Fez provides baseline data on environmentally hazardous microbes and will help food safety managers better implement effective control measures to prevent contamination and safeguard public health.

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Introduction

Food safety remains a major public health concern, as its failure causes an important burden of disease and mortality and constitutes an economic burden for society. According to the WHO (2015), every year nearly 600 million people around the world fall ill after eating contaminated food, and 420.000 die as a result.[1] The WHO regions of Africa and South-East Asia are the most affected by foodborne diseases.[2] In Morocco, the national epidemiological surveillance and health information system reports that the number of cases of food poisoning each year ranges from 1000 to 1600, with hospitalization rates between 30% and 45%. Moreover, approximately 20% to 25% of food service and retail establishments inspected by health services are considered to be at risk. Additionally, prepared foods for consumers are handled or stored in inadequate hygiene conditions, compromising their safety and wholesomeness.[3] Furthermore, as in many countries, the tendency for Moroccans to eat at restaurants rather than at home has increased, requiring these establishments to serve consumers healthy and safe food.[4] If hygiene conditions in the food establishments are poor, foodborne pathogens will undoubtedly cause illness.[5] Previous research conducted from 1986 to 2004, as reported by the US Centers for Disease Control and Prevention (CDC), documented approximately 9.040 foodborne outbreaks (FBOs), with 52% (4.675) attributed to restaurants, including cafeterias and hotels.[6] Another investigation in China revealed that 39% of FBOs took place in restaurants.[7] Austrian studies found that approximately 31% of outbreaks occurred in restaurants, hotels, and cafes.[8]

Food contamination leading to foodborne diseases can be caused by air, water, soil, ingredients used in food preparation, equipment, waste, food contact surfaces, and food workers.[9] Food contact surfaces may pose a potential health hazard if they are not properly cleaned and sanitized.[10] Indeed, during meal preparation in restaurants, food undergoes various manipulations such as cutting, chopping, mixing, etc., which require a clean environment, including utensils and food-contact surfaces, to guarantee food processing safety.[11] Unsanitary contact surfaces and utensils may lead to cross-contamination and raise the risk of pathogenic bacterial contamination in these foods.[12]

Various pathogens, such as *S. aureus, L. monocytogenes, Salmonella spp., Campylobacter jejuni, Yersinia enterocolitica,* and enteropathogenic strains of *E. coli*, can persist on surfaces for extended periods, forming resilient biofilms.[13] Also, it has been reported that bacteria such as *L. monocytogenes, Salmonella spp., E. coli, and S. aureus* have been shown to survive on kitchen utensils and hands, and they are the main causes of foodborne outbreaks.[5] Moreover, multiple studies[14, 15] highlight kitchen utensils and cutlery as significant sources of severe microbiological hazards. Items such as spoons, knives, cutting boards, and plates, as well as employees' hands, were discovered to harbor elevated levels of microorganisms, including *Bacillus cereus, E. coli, Shigella sonnei, Clostridium perfringens, Salmonella spp.,* and *S. aureus.* Furthermore, a previous study has revealed that knives, preparation tables, and mixers are the utensils and surfaces most frequently contaminated with spoilage bacteria, such as *Pseudomona*s and *Enterobacteriaceae*.[16]

Contaminated equipment and surfaces are among the top risk factors for foodborne outbreaks, emphasizing the importance of proper sanitation protocols. Therefore, it is imperative to establish food safety quality management systems and comply with rigorous hygiene standards in the working environment (surfaces, equipment, and utensils) to prevent microbial contamination and safeguard public health.[17] Furthermore, poor hand hygiene among workers, carrying pathogens such as *S. aureus* and *E. coli* on their nails or skin, has been identified as a significant factor in contaminating prepared food with these harmful pathogens.[18] Establishing a food safety control system is essential in preventing diseases associated with foodborne pathogens.[19] Microbial analysis of surfaces serves as a crucial tool for assessing cleanliness and improving hygiene practices. Regular monitoring through microbial counts provides an objective measure of cleanliness, surpassing visual inspections.[20] Moreover, effective hygiene control through bacteriological analysis is essential to ensure acceptable contamination levels and prevent foodborne diseases. Indeed, microbiological analysis of food contact surfaces is crucial for detecting indicator bacteria that reflect poor hygiene, such as aerobic mesophilic bacteria (AMC), *Staphylococcus*, and *Enterobacteriaceae*.[21] Food contact surface swabbing combined with viable cell counting is widely used for these assessments. This method has proven effective for detecting contaminant microbes such as *Klebsiella spp*., *Proteus spp*., *Pseudomonas spp*., *S. aureus*, and other bacteria species.[22] To the best of our knowledge, there is currently no data available on the incidence and microbial ecology of food contact surfaces in restaurants within the Fez prefecture, Morocco. Therefore, the main objective of the current study, conducted for the first time in central Morocco, is to assess the hygienic conditions and bacterial quality of food contact surfaces in collective catering. The results of this study will be used to determine risk surfaces in catering establishments and significantly help restaurants implement proper cleaning strategies.

Methods

Study Site

This study was carried out from July 2021 to January 2022 in six catering establishments randomly selected in different districts of Fez. The Fez prefecture

is located in the Fez-Meknes region, between the north and south of the Kingdom of Morocco (Figure 1). It covers an area of 332.1 km^2, with a total population of around 1.150.131, making it the largest in the region. It is subdivided into two urban communes: the commune of Mechouar Fez Jdid and the commune of Fez, which includes six urban districts (Agdal, Saiss, Zouagha, Mariniyéne, Fez Medina, Jnane El Ward), and three rural communes (Ouled Tayeb, Aïn Bida, Sidi Hrazem).[23]

Food Contact Surface Sampling

Seventeen food contact surfaces having high food preparation activity were examined, including raw meat cutting boards, vegetable cutting boards, knives, sink, spoon holders, mixers, Pizza boards, serving tables, fridge handles, shawarma machine plates, plates, glass, deep fryer, working surface, and weighing machine (Table 1). The surfaces were swabbed using sterile cotton swabs, and a total of 186 swab samples were collected during the entire study period to evaluate the hygienic conditions of the mostly used food contact surfaces. The swabbing method was conducted according to the standard method specified by ISO 18593:2018 (ISO, 2018).[24] A sterile template was prepared and placed over the designated area, ranging from 20 to 100 cm², according to the surface to be sampled. Sterile cotton swabs (Oxoid, UK), pre-moistened with 10 mL of sterile 1% w/v buffered peptone water (Biokar Diagnostics, France), were used to swab the surfaces, incorporating a consistent zig-zag movement in four directions: vertical, horizontal, and two diagonal planes. After swabbing, the swabs were reintroduced into the tubes containing 10 ml of peptone water, labelled, and transported to the laboratory in ice boxes (4°C) for bacteriological analysis. All samples were analyzed in an ISO/International Electrotechnical Commission (IEC) 17025:2005 accredited laboratory[25] (Regional Laboratory of Epidemiological Diagnosis and Environmental Hygiene, Fez) and in the laboratory of the Higher Institute of Nursing and Health Technology, Fez.

Microbial Analysis of Swabs

Total aerobic mesophilic counts (AMC) were enumerated and isolated on Plate Count Agar (PCA) (Biokar Diagnostics, France). Swab samples were mixed uniformly using a vortex (Vortex SHAKER, France) and serially diluted in peptone water, in triplicate. 1 mL of each dilution was spread onto the plate. Labelled Petri dishes were incubated at 30ºC for 72 h, and then dishes containing 30-300 colonies were

Table 1: Distribution of samples according to the food contact surfaces analysed

Type of food contact surface	Samples N*
Raw meat cutting boards	12
Vegetables cutting boards	12
Knives	12
Sink	12
Spoon holder	6
Mixer	6
Pizza board	6
Serving tables	12
Fridge handle	12
Shawarma machine plate	6
Plates	18
Glass	18
Deep fryer	6
working surface	12
Weighing machine	6
Baking surface	6
Salads preparation recipients	24
Total	186

N*: Total number of samples for each type of surface

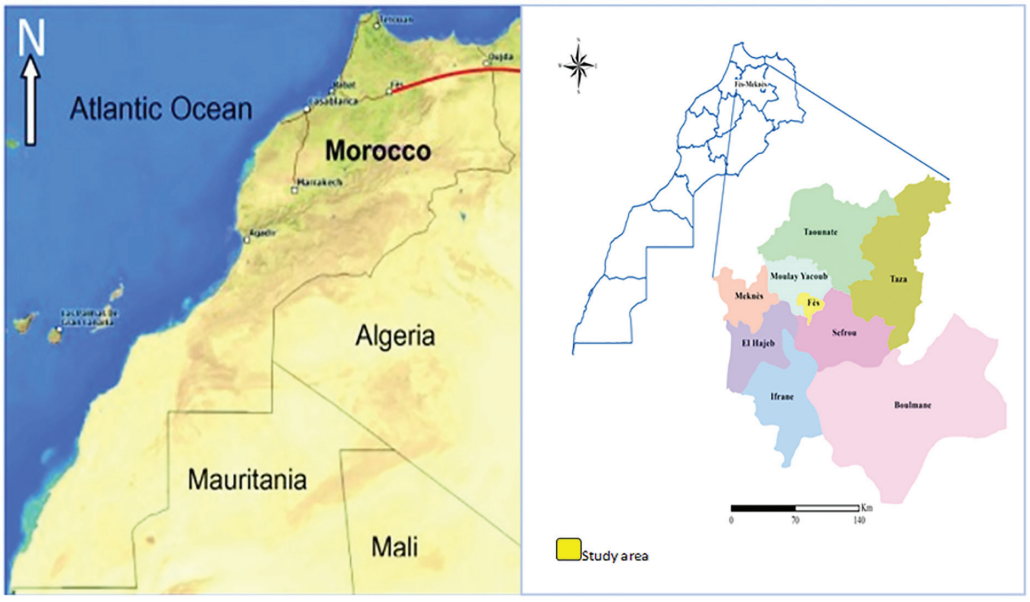

Figure 1: Geographic location of study area . (Designed by Authors). Satellite location Map of Fez, Latitude / Longitude: 34° 2’ 14» N / 4° 59’ 59» W.

counted with a magnifying glass. Also, enumeration of *Enterobacteriaceae* was conducted on Violet Red Bile Lactose (VRBL) Agar (Biokar Diagnostics, France) after 24 hours of incubation at 44±0,5°C, followed by streaking the obtained colonies onto eosin methylene blue agar (EMB) (Biokar Diagnostics, France) to distinguish *E. coli* based on its metallic appearance.

Morphological traits assessed included orientation, size, and pigmentation, which were evaluated through visual examination of microbial isolates cultured on Petri plates. Additionally, cell wall characteristics were analyzed using Gram staining techniques. Biochemical traits, including Cytochrome oxidase (oxidase test), Urease (urease test), Fermentation, and Citrate degradation, were employed for characterization of each isolate, with confirmation utilizing the API 20E® kit (BioMerieux, France). *Pseudomonas spp.* was detected on Cetrimide agar at 37±1°C for 24 hours. Staphylococci detection involved enrichment of swabs in brain heart infusion broth (Oxoid, Basingstoke, UK) supplemented with 5% sodium chloride at 37°C for 24 hours, followed by plating onto Baird Parker agar and subsequent identification based on microscopic characteristics and biochemical assays, including Gram staining, Catalase (catalase test), DNase, Mannitol fermentation, and Coagulase test (rabbit plasma) for confirmation of *S. aureus*. For *Salmonella spp.* detection, swabs were incubated for 18-24 hours at 37±1°C, followed by selective enrichment in Rappaport-Vassiliadis (RV) broth (Biokar Diagnostics, France) at 42±1°C for 18-24 hours. Subsequent sub-culturing onto Hektoen Agar and confirmation using biochemical tests and API 20E® (Biomerieux, France) were carried out for presumptive positive colonies (transparent green or blue-green with or without a black centre and non-lactose fermenting). Isolation and identification of *Listeria spp.* were performed in pre-enrichment Demi-Fraser broth (Biokar Diagnostics, France) for 24 hours at 30±1°C, followed by transfer to Complete Fraser broth (Biokar Diagnostics, France) and incubation at 37±1°C for 24 hours. Subsequent transfer to PALCAM agar (Biokar Diagnostics, France) and incubation at 37±1°C for 24 to 48 hours led to the identification of typical colonies, which were further confirmed using biochemical tests and API *Listeria*® (Biomerieux, France) for suspected isolates of *Listeria monocytogenes*. Bile Esculin Azide Agar (Biokar Diagnostics, France) was used for the selective isolation and identification of enterococci, which hydrolyze esculin in the presence of bile to esculetin. Esculetin then reacts with ferric citrate in the medium to form a dark brown or black precipitate of insoluble iron salts.

Enumeration results were expressed in CFU/cm² and converted to $\log_{10}$CFU/cm². The interpretation of results was conducted following established criteria,[11] which categorized samples into compliant (not detectable to 49 CFU/cm2, i.e. 0 to 1.69 $\log_{10}$CFU/cm²), improvable (between 50 and 499 CFU/cm2, i.e. 1.70 to 2.70 $\log_{10}$CFU/cm²), and non-compliant (exceeded 500 CFU/cm2 i.e. >2.70 $\log_{10}$ CFU/cm²). These criteria were chosen for their practicality, achievability, and reliability in evaluating hygiene and sanitation programs in the food industry and distribution systems.

Statistical Analysis

The study data were analyzed using SPSS (Statistical Package for the Social Sciences) software version 25. The means and standard errors for different microbial counts and compliance rates were calculated and presented in tabular and graphical forms. The Chi-2 statistical test was calculated to determine a relationship between non-compliance and the type of food-contact surface and restaurant. The test was considered statistically significant for a P value<0.05.

Results

Average levels of bacteria isolated from surface samples varied significantly across different samples. Mesophilic aerobic bacteria, *S. aureus*, and *Enterobacteriaceae* exhibited mean levels ranging from 1.59 $\log_{10}$CFU/cm² to 3.93 $\log_{10}$CFU/cm², 0 $\log_{10}$CFU/cm² to 1.49 $\log_{10}$CFU/cm², and between 1.55 and 4.34 $\log_{10}$CFU/cm², respectively (Table 2). The highest counts of aerobic mesophilic bacteria, *Enterobacteriaceae*, and *S. aureus* were observed on raw meat cutting boards, with mean levels of 3.93 $\log_{10}$CFU/cm², 4.34 $\log_{10}$CFU/cm², and 1.49 $\log_{10}$CFU/cm², respectively. Conversely, the lowest levels were detected on the baking surface, with means of 1.59 $\log_{10}$CFU/cm² for aerobic mesophiles and 1.55 $\log_{10}$CFU/cm² for *Enterobacteriaceae*, with undetected *S. aureus.*

Bacterial identification revealed the presence of several microorganisms, depending on the type of sample, including *S. aureus*, coagulase-negative staphylococci, *E. faecalis*, *E. coli, P. mirabilis, P. aeruginosa, K. pneumoniae, and Salmonella.spp* (Table 3). The prevalence of each species varied across different surfaces, with coagulase-negative staphylococci and *S. aureus* predominantly isolated from vegetable cutting boards and sinks at frequencies of 41.66% and 16.66%, respectively. E. coli was the most prevalent on raw meat worktops (41.66%), while *K. pneumoniae* showed the highest occurrence on working surfaces and sinks (25%). *P. aeruginosa* was detected on weighing machines and raw meat cutting boards (16.66%). *P. mirabilis* was identified on raw meat cutting boards (16.66%), whereas *E. faecalis* was detected on the sink and cutting boards (8.33%). Notably, *Salmonella spp.* was detected on only working surfaces, while *L. monocytogenes* was not detected on any surface in contact with food.

Table 2: Average counts of bacteria isolated from food-contact surfaces

Type of food contact surface	Average microbial counts (Log_{10}CFU/cm²±SD ; Min–Max)		
	FMAT*	S. aureus	Enterobacteriaceae
Raw meat cutting boards	3.93±0.97 1.68-4.62	1.49±2.70 0-5.98	4.34±0.10 1.48-5.02
Vegetables cutting boards	2.67±1.26 1.48-4.62	0.86±1.99 0-5.15	2.75±1.37 1.48-5.02
Knives	2.42±1.29 0.30-4.72	0.43±1.50 0-5.23	2.34±1.20 0-4.58
Sink	3.14±1.08 1.48-4.62	1±0.99 0-5.98	2.61±0.53 1.48-2.98
Spoon holder	2.23±1.11 0.30-3.43	-	2.10±1.15 0-2.96
Mixer	2.61±0.98 0.70-3.40	0.88±2.15 0-5.28	2.07±1.26 0-2.98
Pizza boards	2.49±0.79 1.53-3.40	-	2.34±0.67 1.34-2.98
Serving tables	2.14±0.84 1.00-3.57	-	1.96±0.82 1.36-3.63
Fridge handle	2.19±.70 1.60-3.46	-	2.18±0.74 1.54–3.41
Shawarma machine plate	2.51±0.82 1.48-3.49	-	2.40±0.62 1.48-3.00
Plates	1.87±0.58 1.30-2,95	-	1.85±0.56 1.30-2,89
Glass	1.84±0.57 1.00-2.95	-	1.82±0.53 1.36-2.96
Deep fryer	2.49±0.85 1.48-3.49	-	2.33±0.72 1.38-3.00
Working surface	2.97±1.08 1.48-4.62	0.99±2.30 0-5.93	2.85±1.32 1.48-5.02
Weighing machine	2.70±1.10 1.48-4,49	0.88±2.15 0-5.27	2.58±0.99 1.48-4.11
Baking surface	1.59±0.90 0-2.75	-	1.55±0.90 0-2.74
Salads preparation recipients	2.54±0.53 1.28-2.95	0.44±1.49 0-5.30	2.54±0.50 1.49-2.90

FMAT**: Total aerobic mesophilic bacteria, CFU: Colony forming unit, SD: Standard deviation

Compliance with selected criteria varied among food contact surfaces, as depicted in Table 4. Higher compliance rates were observed on glasses (77.8%), plates (72.2%), and baking worktops (66.2%). Conversely, several surfaces exhibited higher non-compliance levels, including raw meat cutting boards (83.3%), sinks (58.3%), salad preparation recipients (54.2%), weighing machines, and working surfaces (50%).

The Chi-2 test confirmed that there was a statistically significant association between the non-compliance and type of food contact surface ($\chi2$=53.395, P=0.010) and restaurant ($\chi2$=48.506, P<0.001). The overall non-compliance rate for the food contact surfaces examined was 36%.

Discussion

This study, conducted in the prefecture of Fez, aimed to assess the levels of microbial contamination on food processing surfaces and utensils across six restaurants, and then to provide a database on restaurant hygiene. The 186 swab samples were collected from 17 types of food contact surfaces, including cutting boards, sinks, knives, plates, and other utensils, and then analysed. Counting microbes on these food contact surfaces is essential for assessing cleanliness and hygiene practices in a catering system.

According to our results, the majority of surfaces did not meet the established microbiological criteria,[11] with AMC ranging from 3.93 log_{10}CFU/cm² to 1.59 log_{10}CFU/cm² on raw meat cutting boards and baking surfaces, respectively. The mesophilic counts were above the reference value, indicating that the cleaning procedures were ineffective and the surfaces were contaminated.[26] These findings are consistent with those reported in a hospital kitchen in Morocco[27] but exceed the levels reported in hotels and restaurants in Ethiopia, a hospital kitchen in Iran, and school canteens in Serbia.[5, 10, 19] This suggests deficiencies in disinfection protocols and cleaning procedures. Indeed, high aerobic microorganism counts on surfaces like cutting boards, preparation areas, and serving areas have been associated with inadequate sanitation practices.[28] Furthermore, the viable counts of *Enterobacteriaceae* and, particularly, *E. coli* are

Table 3: Prevalence of bacteria in food contact surfaces analysed during the study period

Type of food-contact surfaces ; (N**)	Frequency of bacteria in food contact Surfaces; n* (%)								
	SCN	*S. aureus*	*E. faecalis*	*E. coli*	*P. aeruginosa*	*P. mirabilis*	*K. pneumoniae*	*Salmonella. spp*	*L. monocytogenes*
Raw meat cutting boards (12)	4(33.33)	3(25)	1(8.33)	5 (41.66)	2(16.66)	2(16.66)	1(8.33)	-	-
Vegetables cutting boards (12)	5 (41.66)	2(16.66)	1(8.33)	3(25)	-	-	1(8.33)	-	-
Knives (12)	2(16.66)	1(8.33)		2(16.66)	-	-	-	-	-
Sink (12)	5 (41.66)	2(16.66)	1(8.33)	4(33.33)	-	-	3(25)	-	-
Spoon holder (6)	2(33.33)	-		2(33.33)	-	-	-	-	-
Mixer (6)	2(33.33)	1(16.66)		1(16.66)	-	-	-	-	-
Pizza boards (6)	3(50)	-		1(16.66)	-	-	-	-	-
Serving tables (12)	3(25)	-		1(8.33)	-	-	-	-	-
Fridge handle (12)	2(33.33)	-		1(8.33)	-	-	-	-	-
Shawarma machine plate (6)	3(50)	-		2(33.33)	-	-	-	-	-
Plates (18)	3(16.66)	-		1(5.55)	-	-	-	-	-
Glass (18)	3(16.66)	-		1(5.55)	-	-	-	-	-
Deep fryer (6)	2(33.33)	-		2(33.33)	-	-	-	-	-
Working surface (12)	4(33.33)	2(16.66)		3(25)	-	-	3(25)	1(8.33)	-
Weighing machine (6)	2(33.33)	1(16.66)		2(33.33)	1 (16.66)	-	1(16.66)	-	-
Baking surface (6)	2(33.33)	-		1(16.66)	-	-	-	-	-
Salads preparation recipients (24)	6(25)	2(8.33)		3(12.50)	-	-	-	-	-
Total (186)	53(28.5)	14(7.5)	3(1.6)	35(18.8)	3(1.6)	2(1.1)	9(4.8)	1(0.5)	0(0)

N**: Total number of samples for each type of surface n*: Number of samples within N

S. aureus: Staphylococcus aureus; SCN*: Staphylococcus coagulase negative; E. faecalis : Enterococcus faecalis; E. coli: Escherichia coli; P. aeruginosa: Pseudomonas aeruginosa; P. mirabilis:Proteus mirabilis; K.pneumoniae: Klebsiella pneumoniae; L.monocytogenes: Listeria monocytogene*s;-: Absent

Table 4: Percentage and frequency of non-compliance of food contact surfaces analyzed according to the selected criteria

Type of food contact surface	Samples N**	Conformity		
		Compliant n* (%)	Improvable n* (%)	Non-Compliant n* (%)
Raw meat cutting boards	12	1(8.3)	1(8.3)	10(83.3)
Vegetables cutting boards	12	5(41.7)	4(33.3)	3(25)
Knives	12	5(41.7)	5(41.7)	2(16.7)
Sink	12	2(16.7)	3(25)	7(58.3)
Spoon holder	6	2(33.3)	2(33.3)	2(33.3)
Mixer	6	1(16.7)	2(33.3)	3(25)
Pizza board	6	2(33.3)	2(33.3)	2(33.3)
Serving tables	12	7(58.3)	3(25)	2(16.7)
Fridge handle	12	7(58.3)	1(8.3)	4(33.3)
Shawarma machine plate	6	2(33.3)	2(33.3)	2(33.3)
Plates	18	13(72.2)	2(11.1)	3(16.7)
Glass	18	14(77.8)	1(5.6)	3(16.7)
Deep fryer	6	2(33.3)	2(33.3)	2(33.3)
Working surface	12	2(16.7)	4(33.3)	6(50)
Weighing machine	6	2(33.3)	1(16.66)	3(50)
Baking surface	6	4(66.7)	1(16.7)	1(16.7)
Salads preparation recipients	24	5(20.8)	6(25)	13(54.2)
Total	186	76(40,9)	43(23.1)	67(36)

N**: Total number of samples for each type of surface; n*: Number of samples within N

commonly used indicators of tool and equipment hygiene, being frequent causes of foodborne illnesses. This research revealed that *Enterobacteriaceae* counts were notably high compared to studies in Malaysia and Poland[29, 30] ranging from 1.55 $\log_{10}$CFU/cm² on baking surfaces to 4.34 $\log_{10}$CFU/cm² on raw meat cutting boards. In catering establishments, work areas, cutting boards, sinks, and kitchen taps are highlighted

as crucial as key surfaces that may lead to food cross-contamination, especially if they harbor mesophilic aerobic bacteria and *Enterobacteriaceae*.[31] Moreover, *S. aureus*, an indicator of poor personal hygiene, was found at levels meeting established criteria, ranging from 0 $\log_{10}$CFU/cm² to 1.49 $\log_{10}$CFU/cm² on raw meat cutting boards, respectively. Given its prevalence in the human microbiome, improper handling can facilitate its spread to food and food-contact surfaces.

Raw meat work surfaces were found to be the most heavily contaminated areas, largely because of cross-contamination from meat and poor hygiene practices. Meat offers a perfect breeding ground for microbes, and without adequate hygiene protocols, transferring bacteria between meat and work surfaces becomes unavoidable.[27] Microbial counts indicated that cutting boards had the highest level of microorganisms, likely due to their polyethylene material, which can develop pores and cuts from use. These surfaces can harbor microorganisms that are not fully eliminated during cleaning and may become a source of cross-contamination, transferring pathogens to food products or other contact surfaces.[17] Cutting boards should be periodically replaced, especially when they become worn or develop grooves that are difficult to clean. Additionally, color-coded cutting boards should be used for different types of foods. The microbiological cleanliness of cutting boards is influenced by their usage duration; new boards generally have higher cleanliness levels.[30]

Moreover, the rate of non-compliance was associated with the type of surface and the restaurant, revealing a significant overall level of 36%, indicating ineffective cleaning and disinfection of these food contact surfaces. These findings are higher than those reported in a previous study.[32] However, other research[33] has documented even higher non-compliance rates, reaching up to 41.96%. Moreover, microbiological compliance rates varied across different food contact surfaces, with glasses (77.8%), plates (72.2%), and baking worktops (66.2%) showing the highest rates. In comparison, raw meat worktops had the highest non-compliance rate (83.3%). This disparity can be attributed to the raw nature of materials handled on these surfaces and their physical characteristics, which influence contamination risks.[27]

Additionally, our results showed that *E. coli, S. aureus*, *P. aeruginosa, E. faecalis, and P. mirabilis* were found in 18.8%, 7.5%, 1.6%, 1.6%, and 1% of the food contact surfaces sampled, respectively. No contamination with *Listeria spp.* was detected. These findings align with a study conducted in Saudi Arabia, which evaluated the microbial quality of food contact surfaces and yielded similar results.[22] Numerous studies have demonstrated significant levels of *E. coli* and *S. aureus* micro-organisms in food served in restaurants and on food processing surfaces and utensils.[28, 34] Inadequate procedures heighten this risk, increasing the likelihood of foodborne diseases caused by pathogens such as *E. coli* O157, *S. aureus*, and *Salmonella spp.* These pathogens can survive on food processing or handling equipment due to residual food residues and can form biofilms.[26] Furthermore, coagulase-negative staphylococci, *K. pneumoniae,* and *Salmonella spp.* were identified with a frequency of 28.5%, 4.8%, and 0.5%, respectively. As previously reported, the detection of *Staphylococcus spp.* in food samples correlates with substandard hygiene practices among food handlers.[35] Additionally, the presence of *Klebsiella spp.* in food samples may signify lapses in employee hygiene practices, as this bacterium is frequently isolated from individuals with bronchitis, urinary tract infections, and pneumonia.[36] Furthermore, the presence of *Pseudomonas spp.* on food processing contact surfaces has been extensively discussed in the literature. Meliani and colleagues highlighted the favorable conditions for *Pseudomonas spp.* biofilm formation in food processing environments, where these organisms can thrive on nutrient-rich surfaces, and moisture.[37] Additionally, a previous study reported that the presence of *K. pneumoniae*, *Pseudomonas spp.*, and *E. coli* might indicate inadequate handwashing facilities or employees' failure to adhere to proper hand hygiene protocols within the premises.[38] Remarkably, *Salmonella spp.* was detected in only one sample, corroborating the results of a previous research.[39] Given that this bacterium is an important food-borne pathogen for public health, particular attention should be paid to personal hygiene and the disinfection of cooking utensils and surfaces in contact with food.

These results underscore the importance of enhancing various aspects of food safety within the evaluated restaurants, particularly focusing on the sanitation of food contact surfaces, personal hygiene practices, and overall cleanliness.[40] Addressing these areas is essential for elevating the microbial quality of foods prepared and served in these establishments. Achieving complete eradication of microbes is unattainable. Therefore, prioritizing good hygiene, thorough cleaning, and effective sanitation is crucial to minimize the presence of microorganisms on the surfaces in contact with food and in the final product. Moreover, mitigating the risk of cross-contamination necessitates the implementation of safer food handling practices. By adopting rigorous protocols and maintaining strict hygiene standards during food preparation and service, catering establishments can effectively reduce the likelihood of microbial contamination and safeguard consumers' health.

To ensure food safety, commercial operators,

scientists, and consumers need to work together consistently. The key factors in minimizing contamination of food contact surfaces include personal hygiene, effective kitchen design, proper sanitation, and adherence to scientifically-based cleaning practices.[26]

Conclusion

To the best of our knowledge, this is the first study to examine the bacterial quality of surfaces at collective catering in Fez prefecture. Contaminated surfaces in catering establishments pose significant food safety risks, highlighting the critical importance of stringent hygiene practices and thorough cleaning procedures. This study revealed high levels of bacterial counts on food contact surfaces in the restaurants studied, with a significant rate of non-compliance, which requires hygiene conditions to be improved. Implementing a rigorous accreditation system like the Hazard Analysis and Critical Control Points (HACCP) plan could notably elevate cleanliness and sanitation standards across restaurants in the city. Research into the microbial assessment of food contact surfaces should continue in all regions of Morocco to ensure that all restaurants comply with food safety standards and practices, and to help the relevant authorities establish appropriate training programs.

Authors' Contribution

All the authors contributed significantly to this work throughout the study process: Conception, study design, execution, data collection, analysis, and interpretation. They also participated in the writing and revision of the article and approved the publication of the final version of the manuscript by accepting the journal to which the article was submitted.

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Conflict of Interest

None declared.

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