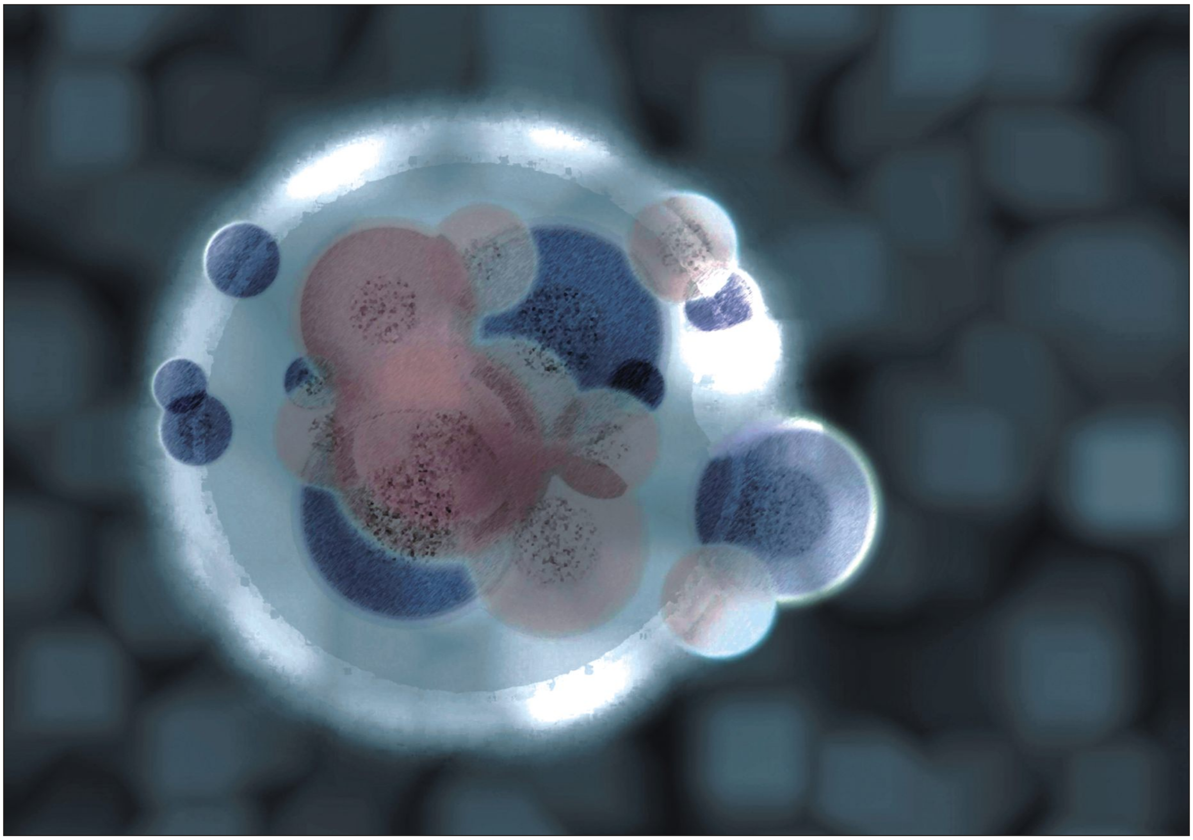

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Research Article
Heavy Microbial Load in the Work Environment, Utensils and Surfaces of Domestic Kitchens

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Abstract
Background and Objective: Foodborne illnesses are a global problem. In common households, these illnesses commonly arise from unsanitary kitchens where work surfaces and utensils carry heavy microbial loads. This investigation aimed to assess the quality of conditions in working areas, especially surfaces that come into physical contact with food, in domestic kitchens in the Unaizah governorate of the Kingdom of Saudi Arabia. **Materials and Methods:** Microbial loads were assessed via swab samples collected from the surfaces of dining tables, food trays, cooking utensils, interior surfaces of refrigerators, washbasins and water taps. These loads are presented in terms of total bacterial counts and counts of *Escherichia coli* that were compared with permissible limits reported in the Microbiological Specifications and Criteria for Foods of the KSA. **Results:** *Salmonella* sp. accounted for 16, 16, 4, 32, 28 and 20% of all microbiota in the samples collected from the aforementioned surfaces, respectively. Of the total air samples tested 68 and 80% were compliant with the total bacterial count and *E. coli* permissible limits, respectively. Furthermore, 40% of the water samples collected from the kitchens under investigation had bacterial counts lower than the permissible limits, where total bacterial counts ranged from $\leq$1 to 2.70 log CFU mL^{-1}, while 48% of the tested water samples were free ($\leq$1) of *E. coli*. On the contrary, 60% of the water samples exceeded the regulatory limits for total bacterial count and 52% for *E. coli*. **Conclusion:** Findings from this study indicate a dire need for strict and continuous monitoring of kitchen practices in the common households of the region of interest, along with the implementation of rules and regulations for the processes of preparing, cooking and distributing food in domestic kitchens to ensure food safety.

Key words: Food contact surface, food work area, domestic kitchen, hygiene condition, microbial load

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In recent times, mass media has made consumers highly aware and informed about food safety and hygiene, which has led to heightened interest in the issue of food contamination. Microorganisms are ubiquitous; they are present everywhere within us and around us in the ecosystem, including our food. While a large proportion of this microbiota is safe or beneficial, pathogenic microbes that are capable of causing disease and illnesses pose a serious concern. Pathogens make their way into food in a multitude of ways. Often, they arise from low-quality raw materials or via unsanitary processing steps practiced in food establishments, such as mishandling of food products by food handlers[1]. It is crucial that sanitary and hygienic conditions are maintained in working environments dealing with food preparation in both domestic and commercial settings to control microbial contamination of food[2]. Martinon *et al.*[3] reported that pathogenic bacteria, such as *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella* spp. and enteropathogenic strains of *Escherichia coli* can form biofilms on food contact surfaces within days and in some cases, within hours. Generally, subpar cleaning processes in workplaces, especially food contact surfaces, allow the formation of such biofilms, which eventually transform into full-fledged reservoirs of hazardous food contamination[4].

Foodborne illnesses are a global problem. The most alarming instance of the hazard caused by contaminated food is the occurrence of approximately 1.5 billion cases of diarrhea in children worldwide that leads to >3 M deaths annually[5,6]. It is a well-established fact that outbreaks of foodborne diseases and pathogens are caused by bad hygiene of personnel, low-quality or mishandled food ingredients and unclean kitchen utensils and surfaces. Therefore, the role of the kitchen, i.e., the place where food is eventually prepared for final consumption, cannot be ignored in the context of food contamination and the spread of pathogens. Research has suggested that kitchens and catering centers, especially the instruments and devices used most extensively therein, may often time be more contaminated than bathrooms and toilet seats[7,8]. In developing or underprivileged regions of the world, unsanitary food handling, storage, preparation and production are commonplace and thus, the chances of Foodborne illnesses are very high. Regardless, there are no accurate statistics available on the outbreaks of food poisoning and infections that likely originate from domestic kitchens in many developing countries.

Moore and Griffith[9,10] highlighted microbiological criteria, such as the count of mesophilic bacteria, coliform groups and *E. coli*, to be useful metrics for assessing the sanitary conditions of work areas and food contact surfaces in kitchens. It is a key criterion that can provide an indication of the safety levels of meals produced in kitchens or by a catering system. Food contamination can occur at any step of food production; therefore, microbiological analyses and testing must be performed during the different steps to pinpoint any poor hygienic conditions or practices that may need rectification. Some commonly employed criteria for this purpose include total aerobic bacterial count and the total counts of *Staphylococcus* and *Enterobacteriaceae* units[11]. There are only a small number of studies that have published data on hygienic conditions and microbial contamination in domestic kitchens; such studies are especially scarce in the Kingdom of Saudi Arabia. Therefore, in this study, the aforementioned microbiological testing was used to assess the hygienic conditions of work areas and food contact surfaces in domestic kitchens located in the Unaizah governorate of KSA.

MATERIALS AND METHODS

Study area: Twenty-five domestic kitchens in Al-Qassim Region, Unaizah Province, KSA were chosen for this study. Samples were collected in 2019-2020.

Sample collection from food contact surfaces: Samples were acquired by applying a sterile swab on different surfaces in the work area, including the dining table, food trays, cooking utensils, interior surfaces of the refrigerator, washbasins and water taps. For this purpose, a plastic template was placed on the target surface covering an area of 100 cm^2. The portion within it was swabbed with sterile cotton wool swabs that were pre-moistened with a 10 mL sterile peptone solution (1%). All swabs thus collected were transferred to the laboratory in an icebox (5°C) for analysis[12,13]. These swabs were analyzed for the total bacterial count, *E. coli*, *Staphylococcus aureus* and for the presence of *Salmonella* sp.[13].

Sample collection from water and air: Water samples were collected from the selected domestic kitchens according to the methods of PHE[12] and Marzano and Bal zaretti[14]. Air samples were collected according to the method described by Hayleeyesus and Manaye[15]. These were tested for total bacterial count and counts of *E. coli*[13].

Microbiological analyses and counting: Counts of microbes have been recorded per cm^2 of the tested surfaces or per mL of the tested water samples by counting all visible colonies on each plate. Results are expressed as log of the colony forming units, i.e., log CFU cm^{-2} or log CFU mL^{-1} of the tested sample. The percentages of samples that conformed to or did not conform to the microbiological criteria outlined by MOMRA were calculated and have been reported in this investigation.

RESULTS AND DISCUSSION

Microbial load on general food contact surfaces in domestic kitchens: The microbial load on work surfaces in terms of total bacterial count in the domestic kitchens included in this study ranged from ≤1-5.13 log CFU cm^{-2} with an average load of 2.90 log CFU cm^{-2}. The total count of *E. coli* ranged from ≤1-3.86 log CFU cm^{-2} with an average load of 1.67 log CFU cm^{-2}, while the count of *S. aureus* ranged from ≤1-4.56 log CFU cm^{-2} with an average value of 1.95 log CFU cm^{-2} given in Table 1. The permissible limit of microbial load on food contact and work surfaces is 1.00-2.00 log CFU cm^{-2} as reported in the Microbiological Specifications and Criteria for Foods (www.momra.gov.sa). Therefore, findings of this study indicated the occurrence of microbes on work surfaces in domestic kitchens to be unsatisfactory, where 80, 40 and 60% of all work surfaces in the sample set exceeded the regulatory limits of total bacterial counts, *E. coli* and *S. aureus*, respectively. Furthermore, 16% of the food contact surfaces were contaminated with *Salmonella* as well.

The presence of specific microbes that can cause food poisoning, such as *E. coli* and *S. aureus*, in work areas and on food contact surfaces is considered a marker of poor sanitary conditions[16,17]. According to the results presented in Table 1, counts of *E. coli* were high on the work surfaces of domestic kitchens included in the sample set, which indicated a lack of good cooking and cleaning practices, as well as improper surface sanitation. There was also a high incidence of *S. aureus* on work surfaces (Table 1). These high levels of microbial contamination detected on the work surfaces of domestic kitchens can be explained by the unsatisfactory and subpar disinfection protocols and cleaning procedures employed in these kitchens. Interaction with individuals, who commonly worked in these kitchens, such as housewives, revealed a poor level of awareness about microbial contamination sources. For instance, most housewives reused cloth towels without disinfection in multiple uses for cleaning of work surfaces. In addition, work surfaces were generally wiped once at the end of the day only. Moist cloth towels are ideal breeding grounds for microbes that can then be transferred to work surfaces that come in contact with the cloth. In turn, cross-contamination can occur between food ingredients and food contact surfaces once biofilms have formed on the latter. Both pathogenic microbes considered in microbiological analyses, i.e., *E. coli* and *S. aureus*, readily form biofilms that are resistant to sanitary procedures and thus, constitute the most important food contamination sources[18]. The application of good hygiene and sanitation during daily practices in domestic kitchens, such as the primary handling of raw materials and even the final preparation and consumption of meals is essential to avoid the spread of pathogenic microbes.

Table 1: Minimum, maximum and average values of microbial load on food contact surfaces in domestic kitchens

	Microbial load (log CFU cm^{-2})		
Values	TBC	*E. coli*	*S. aureus*
Minimum	≤1	≤1	≤1
Maximum	5.13	3.86	4.56
Average	2.90	1.67	1.95

CFU: Colony forming unit, TBC: Total bacterial count, ≤1, viable colony was not detected at the detection limit of <10^1 log CFU cm^{-2}

Table 2: Minimum, maximum and average values of microbial load on surfaces of food trays in domestic kitchens

	Microbial load (log CFU cm^{-2})		
Values	TBC	*E. coli*	*S. aureus*
Minimum	≤1	≤1	≤1
Maximum	5.49	3.51	5.09
Average	2.55	0.63	1.25

CFU: Colony forming unit, TBC: Total bacterial count. ≤1: Viable colony was not detected at the detection limit <10^1 log CFU cm^{-2}

Table 3: Minimum, maximum and average values of microbial load on surfaces of cooking utensils in domestic kitchens

	Microbial load analysis (log CFU cm^{-2})		
Values	TBC	*E. coli*	*S. aureus*
Minimum	≤1	≤1	≤1
Maximum	3.62	1.30	2.83
Average	2.02	0.68	0.62

CFU: Colony forming unit, TBC: Total bacterial count. ≤1: Viable colony was not detected at the detection limit <10^1 log CFU cm^{-2}

Microbial load on specific food contact surfaces in domestic kitchens: A summary of the findings from microbiological analyses performed on food trays and cooking utensils is presented in Table 2 and 3. Total bacterial count ranged from ≤1-5.49 and ≤1-3.62 log CFU cm^{-2} with average values of 2.55 and 2.02 log CFU cm^{-2}, respectively. The mean counts of *E. coli* ranged from ≤1-3.51 and ≤1-1.30 log CFU cm^{-2} for food trays and cooking utensils, respectively, while the counts of *S. aureus* ranged from ≤1-5.09 and ≤1-2.83 log CFU cm^{-2}

Table 4: Minimum, maximum and average values of microbial load on surfaces of refrigerators in domestic kitchens

	Microbial load (log CFU cm^{-2})		
Values	TBC	*E. coli*	*S. aureus*
Minimum	≤1	≤1	≤1
Maximum	5.98	3.96	5.19
Average	3.27	2.06	2.43

CFU: Colony forming unit, TBC: Total bacterial count. ≤1: Viable colony was not detected at the detection limit <10^1 log CFU cm^{-2}

Table 5: Minimum, maximum and average values of microbial load on surfaces of washbasins in domestic kitchens

	Microbial load (log CFU cm^{-2})		
Values	TBC	*E. coli*	*S. aureus*
Minimum	≤1	≤1	≤1
Maximum	6.29	5.92	5.99
Average	3.25	2.17	2.54

CFU: Colony forming unit, TBC: Total bacterial count. ≤1: Viable colony was not detected at the detection limit <10^1 log CFU cm^{-2}

on food trays and cooking utensils, respectively. Based on the results presented in Table 2 and 3, 68 and 60% of the food trays and cooking utensils, respectively, analyzed here had microbial loads that were noncompliant with the permissible levels of total bacterial count. Furthermore, 24 and 32% exceeded the limits outlined for *E. coli* and 48 and 28% exceeded the limits for *S. aureus*. *Salmonella* sp. were detected on the surface of 16% of the food trays and 4% of the cooking utensils. As mentioned before, a lack of knowledge about food safety in housewives and other individuals working in these kitchens may be the major cause behind improper hygiene and sanitation practices. This, in turn, will lead to a high microbial load on food trays and cooking utensils. According to the observations in this study, a common practice in the domestic kitchens included here was the placement of food trays behind the water faucet, which offers ideal living conditions for microbial growth and recontamination and thus, may have contributed to the higher microbial load on the trays tested here. As kitchen tools are highly sensitive and susceptible to microbial contamination, they must be kept in hygienic and low-humidity conditions. They come in contact with food very often and thus, may contaminate food by transferring pathogens from their surfaces, posing a threat to the safety of consumers[8]. On the contrary, households that satisfied the guidelines for microbial loads on food contact surfaces ensured thorough cleaning of food trays and cooking utensils in a dishwasher or washing machine, which has been previously suggested to be an effective means of controlling and reducing microbial contamination of materials used in domestic kitchens[13].

The findings from the microbial analyses of swabs collected from the surfaces of refrigerators and washbasins are presented in Table 4 and 5. The average values of total bacterial count, *E. coli* and *S. aureus* were 3.27, 2.06 and 2.43 log CFU cm^{-2}, respectively, on refrigerator surface and 3.25, 2.17, 2.54 log CFU cm^{-2} on washbasin surface. The percentages of refrigerator and washbasin surfaces that exceeded the regulatory limits for total bacterial count were 96 and 92%, respectively, while 84 and 68% of these two surfaces were noncompliant with permissible limits for *E. coli*. For *S. aureus*, 88 and 84% of the refrigerator and washbasin surfaces had microbial loads exceeding permissible limits. Furthermore, 32 and 44% of the tested refrigerator and washbasin surfaces, respectively, had detectable counts of *Salmonella* sp.

The contamination of internal refrigerator surfaces can be attributed to the transfer of microorganisms directly from contaminated foods, such as fresh vegetables and incompletely washed meat. Lee *et al.*[18] noted that contaminated raw food ingredients can contaminate the internal surfaces of refrigerators, especially if the refrigerators are not cleaned continuously. The practices of many household members in the domestic kitchens included here lacked cleaning of the interior surfaces of their refrigerators. Furthermore, they stored food ingredients in refrigerators in the same packages that were brought in from the market after being purchased. Previously, Borrusso *et al.*[19] have reported refrigeration of foods without changing market-bringing packages to be responsible for the contamination of the internal surfaces of refrigerators and other food products stored in them. In the case of some domestic kitchens in the sample set, the temperature of refrigerators was noted to be higher than the recommended temperature (4°C). In accurate refrigeration temperatures allow pathogenic microbes, such as *E. coli*, *Salmonella* sp., *S. aureus*, *Listeria monocytogenes* and *Yersinia enterocolitica*, to thrive more easily than they would at lower temperatures[20]. Similar to refrigerators, insufficient and sporadic cleaning of washbasins, in addition to their use for cleaning non food items, may cause contamination of the internal surfaces of washbasins.

The percentages of water taps that exceeded the regulatory limits for total bacterial count, *E. coli* and *S. aureus* on their surfaces were 84, 44 and 69% *Salmonella* sp. were detected in 20 of the tested water taps in the kitchens under investigation as well. The average values of total bacterial count, *E. coli* and *S. aureus* were 3.05, 1.02 and 2.25 log CFU per sample, respectively given in Table 6. Mattick *et al.*[21] observed that 50% of the water taps in the kitchens tested in their study were contaminated with *E. coli*. The microbial

Table 6: Minimum, maximum and average values of microbial load on surfaces of water taps in domestic kitchens

	Microbial load (log CFU per sample)		
Values	TBC	*E. coli*	*S. aureus*
Minimum	1.50	$\leq$1	$\leq$1
Maximum	5.40	2.97	4.73
Average	3.05	1.02	2.25

CFU: Colony forming unit, TBC: Total bacterial count. $\leq$1: Viable colony was not detected at the detection limit <10^1 log CFU per sample

Table 7: Minimum, maximum and average values of microbial load detected in the water of domestic kitchens

	Microbial load (log CFU mL^{-1})	
Values	TBC	*E. coli*
Minimum	$\leq$1	$\leq$1
Maximum	3.74	3.04
Average	2.0	1.17

CFU: Colony forming unit, TBC: Total bacterial count. $\leq$1: Viable colony was not detected at the detection limit <10^1 log CFU mL^{-1}

Table 8: Minimum, maximum and average values of microbial load detected in the air of domestic kitchens

	Microbial load (log CFU cm^{-2})	
Values	TBC	*E. coli*
Minimum	$\leq$1	$\leq$1
Maximum	2.88	1.90
Average	1.22	0.21

CFU: Colony forming unit, TBC: Total bacterial count. $\leq$1: Viable colony was not detected at the detection limit <10^1 log CFU cm^{-2}

load on kitchen sponges was majorly accounted for by *Salmonella* sp., *Campylobacter jejuni* and *S. aureus*. Contaminated sponges, when used to wash dishes around water taps, may transfer their microbial load to washbasins and water taps.

Microbial load in water used in domestic kitchens: Water is one of the most important factors that contribute to the outbreak of foodborne illnesses and pathogens. Worldwide, approximately1.8 M people die due to diarrhea and other related diseases caused by contaminated food and drinking water[5]. Water contamination poses a major concern to food safety as water is a key ingredient in many kitchen-based activaties[22]. Results of microbiological analyses of water samples collected from domestic kitchens in this investigation are presented in Table 7. Total bacterial counts ranged from $\leq$1-3.74 log CFU mL^{-1} with an average value of 2.05 log CFU mL^{-1}. The counts of *E. coli* ranged from $\leq$1- 3.04 with an average value of 1.17 log CFU mL^{-1}. This assessment indicated the quality of water resources in the selected domestic kitchens to be unsatisfactory. The 60 and 52% of the water samples analyzed here exceeded the regulatory limits for total bacterial count and *E. coli*, respectively. The standard limit of total bacterial and *E. coli* count in tap water is 2.70 log CFU mL^{-1} or less as outlined in the Microbiological Specifications and Criteria for Foods (www.momra.gov.sa). A possible reason behind water contamination in domestic kitchens may be the lack of continuous cleaning and disinfection of water storage units or a contaminated water supply. The absence of continuous cleaning programs for piped drinking water supply has been reported to be the leading cause of poor sanitation and hygiene status in the previous studies[23]. If individuals working in the kitchen apply regular cleaning and disinfection on water storage units, in addition to using filters on piped water supplies for purification, water safety can be ensured, which will reduce the chance of food poisoning.

Microbial load in the air of domestic kitchens: A summary of findings from microbiological analyses of air samples collected from selected domestic kitchens is presented in Table 8. Total bacterial counts ranged from $\leq$1-2.88 with an average value of 1.22 log CFU cm^{-2}, while *E. coli* counts ranged from $\leq$1-1.90 with an average value of 0.21 log CFU cm^{-2}. The permissible limit of total bacterial count in air samples in food establishments is 1.20 log CFU cm^{-2} or less as reported in the Microbiological Specifications and Criteria for Foods (www.momra.gov.sa). The percentage of tested air samples, whose total bacterial count and *E. coli* count complied with the permissible limits were 68 and 80%, respectively. As this constituted the majority of the tested air samples, it was inferred that the microbial loads in the air of the domestic kitchens investigated here were rather satisfactory. This may be due to the installation of suitable suction fans in sufficient numbers, which recirculate and clean air in kitchens, improving the quality and type of microbes present in the air of kitchens.

CONCLUSION

Assessing microbial loads and hygienic conditions in work areas and on food contact surfaces in domestic kitchens is key to controlling outbreaks of foodborne illnesses and pathogens. Heavy microbial loads (total bacterial count, *E. coli* and *Salmonella* sp.) were recorded on the surfaces of dining table, food trays, cooking utensils, interior surfaces of refrigerator, washbasins and water taps in the domestic kitchens investigated here. Furthermore, water samples collected from domestic kitchens in the study were found to be heavily contaminated with *E. coli*. On the contrary, the microbial load in air samples collected from the kitchens under investigation was satisfactory. It is speculated based on the results that the traditions, educational levels and common practices of individuals frequently working in kitchens, such as housewives, in conjunction with environmental conditions and quality of food ingredients and raw materials affect the microbial load on work and food contact surfaces in domestic kitchens.

SIGNIFICANCE STATEMENT

This study discovered that large numbers of pathogenic and non-pathogenic bacteria reside on work surfaces and utensils commonly used in household kitchens. This demonstration of kitchens being the potential cause of foodborne illnesses can be beneficial for common people by encouraging them to maintain hygienic conditions. Furthermore, this study provides a knowledge base for researchers across the globe to uncover other species of bacteria that are relevant to foodborne illnesses from domestic kitchens.

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