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SHORT COMMUNICATION article

Assessment of bacterial contamination and antimicrobial susceptibility profile in institutional catering: A cross-sectional study of Libyan school canteens

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Abstract: School canteens are critical environments for student health, yet they frequently act as reservoirs for multidrug-resistant foodborne pathogens. This study aimed to evaluate the microbiological quality of environmental surfaces and the hands of food handlers in Al-Marj City, Libya, while determining the antimicrobial susceptibility of the isolates. During the 2024-2025 academic year, 60 swabs were collected from 15 school canteens. Bacteriological identification was conducted using selective media and comprehensive biochemical assays. Antimicrobial susceptibility testing was performed using the Kirby-Bauer disc diffusion method. The overall contamination rate was 53.3%. *Escherichia coli* was the most prevalent isolate (43.8%), followed by *Staphylococcus aureus* (34.4%) and *Proteus mirabilis* (21.9%). A statistically significant disparity was observed in hygiene outcomes based on management gender: male-managed facilities exhibited a 59.6% contamination rate, whereas female-managed facilities showed 12.5%. The high prevalence of fecal indicators and opportunistic pathogens necessitates urgent regulatory oversight and the implementation of mandatory food safety certification for canteen personnel.

Introduction

Foodborne diseases represent a formidable global public health challenge, characterized by high morbidity rates, particularly among school-aged children whose immune systems remain in development [1]. In institutional settings, school canteens serve as primary sources of nutrition, making them critical control points for food safety. In Libya, and within the Al-Marj region, the rapid expansion of educational infrastructure has occasionally outpaced the enforcement of rigorous sanitary protocols. Bacterial contamination in these environments typically stems from systemic lapses, including cross-contamination between raw and processed items, inadequate disinfection of contact surfaces, and poor personal hygiene of handlers [2]. Pathogens such as *Escherichia coli* and *Staphylococcus aureus* are not only indicators of sanitary failure but also potential vectors for antimicrobial resistance (AMR) [3, 4]. Foodborne diseases constitute a critical global public health issue, causing significant morbidity and mortality across all age groups. These illnesses primarily arise from the ingestion of food or water contaminated with pathogenic bacteria, viruses, or parasites. School-aged children are particularly vulnerable due to their developing immune systems and frequent consumption of

meals from school canteens, where hygiene standards may be inconsistent [5]. Globally, the WHO estimates 600 million annual illnesses and 420,000 deaths, with children under five bearing nearly one-third of this fatal burden [6]. School canteens are vital nutritional sources but often pose bacterial risks due to systemic lapses in hygiene and operational procedures. The presence of *E. coli*, *Salmonella spp*., and *S. aureus* often serves as an indicator of poor sanitation and fecal contamination. Studies have identified *Bacillus cereus* and *Salmonella spp*. in school settings, frequently linked to inadequate staff training and irregular hygiene inspections [7, 8]. Similar trends are observed in Egypt and Sudan, where high percentages of students face risks from contaminated school meals [9]. Contamination is often found on food contact surfaces such as knives, cutting boards, and washing stations, highlighting the role of biofilms and inadequate sanitization in bacterial persistence [10, 11].

The emergence of AMR foodborne pathogens is a growing global challenge that complicates clinical treatment. School meals have been documented to harbor multidrug-resistant *E. coli* and *S. aureus*, often stemming from the misuse of antibiotics in livestock or environmental contamination [12]. AMR is projected to cause massive economic damage and millions of deaths by 2050, emphasizing the need for monitoring resistance patterns in institutional settings like canteens. Poor hand hygiene, lack of protective clothing, and nasal carriage of *S. aureus* significantly increase contamination risks. Improper temperature control during storage and the simultaneous preparation of raw and cooked items (cross-contamination) are major factors in microbial proliferation. Effective handwashing with soap and water for 20 seconds remains the most critical intervention for reducing the spread of pathogens. In many developing regions, food safety legislation enforcement is often weak [2, 13, 14]. Challenges include irregular inspections, limited microbiological testing, and a lack of structured certification programs for school canteens. Addressing these gaps through regular training and rigorous monitoring is essential to safeguard student health. This highlights the necessity of this study in Al-Marj City, Libya, as it addresses the critical intersection of institutional food safety and the alarming rise of AMR among foodborne pathogens.

Materials and methods

Study design and sampling framework: A cross-sectional microbiological investigation was conducted during the 2024-2025 academic year. A total of 60 swabs were strategically collected from 15 representative school canteens in Al-Marj City. The sampling protocol targeted four high-risk zones: Food preparation tables, washing sinks and drainage areas, snack-serving stations, and hand swabs from food handlers (each n=15).

Laboratory protocols: Samples were enriched in Nutrient Broth and sub-cultured on MacConkey Agar (for Enterobacteriaceae) and Mannitol Salt Agar (for *Staphylococci*). Isolate identification was confirmed through Gram staining and a suite of biochemical tests, including Catalase, Coagulase, and the IMViC series (Indole, Methyl Red, Voges-Proskauer, and Citrate).

Antimicrobial susceptibility testing: Susceptibility profiles were determined using the Kirby-Bauer disc diffusion method on Mueller-Hinton agar, with results interpreted in accordance with the 2024 Clinical and Laboratory Standards Institute (CLSI) guidelines [15].

Ethical approval: Before data collection, the purpose and procedures of the study were explained to each participant's parent, and students were invited to participate following their class sessions. Written informed consent was obtained from all participants' parents. Ethical approval for the study was obtained from the AIHO (AL-Marj Institute of Education Office) and the Review Board (RB) (MJ-87-2026).

Statistical analysis: Descriptive statistics were used to summarize prevalence, while the Chi-square test assessed the associations between categorical variables (gender vs. contamination rate). A p-value < 0.05 was defined as the threshold for statistical significance.

Results and discussion

Workforce demographics and gender disparity: The study revealed a significant gender imbalance among canteen personnel in Al-Marj City, with males comprising 86.7% of the workforce, compared to 13.3% for females. A statistical analysis confirmed that this disparity in gender distribution is significant ($p < 0.05$). This demographic trend reflects the local socio-economic landscape of the food service sector in Libya, where male workers are predominantly employed in institutional catering roles.

Microbial prevalence and pathogenic profiles: Microbiological analysis identified a high overall contamination rate of 53.3% across the sampled canteens. A total of 32 bacterial isolates were recovered, representing three major pathogenic species (**Table 1**). Thus, *E. coli, the* most frequently isolated bacterium, accounting for 43.75% of the total isolates, serves as a critical indicator of fecal contamination, likely associated with inadequate hand hygiene or poor water quality. *S. aureus:* Represented 34.38%. The presence of *S. aureus* indicates a risk of toxin-mediated food poisoning, often introduced via nasal carriage or poor skin hygiene of the handlers. *P. mirabilis*: Identified in 21.88% of the cases. Although less frequent, its presence points toward lapses in general environmental sanitation.

Table 1: Distribution of the bacterial isolates according to identified bacterial species

Bacterial Species	Isolates	Percentage
Escherichia coli	14	43.75%
Staphylococcus aureus	11	34.38%
Proteus mirabilis	7	21.87%
Total	**32**	**100%**

Spatial distribution of contamination and cross-contamination risks: The distribution of positive cultures varied across different sampling locations (**Figure 1**). The highest rates of positive cultures were obtained from snack tables (37.5%), followed by food preparation tables (25.0%) and water sinks (25.0%). Workers' hands accounted for 12.5% of the isolates. While the differences between sampling sites were not statistically significant ($p > 0.05$), the high loads on contact surfaces highlight their role as primary reservoirs of cross-contamination in the kitchen environment.

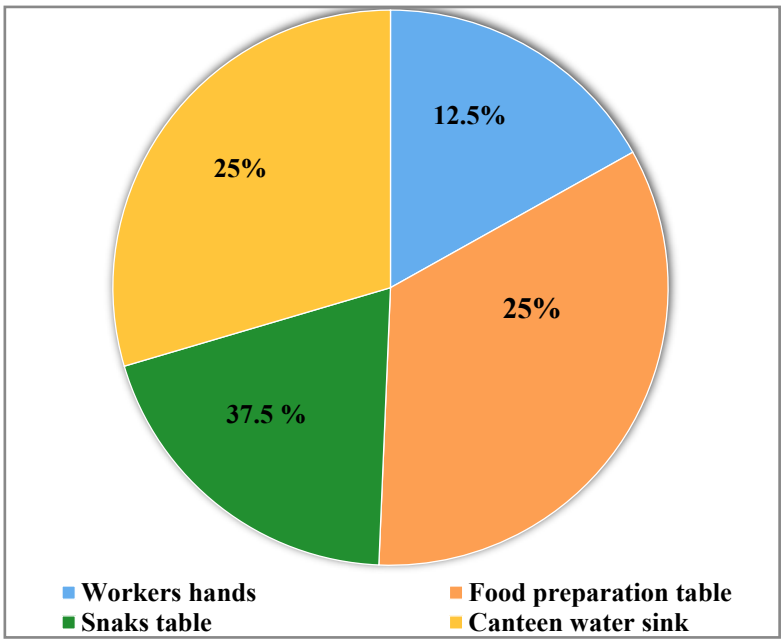

Figure 1: Distribution of the positive-culture samples according to the site of sample collection

The impact of management gender on hygiene outcomes: A striking finding was the correlation between management gender and bacterial prevalence (**Table 2**). Canteens managed by males showed a contamination rate of 59.6%, whereas female-managed facilities showed only 12.5%. This significant "hygiene gap" may be attributed to cultural factors, where females in the region often receive more rigorous domestic training in food handling and sanitation. These results strongly suggest that targeted hygiene training should prioritize male food handlers to bridge this gap.

Table 2: Comparison of contamination prevalence by operator gender

Operator Gender	Samples tested	Positive samples	Prevalence
Male	52	31	59.62
Female	8	1	12.5

Student demographics and environmental bacterial load: The present study demonstrated that canteens serving primary school students (aged 6-12 years) had significantly higher microbial loads than those serving older students ($p = 0.005$). This finding indicates that student age is a statistically significant determinant of environmental microbial contamination within school canteens. The higher contamination levels observed in this age group may be attributed to reduced adherence to personal hygiene practices and increased physical activity, both of which can facilitate the spread of microorganisms within dining environments. Similar associations between hygiene behavior and contamination risk have been reported in recent studies examining school food environments [16, 17]. A significant disparity was also identified between male- and female-managed canteens, with contamination rates of 59.6% and 12.5%, respectively ($p < 0.05$). This pronounced difference suggests that gender-related factors may influence food safety practices and overall hygiene performance. It is plausible that variations in hygiene knowledge, training, and routine practices contribute to this gap. Previous research has demonstrated that food handler behavior and training are critical determinants of contamination risk and food safety outcomes [18, 19]. These findings underscore the necessity of implementing targeted, evidence-based training interventions, particularly for male food handlers, to improve compliance with hygiene standards and reduce microbial contamination [20].

When compared with findings from other regions, the contamination levels observed in this study are consistent with those reported in similar developing-country settings, although they remain significantly higher than levels documented in more regulated environments ($p < 0.001$) [9, 10]. This discrepancy may be explained by differences in infrastructure quality, enforcement of food safety regulations, and the frequency of health inspections. Studies have consistently shown that structured food safety systems and continuous monitoring are associated with significant reductions in contamination levels ($p < 0.05$) [17, 21]. Furthermore, results revealed that student age group and food handler gender remained independent predictors of microbial contamination after adjusting for confounding variables ($p < 0.05$). This reinforces the hypothesis that both behavioral and managerial factors play a critical role in shaping the microbiological safety of school canteen environments. The elevated contamination burden associated with younger students may therefore result from a combination of behavioral exposure risks and insufficient environmental control measures. Collectively, these findings highlight the importance of integrating statistically informed interventions, including targeted hygiene education for students, specialized training programs for food handlers, and strengthened regulatory oversight. Such measures are essential to achieving significant and sustainable improvements in food safety outcomes within school canteens. The findings in Al-Marj align with studies from other developing regions but show significantly higher contamination rates compared to Western European school systems. This gap underscores the critical impact of modern infrastructure and rigorous health inspections on ensuring food safety in institutional settings.

Antibiotic sensitivity pattern of the isolated bacterial species: All *Staph aureus* and *E. coli* isolates exhibited complete susceptibility to all tested antibiotics, including ciprofloxacin, doxycycline, levofloxacin, clindamycin, clarithromycin, amikacin, azithromycin, and nitrofurantoin. In contrast, *Proteus mirabilis* isolates showed high susceptibility to most antibiotics, with 100% sensitivity to levofloxacin, clindamycin, clarithromycin, amikacin, and nitrofurantoin. However, a small proportion of *P. mirabilis* isolates demonstrated resistance to ciprofloxacin and azithromycin (7.1% each) and to doxycycline (14.3%; **Figure 1**). These findings indicate that while all tested Gram-positive and Gram-negative isolates generally remain highly susceptible to commonly used antibiotics, *P. mirabilis* exhibits occasional resistance to certain agents, underscoring the importance of continuous antimicrobial surveillance to guide effective therapy. This highlights the need for continuous antimicrobial surveillance and monitoring to guide effective treatment and ensure prudent use of antibiotics in clinical and food safety contexts [22]. This study recommends implementing compulsory food safety training for all canteen staff. Conduct unannounced microbiological inspections by local health authorities at least once per semester. Ensure continuous access to clean running water and standardized waste disposal systems. Educate students on the importance of washing hands before eating to reduce the environmental bacterial load in canteen areas.

Conclusion: This study confirms that a significant proportion of school canteens in Al-Marj City fail to meet optimal microbiological safety standards.

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