



Detecting and Identifying Bacterial Contamination in School Canteens in Al-Marj City, Libya

Moftah S. Negm ^{1*}, Zahra Hussein Almabrouk ², Abdusalam Aboubaker Abdusalam ³
^{1,2} Department of Microbiology, Faculty of Dentistry, University of Benghazi, Benghazi, Libya
³ Therapeutic Nutrition, College of Medical Technology Ajdabiya, Ajdabiya, Libya

الكشف عن التلوث البكتيري وتحديده في مقاصف المدارس بمدينة المرج، ليبيا

مفتاح سالم نجم ^{1*}، زهرة حسين المبروك ²، عبد السلام أبو بكر عبد السلام ³
^{1,2} قسم الأحياء الدقيقة، كلية طب الأسنان، جامعة بنغازي، بنغازي، ليبيا
³ قسم التغذية العلاجية، كلية التقنية الطبية بأجدابيا، أجدابيا، ليبيا

*Corresponding author: muftah.najem@uob.edu.ly

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Abstract:

School canteens constitute an important component of the food supply system for children and may represent potential sources of foodborne infection when appropriate hygiene and sanitation practices are not maintained. Food handlers, food-contact surfaces, and water sources can contribute to the transmission of pathogenic microorganisms. This study investigated the occurrence and distribution of bacterial contamination in selected school canteens in Al-Marj City, Libya.

A cross-sectional study was conducted between January and April 2025 in selected public and private school canteens in Al-Marj City. A total of 60 swab samples were collected from 15 school canteens, with four samples obtained from each canteen. Sampling sites included food handlers' hands, food preparation surfaces, food preparation tables, and water sinks. Samples were transported under refrigerated conditions to the laboratory and subjected to microbiological examination, including culture, Gram staining, and conventional biochemical tests for bacterial identification.

Bacterial growth was detected in 32 of the 60 samples, corresponding to an overall contamination rate of 53.33%. Gram-negative bacteria accounted for 21 isolates (65.63%), whereas Gram-positive bacteria accounted for 11 isolates (34.37%). Among the identified organisms, *Escherichia coli* was the predominant isolate, comprising 14 isolates (43.75%), followed by *Staphylococcus aureus* with 11 isolates (34.38%) and *Proteus mirabilis* with 7 isolates (21.88%). *E. coli* was detected across all sampling locations, with the highest proportion reported from the snack/food-service table and water sink. *S. aureus* was most frequently recovered from the snack/food-service table, whereas *P. mirabilis* was primarily detected on food preparation and snack/food-service surfaces.

The detection of bacterial contamination in more than half of the sampled canteen sites indicates important deficiencies in hygiene and sanitation practices. The predominance of *E. coli*, *S. aureus*, and *P. mirabilis* highlights potential risks associated with inadequate hand hygiene, contaminated food-contact surfaces, and insufficient sanitation of water-related areas. Strengthening hygiene training for food handlers, improving cleaning and disinfection procedures, and implementing routine microbiological surveillance are recommended to reduce the risk of foodborne illness among schoolchildren.

Keywords: School canteens; food safety; bacterial contamination; *Escherichia coli*; *Staphylococcus aureus*; *Proteus mirabilis*; Al-Marj; Libya

الملخص

تُعد مقاصف المدارس جزءاً مهماً من منظومة توفير الغذاء للأطفال، وقد تشكل مصدراً محتملاً للعدوى المنقولة بالغذاء في حال عدم الالتزام بممارسات النظافة والتعقيم المناسبة. إذ يمكن أن يساهم القائمون على تداول الأغذية، والأسطح الملامسة للطعام، ومصادر المياه في انتقال الكائنات الحية الدقيقة المسببة للأمراض. وقد بحثت هذه الدراسة في مدى انتشار التلوث البكتيري وتوزيعه في مقاصف مدرسية مختارة بمدينة المرج في ليبيا.

أُجريت دراسة مقطعية في الفترة ما بين شهري يناير وأبريل من عام 2025، شملت مقاصف مدارس حكومية وخاصة مختارة في مدينة المرج. وجرى جمع ما مجموعه 60 عينة مسحية من 15 مقصفاً مدرسياً، بواقع أربع عينات من كل مقصف. وشملت مواقع أخذ العينات: أيدي العاملين في تداول الأغذية، وأسطح تحضير الطعام، وطاولات تحضير الطعام، وأحواض المياه. نُقلت العينات إلى المختبر في ظروف مبردة وأُخضعت للفحوصات الميكروبيولوجية، بما في ذلك الاستنبات، وصبغة غرام، والاختبارات الكيميائية الحيوية التقليدية لتحديد نوع البكتيريا.

تم رصد نمو بكتيري في 32 عينة من أصل 60 عينة، مما يعكس معدل تلوث إجمالي قدره 53.33%. وشكلت البكتيريا سالبة الغرام 21 عينة (65.63%)، في حين مثلت البكتيريا موجبة الغرام 11 عينة (34.37%). ومن بين الكائنات التي تم تحديدها، كانت بكتيريا الإشريكية القولونية (*Escherichia coli**) هي الأكثر شيوعاً بواقع 14 عينة (43.75%)، تلتها المكورات العنقودية الذهبية (*Staphylococcus aureus**) بـ 11 عينة (34.38%)، ثم بكتيريا المتقلبة الرائحة (*Proteus mirabilis**) بـ 7 عزلات (21.88%). وقد رُصدت بكتيريا *E. coli** في جميع مواقع أخذ العينات، وسُجلت أعلى نسبة لها في طاولات تقديم الوجبات الخفيفة/الطعام وأحواض المياه. أما بكتيريا *S. aureus** فقد عُزلت بشكل متكرر من طاولات تقديم الوجبات الخفيفة/الطعام، بينما رُصدت بكتيريا *P. mirabilis** بشكل أساسي على أسطح تحضير الطعام وأسطح تقديم الوجبات الخفيفة/الطعام.

يشير رصد التلوث البكتيري في أكثر من نصف مواقع المقاصف التي شملتها الدراسة إلى وجود أوجه قصور هامة في ممارسات النظافة والتعقيم. كما يسلط الانتشار الملحوظ لبكتيريا *E. coli** و *S. aureus** و *P. mirabilis** الضوء على المخاطر المحتملة المرتبطة بعدم كفاية نظافة اليدين، وتلوث الأسطح الملامسة للطعام، وعدم كفاية تعقيم المناطق المرتبطة بالمياه. يُوصى بتعزيز التدريب على النظافة للعاملين في تداول الأغذية، وتحسين إجراءات التنظيف والتطهير، وتطبيق نظام دوري للرصد الميكروبيولوجي؛ وذلك للحد من مخاطر الإصابة بالأمراض المنقولة بالغذاء بين تلاميذ المدارس.

الكلمات المفتاحية: مقاصف المدارس؛ سلامة الغذاء؛ التلوث البكتيري؛ الإشريكية القولونية؛ المكورات العنقودية الذهبية؛ المتقلبة الرائحة (بروتئوس ميرابيليس)؛ المرج؛ ليبيا.

Introduction

Foodborne diseases are a major public health concern and occur when food or water is contaminated with pathogenic microorganisms, parasites, toxins, or hazardous chemical agents (Abuhlega et al., 2020). They impose a substantial global health burden, contributing to morbidity and mortality as well as considerable social and economic consequences, including healthcare costs, school absenteeism, and loss of productivity (Al Shareef et al., 2023). School-aged children, particularly young children, are especially vulnerable to foodborne infections and may experience more severe health outcomes. Therefore, ensuring the microbiological safety of food provided in schools is an important component of protecting children's health.

School canteens and other institutional food-service facilities may become potential sources of foodborne bacterial contamination when appropriate food handling, personal hygiene, cleaning, storage, and sanitation practices are not consistently maintained. Previous studies have reported the presence of potentially pathogenic bacteria, including *Escherichia coli* (*E. coli*), *Salmonella* spp., and *Staphylococcus aureus* (*S. aureus*), in food, food-contact surfaces, and institutional food-service environments (Bereda et al., 2016; Al Shareef et al., 2023). The presence of these microorganisms demonstrates the importance of maintaining adequate hygiene practices and conducting regular microbiological monitoring in food-service settings.

Food handlers are considered an important potential source of bacterial contamination because microorganisms can be transferred from their hands to food and food-contact surfaces. Studies conducted in Portugal and Nigeria detected *E. coli* and *S. aureus* on the hands of food handlers and identified inadequate hand hygiene as an important factor associated with food contamination (Alves et al., 2021; Okoronkwo et al., 2016). In particular, *S. aureus* commonly colonizes the skin and nasal passages and can be transferred to food through direct contact, respiratory droplets, or contaminated equipment (Al Muhanna et al., 2019). Its ability to persist under unfavorable environmental conditions may further contribute to its occurrence in food-service environments (Kim et al., 2018; Wu et al., 2018; Le et al., 2021).

In addition to food handlers, environmental surfaces and food-contact equipment may serve as reservoirs for bacterial contamination when cleaning and disinfection are inadequate, thereby increasing the possibility of cross-contamination (El Ghaza et al., 2023). *E. coli*, a member of the Enterobacteriaceae family, is normally associated with the intestinal microbiota, while its detection in food or food-contact environments may indicate fecal

contamination and inadequate sanitation (Sitaba & Nurlinda, 2022). *S. aureus* is also an important foodborne pathogen because some strains produce heat-stable enterotoxins that can cause food poisoning (Kim et al., 2018; Wu et al., 2018; Le et al., 2021). Although *Proteus mirabilis* is primarily recognized as an opportunistic pathogen, its recovery from food-related environments may also indicate environmental contamination and inadequate hygiene conditions (Ma et al., 2022). These findings collectively suggest that bacterial contamination in school food-service environments may originate from multiple sources, including food handlers, food-contact surfaces, equipment, water, and cross-contamination.

Despite evidence from previous studies demonstrating bacterial contamination in food-service and institutional environments, limited information is available regarding the occurrence and distribution of bacterial contaminants in school canteens in Al-Marj City, Libya. In particular, local data on contamination of food handlers' hands, food preparation surfaces, food-service tables, and water sinks are limited. This lack of local evidence represents an important research gap because the extent and distribution of bacterial contamination in these environments have not been adequately characterized.

Therefore, the present study aims to determine the occurrence, prevalence, and distribution of bacterial contamination in selected public and private school canteens in Al-Marj City, Libya, by detecting and identifying bacterial species isolated from food handlers' hands, food preparation surfaces, food-service tables, and water sinks. The findings are expected to provide baseline microbiological data on the safety of school canteen environments and contribute to the development of appropriate hygiene, sanitation, and food-safety measures for reducing potential risks of foodborne infections among schoolchildren.

3. Materials and Methods

3.1 Study Design and Setting

A cross-sectional study was conducted between January and April 2025 in selected public and private school canteens in Al-Marj City, Libya. The study was designed to assess the occurrence and distribution of bacterial contamination within school canteen environments.

3.2 Sample Collection

A total of 60 swab samples each sample were replicate three time and were collected from 15 school canteens, with four samples obtained from each canteen. The sampling sites were:

- food handlers' hands;
- food preparation surfaces;
- food preparation tables; and
- water sinks.

Sampling was performed using sterile equipment and aseptic techniques to minimize external contamination.

For food preparation surfaces and tables, sterile swabs moistened with sterile saline were used to sample a defined area of approximately 10 × 10 cm. The swabs were firmly rubbed over the selected surfaces before being placed immediately into sterile transport tubes.

For water sink samples, the upper rim and inner surfaces of the sink were swabbed using sterile, saline-moistened swabs. The swabs were then transferred into labeled sterile transport tubes.

Hand samples were collected from food handlers after they had been instructed not to wash their hands for at least 30 minutes before sampling. The swabs were applied to the palms, interdigital spaces, and areas beneath the fingernails to maximize recovery of microorganisms potentially present on the hands.

Sampling procedures performed in school canteens, including sampling of food preparation tables, snack/food-service surfaces, water sinks, and food handlers' hands(Figure 1.)

Each sample was labeled with the relevant sampling information and maintained under refrigerated conditions at approximately 4°C during transportation. Samples were transported promptly to the microbiology laboratory for processing.

3.3 Microbiological Examination

Collected samples were subjected to conventional microbiological examination. Bacterial isolates were recovered using appropriate culture media and subsequently examined based on colony morphology and Gram-staining characteristics. Presumptive identification was confirmed using conventional biochemical tests.

The principal biochemical tests used for bacterial identification included catalase, coagulase, oxidase, indole, urease, citrate utilization, mannitol fermentation, and DNase testing, as appropriate for the suspected organism.

3.4 Gram Staining

Gram staining was performed on representative bacterial colonies to differentiate Gram-positive from Gram-negative organisms according to their staining characteristics and cellular morphology.

3.5 Identification of Bacterial Isolates

Bacterial species were identified based on a combination of colony morphology, microscopic characteristics, and biochemical reactions. The principal organisms identified in the study were *E. coli*, *S. aureus*, and *P. mirabilis*.

Microbiological Examination and Identification of Bacterial Isolates

Collected swab samples were subjected to conventional microbiological examination for the isolation and identification of bacterial contaminants. Samples were inoculated onto appropriate culture media and incubated under suitable conditions. Suspected bacterial colonies were evaluated based on their colony morphology and subjected to Gram staining to determine their cellular morphology and Gram reaction.

Gram staining was performed using the standard procedure, allowing differentiation of bacterial isolates into Gram-positive and Gram-negative groups based on their staining characteristics and microscopic morphology.

Presumptive identification of bacterial isolates was subsequently performed using conventional biochemical tests selected according to the suspected organism. The tests included catalase, coagulase, oxidase, indole, urease, citrate utilization, mannitol fermentation, and DNase tests. The final identification of isolates was based on the combined results of colony morphology, microscopic characteristics, Gram reaction, and biochemical profiles.

The bacterial species identified in the present study included *Escherichia coli*, *Staphylococcus aureus*, and *Protes mirabilis*.

3.6 Data Analysis

The results were summarized using frequencies and percentages. The proportion of each bacterial isolate was calculated based on the total number of bacterial isolates recovered from positive samples.

4. Results

4.1 Overall Bacterial Contamination

Of the 60 swab samples collected from the 15 school canteens, bacterial growth was detected in 32 samples, representing an overall contamination rate of 53.33%. No bacterial growth was detected in the remaining 28 samples (46.67%).

A total of 32 bacterial isolates were recovered and identified from the positive samples.

4.2 Distribution of Bacterial Isolates According to Gram Reaction

Gram staining demonstrated a predominance of Gram-negative bacteria among the recovered isolates. Gram-negative organisms accounted for 21 isolates (65.63%), whereas Gram-positive organisms accounted for 11 isolates (34.37%).

Thus, Gram-negative bacteria represented almost two-thirds of all recovered isolates, while approximately one-third were Gram-positive bacteria (Figure 2). Figure 2. Distribution of bacterial isolates according to Gram-stain reaction.

4.3 Identification of Gram-Positive Bacteria

Among the Gram-positive isolates, *Staphylococcus aureus* was identified as the sole Gram-positive species recovered in this study. Eleven isolates of *S. aureus* were obtained, representing 34.38% of all bacterial isolates.

The recovery of *S. aureus* from school canteen environments is of public health importance because the organism is frequently associated with food handlers and may contaminate food and food-contact surfaces during preparation or service.

4.3.1 Identification of *Staphylococcus aureus*

The identification of *S. aureus* was based on colony morphology, Gram staining, and biochemical characteristics. On blood agar, the isolates produced smooth, circular colonies with a characteristic golden-yellow appearance, and some colonies demonstrated β -hemolysis. Gram staining revealed Gram-positive cocci arranged predominantly in grape-like clusters.

The isolates were catalase-positive and coagulase-positive, supporting their identification as *S. aureus*. They also demonstrated mannitol fermentation on mannitol salt agar, with yellow coloration associated with acid production, and showed DNase activity. The isolates were negative for oxidase, indole, and citrate utilization.

Figure 3. Culture characteristics of *Staphylococcus aureus*: (A) blood agar, (B) MacConkey agar, and (C) mannitol salt agar.

4.4 Identification of Gram-Negative Bacteria

Twenty-one Gram-negative isolates were recovered from the sampled canteen environments. These comprised 14 isolates of *Escherichia coli* (43.75%) and 7 isolates of *Proteus mirabilis* (21.88%).

4.4.1 Identification of *Escherichia coli*

Fourteen isolates of *E. coli* were identified, accounting for 43.75% of all bacterial isolates and representing the most frequently recovered organism in the study. On blood agar, the isolates produced round, smooth, moist colonies. On MacConkey agar, characteristic pink to red colonies were observed, consistent with lactose fermentation.

Microscopic examination following Gram staining demonstrated Gram-negative bacilli appearing as small- to medium-sized rods with rounded ends, occurring singly or in irregular arrangements.

The biochemical profile was consistent with *E. coli*. The isolates were positive for indole and catalase reactions and negative for coagulase, oxidase, urease, and citrate utilization. No growth was observed on mannitol salt agar.

Figure 4. Culture characteristics of *Escherichia coli*: (A) blood agar and (B) MacConkey agar. Figure 4.4. Microscopic appearance of *Escherichia coli*, showing Gram-negative bacilli. Figure 5. Biochemical characteristics of *Escherichia coli*: positive indole and catalase reactions.

4.4.2 Identification of *Proteus mirabilis*

Seven isolates of *P. mirabilis* were identified, representing 21.88% of the total bacterial isolates. On blood agar, the organism demonstrated characteristic swarming motility, producing concentric zones of growth across the agar surface. β -hemolysis was observed in some cultures. On MacConkey agar, the isolates produced pale or colorless colonies, consistent with the inability to ferment lactose.

Microscopic examination demonstrated Gram-negative, motile bacilli appearing as straight, medium-sized rods with rounded ends. The organisms were observed singly or in short arrangements.

Biochemical testing demonstrated characteristics consistent with *P. mirabilis*. The isolates were positive for catalase, urease, and citrate utilization and negative for oxidase, coagulase, and indole. No growth was observed on mannitol salt agar.

Figure 6. Culture characteristics of *Proteus mirabilis*: (A) MacConkey agar and (B) blood agar. Figure 7. Microscopic appearance of *Proteus mirabilis*, showing Gram-negative bacilli.

4.4.3 Summary of Biochemical Characteristics

The principal biochemical characteristics of the bacterial isolates are summarized in Table 4.1. Table 1. Preliminary biochemical characteristics of bacterial isolates recovered from school canteens.

4.5 Distribution of Bacterial Isolates According to Sampling Site

The distribution of bacterial isolates varied according to sampling location. *E. coli* was the most frequently recovered organism and was detected at all sampling sites. The highest proportions of *E. coli* were reported from the snack/food-service table and water sink, with each location accounting for 12.50% of the total isolates.

The widespread detection of *E. coli* across different sampling locations suggests the presence of inadequate sanitation and possible fecal contamination within the canteen environment. The recovery of the organism from

water-related areas is particularly important because contaminated water may contribute to the dissemination of enteric bacteria.

S. aureus was most frequently isolated from the snack/food-service table, where it accounted for 18.75% of the total isolates. This distribution may reflect contamination associated with direct handling of food or frequently touched food-service surfaces.

P. mirabilis was primarily recovered from the food preparation and snack/food-service tables, with each site accounting for 9.38% of the total isolates. Its presence on food-contact surfaces may indicate inadequate cleaning or cross-contamination during food preparation.

The distribution of bacterial isolates according to sampling site is presented in Table 4.2. **Figure 8. Distribution of *S. aureus* according to sampling site. Figure 9. Distribution of *E. coli* according to sampling site. Figure 10. Distribution of *P. mirabilis* according to sampling site. Table 2. Distribution of bacterial isolates according to sampling location in school canteens.**

5. Discussion

School canteens provide food and beverages to large numbers of students and therefore constitute an important setting for food safety interventions. The present study identified bacterial contamination in 32 of 60 samples, corresponding to an overall contamination rate of 53.33%. This finding indicates that more than half of the sampled sites showed evidence of bacterial contamination and suggests that deficiencies in hygiene and environmental sanitation may exist within the investigated school canteens.

5.1 Distribution of Isolates According to Gram Reaction

The present study demonstrated a predominance of Gram-negative bacteria, which accounted for 65.63% of the isolates, compared with 34.37% Gram-positive bacteria. This distribution may reflect the characteristics of the sampled environments, particularly the presence of moist surfaces and water-associated areas that can support the persistence and dissemination of Gram-negative organisms.

The predominance of Gram-negative bacteria has also been reported in investigations of food-service and institutional environments (Elkammoshi et al., 2024; Son et al., 2022). However, differences between studies may arise from variations in sampling locations, environmental conditions, cleaning practices, culture methods, and the number of samples examined.

5.2 Identification of Bacterial Isolates

Three principal bacterial species were identified: *E. coli*, *S. aureus*, and *P. mirabilis*. *E. coli* was the predominant organism, accounting for 43.75% of all isolates. Its frequent recovery from the sampled environments is important because the presence of *E. coli* on food-contact surfaces may indicate inadequate sanitation and possible fecal contamination.

The predominance of *E. coli* is consistent with findings from other food-service investigations in which enteric bacteria have been associated with contaminated food, utensils, hands, and preparation surfaces. The detection of *E. coli* in school canteens is particularly concerning because contamination may be transferred from environmental surfaces to ready-to-eat foods.

S. aureus accounted for 34.38% of the isolates and was the predominant Gram-positive organism. Its presence may be associated with direct or indirect contamination by food handlers because the organism commonly colonizes human skin and nasal passages. Food handlers who do not maintain adequate hand hygiene may therefore contribute to the contamination of food and food-contact surfaces.

The presence of *S. aureus* is also important because some strains produce enterotoxins capable of causing food poisoning. Consequently, preventing contamination during food preparation and maintaining appropriate food storage conditions are important components of food safety.

P. mirabilis represented 21.88% of the isolates. Although it is more commonly recognized as an opportunistic pathogen rather than a primary foodborne pathogen, its recovery from school canteen surfaces indicates environmental contamination and may reflect inadequate cleaning and disinfection practices.

The overall pattern of contamination observed in this study is broadly consistent with previous investigations reporting *E. coli*, *S. aureus*, and other bacterial contaminants in institutional food-service environments (Elkammoshi et al., 2024; Son et al., 2022; El Ghaza et al., 2023).

5.3 Distribution of Bacterial Isolates by Sampling Location

Differences in bacterial distribution were observed among the sampled locations. *E. coli* was detected at all sampling sites, with the highest proportions observed on the snack/food-service table and water sink. This widespread distribution may indicate multiple contamination pathways, including inadequate hand hygiene, contaminated water, and insufficient cleaning of food-contact surfaces.

The presence of *E. coli* in water-associated areas is particularly noteworthy because contaminated water can act as a vehicle for transmission of enteric bacteria. Similar concerns have been reported in food-service environments where inadequate sanitation of water sources and utensils has been associated with bacterial contamination.

S. aureus was most frequently recovered from the snack/food-service table. Because this surface is likely to experience frequent direct contact with food handlers, utensils, and ready-to-eat foods, contamination may occur through repeated handling or inadequate disinfection. Previous research has similarly identified food handlers and frequently touched surfaces as important reservoirs of *S. aureus*.

P. mirabilis was mainly detected on the food preparation and snack/food-service tables. The recovery of this organism from these surfaces may indicate inadequate cleaning or cross-contamination through utensils and equipment.

Overall, the distribution of bacterial isolates across hands, food-contact surfaces, tables, and sinks demonstrates that contamination within school canteens is likely to involve multiple interconnected pathways rather than a single source.

5.4 Public Health Implications

The findings have important implications for food safety in schools in Al-Marj City. The detection of bacterial contamination in more than half of the samples suggests that existing hygiene practices may be insufficient to consistently prevent microbial contamination.

Several measures could contribute to reducing this risk. These include regular and effective handwashing by food handlers, appropriate use of clean protective clothing, routine cleaning and disinfection of food-contact surfaces, proper sanitation of sinks and water-associated areas, and prevention of cross-contamination between raw and ready-to-eat foods.

Food handlers should also receive regular food safety training, with particular emphasis on hand hygiene, environmental sanitation, personal health, safe food handling, and appropriate storage practices. In addition, routine microbiological monitoring could be incorporated into school food safety programs to identify contamination trends and evaluate the effectiveness of corrective measures.

5.5 Strengths and Limitations

An important strength of this study is that samples were obtained from several potentially important contamination sites within school canteens, including food handlers' hands, preparation surfaces, tables, and sinks. The use of culture-based identification combined with Gram staining and biochemical testing also enabled characterization of the principal bacterial isolates.

However, several limitations should be considered when interpreting the findings. The study included a relatively small number of school canteens and samples and was conducted over a limited period. Therefore, the findings may not be generalizable to all schools in Al-Marj City or to other regions of Libya. In addition, the study focused on bacterial contamination and did not investigate viral, parasitic, or chemical hazards. Molecular identification and antimicrobial susceptibility testing were also not included. Future studies incorporating larger sample sizes,

repeated sampling across different seasons, antimicrobial resistance testing, and molecular characterization would provide a more comprehensive assessment of food safety risks.

6. Conclusion

This study demonstrated substantial bacterial contamination within the investigated school canteens in Al-Marj City, Libya. Bacterial growth was detected in 53.33% of the collected samples, with Gram-negative bacteria predominating over Gram-positive organisms.

Escherichia coli was the most frequently identified bacterium, followed by *Staphylococcus aureus* and *Proteus mirabilis*. The distribution of these organisms across food-contact surfaces, water sinks, and other frequently handled areas suggests that inadequate personal hygiene, environmental sanitation, and cross-contamination may contribute to bacterial persistence in school canteen environments.

The findings emphasize the need for strengthened food safety measures in schools. Regular hygiene training for food handlers, effective cleaning and disinfection of food-contact surfaces, appropriate sanitation of water facilities, and routine microbiological surveillance should be implemented to reduce the risk of foodborne illness among schoolchildren.



Figure 1. Sampling procedures performed in school canteens, including sampling of food preparation tables, snack/food-service surfaces, water sinks, and food handlers' hands.

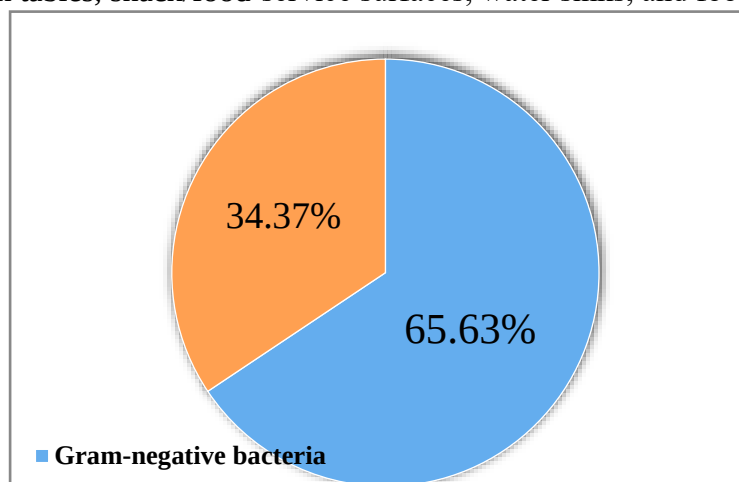


Figure 2. Distribution of bacterial isolates according to Gram-stain reaction.

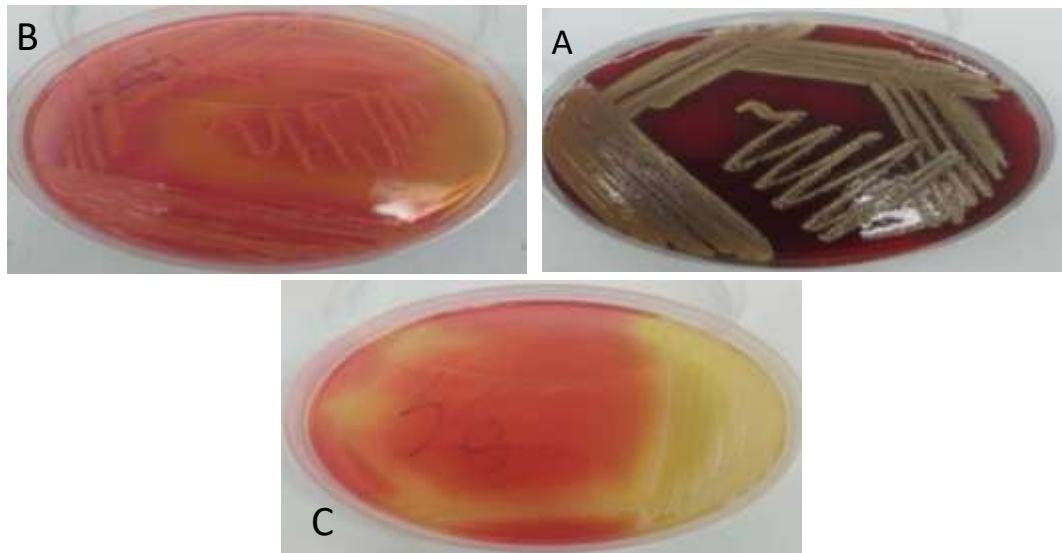


Figure 3. Culture characteristics of *Staphylococcus aureus*: (A) blood agar, (B) MacConkey agar, and (C) mannitol salt agar.

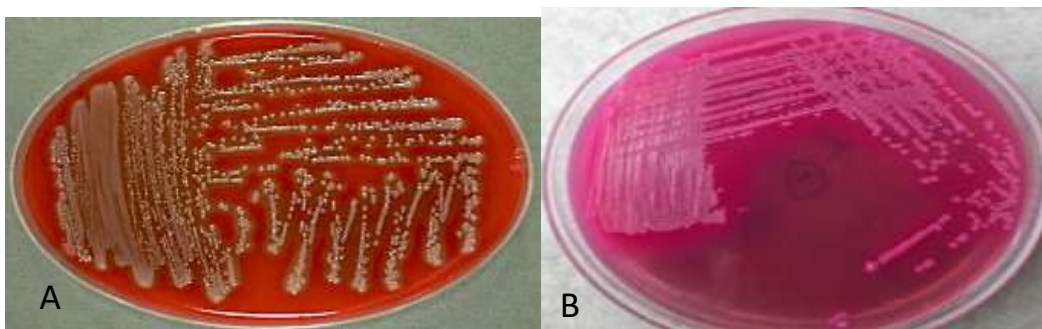


Figure 4. Culture characteristics of *Escherichia coli*: (A) blood agar and (B) MacConkey agar.



Figure 5. Microscopic appearance of *Escherichia coli*, showing Gram-negative bacilli

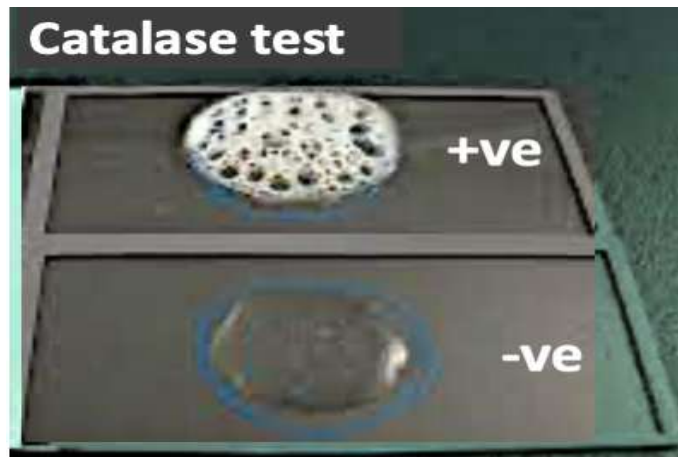


Figure 6. Biochemical characteristics of *Escherichia coli*, showing positive catalase and indole reactions.

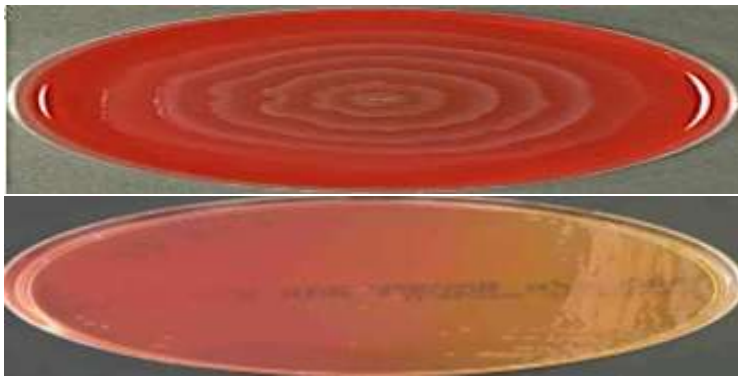


Figure 7. Culture characteristics of *Proteus mirabilis*: (A) MacConkey agar and (B) blood agar

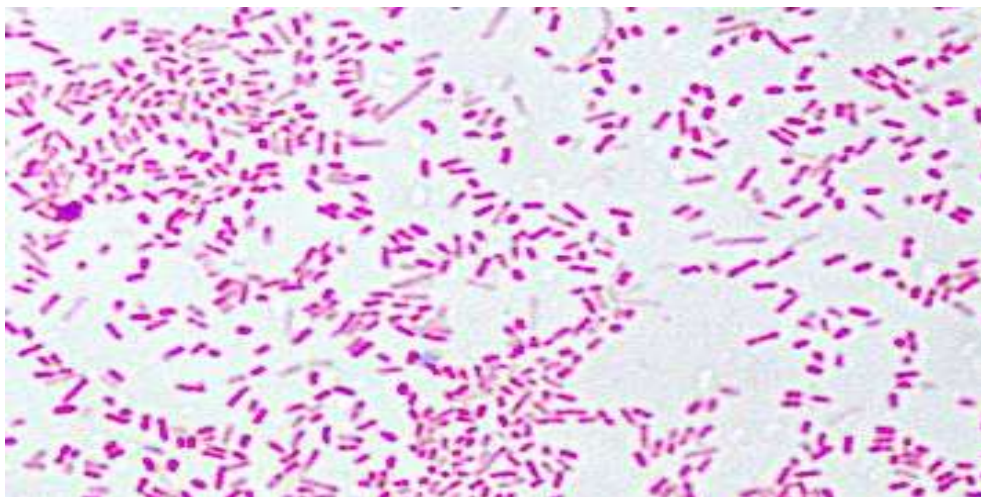


Figure 8. Microscopic appearance of *Proteus mirabilis*, showing Gram-negative bacilli.

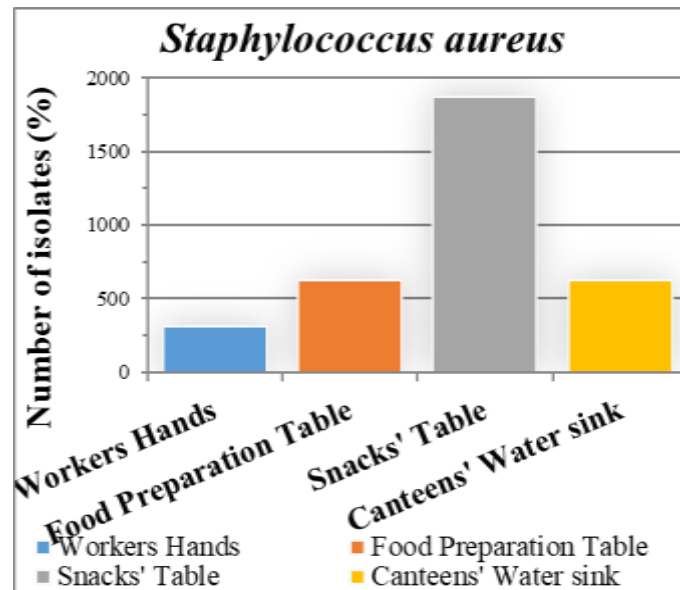


Figure 9. Distribution of *Staphylococcus aureus* according to sampling site.

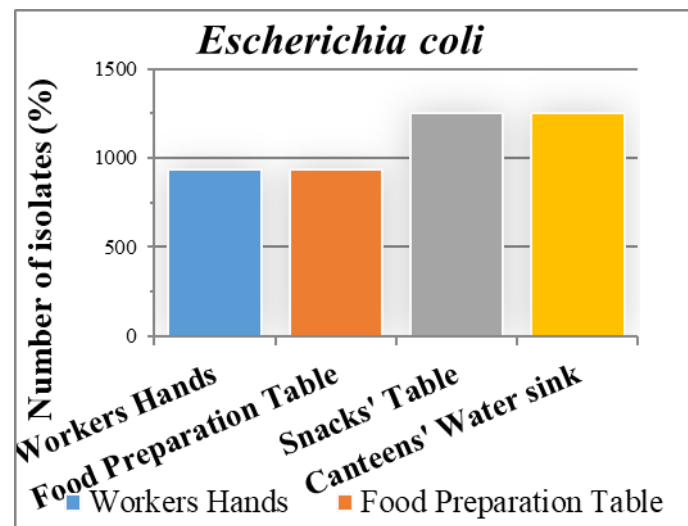


Figure 10. Distribution of *Escherichia coli* according to sampling site.

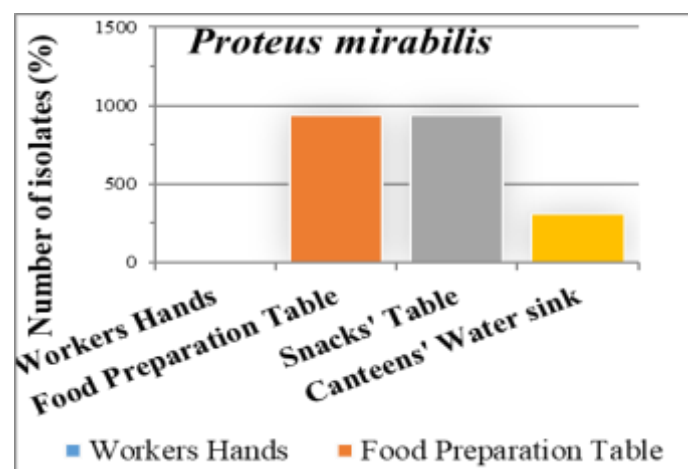


Figure 11. Distribution of *Proteus mirabilis* according to sampling site.

Table 1. Preliminary biochemical characteristics of bacterial isolates recovered from school canteens

Type of bacteria	Biochemical test						
	Oxidase test	Coagulase test	Catalase test	Mannitol fermentation	Citruse test	Urease test	Indol test
<i>Staph. aureus</i>	-	+	+	+	-	-	-
<i>P. mirabilis</i>	-	-	+	-	-	+	-
<i>E. coli</i>	-	-	+	-	-	-	+

Table 2. Distribution of bacterial isolates according to sampling location in school canteens

Bacteria species	<i>Staph. aureus</i>	<i>E. coli</i>	<i>P. mirabilis</i>	Total%
Workers Hands	1 (3.13%)	(%9.38) 3	-	4 (12.5%)
Food Preparation Table	2 (6.25%)	(%9.38) 3	(%9.38) 3	8 (25%)
Snacks' Table	6 (18.75)	4 (12.5%)	(%9.38) 3	13 (40.63 %)
Canteens' Water sink	2 (6.25%)	4 (12.5%)	1 (3.13%)	7 (21.88%)

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