Journal of Human Environment and Health Promotion
Print ISSN: 2476-5481 Online ISSN: 2476-549X

Comparison of Airborne Microbial Populations in Household and Dormitory Refrigerators

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ARTICLE INFO

Article type:
Original article

Article history:
Received: 4 April 2026
Revised: 23 May 2026
Accepted: 10 June 2026
Available online: 22 June 2026

https://doi.org/10.66224/jhehp.750

Keywords:

Refrigerator
Airborne microorganisms
Settle plate method
Index of microbial air contamination (IMA)

ABSTRACT

Background: Airborne microorganisms in refrigerators may compromise the safety and quality of stored foods. This study assessed airborne bacterial and fungal contamination in dormitory and household refrigerators in Eghlid.

Methods: Airborne microorganisms were evaluated in 18 dormitory rooms and five household refrigerators using the passive settle plate method. Nutrient agar and Eosin Methylene Blue (EMB) were used for bacterial isolation, and Sabouraud Dextrose Agar (SDA) for fungal and yeast isolation. Plates were exposed inside refrigerators for 1 h and incubated at 35 ± 2 °C for bacteria and 25 ± 2 °C for fungi and yeasts. Microorganisms were identified using standard microscopic and biochemical methods. Air contamination levels were expressed as the Index of Microbial Air Contamination (IMA) (CFU/plate/h).

Results: Bacterial contamination exceeded fungal and yeast contamination in both refrigerator types. *Staphylococcus aureus* was the predominant bacterium, and Gram-positive bacteria were more prevalent. Among fungi, *Aspergillus spp*. (29%) and *Penicillium spp.* (26%) were the most prevalent genera, whereas *Rhodotorula spp*. (75%) was the predominant yeast. IMA was higher in dormitory refrigerators (26.39 ± 11.66 CFU/plate/h) than in household refrigerators (12.0 ± 4.53 CFU/plate/h) (Mann-Whitney U test, $P = 0.01$).

Conclusion: Airborne microbial contamination was detected in refrigerators, with higher levels in dormitory refrigerators than in household ones.

1. Introduction

Indoor environments can act as important reservoirs for airborne microorganisms that may affect human health through inhalation or contact with contaminated surfaces. Domestic refrigerators are widely used household appliances designed to preserve food quality and reduce spoilage by maintaining low temperatures. Although refrigeration slows microbial growth, its effectiveness depends on several factors, including storage duration, temperature stability, food types, and hygienic conditions (Lalitha et al., 2019; Taha et al., 2025; Alhassan et al., 2022). Typical household refrigerators operate at 4-5 °C; however, temperature fluctuations may occur due to frequent door opening or malfunctioning thermostats. Many bacteria, yeasts, and fungi are psychrotolerant and can survive or grow under such conditions, contributing to food deterioration (Agi et al., 2021; Düven et al., 2021). Microbial contamination in refrigerators can originate from unwashed foods, leaking packages, contaminated containers, or inadequate handling practices. Microorganisms may adhere to food surfaces and refrigerator components, and can become airborne through internal air circulation, temperature changes, and disturbances caused by door opening or food handling. Repeated introduction of food items may further resuspend and redistribute microbial particles within the confined refrigerator space, contributing to both surface and airborne contamination (Agi et al., 2021). Previous studies have also

How to cite: Tavakoli, A. (2026). Comparison of Airborne Microbial Populations in Household and Dormitory Refrigerators. *J Hum Environ Health Promot*, *12*(3), 224-228.

shown that infrequent cleaning practices facilitate microbial growth and cross-contamination, highlighting the need for proper hygienic measures (Düven et al., 2021; Mori et al., 2020). Some microorganisms found in refrigerators may include psychrotrophic food spoilers or potential foodborne pathogens, underscoring the importance of assessing microbial contamination levels for public health (Zhang et al., 2022; Telli et al., 2019). Despite the widespread use of refrigerators, limited data exist on airborne microbial contamination in these appliances, particularly in shared environments such as student dormitories, where multiple users handle and store food in the same unit. Therefore, this study aimed to assess and compare airborne bacterial and fungal contamination in refrigerators used in student dormitories and private households. The findings are expected to improve understanding of hygiene conditions in shared food storage environments.

2. Materials and Methods

2.1 Study Area and Sampled Refrigerators

This cross-sectional environmental microbiological assessment was carried out in Eghlid City, Fars Province, Iran. Air sampling was performed from 23 domestic refrigerators, comprising 18 units located in student dormitories of the Islamic Azad University (Eghlid Branch) and five units from private residential households within the same urban area. All samples were collected without prior cleaning or manipulation of the refrigerators to reflect real-world microbial conditions.

2.2 Air Sampling Procedure

Airborne microbial sampling inside refrigerators was conducted using the passive settle plate method following the recommendations of Pasquarella et al. (2000) with minor modifications. Three culture media were used: Nutrient Agar (NA) for total heterotrophic bacteria, Eosin Methylene Blue Agar (EMB) for Gram-negative bacteria, and Sabouraud Dextrose Agar (SDA) for yeasts and fungi**.** The culture media were prepared in standard sterile Petri dishes (90 mm diameter). All culture media were obtained from Merck, Germany. For each medium, three replicate plates were placed on separate shelves inside each refrigerator. In total, 207 plates were used for microbial sampling (23 refrigerators × 3 media × 3 replicate plates). Sampling plates were positioned on the upper, middle, and lower shelves at approximately the center of each compartment to ensure representative air deposition. The plates were positioned while the refrigerator door was briefly opened and then immediately closed, remaining unopened for 1 h. This exposure duration is consistent with standard passive deposition protocols for indoor microbial monitoring (Pasquarella et al., 2000). After exposure, plates were sealed, labeled, and transported to the laboratory under aseptic conditions. For quality control, additional plates were exposed inside a refrigerator previously disinfected with 70% ethanol and aired for 20 min. One set of control plates was used per sampling day. These plates served as negative controls to verify the absence of procedural contamination (Telli et al., 2019; Sarabi Mohajer et al., 2022). All sampled refrigerators were operating under normal household or dormitory conditions during the sampling process. The internal temperature of the refrigerators was within the typical refrigeration range (approximately 4-8 °C), and no modifications were made to their routine operation during sampling.

2.3 Microbial Enumeration and Identification

All bacterial plates (NA and EMB) were incubated at 35 ± 2 °C for 24-48 h, while fungal plates (SDA) were incubated at 25 ± 2 °C for 5-7 days (Sarabi Mohajer et al., 2022). After incubation, colonies were counted manually and recorded as CFU/plate. Representative colonies grown on NA and EMB plates after incubation were selected based on their morphological characteristics for further identification. Bacterial isolates were evaluated by Gram staining and further characterized using biochemical tests, including catalase, oxidase, coagulase, Indole, Methyl Red, Voges-Proskauer and Citrate utilization (IMViC) tests, and carbohydrate fermentation tests. Fungal isolates grown on SDA plates were identified based on macroscopic colony characteristics (such as color, texture, and growth pattern) and microscopic morphology using lactophenol cotton blue staining. Identification of bacterial and fungal isolates was performed according to standard microbiological and mycological procedures described in reference manuals (MacFaddin, 2000; Larone, 2011).

2.4 IMA Calculation and Contamination Classification

Microbial air contamination was quantified using the Index of Microbial Air Contamination (IMA), defined as the mean number of colonies deposited on a settle plate after 1 h of exposure. IMA values were classified into three contamination levels: low (≤10 CFU/plate), moderate (11-25 CFU/plate), and high (>25 CFU/plate) (Pasquarella et al., 2000). For each refrigerator, the mean colony count of the triplicate plates for each culture medium was first calculated. A single IMA value per refrigerator was then derived by summing the mean bacterial counts (NA + EMB) and the mean fungal counts (SDA), representing the overall microbial deposition rate. This modification was applied to represent the overall microbial deposition across different microbial groups, although it does not reflect the classical IMA as defined by Pasquarella et al. (2000). This procedure prevents the overestimation of colony counts because replicate plates were averaged before summation, thereby minimizing potential double-counting bias, and it should therefore be interpreted as a practical integrative indicator rather than a replacement for the standard single-plate IMA.

2.5 Statistical Analysis

IMA values were compared between dormitory and household refrigerators using the Mann-Whitney U test. The distribution of IMA contamination categories between the

two groups was analyzed using the Fisher-Freeman-Halton exact test. Statistical significance was set at $P < 0.05$. All statistical analyses were performed using SPSS version 22.

3. Results and Discussion

In the present study, airborne microbial populations were investigated in 23 refrigerators located in dormitory and household settings. Refrigerators in dormitories were typically shared by multiple users and appeared to be used more intensively than those in households, which may influence microbial contamination levels. Airborne microbial contamination in domestic refrigerator environments has been reported in previous studies (Altunatmaz et al., 2012; Shahzad et al., 2025). The findings of this study further support the notion that refrigerator environments can harbor detectable levels of airborne bacteria and fungi, emphasizing the importance of proper hygiene and maintenance practices to minimize microbial contamination.

Table 1 summarizes the total number of recovered colonies from both groups. A total of 535 microbial colonies were recovered from all sampled refrigerators, of which 475 (88.8%) originated from dormitory units and 60 (11.2%) from household units. Bacterial colonies on NA constituted the largest proportion of isolates, followed by fungal colonies on SDA.

Table 1. Distribution of microbial colony counts recovered from different culture media in dormitory and household refrigerators

Parameter	Dormitory Refrigerators (n=18)	Household Refrigerators (n=5)	Total
Total bacterial colonies on NA	230 (48.4%)	48 (80.0%)	278
Gram-negative bacterial colonies on EMB	44 (9.3%)	3 (5.0%)	47
Fungal and yeast colonies on SDA	201 (42.3%)	9 (15.0%)	210
Total recovered colonies	475	60	535

Percentages refer to the proportion of colonies relative to the total number of colonies recovered within each refrigerator category (dormitory or household) NA: Nutrient agar; EMB: Eosin methylene blue agar; SDA: Sabouraud dextrose agar

As illustrated in Figure 1, Gram-positive bacteria represented the dominant microbial group recovered from dormitory refrigerators, followed by fungi and yeasts. Among the bacterial isolates, Gram-positive cocci were predominant, with *Staphylococcus aureus* being the most frequently identified species. The main Gram-negative genera detected were *Klebsiella spp.* and *Serratia spp*. The predominance of Gram-positive isolates may be partly attributed to their greater environmental resilience, allowing them to better withstand adverse environmental conditions and desiccation (Otu-Bassey et al., 2017). In household refrigerators, Gram-positive bacteria were also predominant, with approximately 70% of the isolates being Gram-positive cocci, while only a small number of Gram-negative isolates were detected. These findings are consistent with previous reports documenting the frequent occurrence of *S. aureus* in refrigeration environments (Agi et al., 2021; Alhassan et al., 2022; Yong et al., 2023). *S. aureus* is widely distributed on human skin and mucosal surfaces; therefore, it can be readily transferred to refrigerator interiors through food handling or contact with contaminated surfaces (Mori et al., 2020).

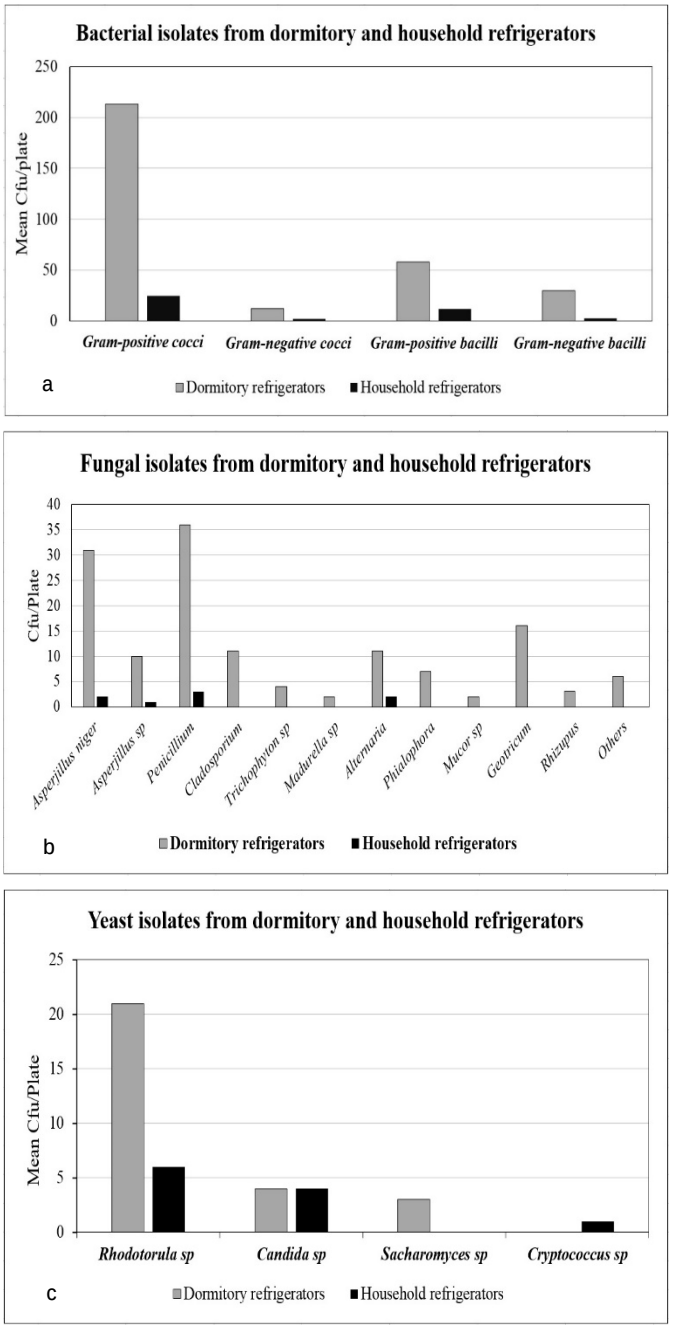

Figure 1. Distribution of microbial isolates recovered from dormitory refrigerators: (a) bacterial isolates, (b) fungal isolates, and (c) yeast isolates identified using the settle plate method

The presence of Enterobacteriaceae, including *Escherichia coli*, has also been documented in refrigerator environments

(Mori et al., 2020; Otu-Bassey et al., 2017). The other study has reported that Gram-positive and Gram-negative psychrotrophic bacteria, such as *Bacillus spp*., *Acinetobacter spp.*, and *Pseudomonas spp*., are capable of surviving in cold environments (Soomro et al., 2024). Fungal isolates belonging to 13 genera were recovered from the sampled refrigerators. Overall, fungal contamination appeared higher in dormitory refrigerators than in household units. *Aspergillus spp.* (29%) and *Penicillium spp.* (26%) were the predominant fungi in household refrigerators. *Rhodotorula* spp. was the most frequently detected yeast in both refrigerator types. These findings are consistent with previous studies reporting *Cladosporium spp.*, *Penicillium spp.*, and *Aspergillus spp.* as common fungi in refrigerator environments (Altunatmaz et al., 2012; Taha et al., 2025; Shahzad et al., 2025; Fazelipour et al., 2020).

To further quantify the overall level of airborne microbial contamination, the Index of Microbial Air Contamination (IMA) was calculated for each refrigerator. Although the classical IMA is based on a single culture medium, the present study used an integrated value obtained from averaged plates across different media. This approach provides a practical summary of overall microbial deposition inside refrigerators. Overall, dormitory refrigerators exhibited higher airborne microbial loads than household units when contamination was evaluated using the IMA. The mean (± SD) IMA in dormitory refrigerators was 26.39 (± 11.66) CFU/plate/1 h (n = 18), compared with 12.0 (± 4.53) CFU/plate/1 h in household refrigerators (n = 5). The Mann–Whitney U test indicated a statistically meaningful difference between the two groups (P = 0.01). These results show a clear trend toward higher airborne contamination in dormitory settings. However, because data on usage intensity and cleaning practices were not collected, the specific factors underlying this difference could not be identified. Refrigerators were also classified according to IMA contamination levels (Table 2). Among dormitory units, 44.4% exhibited high contamination (>25 CFU/plate/1 h), whereas none of the household refrigerators fell into this category. Most household refrigerators (60.0%) showed moderate contamination levels (11-25 CFU/plate/1 h). Although high contamination was more frequent in dormitory units, the difference in the distribution of contamination levels between the two groups was not statistically significant (Fisher-Freeman-Halton exact test, P = 0.12). This difference in statistical significance arises because the Mann-Whitney U test evaluates numerical IMA values, whereas the Fisher-Freeman-Halton test assesses the distribution of contamination categories. However, the absence of highly contaminated household refrigerators may suggest comparatively better hygiene conditions in household settings.

Refrigerators in male dormitories tended to exhibit higher contamination levels compared with those in female dormitories. However, because behavioral and hygiene-related variables were not evaluated, this difference cannot be attributed to any specific factor and should be interpreted with caution (Telli et al., 2019). A variety of practices-including hygiene behavior, usage patterns, maintenance conditions, and door-opening frequency-may influence the level of microbial contamination in domestic refrigerators. Furthermore, the storage of raw foods, leaking packages, contaminated containers, and improper food-handling practices can facilitate microbial growth. Microbial spores may also enter refrigerators through dust and soil attached to food items before to storage (Lalitha et al., 2019; Taha et al., 2025).

A key limitation of this study is that air sampling was performed while refrigerator doors remained closed, which may underestimate microbial exposure under real-use conditions. The passive settle plate method measures microbial deposition as IMA rather than true airborne volumetric concentrations, and therefore may not fully capture transient fluctuations in microbial load. Additionally, detailed information on refrigerator characteristics-such as food types, cleaning frequency, humidity, unit age, and door-opening frequency-was not collected, potentially introducing uncontrolled confounding. Finally, statistical comparisons between groups may have been underpowered due to the small number of household refrigerators sampled.

Table 2. Distribution of refrigerators according to the Index of Microbial Air Contamination (IMA) levels

Contamination level (IMA)	Dormitory refrigerators *n* (%)	Household refrigerators *n* (%)	Total *n* (%)
Low (≤10)	2 (11.1%)	2 (40.0%)	4 (17.4%)
Moderate (11-25)	8 (44.4%)	3 (60.0%)	11 (47.8%)
High (>25)	8 (44.4%)	0 (0.0%)	8 (34.8%)
Total	18 (100)	5 (100)	23 (100)

Values are presented as a number (% within each refrigerator group). Differences in the distribution of contamination levels between dormitory and household refrigerators were analyzed using the Fisher-Freeman-Halton exact test (P = 0.12). IMA: Index of Microbial Air Contamination. Contamination levels were classified according to Pasquarella et al. (2000)

4. Conclusion

This study showed that shared dormitory refrigerators tend to harbor higher levels of airborne microbial contamination than household refrigerators, likely due to shared use and more frequent opportunities for microbial introduction. The detection of organisms such as *Staphylococcus aureus* and *Aspergillus spp.* highlights potential hygiene concerns in refrigerator environments, particularly in communal settings. Although these findings do not indicate direct health outcomes, they suggest that inadequate hygiene practices may facilitate microbial persistence and potential food contamination. As evidence-based interventions could not be identified within the scope of this study, maintaining proper refrigerator hygiene, such as routine cleaning, appropriate food storage, and minimizing cross-contamination, should be considered a precautionary approach to promoting safer refrigeration conditions in both domestic and shared environments.

Authors' Contributions

Arezoo Tavakoli: Conceptualization; Methodology; Software; Validation; Formal analysis; Investigation;

Resources; Data curation; Writing original draft preparation; Visualization; Supervision; Project administration.

Funding

This research received no external funding.

Conflicts of Interest

The author declares no conflict of interest.

Acknowledgments

The author would like to thank the student residents of the dormitory at Islamic Azad University, Eghlid Branch, as well as several families, for their assistance in sample collection.

Ethical Considerations

This study did not involve any human or animal subjects, so ethical approval was not required.

Using Artificial Intelligence

The author did not use AI tools in the preparation of this manuscript.

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