



RESEARCH ARTICLE

Microbial and Heavy Metal Contamination Assessment in Restaurant Foods: A Quality Assurance Study from Erbil City, Kurdistan Region of Iraq

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ABSTRACT

During this study, six different restaurants located in Erbil city were categorized, and a total of 96 samples were collected from them. Samples were gathered, and microbial and chemical tests were performed to evaluate fungal contamination and the presence of lead and cadmium as heavy metals. Final results indicated widespread microbial contamination across all food types tested. *Escherichia coli* and *Staphylococcus aureus* were among the most frequently isolated bacteria, detected in over 70% of samples. Fungal contaminants, including *Penicillium*, *Aspergillus*, and *Candida* species, were also commonly found, with contamination rates exceeding 50% in specific food categories. Heavy metal analysis revealed high levels of lead and cadmium in staple foods. Rice samples from some restaurants contained lead concentrations up to 1.56 ppm and cadmium up to 1.75 ppm, both exceeding international safety limits. Meat-based dishes also showed elevated cadmium levels reaching 1.52 ppm, while salads consistently tested below detectable limits. These findings underscore the urgent need for stricter hygiene protocols, routine screening for microbial and heavy metal contaminants, and targeted training for food handlers to reduce contamination and protect public health.

Keywords: Microbiological contamination, Quality assurance, Heavy metals, Culture media, Consumer needs

INTRODUCTION

Quality assurance plays a vital role in all industrial fields, as well as the food industry. In this specific field, it ensures the safety, hygiene, and overall quality of food products, which is essential for protecting public health and maintaining consumer trust. Among various subsets of the food industry, restaurants, as the key points of food service, must take advantage of effective quality assurance systems to prevent foodborne illnesses. To achieve this goal, different health and safety assurance systems have been introduced.

One of the most widely applied systems is the Hazard Analysis and Critical Control Point (HACCP) system, which systematically identifies, evaluates, and controls biological, chemical, and physical hazards throughout food production. This framework includes different steps, including hazard identification, defining critical control points, establishing safety limits, continuous monitoring, corrective actions, verification, and detailed record-keeping to ensure consistent food safety.^[1]

As well as HACCP, there are Good Manufacturing Practices (GMPs) and Good Hygiene Practices (GHPs) that provide important guidelines to keep food production areas clean and safe. These two systems are applied before HACCP to guarantee proper sanitation and acceptable hygiene during

the process. Alongside Standard Operating Procedures (SOPs), especially those for sanitation, help make sure that all surfaces, tools, and equipment are thoroughly cleaned and sterilized. In addition to all these steps, various rules were set for staff hygiene, helping to prevent any contamination during food preparation and handling. Figure 1 represents the relationship between GMP, GHP, HACCP, Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP), Hazard Analysis and Critical Control Point (HACCP), Quality Assurance and Control Plan QACP, Quality Management System (QMS) and Food Safety Management System (FSMS), Total Quality Management (TQM), and Standard Operating Procedures (SOPs).^[2,3]

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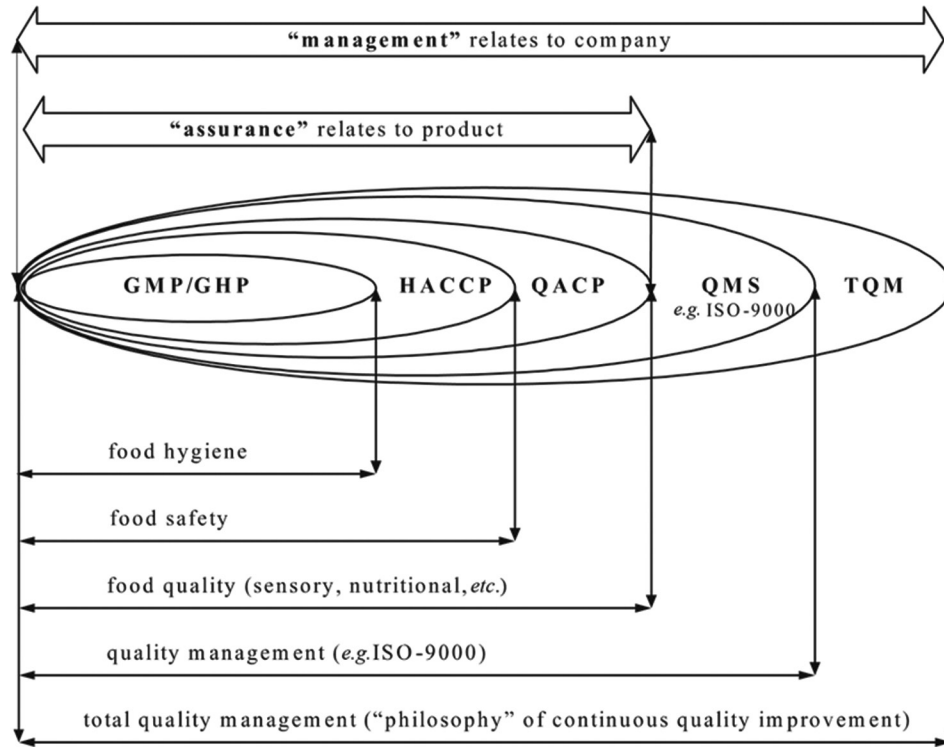


Figure 1: Diagram of the relationship between GMP, GHP, HACCP, QACP, QMS, and TQM.^[2] GMP: Good Manufacturing Practice, GHP: Good Hygiene Practices, HACCP: Hazard Analysis and Critical Control Point, QACP: Queer Affirmative Counselling Practice, QMS: Quality Management System, TQM: Total Quality Management

In order to ensure food safety and quality, restaurants can take advantage of international standards. Certifications like ISO 22000 focus on food safety, while ISO 9001 improves service quality. Other ISO standards address environmental impact, worker safety, and information security. The HACCP system, part of ISO 22000, helps manage food safety risks. GMP are also important guidelines for safe food handling. The Codex Alimentarius sets global food standards to promote fair trade and protect public health. Together, these standards help restaurants provide safe food and protect customers.^[13]

In restaurants, various bacteria commonly found in food pose significant health risks that must be carefully managed. For example, *Citrobacter freundii*, which can be found in environments such as soil, water, and human intestines, can contaminate raw vegetables, meats, and seafood, causing gastrointestinal illnesses that range from mild to severe, particularly in vulnerable individuals.^[4]

Pathogenic strains of *Escherichia coli*, especially those producing Shiga toxins, have been repeatedly linked with outbreaks through contaminated beef, produce, and unpasteurized products, often resulting in symptoms that can lead to serious kidney complications.^[5]

Other opportunistic bacteria, such as members of the *Enterobacter* cloacae complex and *Klebsiella* species, frequently contaminate foods and cause infections, especially in immunocompromised patients. These bacteria are particularly concerning because of their antibiotic resistance, complicating treatment and infection control.^[6] *Enterococcus faecalis* and

Staphylococcus aureus are also important pathogens in food safety, known for contaminating ready-to-eat foods and triggering food poisoning through toxin production, which highlights the need for rigorous hygiene and sanitation practices in food handling.^[7,8] Moreover, bacteria such as *Raoultella ornithinolytica* and other *Staphylococcus* species may contaminate poultry and seafood products, becoming a potential health concern when sanitation is inadequate.^[9,10]

Chemical contamination in food points to ash content determination and heavy metal presence in each food sample. It is important to mention that not all heavy metals are considered toxic; essential metals like copper (Cu), zinc (Zn), manganese (Mn), iron (Fe), nickel (Ni), and chromium (Cr) are beneficial at low levels. However, metals such as lead (Pb), cadmium (Cd), and arsenic (As), which have no biological benefits, are harmful even at low concentrations and are considered chemical contaminants that must be removed.

This study was conducted to evaluate the quality of food and environmental hygiene in six selected restaurants in Erbil city. A total of 96 samples were collected from various parts of restaurants and were checked for microbial and chemical contamination. Preliminary results revealed bacterial contamination in several samples, highlighting concerns related to hygiene and safety practices in some of the restaurants. Thus, this study highlights the urgent need for coordinated food safety initiatives to reduce microbial contamination and toxic metal exposure in Erbil's restaurant industry, thereby safeguarding consumer health and enhancing confidence in local food services.

MATERIALS AND METHODS

Restaurant Selection

Six restaurants, all located in Erbil city, were randomly selected based on their classification into three categories, low, medium, and high quality, with two restaurants representing each category. Permission was received from the Ministry of Health in the Kurdistan region, as well as from each restaurant's management.

Sample Collection

For the standard sample collection process, the guidelines provided by the World Health Organization (WHO) were followed.^[11] Food samples were aseptically collected from six food categories: chicken, rice, burger, kebab, salad, and meat, across the selected restaurants. Approximately 25–50 g of each food item was placed into sterile, labeled polyethylene bags using sterile forceps. Samples were immediately stored in insulated coolers at 4°C and transported to the microbiology laboratory for analysis within 2 h of collection.^[11]

Sample Preparation

To prepare samples in the laboratory, samples were homogenized in 225 mL of sterile buffered peptone water using a stomacher for 2 min. Serial decimal dilutions, up to 10^{-6} , were prepared in sterile saline, 0.85% NaCl, for microbial enumeration and isolation.

To count and recognize the types of existing bacteria in food samples, the following steps were taken. First, to estimate the total number of aerobic mesophilic bacteria in food samples, the standard plate count method on Nutrient Agar was used. Then 10 g of each food sample were homogenized in 90 mL of sterile Buffered Peptone Water (BPW) to create the initial dilution (10^0), followed by tenfold serial dilutions up to 10^{-6} . From appropriate dilutions (typically 10^{-3} to 10^{-6}), 0.1 mL aliquots were spread in triplicate on NA plates, which were incubated aerobically at 37°C for 48 h. Plates yielding 30–300 colonies were selected for enumeration to ensure reproducibility and statistical accuracy.^[14] The TVC was calculated, and the results were expressed as colony-forming units per gram (CFU/g).

Interpretation of Microbial Load

TVC provides a general indication of the microbial quality and hygienic condition of the food samples. Counts exceeding 10^5 CFU/g are typically considered unsatisfactory based on international food safety standards.^[15] Elevated counts may suggest inadequate cooking, post-cooking contamination, or insufficient sanitation during processing or storage. Samples above this threshold were subjected to further pathogen testing through selective media and confirmatory biochemical assays. All culture media were freshly prepared and sterilized; positive controls were included, and all tests were performed in triplicate to ensure reliability. Colony morphology, pigmentation, and odor were documented to assist preliminary bacterial identification.^[16]

Bacterial Isolation and Identification

Selective media were employed to isolate specific bacterial groups: MacConkey Agar for Gram-negative enteric bacteria,

including *E. coli*, *Klebsiella* spp., and *Enterobacter* spp.; Mannitol Salt Agar for *Staphylococcus* spp.; and Bile Esculin Agar for *Enterococcus* spp. Plates were incubated at 37°C for 48 h. Colonies were characterized by morphology and counted.

Microscopic examination with Gram staining and standard biochemical tests (catalase and oxidase) was performed to differentiate bacterial species. Species-level identification was confirmed using the VITEK 2 Compact system, an automated platform widely used in clinical and food microbiology.^[17]

Fungal Isolation and Identification

For fungal detection, 0.1 mL of homogenized samples or their dilutions was plated on Malt Extract Agar supplemented with chloramphenicol (0.05 g/L) to inhibit bacterial growth. Plates were incubated at 28°C for up to 5 days and inspected daily. Fungal colonies were identified through macroscopic characteristics (color, texture, shape) and microscopic examination after Lactophenol Cotton Blue staining, using standard fungal identification keys for *Aspergillus*, *Penicillium*, *Mucor*, and *Candida* species.^[18] All procedures were conducted in triplicate to ensure consistency.

For identifying the types of bacteria, each sample was also cultured in selective culture media. MacConkey Agar for Gram-negative enteric bacteria, Mannitol Salt Agar for *Staphylococcus* spp., and Bile Esculin Agar for *Enterococcus* spp. Colony characteristics were examined, and bacteria were further analyzed using Gram staining and biochemical tests. Finally, species identification was confirmed with the automated VITEK® 2 system, allowing precise determination of the bacterial species contaminating the food.^[12]

Fungal isolation was performed as well. Malt Extract Agar supplemented with chloramphenicol to inhibit bacteria was used for this aim. Plates were incubated at 28°C for 5 days and checked daily. Fungal colonies were identified through macroscopic characteristics (color, texture, shape) and microscopic examination after Lactophenol Cotton Blue staining, using standard fungal identification keys for *Aspergillus*, *Penicillium*, *Mucor*, and *Candida* species.^[18] All procedures were conducted in triplicate to ensure consistency.

Samples were also checked for the presence of heavy metals. All samples were collected aseptically in airtight, sterile polyethylene containers, stored at 4°C, and transported to the laboratory. Samples were washed, if necessary, chopped, and homogenized using a stainless-steel blender.

Food samples with approximately 3 g each were acid-digested using a mixture of concentrated nitric acid and perchloric acid under controlled heating until clear. After cooling and filtration, samples were diluted to 25 mL.

A wet acid digestion method, adapted from the Association of Official Analytical Chemists and WHO protocols, was used to extract heavy metals.^[19] Each sample was treated with a mixture of 10 mL concentrated nitric acid and 2 mL perchloric acid, then heated gradually, not exceeding 180°C, until the solution became clear. After cooling, it was filtered and diluted to 25 mL with deionized water. All glassware was thoroughly cleaned with nitric acid and rinsed to prevent contamination.

Lead and nickel concentrations were measured by atomic absorption spectrophotometry at wavelengths of 283.3 nm and 232.0 nm, respectively. Calibration curves were generated using certified standards, and concentrations were reported in parts per million (ppm) or milligrams per kilogram (mg/kg).^[20]

Quality assurance included blanks and recovery tests alongside samples, with all measurements performed in triplicate. Detection limits were 0.01 ppm for Pb and 0.02 ppm for Ni. Obtained concentrations were compared to maximum permissible limits defined by Codex Alimentarius Commission and the European Food Safety Authority, Pb between 0.1 and 0.3 ppm, depending on food type, and Ni generally between 0.2 and 0.5 ppm. Values exceeding these limits suggest potential health risks due to long-term exposure, especially in staple foods such as rice and meat.

RESULTS AND DISCUSSION

Bacterial Identification

In this study, bacterial isolates obtained from restaurant food samples were characterized through a combination of morphological observations, microscopic examination, biochemical testing, and colony morphology on selective media. Species-level identification was confirmed using the VITEK automated system, a widely recognized tool in clinical and food microbiology diagnostics. Table 1 shows the total microbial count of each sample.

Conventional methods correlated strongly with VITEK results. Gram-positive isolates, mainly *Staphylococcus* and *Enterococcus* species, were consistently identified. These

Table 1: Total microbial counts (log CFU/g) of contaminant microorganisms in restaurant food samples

Food sample	Restaurant code	Microbial total counts (Log CFU/g) for restaurant food samples
Chicken	1	5.18
	2	5.38
	3	6.70
Rice	1	5.26
	2	5.41
	3	6.54
Burger	1	6.42
	2	6.48
	3	6.76
Kebab	1	6.52
	2	6.55
	3	6.78
Salad	1	6.49
	2	6.67
	3	6.85
Meat	1	5.32
	2	5.46
	3	6.60

CFU/g: Colony-forming units per gram

bacteria exhibited typical coccoid morphology arranged in clusters or chains, with positive catalase and negative oxidase reactions. Their colony appearances, including the distinctive golden-yellow pigment of *S. aureus* and the smooth white sheen of *Staphylococcus epidermidis*, matched established diagnostic criteria.^[21] Notably, *S. aureus*, *S. epidermidis*, *Staphylococcus gallinarum*, and *E. faecalis* all exhibited these characteristic features, aligning with documented features of facultative anaerobic Gram-positive food contaminants.^[22]

Gram-negative isolates included species such as *Klebsiella pneumoniae*, *E. coli*, *R. ornithinolytica*, *C. freundii*, and *Enterobacter cloacae*. Morphologically, these were rod-shaped, catalase-positive, and oxidase-negative bacteria with colonies varying from mucoid to glossy cream, consistent with their capsulated nature.^[23] A significant achievement was the precise differentiation of *R. ornithinolytica*, often misidentified as *Klebsiella* by traditional methods, demonstrating the VITEK system's superior discriminatory capacity.^[24] This distinction holds clinical and food safety importance due to the emerging pathogenicity of *R. ornithinolytica*.^[25]

The combined use of conventional and automated diagnostics helps the validity of an integrative identification approach, which is critical for rapid and accurate detection of foodborne bacteria, thereby supporting contamination risk assessment and improved food safety management.^[26]

Fungal Identification

Fungal isolates from food samples were identified based on morphological characteristics, microscopic features, and colony appearance. These identifications were further verified using MALDI-TOF mass spectrometry, offering species-level resolution.

Penicillium chrysogenum was identified by its classic blue-green, velvety, or powdery colonies with branched brush-like conidiophores and oval conidial chains. *Penicillium expansum* showed similar morphology but differed in conidial shape and exudate production. Recent metabolomic insights highlight their role in fermentation and production of secondary metabolites, including proteases, lipases, and mycotoxins such as roquefortine C and patulin.^[27]

Mucor spp. Presented with broad, non-septate hyphae, spherical sporangiospores, and fast-growing cottony colonies turning gray within 48–72 h. These features correspond to standard classifications of Mucorales, confirmed by KOH mounts and Lactophenol Cotton Blue staining, revealing coenocytic hyphae and rhizoid structures.^[28] Recognized as frequent agents of plant spoilage, *Mucor* identification benefits from direct microscopy alongside culture techniques.

Aspergillus niger isolates showed septate hyphae, black granular colonies with radiating margins, and dark conidia. *Aspergillus fumigatus* produced blue-green velvety colonies with columnar heads. Both species' features align with standard mycological profiles, facilitating accurate species differentiation in food safety contexts.

Yeasts identified as *Candida* spp. Showed oval budding cells with pseudohyphae, smooth colonies, and was distinct from filamentous molds.

These fungal contaminants are notable for their spoilage potential and health risks due to mycotoxin production. *Penicillium* species notably produce patulin and roquefortine C, common food contaminants with toxic effects.^[29] *Mucor* species contribute to rapid post-harvest spoilage, exemplified in fruits such as plums. The utilization of enhanced detection protocols (e.g., modified KOH-LCB staining) can achieve early fungal detection rates near 92%, critical under resource-limited conditions. The fungi identified here underscore the necessity of rigorous hygiene and monitoring during food preparation and storage to prevent mycotoxin contamination.

Microbial Contamination in Food Samples from Erbil City Restaurants

Microbiological analysis of six food types, including chicken, rice, burgers, kebabs, salads, and meat, all collected from three restaurants in Erbil, revealed extensive contamination by diverse bacterial and fungal species, reflecting substantial food safety risks.

Chicken samples from Restaurant 1 showed contamination by *Enterobacter cloacae*, *S. aureus*, *R. ornithinolytica*, and *Penicillium chrysogenum*. Restaurant 2's chicken harbored *E. coli*, *S. epidermidis*, *C. freundii*, and *Penicillium* species. At the same time, Restaurant 3's samples contained *E. faecalis*, *E. coli*, *R. ornithinolytica*, and *P. expansum*—the recurrent presence of *E. coli* and *Staphylococcus* spp. Strongly indicates lapses in hygiene and possible cross-contamination during food handling or processing.

Rice samples were frequently contaminated with spore-forming bacteria. Notably, *Bacillus cereus* was found in all restaurants, with *Bacillus subtilis* present in two. Fungal contaminants included *Mucor*, *Candida*, and *A. niger*. Detection of these organisms suggests improper storage and temperature control, conditions that facilitate spore germination and mold proliferation.

Burgers contained a broad spectrum of bacteria, including *Enterobacter cloacae*, *E. faecalis*, *S. epidermidis*, *Klebsiella oxytoca*, and *Klebsiella aerogenes*, along with fungal contamination by *Candida* and *Penicillium* species. The presence of *E. coli* and *S. aureus* further indicates potential contamination from raw materials or preparation practices.

Kebab samples were heavily contaminated with Gram-negative bacteria such as *K. aerogenes*, *K. oxytoca*, *Enterobacter cloacae*, and *E. coli*, as well as Gram-positive bacteria such as *S. aureus*, *S. gallinarum*, and *E. faecalis*. The pervasive detection of *E. coli* across all kebab samples suggests cross-contamination stemming from raw meat or inadequate cooking.

Salads, often considered high-risk due to minimal processing, were contaminated by a mix of opportunistic and spoilage organisms, including *Enterobacter cloacae*, *E. coli*, *Klebsiella* spp., *E. faecalis*, *Staphylococcus* spp., *R. ornithinolytica*, *A. fumigatus*, and other *Aspergillus* species. This diverse contamination profile points to inadequate washing of vegetables, contaminated surfaces, or poor storage conditions.

Meat samples also exhibited extensive contamination by *E. coli*, *Enterobacter cloacae*, *K. pneumoniae*, *K. aerogenes*, *E. faecalis*, *S. aureus*, and *S. gallinarum*. Fungal presence

included *Candida*, *Penicillium*, and *Aspergillus* species. Detection of *K. pneumoniae* and *E. coli* signals potential lapses in cooking or cross-contamination during handling.

The predominance of *E. coli*, *S. aureus*, *Enterobacter cloacae*, and *Klebsiella* spp. Across all food types, there are significant hygienic shortcomings. The frequent isolation of molds such as *Aspergillus*, *Mucor*, and *Penicillium* further indicates problems such as poor cleaning, cross-contamination, and improper storage temperatures, especially worrying for salads since they are served raw and do not get cooked to kill bacteria.

Heavy Metals Contamination of Food Samples

Testing also found unsafe levels of lead and cadmium in several food items. Table 2 shows the final results of each food sample tested for heavy metal presence. The results of each food sample will then be discussed.

Analysis of chicken samples from the three restaurants revealed generally low contamination levels. Cadmium was detected at 0.035 ppm in Restaurant 1, though no lead was found. Conversely, Restaurant 2 showed detectable lead at 0.022 ppm without any cadmium presence. Restaurant 3 had no detectable levels of either metal. These results suggest minimal contamination in chicken, potentially linked to environmental factors or feed composition. However, the variation between restaurants may reflect differences in sourcing or handling protocols. Rice showed the highest heavy metal concentrations among all tested foods. Restaurant 1 recorded lead at 1.56 ppm and cadmium at 0.56 ppm, while Restaurant 2 had cadmium at an even greater 1.40 ppm but

Table 2: Concentration of lead (Pb) and cadmium (Cd) in food samples from Restaurants in Erbil City

Food sample	Restaurant code	Lead (Pb) (ppm)	Cadmium (Cd) (ppm)
Chicken	1	ND	0.035
	2	0.022	ND
	3	ND	ND
Rice	1	1.558	0.559
	2	ND	1.399
	3	ND	ND
Burger	1	0.046	ND
	2	ND	1.524
	3	0.034	0.026
Kebab	1	0.034	1.749
	2	ND	ND
	3	0.028	0.013
Salad	1	ND	ND
	2	ND	ND
	3	ND	ND
Meat	1	0.059	0.029
	2	ND	ND
	3	ND	ND

no detectable lead. Restaurant 3 exhibited no contamination. The elevated heavy metal levels, particularly in restaurants 1 and 2, raise concerns about contaminated irrigation water, polluted soil, or poor storage conditions. Given rice's status as a dietary staple, such contamination poses a significant public health risk.

Burger samples displayed varied contamination profiles. Lead was found at 0.046 ppm in Restaurant 1 and 0.034 ppm in Restaurant 3. Notably, Restaurant 2's burgers contained a high cadmium concentration of 1.52 ppm, while Restaurant 3 showed trace cadmium (0.026 ppm). This suggests multiple contamination sources, including ingredients and kitchen equipment, with the elevated cadmium levels representing a potential long-term health hazard.

Kebabs had particularly concerning cadmium contamination in Restaurant 1 at 1.75 ppm, the highest level recorded in this study, alongside lead at 0.034 ppm. Restaurants 3 showed lower levels of both metals (Pb = 0.028 ppm, Cd = 0.013 ppm), whereas Restaurant 2 had no detectable contamination. Since kebabs are generally cooked on metal skewers or grills, contamination may arise not only from the meat itself but also from cooking utensils, especially in Restaurant 1.

No lead or cadmium contamination was detected in salad samples across all restaurants. This likely reflects sourcing from less polluted environments and thorough washing and handling. Compared to meat and rice dishes, salads appear safer regarding heavy metal exposure, possibly due to their minimal processing and limited contact with cooking equipment.

Meat samples showed moderate contamination in Restaurant 1, with 0.059 ppm lead and 0.029 ppm cadmium detected. However, Restaurants 2 and 3 showed no traces of these metals. The contamination in Restaurant 1's meat could be related to farming practices or post-slaughter contamination. Although only one location showed contamination, this underscores the need for more stringent quality control in the meat supply chain.

Together, these results highlight a troubling combination of microbial and heavy metal contamination in common foods served at several restaurants in Erbil City. The frequent presence of bacteria such as *E. coli*, *S. aureus*, and various members of the Enterobacteriaceae family, along with widespread growth of fungi known to cause spoilage and produce harmful toxins, points to serious issues with food safety. On top of that, detecting lead and cadmium in staple dishes such as rice, kebabs, and burgers adds another layer of concern due to the long-term health risks these metals pose.

These findings expose significant weaknesses in how food is handled, stored, and sourced within the local restaurant industry. They highlight a pressing need for thorough food safety measures that address both microbial contamination and chemical hazards, thereby better protecting consumers from foodborne illnesses and harmful exposures.

CONCLUSION

This study comprehensively assessed the microbial and chemical quality of food samples collected from six restaurants

in Erbil, analyzing 96 samples from a range of commonly consumed dishes. The findings reveal a high prevalence of bacterial contamination, with *E. coli* and *S. aureus* detected in approximately 70% of samples across multiple food categories. Fungal contaminants, including species of *Penicillium*, *Aspergillus*, *Mucor*, and *Candida*, were also commonly identified, particularly in rice and meat dishes, affecting more than half of these samples. Such widespread microbial presence indicates significant shortcomings in hygiene and food handling practices within these establishments.

Heavy metal analysis indicated that rice samples demonstrated the highest levels of lead and cadmium contamination. For instance, lead concentrations reached 1.56 ppm and cadmium 0.56 ppm in samples from one restaurant. In comparison, cadmium levels of up to 1.40 ppm were recorded at another—both exceeding international safety thresholds as defined by Codex Alimentarius. Meat-based dishes, including kebabs and burgers, also showed elevated cadmium levels, with concentrations up to 1.75 ppm and 1.52 ppm, respectively, alongside lower but notable lead levels (0.03–0.06 ppm). Chicken displayed comparatively low contamination, and importantly, salad samples consistently tested free of detectable heavy metals.

These findings underscore critical gaps in food safety protocols related to sourcing, preparation, and storage. The confluence of extensive microbial contamination and elevated heavy metal residues in staple foods poses considerable public health risks. Environmental factors, combined with inadequate processing and sanitation measures, likely contribute to this contamination.

REFERENCES

1. A. Demirci, H. Feng and K. Krishnamurthy. *Food Safety Engineering*. Springer International Publishing, Cham, 2020.
2. T. Sikora. Methods and systems of food quality and safety assurance. *Polish Journal of Food and Nutrition Sciences*, vol. 14, no. 1, pp. 41-48, 2005.
3. M. Stanga. *Sanitation: Cleaning and Disinfection in the Food Industry*. Wiley-Vch, Weinheim, 2010.
4. I. E. Warnow, Y. A. Ayoola, A. Daniel, M. P. Raymond, M. L. Abubakar, R. Y. Adeniji, Z. Joel, H. Abdulkarim, M. Manga and H. I. Okolie. *Citrobacter freundii*: A cause of cardiac tamponade and empyema thoracis in a Nigerian child. *Journal of Cardiovascular Echography*, vol. 30, no. 2, pp. 121-121, 2020.
5. M. Basavaraju and B. S. Gunashree. *Escherichia Coli: An Overview of Main Characteristics*. InTechOpen, London, 2022.
6. M. L. Mezzatesta, F. Gona and S. Stefani. *Enterobacter cloacae* complex: Clinical impact and emerging antibiotic resistance. *Future Microbiology*, vol. 7, no. 7, pp. 887-902, 2012.
7. R. Halkai, M. N. Hegde and K. Halkai. *Enterococcus faecalis* can survive extreme challenges - overview. *Journal of Health and Allied Sciences NU*, vol. 2, no. 3, pp. 49-53, 2012.
8. D. S. Ondusko and D. Nolt. *Staphylococcus aureus*. *Pediatrics in Review*, vol. 39, no. 6, pp. 287-298, 2018.
9. R. Hajjar, G. Ambaraghassi, H. Sebahang, F. Schwenter and S. H. Su. *Raoultella ornithinolytica*: Emergence and resistance. *Infection and Drug Resistance*, vol. 13, pp. 1091-1104, 2020.
10. G. M. Szafraniec, P. Szeleszczuk and B. Dolka. A review of current knowledge on *Staphylococcus agnetis* in poultry. *Animals an Open Access Journal from MDPI*, vol. 10, no. 8, 2020.
11. CDC. *Biosafety in Microbiological and Biomedical Laboratories*. 6th ed. Centers for Disease Control and Prevention National

- Institutes of Health, Bethesda, 2020.
12. I. M. Sulaiman, P. Banerjee, Y. H. Hsieh, N. Miranda, S. Simpson and K. Kerdahi. Rapid detection of *Staphylococcus aureus* and related species isolated from food, environment, cosmetics, a medical device, and clinical samples using the VITEK MS microbial identification system. *Journal of AOAC International*, vol. 101, no. 4, pp. 1135-1143, 2018.
 13. N. Rolland, V. Girard, V. Monnin, S. Arend, G. Perrin, D. Ballan, R. Beau, V. Collin, M. D'Arbaumont, A. Weill, F. Deniel, S. Tréguer, A. Pawtowski, J. L. Jany and J. Mounier. Identification of food spoilage fungi using MALDI-TOF MS: Spectral database development and application to species complex. *Journal of Fungi (Basel)*, vol. 10, no. 7, pp. 456-456, 2024.
 14. World Health Organization. *Guidelines for the Assessment of Chemical Contaminants in Food: Heavy Metals and Food Safety*. WHO Press, Geneva, Switzerland, 2023.
 15. Y. Tamiru, A. Ayelign, A. Mulugeta and S. Gebremedhin. Microbiological safety assessment of ready-to-eat cooked foods in the Addis Ababa school feeding program, Ethiopia. *Heliyon*, vol. 10, no. 18, p. e38110, 2024.
 16. B. Kootallur, M. Mani and C. Thangavelu. Bacterial identification in the diagnostic laboratory: How much is enough? *Indian Journal of Medical Microbiology*, vol. 29, no. 4, p. 336, 2011.
 17. I. Nakasone, T. Kinjo, N. Yamane, K. Kisanuki and C. M. Shiohira. Laboratory-based evaluation of the colorimetric VITEK-2 compact system for species identification and of the advanced expert system for detection of antimicrobial resistances: VITEK-2 compact system identification and antimicrobial susceptibility testing. *Diagnostic Microbiology and Infectious Disease*, vol. 58, no. 2, pp. 191-198, 2007.
 18. E. O. Olumuyiwa, M. T. Ajetunmobi, O. F. Adeniji and A. K. Ogunyemi. Morphological and molecular identification of fungi isolated from spoilt apples in Ota metropolis. *BMC Microbiology*, vol. 25, no. 1, p. 360, 2025.
 19. World Health Organization. *Food Safety*; 2024. Available from: <https://www.who.int/news/room/fact/sheets/detail/food/safety> [Last accessed on 2025 Apr 10].
 20. W. S. Zhong, T. Ren and L. J. Zhao. Determination of Pb (lead), Cd (cadmium), Cr (chromium), Cu (copper), and Ni (nickel) in Chinese tea with high-resolution continuum source graphite furnace atomic absorption spectrometry. *Journal of Food and Drug Analysis*, vol. 24, no. 1, pp. 46-55, 2016.
 21. R. E. Araujo Piraine, D. G. Nickens, D. J. Sun, F. P. Leivas Leite and M. L. Bochman. Isolation of wild yeasts from Olympic National Park and *Moniliella megachiliensis* ONP131 physiological characterization for beer fermentation. *Food Microbiology*, vol. 104, p. 103974, 2022.
 22. G. Milani. *Exploring Pathogenic Bacteria Dynamics and Antimicrobial Resistance Gene Transfer Across the Food Chain: Significance for Food Safety and Public Health*. Depositolegale, 2025. Available from: <https://hdl.handle.net/20.500.14242/160491> [Last accessed on 2025 Apr 10].
 23. S. Navon-Venezia, K. Kondratyeva and A. Carattoli. *Klebsiella pneumoniae*: A major worldwide source and shuttle for antibiotic resistance. *FEMS Microbiology Reviews*, vol. 41, no. 3, pp. 252-275, 2017.
 24. P. Seng, M. Drancourt, F. Gouriet, B. La Scola, P. E. Fournier, J. M. Rolain and D. Raoult. Ongoing revolution in bacteriology: Routine identification of bacteria by matrix-assisted laser desorption ionization time-of-flight mass spectrometry. *Clinical Infectious Diseases*, vol. 49, no. 4, pp. 543-551, 2009.
 25. S. Panwar, K. S. Duggirala, P. Yadav, N. Debnath, A. K. Yadav and A. Kumar. Advanced diagnostic methods for identification of bacterial foodborne pathogens: Contemporary and upcoming challenges. *Critical Reviews in Biotechnology*, vol. 43, pp. 982-1000, 2022.
 26. X. Sun, H. Yang, G. Huo, L. Li and G. Lyu. Study on enzyme activities and metabolomics of two *Penicillium chrysogenum* strains during fermentation of soybean paste. *Frontiers in Microbiology*, vol. 16, p. 1570939, 2025.
 27. D. K. Shanahan. *Dimorphic Fungi, Molds, and Mold-Like Agents of Medical Importance*. ResearchGate, Berlin, pp. 354-438, 2024.
 28. H. P. Bartholomew, D. Luciano-Rosario, M. J. Bradshaw, V. L. Gaskins, H. Peng, J. M. Fonseca, W. M. Jurick 2nd. Avirulent isolates of *Penicillium chrysogenum* to control the blue mold of apple caused by *P. expansum*. *Microorganisms*, vol. 11, no. 11, pp. 2792-2792, 2023.