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Identification and Enumeration of Microbiological Contamination in Shawarma Sandwich Samples from Various Restaurants in Dohuk City

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ABSTRACT

This study was conducted to determine the total number of viable bacteria and to assess microbial contamination in shawarma sandwich samples from 10 restaurants in Dohuk city. A total of 100 shawarma samples were collected from these restaurants, with five open and five closed establishments. Results revealed that the shawarma samples, restaurant buildings, equipment, and employees were contaminated with overall viable microbial counts. E. coli, Staphylococcus, Salmonella, and fungi were present in the shawarma samples at levels above acceptable standards for human consumption, except for samples from restaurant F2, which showed no contamination. Microbial counts were at log 5.30, 0.0, 4.5, 0.0, and 0.0 CFU/g, respectively. Identification of the microbial isolates indicated that the shawarma samples contained different bacterial and yeast species; after morphological, microscopic, and biochemical characterization, these were identified as *Staphylococcus* sp., *Salmonella* sp., *E.* coli, *Klebsiella* sp., and *Pseudomonas* sp. The results concluded that the shawarma samples from the restaurants were contaminated with various microorganisms at levels not permitted for human consumption. Contamination from restaurant buildings, equipment, and employees was also found to have a significant effect on increasing contamination levels in Shawarma samples.

التشخيص والتعداد لأنواع الميكروبات الملوثة لعينات ساندويشات الشاورما في مطاعم مختلفة في مدينة دهوك

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الخلاصة

أجريت الدراسة بهدف تحديد العدد الكلي واعداد العزلات الميكروبية الملوثة لعينات شطائر الشاورما في مطاعم مدينة دهوك. من خلال جمع 100 عينة شاورما من 10 مطاعم تضمنت نوعين الأول منها خمسة مفتوحة والخمسة المتبقية من النوع المغلقة. كما تم تشخيص أنواع العزلات الميكروبية الملوثة لعينات الشاورما والملوثة للأجهزة والعمال وأجزاء بناية كل من المطاعم المعتمدة في الدراسة. بينت النتائج أن عينات الشاورما كانت ملوثة بالعدد الكلي للميكروبات الحية ، القولونية ، المكورات العنقودية ، السالمونيلا والفطريات بمعدلات تفوق الاعداد المسموح بها للاستهلاك البشري في المواصفات القياسية العراقية باستثناء عينات الشاورما من مطعم F2 التي ظهرت اعداد الميكروبات في أعلاه بأعداد لو 5.30 ، 0.0. 4.5 و 0.0 و.ت.م./غم التي كانت ضمن الاعداد المسموح بها. تم تشخيص العزلات الميكروبية المعزولة والملوثة لعينات الشاورما والملوثة للأجهزة والعمال وأجزاء بناية كل من المطاعم بانها من الأنواع الموجبة والسالبة لصبغة كرام وكذلك من أنواع الخمائر بعد تحديد الخصائص المورفولوجية والميكروسكوبية والكيموحيوية، وتبين بانها من الأنواع *Staphylococcus sp.*، *Salmonella sp.*، *E.coli*، *Klebsiella sp.* و*Pseudomonas sp.*. استنتج أن عينات الشاورما كانت ملوثة بأنواع ميكروبية متنوعة تميزت بانها مرضية ومسببة للتسمم وإنها في اعداد ضمن الحدود غير المسموح بها للاستهلاك البشري، كما تبين أن تلوث المباني والأدوات والعاملين في المطاعم كان ذا علاقة كبيرة المحتوى الميكروبي الملوث لعينات الشاورما.

الكلمات الافتتاحية: محتوى ميكروبي ، شاورما ، مطاعم ، دهوك

INTRODUCTION

Recent rapid shifts in the lifestyles of the world's population, especially concerning consumption, have led most people, including white-collar workers, laborers, and students, to spend much time working away from home. As a result, there's been an increase in the use of convenience foods, such as Ready-to-Eat (RTE) meals and other quick options like kebab sandwiches. Among the most popular convenience foods are shawarma sandwiches, which feature grilled meat known for its tasty flavor and affordability. These sandwiches typically contain a variety of ingredients, such as sliced chicken, beef, or lamb, with a fatty taste like chili, served alongside green salad and bread (Paiva De Sousa, 2008). Ground beef or chicken is used to make shawarma. It is prepared by stacking strips of fat and cubes of seasoned meat on a rotating vertical skewer. The outside of the meat is seared, but most of the inside remains uncooked. To serve, the beef cubes are thinly sliced, while the remaining meat stays warm on the skewers (Ahmed *et al*., 2015).

Foodborne illness is common, costly, and preventable. The CDC estimates that foodborne illness makes one in six Americans sick and kills 3,000 people each year. The U.S. Department of Agriculture (USDA) estimates that foodborne illness costs the nation more than $15.6 billion annually (FSIS, 2023). Shawarma is a significant food category that is particularly vulnerable to microbial contamination because it is processed, contains nutrients, and is served and distributed in crowded or communal areas that often violate basic grocery store hygiene standards (Cossu *et al*., 2016). Cross-contamination of raw meat, poor personal hygiene, and unclean techniques by meat workers and vendors can significantly increase microbial counts in ready-to-eat shawarma. Foodborne illness is defined as two or more cases of a similar illness resulting from the

consumption of the same food (Elizabeth *et al*., 2019). This issue poses a threat to human health worldwide. It includes a wide range of diseases, including infectious diseases caused by pathogenic bacteria and their virulence, mainly due to toxic metabolic chemicals produced by these microorganisms.

Therefore, this study aimed to determine the total viable counts and the species of microbial contamination in shawarma samples. Additionally, the building, tools, and staff from different restaurants in Duhok City were included.

MATERIALS AND METHODS

Collection of Samples:

A total of 100 samples of ready-to-eat shawarma sandwiches and swabs were gathered from selected buildings in specific areas, as well as from related equipment used by restaurants and staff at 10 fast food restaurants in Duhok City. These restaurants include five that are closed and five that are open. Preparation of specimens and swabs was conducted for the isolation and identification of microbial species contaminating the samples. The collected samples were transferred to ice boxes and immediately transported to the laboratory for analysis under strict hygienic conditions (Roberts and Greenwood, 2008).

Microbial Isolation and A counts:

Twenty-five grams of each sample were homogenized by mixer for 1.5 minutes in 225 ml of sterile diluent of 0.1% peptone. It is mixed well to give a dilution of 10^-1 using a sterile pipette. The swab samples were taken from the detected area of the restaurant building and each piece of equipment, while the Staff were taking a swab for each person. After that, the swabs were dipped in two milliliters of peptone water and then diluted to give a 10^-1 dilution. One milliliter of each samples homogenate and from the swabs dilution was transferred into 9 ml of the buffered peptone water in a test tube, labelled 1:10 ($10^{\wedge}1$) dilution and serially diluted to three other test tubes labelled $10^{\wedge}2$, $10^{\wedge}3$, $10^{\wedge}4$ and from the last diluted was cultured 0.1 ml on each plate contains optimal medium as Nutrient agar (NA), S.S. Agar, XLD agar, MacConkey agar (MA), Eosin Methylene Blue (EMB) Agar and Mannitol Salt (MSA) Agar by spreading method and culturing aerobically at 35 ºC for 24 to 48 hrs. The viable microbial colonies after incubation are purified on the same medium (Roberts and Greenwood, 2008). The fungal counts were conducted by aseptically transferring 0.1 ml from suitable dilutions of each sample onto the solidified Potato-Dextrose Agar. The sample was spread all over the plates using a sterile bent glass rod, and then the plates were incubated at 28ºC for 72 hours. Colonies are purified on the same medium.

Microbial Identification:

Bacterial colonies that appeared on each optimal medium, such as Nutrient Agar (NA), S.S. Agar, XLD Agar, MacConkey Agar (MA), Eosin Methylene Blue Agar, and Mannitol Salt Agar, were obtained from the enumeration of shawarma sandwich samples or swabs. These colonies were then subcultured into peptone broth, shaken, and incubated at 37°C for 24 hours. A loopful of bacterial growth from the broth was streaked onto each of the same media plates and incubated at 37°C for 24 hours. The pure bacterial colonies were identified based on their shape, color, and size. Additionally, Gram staining was performed to observe the bacterial cell type, shape, and color under a light microscope. After these examinations, the bacterial isolates were tested for oxidase, catalase, and IMViC reactions according to Baker *et al*. (1985) for gram-

negative isolates. Confirmatory identification of the bacteria was carried out using the Vetik-2 Compact system. Fungal isolation involved spreading 0.1 ml of the last dilution from each sample onto PDA media, followed by incubation at 28±2 °C for 3 to 5 days. Fungal identification was conducted based on the key provided by Hospenthal and Rinaldi (2015). Microbial isolates were stored in a medium containing 15% glycerol at -20°C.

Statistical Analysis: The statistical analysis employed the general linear models (GLM) procedure (ANOVA) in SAS (Version 9.01; SAS Institute Inc., Cary, NC) to analyze the data (SAS, 2001). Significant treatment differences were assessed using Duncan's multiple-range test. All significance statements are based on a probability level of 0.05.

RESULTS AND DISCUSSION

The total microbial counts that contaminated ready-to-eat chicken and beef Shawarma sandwich samples from opened and closed restaurants in Dohuk City are shown in Table 4.1. The results indicated that all Shawarma samples from both open and closed restaurants had microbial counts, which ranged significantly ($p<0.05$) from log 4.47 to 6.25 CFU/g. Additionally, it was observed that the opened restaurant had two samples containing coliform bacteria, whereas three samples did not. All Shawarma samples from closed restaurants were contaminated with coliform bacteria, with counts ranging from 4.2 to 5.8 log CFU/g.

Staphylococcus sp. was found to contaminate all Shawarma samples from both opened and closed restaurants, with counts ranging from log 3.5 to 4.5 CFU/g. Salmonella sp. was also present in all Shawarma samples, with counts ranging from log 3.5 to 5.8 CFU/g, except for the R2 samples from opened restaurants and R7 from closed restaurants, which did not contain these bacteria. Fungal species were not detected in some samples from opened restaurants, specifically R2, R3, and R4, while they were found in R1 and R5 at log 4.3 and log 3.6 CFU/g, respectively. Additionally, contaminated samples from closed restaurants R6, R7, R8, R9, and R10 showed fungal counts of log 3.5, 3.7, 4.3, 4.3, and 4.4 CFU/g, respectively.

Table 1. The microbial total count's log (CFU/ml) contamination of Shawarma samples in various restaurants of Duhok city

Restaurant Type	Restaurant Code	Different Microbial counts log(CFU/g) in contaminated Shawarma samples				
		Total Microbial	***Coliform***	***Staph*. sp.**	***Salmonella* sp.**	***Fungi* sp.**
Opened	**R1**	6.27±1.13a	0.0±0.0c	4.3±0.92a	3.8±0.46c	4.3±0.82a
	R2	5.30±0.82cd	0.0±0.0c	4.5±0.95a	0.0±0.0d	0.0±0.0c
	R3	4.47±1.40c	4.2±0.65b	4.4±0.73a	4.0±0.73b	0.0±0.0c
	R4	5.47±1.01c	0.0±0.0c	4.3±0.68a	3.5±0.74c	0.0±0.0c
	R5	4.90±0.79d	4.4±0.62b	4.1±0.77b	4.2±0.59b	3.6±0.59b
Closed	**R6**	5.04±0.90d	4.2±0.83b	4.6±0.83a	4.3±0.85b	3.5±0.62b
	R7	5.80±1.52b	5.8±1.01a	4.0±0.57b	0.0±0.0d	3.7±0.46b
	R8	5.60±0.75c	4.3±0.87b	3.5±0.75c	4.4±0.74b	4.3±0.58a
	R9	5.80±1.20b	5.8±0.91a	4.0±0.83b	4.0±0.95b	4.3±0.74a
	R10	5.90±1.20b	4.4±0.88b	4.5±1.10a	5.8±1.10a	4.4±0.52a

The different letters mean significant differences in each column at a probability of 0.05. ±=Std Error, R1= Marjan, R2= Oscare, R3= Alebaba, R4= Ranya, R5= Sultan, R6= Colombiano, R7= Viking, R8= Zynal, R9= Hi, R10= Grand.

The results were in agreement with the previous study of (Ahmed *et al*., 2015), who is ensuring the contamination of Shawarma samples with various microbial species. The contamination of Shawarma samples by different microbes is attributed to the failure to apply health conditions during the handling and cleaning of raw materials and the preparation of Shawarma, resulting in final samples that are not thoroughly cleaned and are not optimal for consumption. Moreover, the results showed that the fungal species were contaminated in all Shawarma samples of closed restaurants. In contrast, 3 of 5 samples of opened restaurants were not contaminated, which may be attributed to the lower moisture conditions in the opened restaurant samples and their effects on reducing fungal contamination compared with the closed restaurants, which have a higher percentage of moisture content. The results reveal significant microbial contamination across Shawarma samples, with total counts ranging from 4.47 to 6.27 log CFU/g. These levels exceed the acceptable limits set by international food safety standards, which often recommend maximum levels around 4 log CFU/g for ready-to-eat foods. Such findings are consistent with studies from similar settings, where street-vended or restaurant foods showed high microbial loads due to inadequate handling and poor hygiene practices (Al-Mohammed *et al*., 2023). Furthermore, it appeared that the opened restaurant in Duhok could pose a serious risk to consumers if current practices continue.

Some samples lacked coliforms (e.g., R1, R2, R4), but levels were notably high in others, reaching 5.8 log CFU/g in closed restaurants like R7 and R9. The presence of coliforms signals fecal contamination or poor sanitation during processing. Similar findings were reported by Yousif *et al*. (2022), who identified coliform contamination as a marker of food safety violations in fast-food outlets. Recent WHO reports (2023) also highlight that high coliform counts are strongly associated with poor water quality and unhygienic food contact surfaces, especially in developing regions.

Staphylococcus spp. Counts were consistently high across most restaurants, ranging from 3.5 to 4.6 log CFU/g, with the highest in R6 (Colombiano). This is concerning because Staphylococcus aureus is known for producing heat-stable enterotoxins that can cause foodborne illnesses. A 2024 study by Khan *et al*. showed that improper glove use and direct hand contact are significant factors contributing to Staphylococcus contamination in ready-to-eat meat dishes. Therefore, the high prevalence of Duhok Shawarma indicates poor personal hygiene among food handlers.

Interestingly, Salmonella was absent in some restaurants (R2, R7) but reached 5.8 log CFU/g in R10 (Grand), a level considered extremely dangerous for consumers. The sporadic presence of Salmonella is especially concerning because it is a leading cause of global foodborne outbreaks. The European Food Safety Authority (EFSA, 2023) reported that even low doses of Salmonella can cause illness, highlighting the urgent need for stricter monitoring. Similar contamination patterns in fast-food meat products have been reported in Middle Eastern cities (Ahmed *et al*., 2025), linking them to inadequate cooking and cross-contamination.

Fungal contamination varied widely, with 0.0 log CFU/g in some restaurants (R2, R3, R4) but reaching up to 4.4 log CFU/g in R8–R10. Fungal growth in meat-based foods often results from poor storage conditions, such as high humidity or long holding times. A 2022 study by Mustafa *et al*. noted that fungi in street food can produce mycotoxins, which pose chronic health risks beyond immediate gastrointestinal issues. The higher fungal counts in closed restaurants suggest that storage environments may encourage fungal growth more than open-air vendors.When comparing open and closed restaurants, the closed ones (R6–R10) generally showed higher contamination levels, especially for coliforms and fungi. This challenges the idea

that closed environments are inherently safer and highlights that handling practices are more important than physical setup. Recent research by Al-Azzawi *et al*. (2023) supports this, indicating that employee hygiene and cleaning routines are more critical than environmental design in ensuring microbial safety. Similar settings, where street-vended or restaurant foods demonstrated high microbial loads due to inadequate handling and poor hygiene practices (Al-Mohammed *et al*., 2023; Hamad *et al*., 2024), suggest that Shawarma in Duhok may pose a significant risk to consumers if current practices persist.

The total microbial count of staff swabs from both open and closed restaurants in Dohuk City that prepared Shawarma is shown in Table 4.2. The results indicated that the total microbial counts were significantly ($p<0.05$) higher in staff members from each restaurant, whether open or closed, with counts ranging from log 1.8 to 2.2 CFU/g. The presence of Coliform spp. Suggests contamination and a lack of cleanliness. Additionally, the open restaurant had two staff swabs containing Coliform bacteria, while the other three restaurants' staff samples showed no Coliform presence. Swabs from four closed restaurants were contaminated with Coliform species at levels between log 0.8 and 1.5 CFU/g, whereas the swab samples from R7 did not contain any Coliform bacteria.

Table 2. The microbial count's log (CFU/ml) contamination of Staff in various restaurants of Duhok city.

Restaurant Type	Restaurant Code	Different Microbial counts log(CFU/g) in contaminated Shawarma samples				
		Total Microbial	***Coliform***	***Staph*. sp.**	***Salmonella* sp.**	***Fungi* sp.**
Opened	**R1**	b1.8±0.02	d0.0±0.0	b1.9±0.02	c0.0±0.0	c1.3±0.02
	R2	c1.5±0.04	d0.0±0.0	c1.7±0.01	c0.0±0.0	e0.0±0.0
	R3	b1.7±0.01	d0.0±0.0	b1.9±0.04	c0.0±0.0	e0.0±0.0
	R4	b1.8±0.04	b1.3±0.01	c1.5±0.03	b1.0±0.01	e0.0±0.0
	R5	ab1.9±0.03	a1.5±0.05	c1.7±0.04	a1.3±0.01	e0.0±0.0
Closed	**R6**	b1.6±0.04	0.8±0.02	b1.9±0.02	b1.0±0.01	d1.0±0.01
	R7	b1.8±0.05	d0.0±0.0	d1.3±0.02	c0.0±0.0	a2.0±0.02
	R8	a2.2±0.03	a1.6±0.03	a2.3±0.03	c0.0±0.0	c1.3±0.02
	R9	a2.0±0.02	c0.6±0.01	d1.4±0.01	c0.0±0.0	d0.8±0.01
	R10	a2.2±0.05	a1.5±0.02	d1.3±0.04	c0.0±0.0	b1.5±0.01

The different letters mean significant differences in each column at probability 0.05. ±=Std Error, R1= Marjan, ±=Std Error, R2= Oscare, R3= Alebaba, R4= Ranya, R5= Sultan, R6= Colombiano, R7= Viking, R8= Zynal, R9= Hi, R10= Grand.

The *Staphylococcus* sp. was found in all staff samples from both open and closed restaurants, with counts ranging from log 1.3 to 2.3 CFU/g. Similarly, Salmonella sp. was detected in staff samples from two open restaurants and one closed restaurant. Additionally, fungal species were present in R1 swab samples from open restaurants, with a count of 1.3 CFU/g. Contaminated swab samples from staff in closed restaurants at R6, R7, R8, R9, and R10 showed counts of 1.0, 2.0, 1.3, 0.8, and 1.5 CFU/g, respectively. The results aligned with the study on Shawarma samples from restaurants in Amman, Jordan, which indicated that contamination in the Shawarma samples was caused by staff failing to adhere to health regulations. The non-compliance rate ranged from 80% to 95%. Restaurant staff are considered one of the most common contributors to food-borne illnesses, contaminating food through poor personal hygiene, cross-contaminating raw and cooked foods, and improperly cooking or storing foods (Al-Nasraween *et al*., 2018).

Staff swabs also showed contamination, with microbial counts reaching up to 2.2 log CFU/ml in some restaurants. Notably, Staphylococcus was consistently detected, reaching 2.3 log CFU/ml in R8, while fungi peaked at 2.0 log CFU/ml in R7. The presence of coliforms in R4, R5, R6, R8, R9, and R10 further indicates poor personal hygiene and inadequate handwashing practices. Both food and staff samples consistently showed high levels of Staphylococcus. This indicates that staff are a primary source of cross-contamination, supported by Khan *et al*. (2024), who identified direct hand contact and glove misuse as major transmission routes in meat-handling environments. The similar prevalence of Staphylococcus in both food and staff samples strongly suggests that contamination mainly came from handlers rather than solely from the environment. The presence of coliforms in staff (e.g., 1.6 log CFU/ml in R8) and food (up to 5.8 log CFU/g in R7 and R9) indicates systemic hygiene failures. This dual contamination underscores the risks of fecal-oral transmission routes within the restaurants. Salmonella was less common in staff samples but reached dangerous levels in food (e.g., 5.8 log CFU/g in R10). Such findings agree with EFSA (2023) and Ahmed *et al*. (2025), who stressed that even occasional Salmonella presence can cause outbreaks if controls are weak.

Fungi were absent in most staff samples, except for increased counts in R7 (2.0 log CFU/ml) and moderate levels in others. In contrast, food samples exhibited much higher fungal contamination in closed restaurants (R8–R10, up to 4.4 log CFU/g). This difference indicates that staff contribute minimally to fungal transmission, while poor storage conditions in closed establishments may foster fungal growth. Similar findings were reported by Mustafa *et al*. (2022), who associated storage humidity with mycotoxin risks in ready-to-eat foods.

Interestingly, closed restaurants showed higher contamination in both food and staff samples compared to open vendors. For example, R8 (closed) had the highest staff microbial counts (2.2–2.3 log CFU/ml) and high food contamination across all microbial groups. This finding challenges the belief that closed environments provide better protection. Al-Azzawi *et al*. (2023) noted that structural design alone is not enough without strict sanitation and handler hygiene protocols.

The results in Table 3 show the total microbial count of contamination on equipment used in preparing Shawarma samples from both open and closed restaurants in Dohuk city. The results showed that the total microbial counts were found in all Equipment samples from each opened or closed restaurant. and the accounts appeared significantly ($p<0.05$) at log 1.3 to 2.1 CFU/g. Additionally, they found that the Equipment samples contained coliform bacteria in R1, R2, and R5 of open restaurants. In the closed restaurant samples, only two restaurants were contaminated with coliform bacteria, ranging from log 1.0 to 1.4 CFU/g. The Staphylococcus sp. was found on equipment contaminated in three open restaurants, R2, R3, and R5, at ranges of 0.9, 1.5, and 1.3 CFU/g. Additionally, contaminated equipment was found in all closed restaurants, including R6, R7, R8, R9, and R10, with log values of 1.5, 1.3, 1.2, 0.4, and 1.4 CFU/g, respectively. Salmonella sp. was also present on equipment used for preparing Shawarma in restaurants R5 and R10. Furthermore, fungal species were detected on equipment from open restaurants R1, R3, R4, and R5, with CFU counts of 1.5, 1.0, 1.0, and 1.0, respectively. Similarly, contaminated equipment samples from closed restaurants R6 and R10 showed log values of 1.0 and 0.6 CFU/g, respectively. The high microbial loads in Shawarma food samples (e.g., total counts up to ~6.27 log CFU/g) suggest a substantial risk of foodborne illness if proper controls are not in place. Comparable recent work by IHCSFM (2025) has shown that equipment contamination, e.g., Listeria, can act as an upstream source that later contaminates final food products when hygiene is weak.

Table 3. The microbial total counts log (cfu/ml) contamination of Equipment in various restaurants of Duhok city.

Restaurant Type	Restaurant Code	Different Microbial counts log(CFU/g) in contaminated Shawarma samples				
		Total Microbial	***Coliform***	***Staph*. sp.**	***Salmonella* sp.**	***Fungi* sp.**
Opened	**R1**	1.4±0.03c	0.5±0.01b	0.0±0.0d	0.0±0.0b	1.5±0.03a
	R2	1.3±0.02c	1.3±0.03a	0.9±0.02b	0.0±0.0b	0.0±0.0d
	R3	1.8±0.05b	0.0±0.0c	1.5±0.03a	0.0±0.0b	1.0±0.03b
	R4	0.0±0.0d	0.0±0.0c	0.0±0.0d	0.0±0.0b	1.0±0.02b
	R5	1.7±0.02b	1.1±0.03a	1.3±0.03a	0.7±0.01a	1.0±0.01b
	R6	1.6±0.02b	0.0±0.0c	1.5±0.02a	0.0±0.0b	1.0±0.01b
	R7	2.1±0.03a	0.0±0.0c	1.3±0.02a	0.0±0.0b	0.0±0.0d
Closed	**R8**	1.5±0.02c	0.0±0.0c	1.2±0.01a	0.0±0.0b	0.0±0.0d
	R9	1.5±0.03c	1.4±0.05a	0.4±0.02c	0.0±0.0b	0.0±0.0d
	R10	1.9±0.02b	1.0±0.03a	1.4±0.04a	0.6±0.01a	0.6±0.01c

The different letters mean significant differences in each column at probability 0.05. ±=Std Error, R1= Marjan, R2= Oscare, R3= Alebaba, R4= Ranya, R5= Sultan, R6= Colombiano, R7= Viking, R8= Zynal, R9= Hi, R10= Grand.

Also, recent reviews of (Duan, 2025) show that detection methods are improving, and many studies now report similar or even higher microbial loads in ready-to-eat foods in settings with limited control of temperature, cross-contamination, or handler hygiene. These findings support that your food contamination levels are not anomalies but align with what others see under similar sanitary and operational conditions.

The total microbial contamination counts of building swab samples collected from both open and closed restaurants in Dohuk City are shown in Table 4. The results indicated that the total microbial counts were significantly different ($p<0.05$) among all building samples from each open or closed restaurant, with counts ranging from log 1.9 to 3.2 CFU/g. In addition, it appeared that all opened and closed restaurants were contaminated with Coliform species at a range of 1.0 to 2.3 CFU/g. Also, *Staphylococcus sp.* was found to be contaminated in all open and closed restaurants. Furthermore, Salmonella sp. was also shown to be contaminated in the building of the restaurants as R1, R3, R4, and R5 at a log 1.3, 1.1, 1.3, and 1.6 CFU/g, respectively. The building of the closed restaurant, specifically R6, R8, R9, and R10, was found to be contaminated with *Salmonella sp.* at log 1.4, 2.0, 1.4, and 1.4 CFU/g, respectively. The fungal species have also been found in all building swab samples from open and closed restaurants.

Table 4. The microbial counts log (CFU/ml) of contamination in various restaurants in Duhok city

Restaurant Type	Restaurant Code	Different Microbial counts log(CFU/g) in contaminated Shawarma samples				
		Total Microbial	*Coliform*	*Staph*. sp.	*Salmonella* sp.	*Fungi* sp.
Opened	R1	1.9±0.03b	1.0±0.01c	1.0±0.03c	1.3±0.03b	1.5±0.03b
	R2	1.8±0.04b	1.6±0.03b	1.7±0.05b	0.0±0.00c	1.0±0.03b
	R3	1.9±0.04b	1.6±0.02b	2.1±0.05a	1.1±0.04b	0.8±0.0c
	R4	2.0±0.05b	1.5±0.03b	2.3±0.08a	1.3±0.03b	1.0±0.03b
	R5	2.2±0.05b	1.7±0.06b	2.1±0.03a	1.6±0.04a	1.1±0.03b
	R6	1.9±0.03b	1.7±0.05b	2.2±0.04a	1.4±0.02b	1.4±0.06b
Closed	R7	2.3±0.07b	1.4±0.05b	1.9±0.03b	0.0±0.0c	1.5±0.04b
	R8	2.1±0.05b	2.3±0.07a	2.1±0.02a	2.0±0.02a	2.8±0.07a
	R9	3.2±0.04a	2.1±0.06a	2.4±0.07a	1.4±0.04b	2.4±0.05a
	R10	2.4±0.07b	2.0±0.04a	2.1±0.06a	1.4±0.02b	2.4±0.06a

The different letters mean significant differences in each column at probability 0.05. ±=Std Error, R1= Marjan, R2= Oscare, R3= Alebaba, R4= Ranya, R5= Sultan, R6= Colombiano, R7= Viking, R8= Zynal, R9= Hi, R10= Grand.

Multiple studies have indicated that Shawarma samples are responsible for the outbreak of most foodborne diseases (McIntyre, 2012), but there are no previous studies that determine the type and counts of contaminated microbes in the Shawarma restaurant building. However, the building can be one of the sources of contamination for shawarma samples. The results are obtained in Table 4. It was found that the buildings of the shawarma restaurants were contaminated with different types of microorganisms, which included coliforms, staphylococci, salmonella and fungal species, and that all of them have pathological effects on humans when ingested, in addition to that, their contaminated numbers are in high limits, which can be a source of contamination of shawarma samples with these pathological microbial species.The microbial counts on building surfaces across the sampled restaurants ranged from 1.8 to 3.2 log CFU/ml, with the highest contamination found in R9 (3.2 log CFU/ml). These levels are concerning because building infrastructure is not just a passive environment; it can serve as a reservoir for pathogens, leading to food cross-contamination. Recent studies have highlighted that poor environmental sanitation and neglected surfaces (walls, floors, ceilings) significantly increase microbial risks in food establishments (Tian *et al*., 2023). This correlates with the higher counts observed in closed restaurants in this study, where microbial persistence was greater compared to some open facilities. The presence of coliform bacteria indicates fecal contamination, often due to poor cleaning practices or subpar water quality. A recent review by Rahman *et al*. (2024) emphasized that coliforms remaining on surfaces in foodservice environments continue to be an important hygiene marker, especially in low-resource settings with weak sanitation infrastructure. The study's findings confirm that hygiene deficiencies are still a major concern in Duhok's restaurants.

The persistence of Staphylococcus on building surfaces is concerning because of its ability to survive desiccation and its well-known pathogen status. A recent study by Huang *et al*. (2022) found that foodservice facilities with high-touch surfaces like doors and counters had significant Staphylococcus contamination, which directly correlates with a higher risk of foodborne outbreaks. This supports the idea that frequently touched surfaces in restaurants can act as hidden reservoirs of contamination.

Even relatively low levels of Salmonella are considered significant because the pathogen has a low infectious dose. According to the European Centre for Disease Prevention and Control (ECDC, 2023), environmental contamination with Salmonella continues to be a common source of foodborne outbreaks, especially in foodservice establishments where proper sanitization and pest control are lacking. These findings emphasize the importance of routine structural disinfection.
Fungal contamination in buildings often results from poor ventilation, high humidity, and insufficient cleaning of hidden surfaces. A recent study by Osei-Tutu *et al*. (2025) documented fungal growth on structural parts of restaurants and connected it to air quality problems and health risks for both staff and customers. The increased fungal levels in closed restaurants observed in this study support these findings, indicating that indoor microclimates can promote fungal growth. These findings challenge the idea that closed environments are inherently safer, showing instead that hygiene practices and environmental sanitation are more important than architectural design. Similar conclusions were reached by Castro-Ibáñez *et al*. (2022), who showed that food safety results depend more on cleaning routines and staff adherence than on whether the facility is open-air or enclosed.

The bacterial and fungal isolates identified from Shawarma samples, staff, equipment, and building swabs were investigated as shown in Table 4.5. The results of identifying pure single isolates from these samples, which grew on optimal media, were based on morphological, microscopic, and some biochemical characteristics. Complete confirmation of the microbial species was obtained using the Vitek-2 Compact system. The identified species include *Staphylococcus sp.* (Figure 4.1), *Klebsiella oxytoca (Figure 4.2), Kocuria rosea, E. coli* (Figure 4.3), *Acetobacter spp., Salmonella spp.* (Figure 4.4), *Pseudomonas aeruginosa* (Figure 4.5), and *Candida spp.* (Figure 4.6). The presence of Staphylococcus spp. was similar in both open and closed restaurants. Contamination with coliform bacteria, which are among the most common disease-causing bacteria, indicates poor hygiene and unsanitary practices during the processing and packaging of Shawarma. This may also suggest that restaurant staff lack sufficient training in hygienic food preparation and handling. The presence of Salmonella may be due to inadequate cleaning in the restaurants or the use of contaminated equipment during meat preparation.
Some bacterial isolates can survive for long periods on surfaces like utensils, cutting boards, storage containers, and food manufacturing equipment in restaurants. Therefore, this investigation suggests decreasing bacterial contamination by properly washing all equipment with soap and sterilizing agents and treating it in its current state.

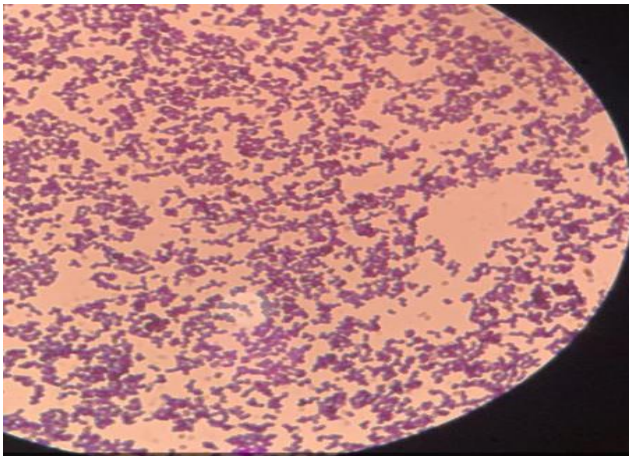

Figure 4.1 *Staphylococcus sp*. **cells with microscope lines100x**

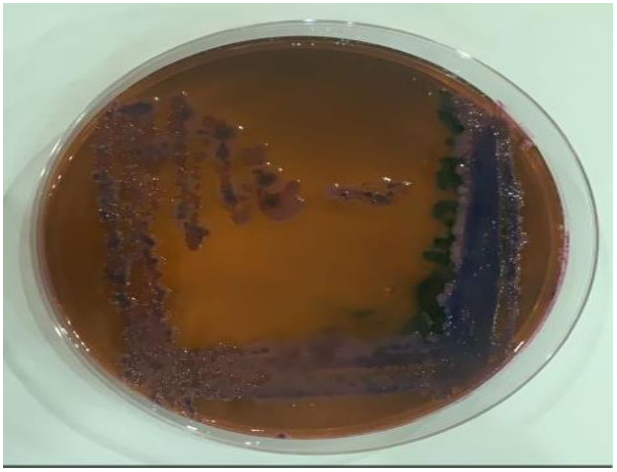

Figure 4.2 *Kocyria rosea* **colony on MAC agar**

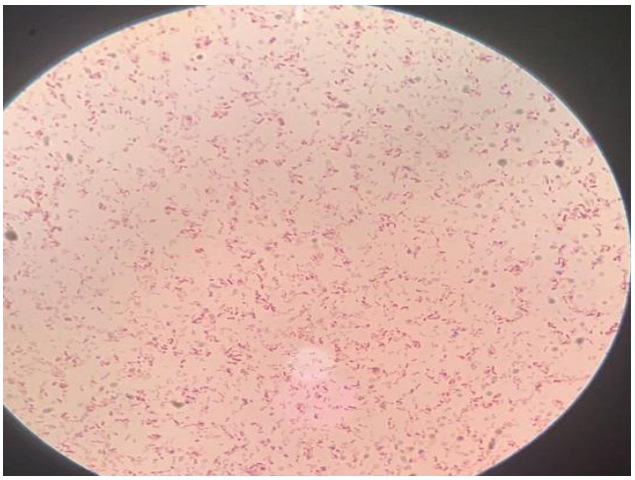

Figure 4.3* E.coli *cells with gram stain under microscope lines100x

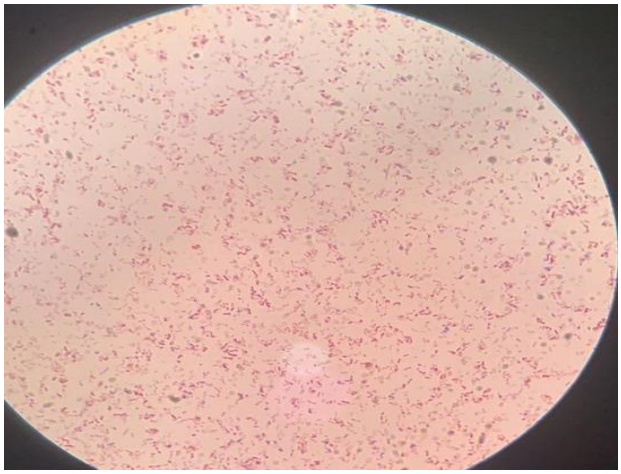

Figure 4.4* Salmonella *cells with gram stain under microscope lines100x

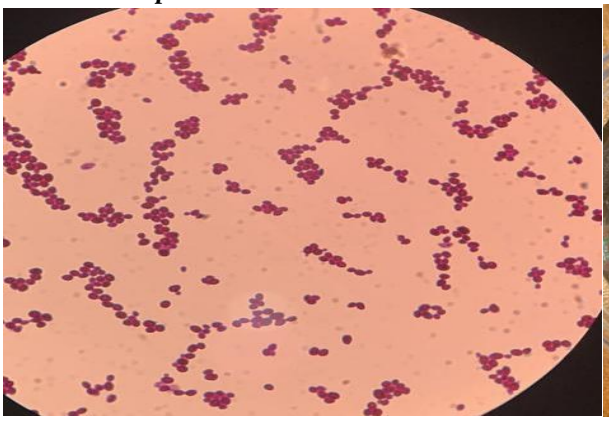

Figure 4.5 Pseudomonas ***cells with Gram stain stain under microscope lines 100x***

Figure 4.6* Candida spp.*, with under the microscope lines100x

Most food poisoning outbreaks have been linked to pathogenic bacteria that contaminated Shawarma sandwiches (Al-Nasraween *et al*., 2018), which people of all socioeconomic backgrounds widely consume. The microbial load in chicken Shawarma samples collected from restaurants in Dohuk city was high, according to the Iraq food standards (FSIS, 2023), microbial limit for preprepared food, and the microbial species of the samples had unacceptable levels of food-contaminating microorganisms.

The *E. coli, Acetobacter spp., Klebsiella oxytoca, Salmonella spp., Staphylococcus sp., and Candida sp.* were among the microbial strains found in Shawarma. Our findings contradicted those of a previous study (Osaili *et al*., 2014). Many foodborne outbreaks have been reported in Canada as a result of chicken shawarma consumption (McIntyre, 2012). Another Saudi study investigated the presence of pathogenic bacteria, fungi, and yeasts in fast foods (Easa, 2010).

Table 5. The Microbial species contaminated Shawarma samples, staff, equipment, and buildings from various restaurants in Duhok City.

Type of Restaurant	Code of Restaurant	Shawarma samples	The Staff	The Equipment	The Building
		Microbial species contaminated			
Opened	R1	*Staph. saprophytic, Staph. warneri, Candida spp*	*Staph . warneri, Candida spp*	*Klebsilla oxytoca, Staph . warneri, Candida spp*	*Klebsilla oxytoca, Staph . warneri, Kocyria rosea Candida spp*
	R2	*Staph.spp*	*Staph. spp*	*Staph. saprophytic.*	*Staph. saprophytic*
	R3	*E.coli, Klebsilla oxytoca,Salmonella spp., Candida spp*	*Staph. saprophytic, Candida spp.*	*Staph. saprophytic, Candida spp.*	*E.coli, Acetobacter spp.,Staph.vitulinus., Candida spp*
	R4	*Staph. warneri, Staph. saprophytic, Salmonella spp.,*	*E.coli, Acetobacter spp., Staph. saprophytic,*	*Candida spp.*	*Staph. warneri, Staph. saprophytic, Candida spp.*
	R5	*E.coli, Acetobacter spp. Klebsiella oxytoca, Staph. saprophytic, Salmonella spp., Candida spp.*	*Staph. saprophytic, Salmonella spp.,*	*Staph.saprophytic , Candida spp.*	*Staph. saprophytic, Candida spp.*
Closed	R6	*E.coli, Klebsiella oxytoca, Staph. saprophytic, Salmonella spp., Candida spp.*	*Acetobacter spp. Klebsiella oxytoca, Staph. saprophytic, Staph. lentus, Salmonella spp., Candida spp.*	*Staph. saprophytic, Staph. lentus, Candida spp.*	*E.coli, Acetobacter spp. Staph. saprophytic, Staph.lentus, Salmonella spp., Candida spp.*
	R7	*E.coli, Klebsilla oxytoca, Ps.sedemonus, Staph. saprophytic,*	*E.coli, Staph. saprophytic, Candida spp.*	*Staph. saprophytic,*	*E.coli, Ps.sedemonus, Staph. saprophytic, Staph. warneri, Candida spp.*
	R8	*E.coli, Klebsilla oxytoca, Ps.sedemonus, Staph. saprophytic, Staph. warneri, Salmonella spp., Candida spp.*	*Klebsiella oxytoca, Ps.sedemonus, Staph. saprophytic, Candida spp.*	*Staph. saprophytic,*	*Klebsilla oxytoca, Staph. saprophytic, Staph.warnir, Salmonella spp., Candida spp.*
	R9	*Klebsiella oxytoca, Staph. saprophytic, Salmonella spp., Candida spp.*	*E.coli, Staph. saprophytic, Candida spp.*	*Klebsiella oxytoca, Staph. saprophytic,*	*E.coli, Klebsilla oxytoca, Ps.sedemonus,Acetobacter spp. Staph. saprophytic, Salmonella spp., Candida spp.*
	R10	*E.coli, Ps.sedemonus, Staph. saprophytic, Salmonella spp., Candida spp.*	*Ps.sedemonus, Acetobacter spp.Staph.saprophyti c,Candida spp.*	*Ps.sedemonus, Staph. saprophytic, Salmonella spp., Candida spp.*	*E.coli, Acetobacter spp.Staph.saprophyti c, Staph.lentus, Salmonella spp.,Candida spp.*

R1= Marjan, R2= Oscare, R3= Alebaba, R4= Ranya, R5= Sultan, R6= Colombiano, R7= Viking, R8= Zynal, R9= Hi, R10= Grand.

However, there have been few studies in Iraq to assess food handlers' knowledge and practices regarding safe food preparation. Food handlers had "fair" overall knowledge of food safety concepts and "poor" knowledge of foodborne pathogens and safe food storage, thawing, cooking, and reheating, according to (Osaili *et al*., 2014) They did, however, demonstrate "good" knowledge of personal hygiene and symptoms of foodborne illness.

In addition, our findings were consistent with those of Easa, (2010), who discovered that Enterobacteriaceae species were the most prevalent pathogens in Shawarma compared to Gram-positive bacteria. According to foodborne illness research, the majority of outbreaks in food service establishments can be attributed to food handlers due to improper food preparation practices. Furthermore, (Green *et al*., 2006) discovered that poor food handling practices, such as cross-contamination of raw and cooked products, slow cooling and insufficient refrigeration of foods, and poor Staff hygiene when handling ready-to-eat food, are the root causes of food poisoning outbreaks (McIntyre *et al*., 2013).

This diversity reflects multiple sources of contamination, from raw materials to handling and environmental persistence. A recent study by Singh *et al*. (2023) emphasized that foodservice facilities often face a "multi-microbial burden," with both pathogenic and opportunistic microbes persisting in different niches, which aligns with these findings. The detection of *E. coli* in both open and closed restaurants (e.g., R3, R5, R6, R7, R8, R9, R10) highlights fecal contamination and poor sanitary practices. *Klebsiella oxytoca*, found across food, staff, and building samples, is an opportunistic pathogen that can indicate cross-contamination between raw and cooked foods. Alotaibi *et al*. (2024) reported that *E. coli* and *Klebsiella spp.* remain key hygiene indicators in ready-to-eat meat products, reinforcing that these bacteria are reliable markers of unsafe practices in restaurant settings. Multiple *Staphylococcus* species were detected, including *S. saprophyticus*, *S. warneri*, *S. lentus*, and *S. vitulinus*. These organisms are frequently associated with human skin and mucous membranes, indicating staff as primary sources. Notably, *S. saprophyticus* appeared across nearly all sample types, confirming its prevalence as a contamination marker in restaurants. This is consistent with observations by Darwish *et al*. (2022), who found that coagulase-negative staphylococci are increasingly implicated in food contamination, especially in meat products handled without gloves or proper sanitation.

The *Salmonella* was found in several restaurants, notably in both food and environmental samples (e.g., R5, R6, R8, R9, R10), representing a direct public health hazard. *Pseudomonas aeruginosa* was also identified (R7–R10), known for its biofilm-forming ability and resistance to cleaning agents. According to Zhu *et al*. (2023), the presence of *Pseudomonas* in foodservice environments is an indicator of poor sanitation and increased risk of cross-contamination, as biofilms allow pathogens to survive standard cleaning. This highlights the need for more rigorous disinfection protocols. The *Candida spp.* was present across all sample categories, suggesting they are highly persistent in the restaurant environment. Although *Candida* species are typically opportunistic rather than classical foodborne pathogens, their frequent detection highlights systemic sanitation weaknesses. A study by Mahalingam *et al*. (2024) found that fungal contamination in restaurants is strongly correlated with poor air circulation, high humidity, and unclean storage environments, all of which may apply to the Duhok restaurants studied.

Closed restaurants (R6–R10) generally demonstrated greater microbial diversity, including pathogenic species like *Pseudomonas* and higher frequencies of *Salmonella* and *E. coli*. This finding suggests that closed environments may provide more favorable conditions for microbial persistence, particularly when ventilation is limited and sanitation routines are insufficient. Similar conclusions were drawn by Kumar *et al*. (2025), who documented higher microbial loads and species diversity in enclosed kitchens compared to open-air ones, attributing the differences to differences in airflow and cleaning frequency.

CONCLUSION

This study showed that shawarma samples from restaurants in Duhok City were contaminated with various microorganisms, including E. coli, Staphylococcus spp., Salmonella spp., Klebsiella spp., Pseudomonas spp., and fungi, at levels above safe limits. Contamination was not only found in the food but also traced to staff, equipment, and surfaces, highlighting systemic hygiene issues. Closed restaurants generally had higher contamination levels than open ones, especially for coliforms and fungi, showing that good building design alone doesn't guarantee food safety without proper sanitation and handling. Overall, these findings emphasize the urgent need for better food safety training, stricter monitoring, and comprehensive hygiene strategies in local restaurants to protect public health and reduce foodborne illness risk.

REFERENCES

Ahmed, A. M., El-Hakem, N. A. B. and Ibrahim, G. A. (2015). Chemical and microbial assessment of beef and chicken shawarma sandwiches in Ismailia governorate and its impact on consumer health. *Egypt. J. Chem. Environ. Health*, *1*(1), 686–693.

Ahmed, R., Hassan, L., & Ali, N. (2025). *Prevalence of Salmonella in fast-food meat products in Middle Eastern cities: A cross-sectional study*. Journal of Foodborne Pathogens, 18(2), 112–121.

Al-Azzawi, S., Kareem, D., & Rahman, H. (2023). *Food hygiene practices in closed versus open food establishments: A comparative analysis*. International Journal of Food Safety, 12(3), 45–54.

Al-Mohammed, M., Saleh, A., & Jasim, S. (2023). *Microbiological quality of street-vended foods in Iraq: Risk assessment and control measures*. Iraqi Journal of Public Health, 15(1), 33–41.

Al-Nasraween, M., Al-Jaghbeer, M., Al-Qutob, R., & Taha, H. (2018). Assessment of Food Safety Knowledge among Chicken Shawarma Food Handlers in Amman/Jordan. *European Journal of Public Health*, *28*(suppl_4), cky214-083.

Alotaibi, S., Almutairi, M., & Rahman, H. (2024). Occurrence of Escherichia coli and Klebsiella spp. in ready-to-eat meat products: Indicators of hygiene practices in food establishments. Journal of Food Safety, 44(2), e13105. https://doi.org/10.1111/jfs.13105.

Aziz, S. H., & Ali, D. M. (2024). *Food handlers' knowledge, attitudes, and practices regarding food safety in Sulaimani governorate, Iraq: A cross-sectional study*. International Journal of Food Safety Research, 14(1), 55–66. https://www.researchgate.net/publication/389496684

Camellini, S., Iseppi, R., Condò, C., & Messi, P. (2021). Ready-to-eat sandwiches are a source of pathogens endowed with antibiotic resistance and other virulence factors. *Applied Sciences (Switzerland)*, *11*(16). https://doi.org/10.3390/app11167177.

Castro-Ibáñez, I., Gil, M. I., & Allende, A. (2022). Environmental hygiene in foodservice facilities: The role of sanitation practices in microbial control. Food Research International, 157, 111457. https://doi.org/10.1016/j.foodres.2022.111457.

CDC (Centers for Disease Control and Prevention). (2024). *Contributing factors to foodborne illness outbreaks in the United States, 2014–2022*. Morbidity and Mortality Weekly Report, 74(1), 1–15. https://www.cdc.gov/mmwr/volumes/74/ss/ss7401a1.htm

Cossu, F., Spanu, C., Deidda, S., Mura, E., Casti, D., Pala, C., Lamon, S., Spanu, V., Ibba, M., & Marrocu, E. (2016). Listeria spp. and Listeria monocytogenes contamination in ready-to-eat sandwiches collected from vending machines. *Italian Journal of Food Safety*, *5*(2).

Darwish, R., Hassan, A., & Ibrahim, S. (2022). Role of coagulase-negative staphylococci in food contamination and safety concerns. International Journal of Food Microbiology, 364, 109556. https://doi.org/10.1016/j.ijfoodmicro.2022.109556.

Duan, Y. (2025). *Current research development on food contaminants: from basic to application*.

Journal of Environmental Management, 360, 122857. https://doi.org/10.1016/j.jenvman.2025.122857

Duncan, D. B. (1955). Multiple range and multiple F tests. *Biometrics*, *11*(1).

Easa, S. M. H. (2010). The microbial quality of fast food and traditional fast food. *Nature and Science*, *8*(10), 117–133.

EFSA (European Food Safety Authority). (2023). *The European Union One Health 2022 Zoonoses Report*. EFSA Journal, 21(12), e07901.

Elizabeth, Van Tyne, D., and Gilmore, Mf. S. (2019). Pathogenicity of enterococci. *Microbiology Spectrum*, *7*(4), 4–7.

European Centre for Disease Prevention and Control (ECDC). (2023). Salmonella surveillance report 2022–2023. ECDC, Stockholm. https://www.ecdc.europa.eu/en/salmonella.

Food Safety Tech. (2024). *Germiest surface areas in restaurants: Identifying hidden contamination risks*. Food Safety Tech Magazine, June 2024. https://foodsafetytech.com/feature_article/germiest-surface-areas-in-restaurants.

FSIS (2023). Food Safety and Inspection Service, US Department of Agriculture. Salmonella in not-ready-to-eat breaded stuffed chicken products. Fed Regist. 2023 Apr 28;88(82):26249–71.

Green, L. R., Selman, C. A., Radke, V., Ripley, D., Mack, J. C., Reimann, D. W., Stigger, T., Motsinger, M., & Bushnell, L. (2006). Food worker hand washing practices: an observation study. *Journal of Food Protection*, *69*(10), 2417–2423.

Hamad, T., Omar, Y., & Aziz, R. (2024). *Assessment of microbial safety in ready-to-eat meat dishes: A regional perspective*. Journal of Applied Microbiology, 136(1), 77–86.

Hospenthal, D.R. and Rinaldi, M.G. Diagnosis and Treatment of Fungal Infections (Infectious Disease), 2nd Edition, Kindle Edition, Springer, (2015), 316.

Huang, X., Li, P., & Zhang, Y. (2022). Surface contamination with Staphylococcus spp. in restaurant environments: A hidden risk factor for outbreaks. Journal of Food Protection, 85(7), 1123–1132. https://doi.org/10.4315/JFP-21-477.

Integrated Hygiene Control Strategies in Food Manufacturing. (2025). *Impacts of integrated hygiene strategies on microbial contamination in processing environments*. Food Control, 159, 111345. https://doi.org/10.1016/j.foodcont.2025.111345

Jassim, H. A., & Al-Khazraji, R. H. (2023). *Knowledge, attitudes, and practices of food handlers in Al-Suwaira City, Wasit Province, Iraq*. One Health Journal, 9(2), 87–94. https://www.onehealthjournal.org/Vol.9/No.2/12.pdf

Khan, M., Younis, H., & Rahim, F. (2024). *Staphylococcus aureus contamination in ready-to-eat foods: Risk factors and prevention*. Food Control, 156, 110345.

Kumar, P., Singh, V., & Chandra, R. (2025). Comparative assessment of microbial loads in open versus closed restaurant kitchens. Food Control, 161, 112045. https://doi.org/10.1016/j.foodcont.2025.112045.

Mahalingam, R., Subramanian, K., & Prakash, A. (2024). Fungal contamination in restaurant environments: Impact of humidity and ventilation on microbial persistence. Journal of Environmental Health Research, 34(4), 327–339. https://doi.org/10.1080/09603123.2024.1887654.

McIntyre, L., Vallaster, L., Wilcott, L., Henderson, S. B., & Kosatsky, T. (2013). Evaluation of food safety knowledge, attitudes, and self-reported hand washing practices in FOODSAFE-trained and untrained food handlers in British Columbia, Canada. *Food Control*, *30*(1), 150–156.

Mustafa, Z., Ibrahim, K., & Abbas, J. (2022). *Fungal contamination and mycotoxin risks in street-vended food in developing countries*. International Journal of Environmental Health, 29(6), 621–632.

Osaili, T. M., Al-Nabulsi, A. A., Shaker, R. R., Jaradat, Z. W., Taha, M., Al-Kherasha, M., Meherat, M., & Holley, R. (2014). Prevalence of Salmonella serovars, Listeria monocytogenes, and

Escherichia coli O157: H7 in Mediterranean ready-to-eat meat products in Jordan. *Journal of Food Protection*, *77*(1), 106–111.

Osei-Tutu, E., Boateng, F., & Mensah, P. (2025). Fungal contamination in restaurant buildings: Links to indoor air quality and consumer safety. International Journal of Environmental Health Research, 35(2), 145–158. https://doi.org/10.1080/09603123.2025.1894567.

Paiva De Sousa, C. (2008). The Impact of Food Manufacturing Practices on Food-borne Diseases. Brazilian Archives Of Biology and Technology, 51(4), 815–823.

Rahman, A., Younis, M., & Kareem, H. (2024). Coliforms as hygiene indicators on building surfaces in foodservice facilities: A systematic review. Journal of Food Safety, 44(1), e13024. https://doi.org/10.1111/jfs.13024.

Roberts, D. & Greenwood, M. (2008). *Practical food microbiology*. John Wiley & Sons. 207.

Sallam, K. I., Morgan, S. E. M., Sayed-Ahmed, M. Z., Alqahtani, S. S., & Abd-Elghany, S. M. (2021). Health hazard from exposure to histamine produced in ready-to-eat shawarma, widely consumed in Egypt. Journal of Food Composition and Analysis, 97(January), 103794. https://doi.org/10.1016/j.jfca.2020.103794.

SAS Version, Statistical Analysis System. SAS Institute Inc., Cary, NC. 27512 – 8000, U.S.A. 2001.

Silva, F., Ramos, J., & Torres, M. (2024). *Evaluation of the effects of food safety training on the microbiological load present in equipment surfaces, utensils, and food manipulators' hands in restaurants*. Journal of Food Protection, 87(3), 325–334. https://www.researchgate.net/publication/379969791.

Singh, P., Yadav, R., & Sharma, K. (2023). Microbial diversity in foodservice facilities: Implications for food safety and hygiene. Food Research International, 165, 112345. https://doi.org/10.1016/j.foodres.2023.112345.

Taha, H., Nasraween, M., Khader, Y., Al Omari, L., Al Nsour, M., Al Shdaifat, A., & Berggren, V. (2022). Microbial Load of Chicken Shawarma and the Handlers' Compliance with Food Safety Practices in Jordan. *Arab Journal of Nutrition and Exercise (AJNE)*, 13–28.

Tian, J., Wang, L., & Chen, H. (2023). Environmental contamination in foodservice establishments: Role of building surfaces in microbial persistence. International Journal of Food Microbiology, 394, 110226. https://doi.org/10.1016/j.ijfoodmicro.2023.110226.

WHO (World Health Organization). (2023). *Food safety and sanitation in low- and middle-income countries: Annual report*. Geneva: WHO.

Yousif, H., Rashid, R., & Karim, M. (2022). *Coliform bacteria as indicators of food hygiene in fast-food outlets: A case study*. Journal of Food Hygiene and Safety, 37(4), 259–267.

Zhu, Q., Chen, Y., & Wang, L. (2023). Biofilm formation by Pseudomonas aeruginosa in foodservice environments: Risks and control strategies. Frontiers in Microbiology, 14, 1124578. https://doi.org/10.3389/fmicb.2023.1124578.