Analyzing Foodborne Pathogens in the Jeddah Region Statistically

Yasser Matar Haziz Almutairi[1], Rashed Mohammed Alghamdi[2,*]

[1] *Microbiology lab in General Khulais Hospital, Empowered by Makkah Healthcare Cluster, Khulais, 25525, Saudi Arabia, Telephone: +966-554466591, Email: yaalmutairi@moh.gov.sa*
[2] *Department of Laboratory Medicine Faculty of Applied College Al-Baha University, Alaqiq, 65779-7738, Saudi Arabia*

Ccorrresponding author: Rashed Mohammed Alghamdi
Email: rmalghamdi@bu.edu.sa

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ABSTRACT

Foodborne pathogens are becoming a globally challenging health problem and are perceived as major health concerns in the Kingdom of Saudi Arabia (KSA). Contamination results from unclean raw food materials and particles, the use of polluted water or contaminated containers, and unhygienic preparation processes. This research aimed to identify the prevalence of foodborne pathogens in food outlets such as restaurants, cafeterias, and cafés in the Jeddah region of Saudi Arabia and analyze the data collected by health inspectors to obtain useful statistics. These data will help us study the number of foodborne pathogen outbreaks in the Jeddah region, including the causative organisms, diseases, symptoms, and case numbers. This prevalence of foodborne pathogens was investigated in food places such as restaurants, cafeterias, and coffee shops. Food samples were collected from 235 locations, including meat products, dairy products, potatoes, sauces, vegetables (salads), and sweet foods. The isolates were detected using biochemical tests and API 20E. The results confirmed the presence of two types of foodborne pathogens in the food samples, namely *Escherichia coli* and *Salmonella* bacteria. The largest percentage of food samples were infected with *E. coli* (84.7%). The remaining percentage of food samples were infected with *Salmonella* (15.3%).

1. Introduction

Food products inherently harbor a microbiota, which may include pathogenic bacteria capable of causing deterioration (Böhme et al., 2012). Identifying pathogens in food and beverages before ingestion is crucial to prevent serious infections (Chattaway et al., 2011). Hence, it is imperative to distinguish between food spoilage and foodborne pathogens. Food spoilage refers to food that has degraded (e.g., due to fungi, mold, or yeast) (Okanlawon et al., 2023), while foodborne pathogens are biological agents capable of causing diseases or illnesses (Hubert Company, 2022). These pathogens are responsible for a wide array of illnesses, posing significant threats to human health and the economy. Common pathogenic organisms include bacteria (e.g., *Salmonella* spp., *Clostridium botulinum*, *Bacillus cereus*, *Staphylococcus aureus*, *Campylobacter jejuni*, *Listeria monocytogenes*, *Clostridium perfringens*, *Cronobacter sakazakii*, *Escherichia coli*, *Yersinia enterocolitica*, *Shigella* spp., and *Vibrio* spp.), parasites (e.g., *Trichinella spiralis*, *Cyclospora cayetanensis*, and *Toxoplasma gondii*), and viruses (e.g., Hepatitis A and Noroviruses) (Bintsis, 2017).

Various strategies have been proposed to extend the shelf life of food and mitigate foodborne pathogens. These strategies include pasteurization, canning, cooling, freezing, drying, and the addition of preservatives (Popa, et al., 2019). Additionally, monitoring and testing activities are pivotal in this process. Food manufacturers and health inspectors should assess the microbial load in products to ensure compliance with safety standards (Nielsen, 2010). Many countries have opted to centralize their food control systems, establishing a primary authority responsible for overseeing the entire food chain, from farm to fork, as a means to enhance the administrative structure for food control (Al-Kandari & Jukes, 2012).

National food control agencies worldwide have implemented food laws and regulations to uphold food safety (World Health Organization, 2019). Presently, most countries endeavor to enhance food quality and microbial control through the enactment of regulations and the adoption of specified systems, such as the Hazard Analysis Critical Control Point (HACCP). HACCP is a proactive approach to food safety that identifies and mitigates potential hazards during food production, including microbial contamination. Widely utilized in the food industry, HACCP aims to prevent and minimize contamination risks (Chaturvedi et al., 2013; Wiedmann et al., 2019). While food safety efforts often focus on physical inspection and laboratory testing of finished products, initiatives to raise awareness about factors contributing to foodborne illnesses have received comparatively less attention, suggesting a need for improved consumer education on this issue (Al-Mohaithef, 2021). Therefore, monitoring and controlling the microbial load in food is essential for ensuring food safety and quality. This necessitates a combination of good manufacturing practices, regulatory standards, testing, and preservation techniques to mitigate the risk of foodborne illnesses and spoilage.

1.2 Statement of the Problem

Food-borne disease (FBD) causes significant economic losses, a decline in quality of life, and decreased productivity (Scharff RL, *et al*., 2012). Moreover, there are no accurate projections of the global impact of FBD. However, 1.9 million children die worldwide each year from diarrheal infections, which make up a sizable component of FBD. Despite developments in food laws and food management that help lower the occurrence of food contamination, food-borne infections remain a major concern for people worldwide (Bhunia *et al*., 2018). Foodborne diseases are a common public health problem (Drudge *et al*, 2019). They are also known as "food poisoning" and are primarily caused by eating contaminated food containing parasites, bacteria, viruses, chemicals, and toxins. In 2010, the World Health Organization (WHO) estimated that there were 600 million cases of foodborne illness and 420,000 fatalities worldwide. The WHO Health Organization classifies the Eastern Mediterranean Region (EMR) as the third-worst region (World Health Organization, 2015). Public health is significantly impacted by foodborne illness through direct and indirect healthcare costs, which can include lost productivity (Hoffmann *et al*, 2014); 3081 periodic occurrences of foodborne illness have been reported in the Saudi Arabian Ministry of Health's Statistical Yearbook for 2020 with 1258 of those cases occurring in people between the ages of 15 and 45 years old (McLinden *et al*., 2014). Alhadlaq et al. (2023) confirmed the presence of *E. coli* O157:H7 in raw meat imported from food samples obtained from the Kingdom of Saudi Arabia. In a recent study conducted by Ashgar et al. (2023), most food samples (crushed and sliced green salad) in the Kingdom of Saudi Arabia were contaminated with pathogenic bacteria. Alsayeqh (2020) confirmed that the reported rates of foodborne diseases in the Kingdom of Saudi Arabia are underestimated compared to regional and global rates. It is crucial to undertake a thorough examination and analysis of the microorganisms that cause foodborne illnesses to monitor food safety procedures, prevent the spread of contamination, protect public health, and guarantee the security of the food supply chain (Melebari, 2023). The current study attempted to bridge this gap by identifying the prevalence of foodborne pathogens in food outlets and analyzing the data collected by health inspectors.

1.3 Objectives of the Study

Microbial contamination in food poses a significant risk of foodborne illnesses. Utilizing rapid tools to investigate microbial hazards at the point of sale is essential for preventing outbreaks of foodborne diseases. This study aimed to assess the prevalence of foodborne pathogens in various food outlets, including restaurants, cafeterias, and cafés, in the Jeddah region of Saudi Arabia. Additionally, the study aimed to analyze data collected by health inspectors to derive useful statistical insights. Data were sourced from the Jeddah Plat City Council after analyzing multiple food samples from the marketplace using microbiological testing methods.

1.4 Significance of the Study

Foodborne diseases represent critical public health concerns, particularly in the Kingdom of Saudi Arabia, where they are discussed at the international level. The incidence of foodborne infections is increasing daily, posing ongoing challenges to both human health and the global food industry. It is imperative to analyze the prevalence of foodborne pathogens in various regions across the Kingdom of Saudi Arabia.

2. Literature Review

2.1 Microbial load

Food microbiology is the study of microorganisms that colonize, alter, and process food, as well as those that contaminate and spoil it. It contains a diverse range of microorganisms, including pathogenic-, probiotic-, fermentative-, and spoilage bacteria as well as molds, yeasts, viruses, and prions. It includes various meals and beverages that combine a wide range of environmental conditions that may affect microbial survival, growth, and load (Adams & Moss, 2008; Laranjo et al., 2019). Thus, it is of utmost importance to measure the microbial load in food, which can widely vary depending on factors such as the type of food, processing and handling activities, and storage conditions. Some foods naturally have higher microbial loads, whereas others are more susceptible to contamination during processing. The manufacturing procedures have significant impacts on microbial loads, which vary according to the work conditions (Hosein et al., 2008). This variance has led to the emergence of variability in the microbial load. Microbial food variability is the result of different food bacteria with a wide range of sizes, varieties, and characteristics (Bacon and Sofos, 2003).

2.2 Foodborne Pathogens

The human body contains harmless microorganisms (primarily bacteria) that are part of the regular gut and skin microbiota. These microorganisms aid many vital bodily processes. However, several microorganisms are also pathogenic. Pathogens enter the body through the digestive tract and cause foodborne illnesses. These illnesses can be caused by food and water that have not been properly prepared or are contaminated (Leach et al., 2010). The pathogens included *Acinetobacter* spp., *Bacillus cereus*, *Bacillus subtilis*, *Citrobacter koseri*, *Campylobacter jejuni*, *Clostridium freundii*, *Clostridium perfringens*, *Clostridium difficile*, *Enterobacteriaceae cloacae*, *E. sakazakii*, *Klebsiella oxytoca*, *Escherichia coli O157:H7*, *Klebsiella pneumoniae*, *Salmonella enteritidis*, *Listeria monocytogenes*, *Shigella sonnei*, *Salmonella typhimurium*, *Staphylococcus aureus*, *Yersinia pestis*, and *Vibrio cholerae* (He et al., 2013). The most common types are described below.

2.2.1 *Escherichia coli*

E. coli is gram-negative and does not produce spores. In addition to being mobile, some rods are flagellated, while others are not (Schau, 1985). Many *E. coli* strains belong to large and diverse groups of bacteria. Most *E. coli* strains are harmless; however, some strains have acquired pathogenic characteristics, such as the ability to produce toxins (Schau, 1985). These pathotypes are a major public health concern because they have low infectious doses and spread through ubiquitous routes, including food and water (Croxen et al., 2013). Enterohemorrhagic *E. coli* (EHEC) is also known as shigatoxin—producing *E. coli* [STEC], as one example. STEC strain O157:H7 is estimated to cause 63,000 illnesses, 2,100 hospitalizations, and 20 deaths annually (Scallan et al., 2011). In 1982, investigators linked the consumption of undercooked ground meat to outbreaks of O157:H7, which has emerged as a significant public health threat (Scallan et al., 2011). A wide variety of foods, (including fresh produce) has been used as a vehicle for *E. coli* O157:H7 outbreaks. Food producers must report the presence of *E. coli* O157:H7 to health authorities (Scallan et al., 2011). *E. coli* is transmitted through food or water contaminated with the feces of infected humans or animals. Contamination frequently occurs during the slaughter and processing of animal products (Croxen et al., 2013). Animal manure used as a fertilizer for crops can contaminate produce and irrigation water (Croxen et al., 2013). *E. coli* can survive for long periods in the environment and proliferate in vegetables and other foods (Scallan et al., 2011).

2.2.2. *Salmonella* spp.

Enterobacteriaceae have pathogenic characteristics and are a common cause of enteric infections (food poisoning) worldwide. Depending on growing conditions, *Salmonella* species are Gram-Negative rod-shaped bacteria (bacillus) and range in size from 0.7 to 1.5 mm in diameter and 2 to 6 mm in length. These species have peritrichous flagella, do not form spores, and are predominantly motile (Ehuwa et al., 2021). Salmonella are chemoorganotrophic bacterium, which are aerobic and facultative anaerobic microorganisms that can grow with oxygen and survive without it through anaerobic respiration and fermentation. The *Salmonella* genus is divided into two species that can cause illnesses in humans: *S. enterica* and *S. bongori* (Schmidt & Rodrick, 2010).

Several other *Salmonella* species can cause enteric infectious diseases including *Salmonella enterica* subsp. Direct contact with fecal matter and cross-contamination during food processing are the main routes of transmission (Wu et al., 2016). Ingestion of contaminated food or water is the most common way for this pathogen to spread, followed by contact with domestic animals or livestock, contamination of surfaces, and transmission through feces and saliva. Different types of infections can occur, such as gastroenteritis, bacteremia, typhoid fever, and asymptomatic carriers. As Forsythe (2003) and Chaves et al. (2016) noted, this depends on the infected person's age, health status, and infectious dose.

Salmonella is a foodborne disease caused by these bacteria. It is one of the most common diarrheal illnesses worldwide. The consequences of food contamination include abdominal pain, vomiting, and diarrhea. After consuming a large infectious dose, these symptoms appear after a 12–72 hour incubation period and last for 4–7 days. People with weakened immune systems, such as those who are immunocompromised, over 60 years of age, and young children under 5 years of age, may die owing to severe dehydration (Wang and Hammack, 2014; Cohn et al., 2021).

According to recent estimates issued by the World Health Organization, food contamination by biological or chemical agents accounts for over 70% of the approximately 1.5 billion episodes of diarrhea that occur worldwide each year. The severity of the issue is indicated by the high frequency of diarrheal infections, particularly among youngsters in the area, which is estimated at 3.3 to 4.1 episodes per child per year (World Health Organization, 2023). Generally, these diseases are caused by eating raw or ready-to-eat foods that have not been sufficiently heat treated to inactivate this microorganism, resulting in these diseases. This is especially true for raw fruit and vegetable products that may be contaminated by soil or polluted irrigation water, including unpasteurised dairy products, meat, eggs, and their derivatives (Ricke, 2021). The diseases caused by foodborne pathogens are shown in Table 1.

Table 1 Diseases caused by foodborne pathogens

Disease or Clinical Symptoms	Pathogens/Toxins Involved

Vomiting, diarrhoea, dysentery	*Staphylococcus, Bacillus, Cronobacter, Salmonella, Shigella, Vibrio, Norovirus, Rotavirus, Entamoeba; Cryptosporidium; Cyclospora; Giardia; Cystoisospora; Taenia*
Arthritis (reactive arthritis, Reiter's syndrome, rheumatoid arthritis)	*Campylobacter, Salmonella, Shigella, Yersinia*
Hemorrhagic uremic syndrome (HUS), kidney disease	Shiga-toxin-producing *E. coli* (STEC); *Shigella* spp.
Hepatitis and jaundice	Hepatitis A virus (HAV), Hepatitis E virus (HEV)
Guillain-Barre syndrome (GBS)	*Campylobacter*
CNS/meningitis/encephalitis	*Listeria*, bovine spongiform encephalopathy (BSE)
Miscarriage, stillbirth, neonatal infection	*Listeria, Toxoplasma*
Paralysis	*Clostridium botulinum*, fish and shellfish toxins, *Campylobacter*
Malignancies and autoimmune diseases	Mycotoxin
Allergic response	Fish and shellfish toxins

Ray & Bhunia (2014, p. 306)

The Middle East and North Africa (MENA) region is especially concerning. It includes the Eastern Mediterranean countries, which have the third-highest estimated burden of FBDs per population after the African and Southeast Asian regions, according to the WHO (Havelaar et al., 2015). In this region, 32 million children under the age of five are thought to be infected with FBD. In addition, *E. coli*, non-typhoidal *Salmonella*, *Campylobacter*, and norovirus account for 70% of FBD cases in this region. In general, *Shigella* spp., *Salmonella* spp., and other pathogens, including the hepatitis A virus and parasites, are responsible for most of the common gastrointestinal infections in the region (World Health Organization, 2017). Unpasteurized dairy products are a contributing factor to FBDs recorded in Algeria, Kuwait, Jordan, Saudi Arabia, Oman, Lebanon, Syria, and the Palestinian Authority (World Health Organization, 2018).

2.3 Testing and monitoring food pathogens

The consumption of contaminated food and other products can result in foodborne diseases (Noor et al., 2019). The term "foodborne diseases" (FBD) refers to a broad range of disorders caused by the consumption of food contaminated with microorganisms (Byrd-Bredbenner et al., 2013). Monitoring can help ensure that the identified risks are controlled. For instance, it is possible to examine staff behavior to determine whether food safety protocols are being followed. Monitoring and testing activities must be documented to prove that the identified hazard has been controlled or that corrective action has been taken when a hazard is determined not to be under control (Australia New Zealand Food Standards Code, 2007). Food processors can maintain a high level of hygienic food production using microbiological monitoring to identify the presence of microorganisms, particularly harmful microorganisms. It aids in the production of safe food items that adhere to international standards and regulations and prevents the release of potentially contaminated products into the market (Manju & Mishra, 2021). The final product, such as a bottled beverage or a prepared food item, cannot be the only product that is subject to quality assurance examination. In contrast, it is necessary to undertake in-process quality control tests as well as ongoing monitoring of incoming raw materials throughout the production process. Microbiological and aseptic testing constitute a large part of this type of quality control (Sartorius, 2014).

2.4 Preservation Techniques

Various preservation techniques are used to control microbial load and extend the shelf life of food products. These include pasteurization, canning, refrigeration, freezing, drying, and the use of preservatives. The main goal of food preservation is to stop or slow the growth of microorganisms, such as molds, yeasts, and bacteria, because their growth leads to food spoilage. It also aims to slow down enzymatic reactions that occur during the raw material's post-harvest, post-slaughter, or shelf life (Popa et al., 2019). The main food preservation techniques are as follows.

→ **Pasteurization:** heat treatments normally applied for up to a few minutes at temperatures between 60 and 80 °C to remove a particular infection or pathogen connected to a product (Adams & Moss, 2008).

→ **Canning:** placing food in a container and applying heat to extend its shelf life. An ideal thermal procedure eliminates potentially harmful bacteria, reduces or eradicates existing spoilage organisms, and positively impacts the food's nutritional and physical qualities (Rajput et al., 2022).

→ **Preservatives:** substances added to a variety of food products, pharmaceutical dosage forms, and cosmetic preparations to maintain product consistency and quality, extend the shelf life of food, improve or maintain nutritional value, preserve palatability and wholesomeness, provide leavening (yeast), control pH, enhance flavor, or add color by preventing spoilage (Dwivedi et al., 2017).

→ **Dehydration** or drying of food is used to reduce losses while increasing its commercial value. Sundrying and solar drying, both of which require the use of solar dryers, are natural drying processes. Radiation, freeze-drying, osmotic drying, dielectric drying, and other artificial drying techniques are available. Food drying now uses cutting-edge technologies, such as microencapsulation and nanotechnology (Adeyeye et al., 2022).

→ **Refrigeration:** The food chain now requires refrigeration as a necessary component. It is utilized throughout the value chain, from farm and food production to distribution, retail, and home consumption. To halt the physical, microbiological, and chemical processes that could lead to food deterioration, the food industry uses chilling and freezing operations, wherein the food is cooled from ambient to temperatures above 0°C in the former and between -18°C and -35°C in the latter (Popa et al., 2019).

→ **Freezing**: The shelf life of many goods can be successfully extended by freezing. Despite the development of numerous new technologies, including high-pressure, infrared radiation, pulsed electric field, and ultrasound freezing, freezing remains one of the most popular ways to preserve food. When energy is lost from a substance chilled below its freezing point, water is transformed into ice, thereby changing the physical state of the substance. The temperature is typically further lowered to a storage level such as -18°C (Rahman & Velez-Ruiz, 2020).

2.5 Hazard Analysis and Critical Control Points (HACCP)

A variety of procedures are currently available to meet consumer demand for fresh, safe, healthy, and free of hazardous bacteria and chemical preservatives. These procedures allow food to maintain its nutritional value and organoleptic qualities while extending its shelf life (Habibat & Fapohunda, 2023). The food sector relies heavily on microbiological control to ensure that healthy foods are free of hazardous bacteria and chemical preservatives (Chaturvedi et al., 2013). Many strategies have been developed, including the use of microbial control systems such as HACCP: a scientific method that avoids cross-contamination and ensures safety during food processing. The food-processing industry has been focusing on prevention since the HACCP system gained popularity, and any deviations have been promptly fixed to address issues with food safety (Manju & Mishra, 2021). The significance of the HACCP system lies in its capacity to ensure food safety and enhance quality control, with a focus on identifying a specific targeted critical control point (CCP) for each hazard identified as reassuringly likely to occur (Wiedmann et al., 2019).

2.6 Laws and regulations for food safety

Food legislation often includes a section or clause that specifies various topics that may be addressed through regulations to fulfil the law's objectives. Most legal systems agree that there should be at least two avenues for legislation adoption: primary and secondary laws. Primary law establishes important violations as well as the fundamental rules of legal power. The complete legislative process, including extensive debates and considerations in parliament, is typically used to approve this type of legislation. Primary legislation is expected to include a clause that allows for a streamlined process for adopting secondary legislation (sometimes referred to as regulations or decrees). Consequently, making changes to this secondary law will be simpler (World Health Organization, 2023). In addition to the existing regulatory guidelines for the use of food additives, microbiological poisoning, food safety, and instructions for food handlers, the Saudi municipality recently released regulatory guidelines for sanitarian and HACCP implementation. The Ministry of Health reviews market food inspections through the Public Administration of Environmental Health (Alsubaie & Berekaa, 2020). The Saudi Food and Drug Authority (SFDA) was established as the Saudi government organization responsible for developing rules and guidelines for food, unprocessed animal feed products, and processed animal feed products (Hallman & Mousa, 2019).

2.7 Consumer education

It is important to maintain hygienic food preparation practices to prevent the growth and survival of foodborne pathogens (Scallan et al., 2011). Moreover, the expansion of fast food businesses operated by poorly educated personnel from developing countries who do not possess adequate food safety training has further aggravated this situation (Cetinkaya et al., 2008). The development of ongoing consumer education on several aspects of food safety (storage, preparation, and handling) is necessary. Early childhood should be the starting point for this education. The target audience for food safety education includes food handlers and all consumers, particularly males, of all age groups, as the majority of food safety-related morbidities are caused by unsafe household food behaviors and are easily avoidable (Boulos & Abouelezz, 2020). Grujić et al. (2013) have confirmed that consumers must be better informed and educated about food quality and safety, labels and labelling, as well as how to use and interpret label material.

3. Methodology of the Study

First: The research methodology:

The researcher adopted the descriptive analytical approach as the research method, as it suited the nature and objectives of the study. Delah (2018, pp. 140-141) was used as this approach since it focuses on studying the relationships between entities, existences, events, and circumstances.

Second: The research delimitations (Region):

This study was conducted in Jeddah, a Saudi Arabian city located along the eastern coast of the Red Sea. Jeddah is a commercial center and tourist destination with a population of (3.4) million people, making it the second-largest city after Riyadh. The research data was collected between January and September in the year 2022. Three different food outlets—restaurants, buffets, and cafés—affiliated with the Jeddah Municipality in the Kingdom of Saudi Arabia were selected for food sampling by the Jeddah Council Data Center. These settings were selected because they were popular among buyers, employees, and students.

Third: the study sample:

The research sample included several commonly consumed foods that were highly favored by the residents of Jeddah. The total number of samples collected was (8393), which were collected from (19) districts within the Jeddah region (Table 2).

Table 2 Distribution of research samples according to region

Municipalities	Samples numbers	Percentages
Obour	620	7.4
North Obour	256	3.1
Abraq Alraghama	143	1.7
Um Alselm	184	2.2
Al-balad	740	8.8
Al-jamah	732	8.7
South	503	6.0
Al-Sharfiah	597	7.1
Al-safaa	274	3.3
Al-Aziziah	799	9.5
Al-Matar	991	11.8
Al-Malysa	226	2.7
Bryman	408	4.9
Thwal	112	1.3
Jeddah Historical	95	1.1
Jeddah Al-Jadedah	914	10.9
Guzam	184	2.2
Thahban	203	2.4
Taiba	412	4.9
Total	**8393**	**100.0**

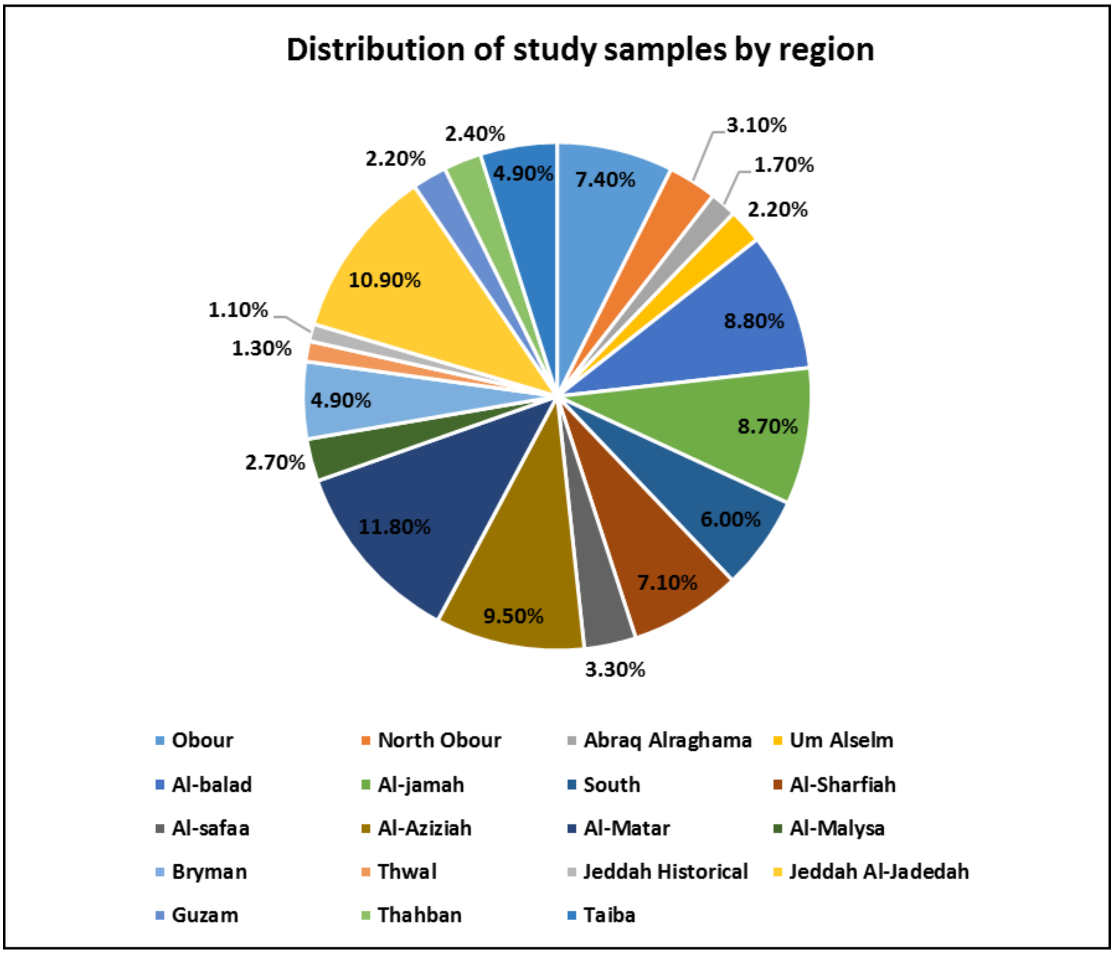

Figure 1 Distribution of research samples according to region

The total number of the collected samples was 8,393 distributed across 19 municipalities (Figure 1). The highest percentage of food samples obtained was from the "Al-Matar" municipality, with a 991 samples (11.8%).

Fourth: Procedures for collecting the research sample (food samples):

- **First procedure:** Obtaining a certified letter from the Jeddah Municipality.
- **The second procedure** involved collecting data on 8,393 food samples representing 11 different food types, including meat, dairy, potatoes, sauces, salads, and deserts, all of which are dishes that are frequently ordered from restaurants in the research municipalities and will be presented in detail as follows (Table 3 and Figure 2).

Table 3 Food sample types

Percentages	Food types	
20.9	Meat	**Food Samples (8393)**
9.80	Fruits	
3.40	Taameya	
15.30	Vegetables	
7.70	Egg	
7.70	Legumes	
3.80	Potatos	
10.60	Starches	
6.40	Appetizer	
8.90	Drinks	
5.50	Dairy	
100		

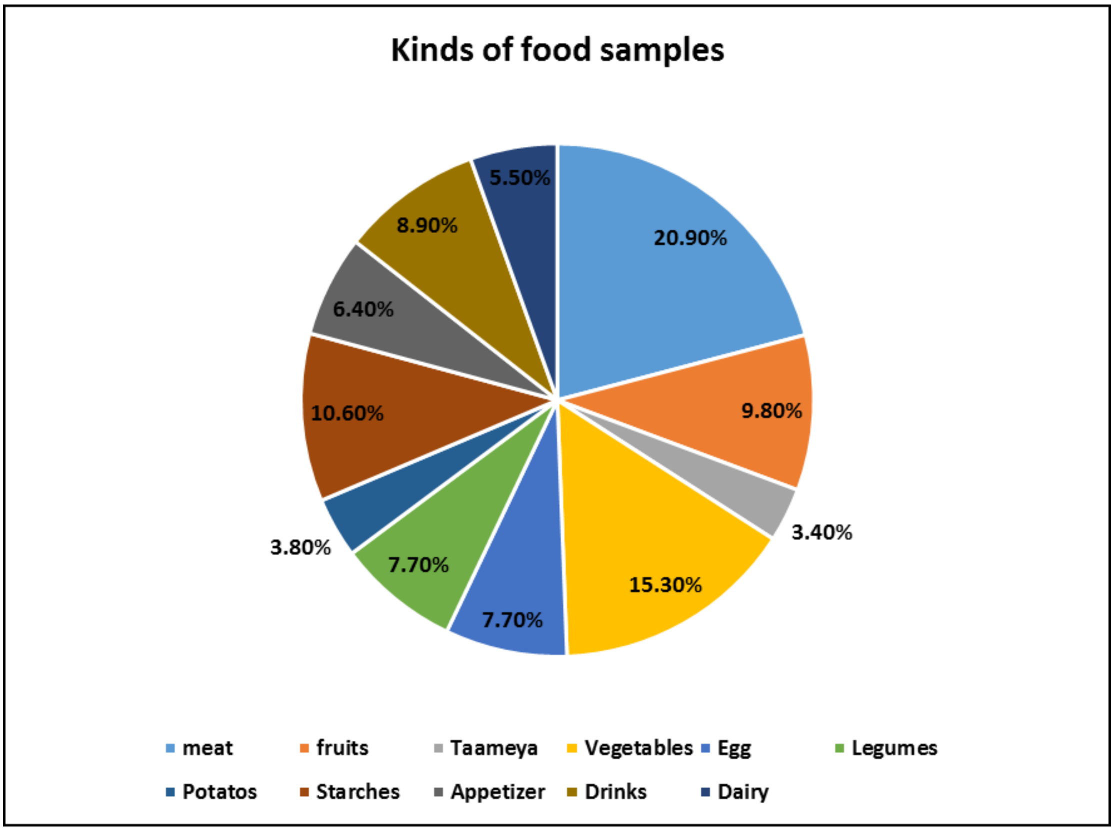

Figure 2 Food samples types

The food samples were collected from the previously mentioned areas of Jeddah, with a total of 8393 samples classified into 11 kinds of food, where the highest percentage of the food types was allocated to meat (20.9 %), while the lowest percentage was allocated to taameya (3.40%).

- **Third procedure**: samples were filled into (500 mL) bottles by concolic employees and stored in ice boxes in accordance with the requirements of the Microbiological Research Laboratory of the Jeddah Municipality for Analysis.
- **Fourth procedure:** sequential identification numbers were assigned to the store names to ensure confidentiality.
- **Fifth procedure**: this work was conducted in accordance with the ethical standards of Al Baha University.

Fifth: Procedures for testing and processing research samples (Food Samples):

The samples were processed and tested at the Microbiological Research Laboratory of Jeddah Municipality using the following steps:

- **Procedure 1:** Enrichment broths were incubated on Bird-Parker agar (Oxoid, England), XLD agar (Oxoid, England), Eosin Methylene Blue (EMB) agar (HIMEDIA, India), blood agar (HIMEDIA, India), and blood agar supplemented with 5% sheep blood**.**
- **Procedure 2:** The plates were then incubated for bacterial growth in an aerobic environment for 24–48 hours at 37 °C.
- **Procedure 3:** Gram and colony staining were used to examine bacterial colonies.
- **Procedure 4:** A portion of the isolated colony was streaked on nutrient agar and incubated aerobically for 24 h at 37 °C to obtain pure cultures. Catalase activity and coagulase tests were performed on the isolates using a MASTASTAPHTM kit.
- **Procedure 5:** The isolates were biochemically characterized using API 20E strips (BioMérieux, France).

Sixth: Statistical Methods:

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS). The results were then extracted using various statistical methods, including frequency, percentage, and chi-square tests.

4. Results

This section presents the results obtained after collecting data using the aforementioned statistical methods.

First: Distributing the foods collected from cafeterias in the specified research municipality in the Jeddah region.

Frequencies, percentages, and chi-square tests were calculated (Table 4).

Table 4 Distribution of foods collected from cafeterias in the study area

Municipality	Cafeterias		Chi-Square	Sig
	Sample numbers	Percentages		
Obour	190	7.4	1186.261[a]	.000
North Obour	50	1.95		
Abraq Alraghama	20	0.78		
Um Alselm	50	1.95		
Al-balad	300	11.68		
Al-jamah	230	8.96		
South	153	5.96		
Al-Sharfiah	125	4.87		
Al-safaa	80	3.12		
Al-Aziziah	100	3.89		

Al-Matar	256	9.97		
Al-Malysa	121	4.71		
Bryman	135	5.26		
Thwal	50	1.95		
Jeddah Historical	38	1.48		
Jeddah Al-Jadedah	353	13.75		
Guzam	95	3.7		
Thahban	52	2.02		
Taiba	170	6.62		
Total	**2568**	**100**		

a. 0 cells (0.0%) had expected frequencies of < 5. The minimum expected cell frequency is 135.2.

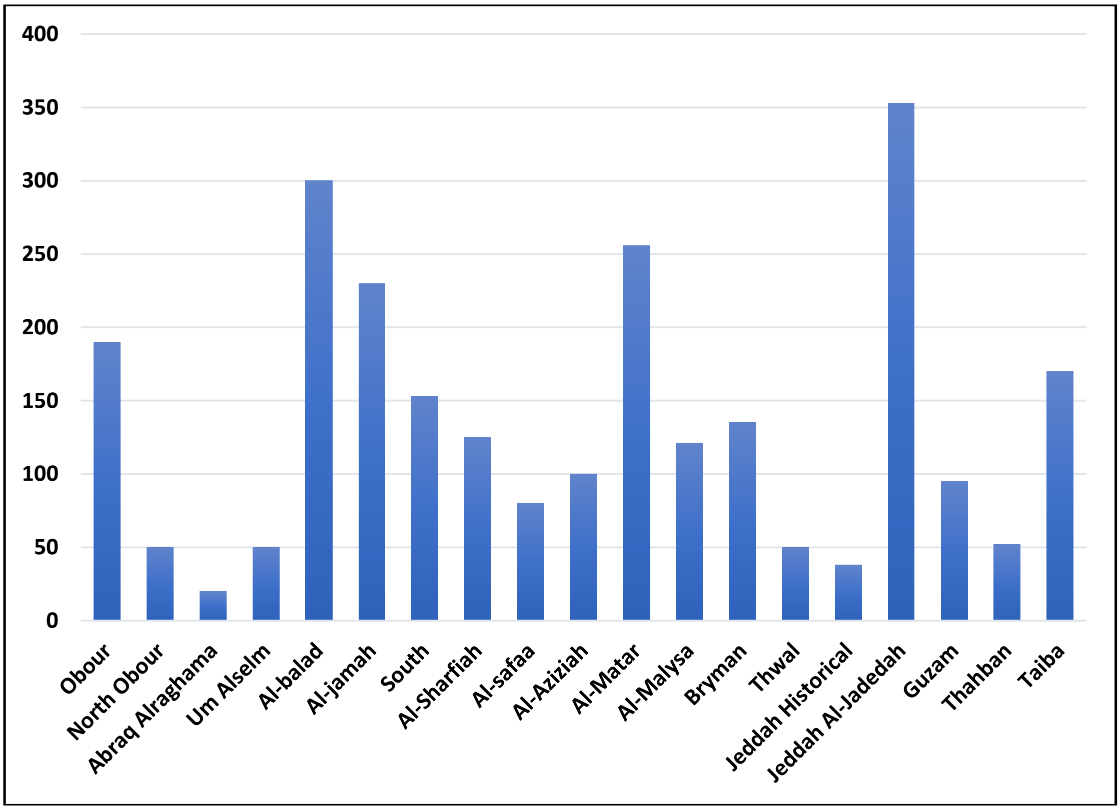

Figure 3 Distribution of food collected from cafeterias in the study area

Figure 3 illustrates the number of food samples collected from various cafeterias in different municipalities of Jeddah, with a total of (2568) samples. The highest number (percentage) of food samples collected was 353 (13.75%) from the municipality of "Jeddah Al-Jadedah." This was followed by 300 samples (11.68%) from the "Al-balad" municipality, while the lowest number (percentage) of food samples was 20 (0.78%), and obtained from the "Abraq Alraghama" municipality.

This result is consistent with the statistical indicators listed in Tables 1-4 regarding the significant correlation between the distribution of foods collected from cafeterias and the study areas in the Jeddah municipalities, where the chi-square value reached (1186.261[a]) at a significance level of (.000).

Second: Distributing the foods collected from coffee shops in the specified research municipalities in the Jeddah region.

Frequencies, percentages, and chi-square tests were calculated (Table 5).

Table 5 Distribution of foods collected from Coffee shops in the study area.

Municipality	Coffee shops		Chi-Square	Sig
	Sample numbers	Percentage		
Obour	100	5.37	897.956[a]	.000
North Obour	75	4.03		
Abraq Alraghama	10	0.54		
Um Alselm	50	2.68		
Al-balad	150	8.05		
Al-jamah	110	5.9		
South	121	6.49		
Al-Sharfiah	200	10.74		
Al-safaa	53	2.84		
Al-Aziziah	217	11.65		
Al-Matar	230	12.35		
Al-Malysa	37	1.99		
Bryman	130	6.98		
Thwal	15	0.81		
Jeddah Historical	25	1.34		
Jeddah Al-Jadedah	158	8.48		
Guzam	36	1.93		
Thahban	26	1.4%		
Taiba	120	6.44		
Total	1863	100		

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 98.1.

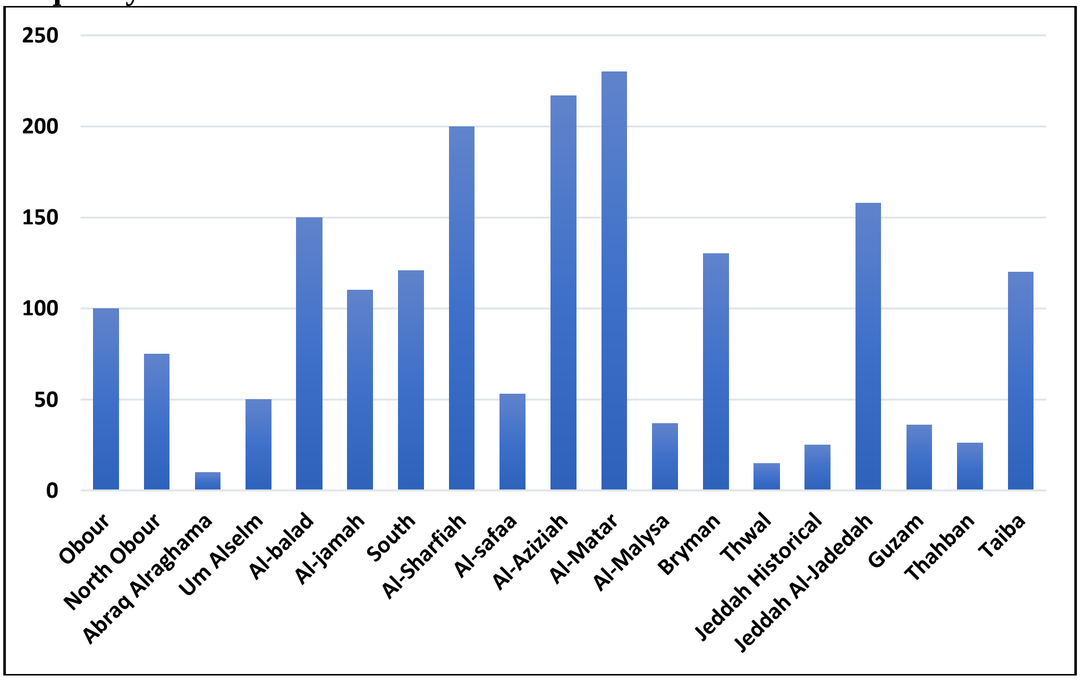

Figure 4 Distribution of foods collected from coffee shops in the study area. There was a total of 1863 samples.

The highest number (percentage) of food samples collected was 230 (12.35%) belonging to Al-Matar, followed by 217 (11.65%) belonging to the Al-Aziziah region, while the lowest percentage of food samples was 10 (0.54%) belonging to the Abraq Alraghama municipality (Figure 4) .

The previous results were consistent with the statistical indicators shown in Table 4. Regarding the significant correlation between the distribution of foods collected from coffee shops and the study areas in the Jeddah region, the chi value reached (897.956[a]) at a significance level (.000).

Third: Distributing the foods collected from restaurants in the specified research areas in the Jeddah region.

Frequencies, percentages, and chi-square tests were calculated (Table 5).

Table 5 Distribution of foods collected from restaurants in the study area.

Municipality	Restaurants		Chi-Square	Sig
	Samples numbers	Percentage		
Obour	330	8.33	1990.908[a]	.000
North Obour	131	3.31		
Abraq Alraghama	113	2.85		
Um Alselm	84	2.12		
Al-balad	290	7.32		
Al-jamah	392	9.89		
South	229	5.78		
Al-Sharfiah	272	6.87		
Al-safaa	141	3.56		
Al-Aziziah	482	12.17		
Al-Matar	505	12.75		
Al-Malysa	68	1.72		
Bryman	143	3.61		
Thwal	47	1.19		
Jeddah Historical	32	0.81		
Jeddah Al-Jadedah	403	10.17		
Guzam	53	1.34		
Thahban	125	3.15		
Taiba	122	3.08		
Total	**3962**	**100**		

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 208.5.

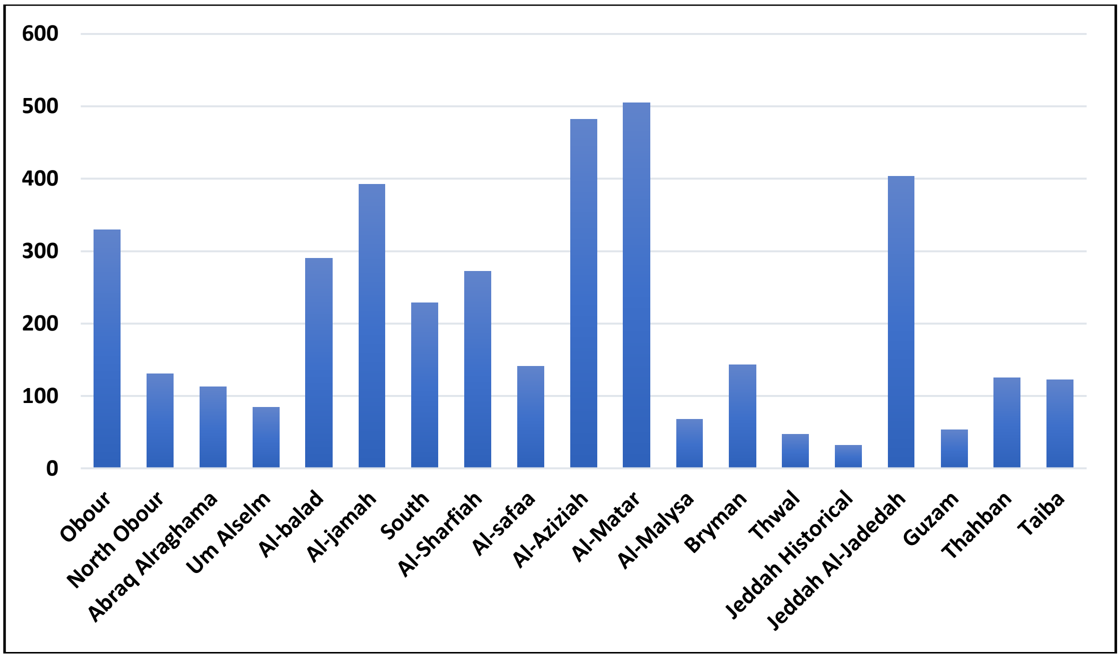

Figure 5 Distribution of foods collected from restaurants in the study area

Figure 3.4 illustrates the number of food samples collected from various restaurants in different municipalities of Jeddah, totaling (3,962) samples. The highest number (percentage) of collected food samples was 505 (12.75%) from the "Al-Matar" municipality, followed by 482 (12.17%) in the "Al-Aziziah" municipality. The lowest percentage of food samples was represented by a percentage of (0.81%) with a number of (32 samples), which belonged to the Jeddah Historical" region.

The above results are consistent with the statistical indicators presented in Table 3 and 4 regarding the significant correlation between the distribution of food items collected from restaurants and the study areas in Jeddah. The calculated chi-square value was (1990.908[a]) with a significance level of (.000).

Fourthly: the presentation and analysis of the main research objective, which focuses on identifying the "prevalence of foodborne pathogens in food settings such as restaurants, cafeterias, and cafes in the Jeddah region of Saudi Arabia".

To achieve the primary goal of this research, frequencies and percentages were calculated, and the types of foodborne pathogens were identified in food settings such as restaurants, cafeterias, and cafés in the Jeddah region of the Kingdom of Saudi Arabia (Table 6).

Table 6 Types of foodborne pathogens in the collected food samples (N = 235)

Isolated bacteria	Sample number (n)	Percentage
E. coli	199	84.7
Salmonella	36	15.3
Total	235	100

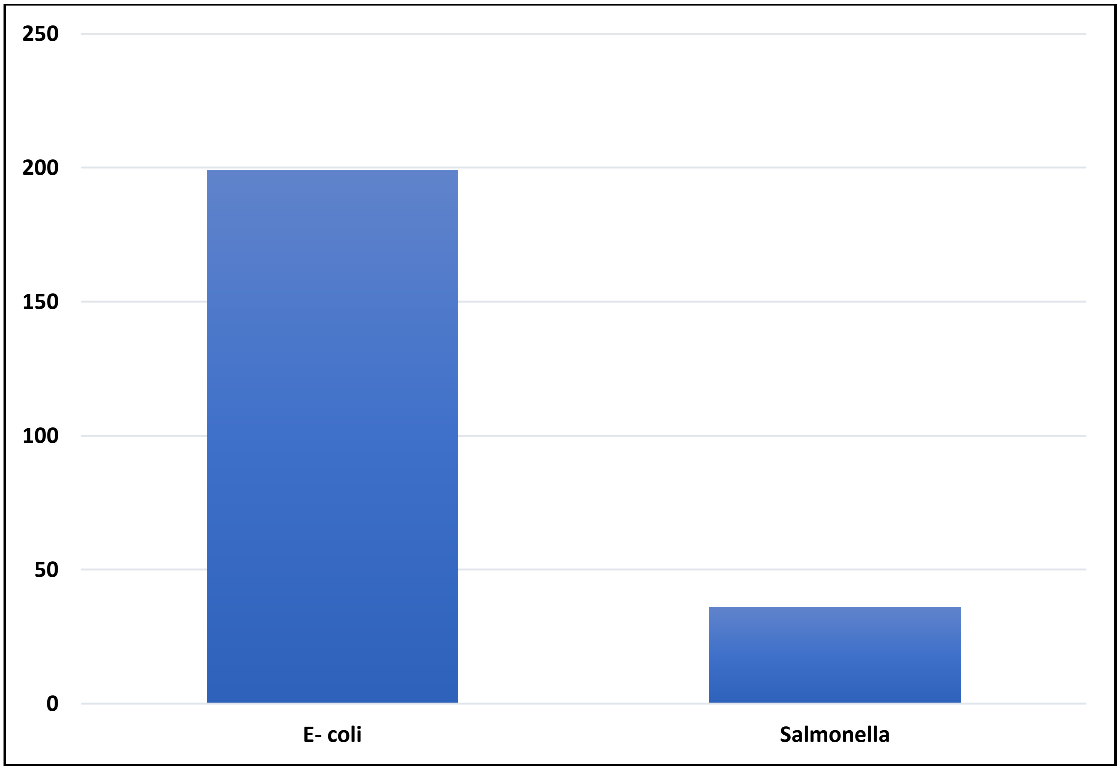

Figure 6 Types of foodborne pathogens in the collected food samples (N =235)

There were 235 food samples out of the collected food samples were deemed unfit for consumption with the presence of 199 (84.7%) *E. coli* and 36 (15.3%) *Salmonella* bacteria (Figure 6).

5. Discussion

There were a total of 235 food samples that were deemed unfit for consumption out of the collected samples food outlets from restaurants, cafeterias, and cafés in the Jeddah region of Saudi Arabia. The results confirmed the presence of two types of foodborne pathogens in the food samples (*E. coli* and *Salmonella*). This may be attributed to non-compliance with health standards during food preparation, storage, and distribution, which leads to contamination with germs and bacteria. These results may be owing to food being exposed to improper and unhealthy use of chemicals, such as pesticides and preservatives, which results in food contamination. In addition, food exposed to environmental pollutants such as lead, and airborne pollutants, such as dust or smoke affect the safety and quality of food because of air, water, and soil pollution. Animals getting sick and becoming infected with bacterial infections and various viruses are considered one of the most important causes of contamination of meat and dairy products. This was consistent with the study by Bharathirajan *et al.* (2013), wherein pathogens such *E. coli*, *Salmonella spp.*, *Campylobacter*, and *Listeria* were found in home freezers when samples were isolated from stores and counted to evaluate the prevalence of harmful microorganisms. This obviously shows very poor consumer refrigerator management and cleanliness standards, endangering consumer health. Iyer et al. (2013) reported the presence of pathogenic *Salmonella* and *E. coli* contaminants in meat from various outlets in Jeddah, Saudi Arabia. They studied 60 meat samples from different branches, including supermarkets, groceries, and local butcheries. They found that local butcheries in open markets harbored *Salmonella* as well as *E. coli* to a greater percentage in comparison than grocery stores and large hypermarkets, clearly indicating that proper handling and food storage conditions are major factors involved in the dissemination of food-borne pathogens.

The results of inspection and sample processing reports indicated that the largest percentage of food samples (84.7 %) were infected with *E. coli*. This may be owing to the presence of some types of food that cause infection with this type of bacteria, such as eating breakfast that is not cooked well or swallowing a small amount of contaminated swimming pool water. Some *E. coli* strains cause diarrhea. *E. coli* strain O157:H7 belongs to a group of *E. coli* strains that secrete a strong toxin that destroys the lining of the small intestine and may result in bloody diarrhea. *E. coli* infections can occur when this bacterial strain is ingested. Eating contaminated foods, such as meat, is also one of the most important and common causes of *E. coli* infections. *E. coli* present in the small intestine of the carcass can spread to the meat when it is slaughtered. Ground meat, which is a combination of meat from many carcasses, increases the likelihood of bacterial contamination and infection. Animal milk is also prone to contamination by *E. coli* that spread in the udders of animals or in the milking machines used. In addition to fresh agricultural products, including vegetables and fruits, which can be contaminated by the fields in which they are grown, certain types of vegetables such as spinach and lettuce are particularly exposed to this type of contamination. This is consistent with the findings of Altalhi et al. (2010) who collected meat samples from different establishments in Taif, Korea. These meat samples were significantly contaminated with several *E. coli* strains that were extremely resistant to a variety of antibiotics, which is consistent with the study of Al-Dughaym & Altabari (2010), which revealed a significant prevalence of *E. coli* in chicken meat from Saudi Arabia's Al-Ahsa markets. Ali et al. (2010) conducted a similar investigation on the microbial contamination of raw meat and its surroundings in retail stores in Pakistan. Their findings revealed a significant frequency of a variety of food-borne diseases, including *E. coli* O157:H7. Filled baguettes and salads have the highest bacterial frequency (Christison et al., 2008). Furthermore, *E. coli*-related diarrhea is quite common in both travellers and young children in underdeveloped nations. However, none of the collected food samples contained E. coli 0157. H7 strain. This result is inconsistent with that of Alhadlaq et al. (2023), who confirmed the presence of *E. coli* O157:H7 in imported raw meat from food samples taken from the Kingdom of Saudi Arabia.

The sample testing and processing reports also indicated that the remaining percentage of food samples contain *Salmonella* (15.3%). This highlights the fact that *Salmonella* spp. are among the most significant causes of foodborne illnesses, a critical health issue internationally and in the Kingdom of Saudi Arabia. *Salmonella* infection, also known as salmonellosis, is a common bacterial disease that affects the intestine. *Salmonella* typically resides in the intestines of animals and humans. Infection with these bacteria can occur through the consumption of contaminated water or food. Certain types of food can facilitate the transmission of bacterial infections, including meat, fish, and various seafood, where feces can contaminate raw meat and poultry during the cutting process. Seafood can also become contaminated when harvested from polluted water, and raw or undercooked eggs can also be a source of infection. Although eggshells seem to be an ideal barrier against contaminants, some infected poultry may lay eggs containing Salmonella before the eggshells are formed. Moreover, raw eggs are used in the preparation of various sauces, such as mayonnaise and Toumeya (Arabic Garlic Aioli). Fresh fruits and vegetables are susceptible to *Salmonella* contamination when irrigated with *Salmonella*-contaminated water. Failure to adhere to food safety standards during food preparation may contribute to *Salmonella* spread.

Additionally, *Salmonella* can be transmitted from infected animals, especially pets that carry *Salmonella* to their feathers or skin. Although eggs, pork, and poultry are frequently linked to *Salmonella* outbreaks, other foods, including fruits and vegetables, can also be contaminated (CDC, 2012). More recently, the CDC announced that 258 people from 24 states and the District of Columbia had contracted epidemic strains of *Salmonella Bareilly* (247 people) or *Salmonella Nchanga* (11 people), which is consistent with the study of Al-Mazrou (2004) who reported *Salmonella* food poisoning in Saudi Arabia. He found a steady increase in food poisoning incidents in the KSA, especially during the summer months and the Hajj season, with meat and chicken being the main sources of these outbreaks. Recent reports of meat contamination with *Salmonella* in KSA are increasing ،Another study reported a significant presence of *Salmonella* in meat samples from AlAhsa markets in Saudi Arabia (Al-Dughaym and Altabari, 2010). *Typhimurium* and *Enteritidis* are the two most widespread serotypes that cause human salmonellosis

In light of the research findings, the researcher recommended the importance of the food that is manufactured and presented to customers being prepared healthily and safely for human consumption, and therefore it is recommended that all food outlets follow food safety standards and microbial quality control rules in the Kingdom of Saudi Arabia in the Jeddah region.

Author contributions
Funding
Declaration of competing interest

List of References

Adams, M. R., & Moss, M. O. (2008). *Food Microbiology* (3rd edition). UK: Royal Society of Chemistry.

Adeyeye, S. A. O., Ashaolu, T. J., & Babu, A. S. (2022). Food Drying: A Review. *Agricultural Reviews*, 2022, 1-8. https://doi.org/10.18805/ag.R-2537

Al-Dughaym, A. M. and Altabari, G. F. (2010). Safety and quality of chicken meat products from Al Ahsa, Saudi Arabia. Saudi Journal of Biological Sciences 17(1), 37–42. https://doi.org/10.1016/J.SJBS.2009.12.006

Alhadlaq, M.A., Mujallad , M. I., Alajel, S. M. I. (2023). Detection of Escherichia coli O157:H7 in meat products imported from Saudi Arabian ports in 2017. *Scientifc Reports, 13*(2023), 1-6. https://doi.org/10.1038/s41598-023-30486-2

Al-Kandari, D. and Jukes, D. J. (2012). Food control system in Saudi Arabia: centralizing food control activities. *Food Control, 28*(2012), 33-46. https://doi.org/10.1111/1750-3841.15552

Al-Mazrou. (2004). Food poisoning. *Saudi Medical Journal*, 25(1). www.smj.org.sa

Al-Mohaithef M. (2021). Awareness of Foodborne Pathogens among students: A cross-sectional study in the Kingdom of Saudi Arabia. *International Journal of Food Science, 2021*, 9971748. https://doi.org/10.1155/2021/9971748

Alsayeqh, A. F. (2020). *Salmonella* in Saudi Arabia: An underestimated disease? *Alexandria Journal of Veterinary Sciences, AJVS, 67*(1), 30-38.

Alsubaie, A. S. R., & Berekaa, M. M. (2020). Food Safety in Saudi Arabia: A Public Health Priority. *Annals of Medical and Health Sciences Research 10*, 1142-1147.

Altalhi, A. D., Gherbawy, Y. A. & Hassan, S. A. (2010). Antibiotic-resistant *Escherichia coli* isolated from raw retail chicken meat in Taif, Saudi Arabia. *Foodborne Pathogens and Disease* 7(3), 281–285. https://doi.org/10.1089/FPD.2009.0365

Ashgar, S. S., Momenah, A. M., Khidir, E. B., Alharthi, A. A., Al –Said, H. M., Jalal, N. A., et al. (2023). Prevalence of Enteric Pathogens in the Prepackaged Salads in Makkah City, Saudi Arabia. *Egyptian Journal of Medical Microbiology*, 32(2), 73-77. http://dx.doi.org/10.21608/ejmm.2023.287944

Australia–New Zealand Food Standards Code. (2007). *Food Safety Programs A guide to Standard 3.2.1 Food Safety Programs*. Food Standards Australia, New Zealand, Canada.

Bacon, R.T., Sofos, J.N. (2003). Characteristics of biological food hazards In: Schmidt RH, Rodrick GE, editors. Food Safety Handbook. New Jersey: John Wiley & Sons. pp. 157–195.

Bhunia, A. K. Food-borne microbial pathogens: mechanisms and pathogenesis Springer: Berlin/Heidelberg, Germany, 2018.

Böhme, K., Barros-Velázquez, J., & Cañas, B. (2012). Species identification of food spoilage and pathogenic bacteria using MALDI-TOF mass spectrometry *Journal of Proteome Research, 9*(6), 29-46.

Boulos, D. N. K., Abouelezz, N. F. (2020). Food safety knowledge, attitudes, and self-reported practices among Medical Students at Ain Shams University, Egypt. *The Egyptian Journal of Community Medicine*, 38(2), 37-44.

Byrd-Bredbenner C, Berning J, Martin-Biggers J Quick, V. (2013). Food safety in home kitchens: literature synthesis. *International Journal of Environmental Research and Public Health*. 10(9), 4060-4085. https://doi.org/10.3390/ijerph10094060

CDC: *Salmonella* Bareilly and Nchanga infections associated with raw scraped ground tuna product–Salmonella. (n.d.). Retrieved December 16, 2022, https://www.cdc.gov/salmonella/bareilly-04-12/index.html

Cetinkaya, F., Cibik, R., Ece Soyutemiz, G., Ozakin, C., Kayali, R., & Levent, B. (2008). *Shigella* and *Salmonella* contamination of various foodstuffs in Turkey. Food Control, 11(19), 1059–1063. https://doi.org/10.1016/J.FOODCONT.2007.11.004

Chattaway, M.A., Dallman, T., Okeke, I.N., Wain, J. (2011). Enteroaggregative *E. coli* O104 from an outbreak of HUS in Germany in 2011. Could this happen again? *The Journal of Infection in Developing Countries*. 5, 425–436. https://doi.org/10.3855/jidc.2166

Chaturvedi, M., Kumar, V., Singh, D. & Kumar, S. (2013). Assessment of the microbial load of common vegetables among two different socioeconomic groups. *International Food Research Journal 20*(5), 2927-2931.

Christison, C.A., Lindsay, D., Holya, A.V. (2008). Microbiological survey of ready-to-eat foods and associated preparation surfaces in retail delicatessens, Johannesburg, South Africa. *Journal of Food Control*. 19: 727–733. https://doi.org/10.1016/j.foodcont.2007.07.004

Croxen, M. A., Law, R. J., Scholz, R., Keeney, K. M., Wlodarska, M., & Finlay, B. B. (2013). Recent Advances in Understanding Enteric Pathogenic *Escherichia coli*. Clin Microbiol Rev 26(4): 822. https://doi.org/10.1128/CMR.00022-13

Drudge, C., Greco, S., Kim, J., Copes, R. (2019) Estimated annual deaths, hospitalizations, and Emergency Department and physician office visits from foodborne illnesses in Ontario. *Foodborne Pathogens and Disease*. 16, 173-179. https://doi.org/10.1089/fpd.2018.2545

Ehuwa, O., Jaiswal, A. K., and Jaiswal, S. (2021). *Salmonella*, Food Safety and Food Handling Practices. *Foods* 10(5), 907. https://doi.org/10.3390/FOODS10050907

Food safety. (n.d.). Retrieved December 16, 2022. https://www.who.int/news-room/fact-sheets/detail/food-safety.

Foodborne Germs and Illnesses | CDC. (n.d.). Retrieved December 14, 2022, https://www.cdc.gov/foodsafety/foodborne-germs.html

Fung, F., Wang, H.S., Menon, S. (2018). Food Safety in the 21st century. *Biomedical Journal* 41, 88–95. https://doi.org/10.1016/j.bj.2018.03.003

Grujić, S., Grujić, R., Petrović, D., & Gajić, J. (2013). Importance of consumers' knowledge of food quality, Labeling, and safety in food choices. *Journal of Food Research, 2*(5), 57-65. http://.doi.org/10.5539/jfr.v2n4p57

Habibat, A. O., Fapohunda, S. O. (2023). Appraisal of Novel Technologies for Microbial Inactivation in Food. *World Journal of Food Science and Technology, 7*(3), 57-66. http://.doi.org/10.11648/j.wjfst.20230703.13

Hallman, A., Mousa (2019). *Food and Agricultural Import Regulations and Standards Report*. FAIRS Annual Country Report.

Havelaar, A.H., Kirk, M.D., Torgerson P.R., Gibb, H.J., Hald, T., Lake, R., et al. (2015). World Health Organization global estimates and regional comparisons of the burden of foodborne diseases in 2010. *PLoS Med*. 12, e1001923. https://doi.org/10.1371/journal.pmed.1001923

He, X., Patfield, S., Hnasko, R., Rasooly, R., Mandrell, R.E. (2013). A polyclonal antibody-based immunoassay detects seven subtypes of Shiga toxin 2 produced by *Escherichia coli* in human and environmental samples. *PLoS One*. 8, e76368. https://doi.org/10.1371/journal.pone.0076368

Hoffmann, S., Batz, M.B., Morris, J.G., Jr. (2012). Annual cost of illness and quality-adjusted life-year losses due to 14 foodborne pathogens in the United States. *Journal of Food Protection* 75, 1292-1302. https://doi.org/10.4315/0362-028x.jfp-11-417

Hosein, A., Muñoz, K., Sawh, K., & Adesiyun, A. (2008). Microbial Load and the Prevalence of *Escherichia coli*, *Salmonella* spp., and *Listeria* spp. in ready-to-eat Trinidad products *The Open Food Science Journal* 2008, 23-28. http:/doi.org/10.2174/1874256400802010023

Hubert Company. (2022). Food Spoilage vs. Food Pathogens: What is the difference? Hubert Company, LLC. https://www.hubert.com/resources/article/the-difference-between-food-spoilage-and-food-pathogens

Iyer, A., Kumosani, T., Yaghmoor, S., Barbour, E., Azhar, E. & Harakeh, S. (2013). *Escherichia coli* and *Salmonella* spp. in meat from Jeddah, Saudi Arabia. *Journal of Infection in Developing Countries*, 7(11), 812–818. https://doi.org/10.3855/jidc.3453

Kamleh, R., Jurdi, M., Annous, B.A. (2012). Management of microbial food safety in Arab countries. *Journal of Food Protection*. 75:2082–90. https://doi.org/10.4315/0362-028x.jfp-11-405

Khan, M.M, Pyle, B.H, Camper, A.K. (2010). Specific and rapid enumeration of viable but non-culturable and viable Gram-negative bacteria using flow cytometry. *Applied Environmental Microbiology*. 76, 5088–5096. https://doi.org/10.1128/aem.02932-09

Laranjo, M., Córdoba, M. D. G., Semedo-Lemsaddek, T., Potes, M. E. (2019). Food Microbiology. *BioMed Research International*, 2019, 8039138. https://doi.org/10.1155/2019/8039138

Leach, K.M., Stroot, J.M., Lim, D.V. (2010). Same-day detection of *Escherichia coli* O157: H7 in spinach using electrochemiluminescent and cytometric bead array biosensors. *Applied and Environmental Microbiology*. 76, 8044–8052. https://doi.org/10.1128/aem.01990-10

Manju, G. & Mishra, S. K. (2021). Monitoring of the microbiological environment during food processing. *Indian Food Industry Magazine, 3*(2), 46-56.

McLinden, T. T., Sargeant, J.M., Thomas, M.K., Papadopoulos, A., Fazil, A. (2014) Component costs of foodborne illnesses: A scoping review. *BMC Public Health*. 14, 509. https://doi.org/10.1186/1471-2458-14-509

Melebari, M. (2023). Incidence of potentially pathogenic bacteria at restaurants in Al-Mandaq City, Saudi Arabia: First study. *Journal of Pure and Applied Microbiology*, 17(3), 1916-1925. https://doi.org/10.22207/JPAM.17.3.57

Nielsen, S. S. (2010). *Food Analysis* (4th Edition). Springer Science and Business Media LLC.

Noor R. (2019). Insight into foodborne diseases: proposed models for infections and intoxications. *Biomedical and Biotechnology Research Journal*. 3, 135. https://doi.org/10.4103/bbrj.bbrj_86_19

Okanlawon, T. S., Adeyemo, S. M., Agbaje, I. S. (2023). Isolation and identification of microorganisms associated with jollof rice sold at Bukateria in Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. *GSC Biological and Pharmaceutical Sciences*, 22(01), 178–185. http://doi.org/10.30574/gscbps.2023.22.1.0274

Popa, E. E., Miteluț, A. C., Popa, M. E. (2019). Trends in refrigeration technologies used for food preservation: a review. *Scientific Bulletin. Series F. Biotechnologies, XXIII*(2019), 205-210.

Prajapati, P., Dwivedi, S., Vyas, N., Malviya, S., Kharia, A. (2017). Review on Food Preservation: Methods, harmful effects, and better alternatives. *Asian Journal of Pharmacy and Pharmacology, 3*(6), 193-199.

Rahman, M. S., Velez-Ruiz, J. F. (2020). Food Preservation by Freezing. In *Handbook of Food Preservation*, CRC Press.

Rajput, H., Goswami, D., Arya, M., Randhawa, A. (2022). Technology for Canning. *Global Hi-Tech Horticulture*, 6, 135-151.

Ray, B., & Bhunia, A. (2014). Fundamental Food Microbiology (5th efdition). USA: Taylor and Francis Group, LLC.

Sartorius AG. (2014). *Microbiological Testing of Foods, Beverages, Drinking Water and Pharmaceuticals*. Sartorius Publications.

Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M. A., Roy, S. L., et al. (2011). Foodborne illness acquired in the United States: Major pathogens. *Emerging Infectious Diseases*, 17(1), 7–15. https://doi.org/10.3201/EID1701.P11101

Scharff, R.L. (2012) Economic Burden from Health Losses Due to Foodborne Illness in the United States. *Journal of Food Protection*. 75(1), 123-131. https://doi.org/10.4315/0362-028x.jfp-11-058

Schau, H.-P., Mitscherlich, E. E. H., Marth, E. H. (1985). Microbial survival in the environment — Bacteria and Rickettsiae Important in Human and Animal Health. *Journal of Basic Microbiology*, 25(10), 674–674. https://doi.org/10.1002/JOBM.3620251017

Schmidt, R. H., & Rodrick, G. E. (n.d.). Food safety handbook.

Todd, E. (2020). Foodborne disease prevention and risk assessment. *International Journal of Environmental Research and Public Health* 17, 5129. https://doi.org/10.3390/ijerph17145129

WHO. Food safety. In Fact Sheet; World Health Organization: Geneva, Switzerland, 2019; Available online: https://www.who.int/news-room/fact-sheets/detail/food-safety (accessed on 8 November 2019).

WHO. Workshop on the Coordination and Capacity Building of the PulseNet Middle East Laboratory Network. WHO Regional Office for the Eastern Mediterranean: Muscat, Oman, 2018, p. 16.

Wiedmann, M., Belias, A., Sullivan, G., & David, J. (2019). *Environmental Monitoring Handbook for the Food and Beverage Industries*. United States of America.

World Health Organization. (2023). Food Safety and Nutrition Food Law Guidelines. https://www.afro.who.int/publications/food-safety-and-nutrition-food-law-guidelines

World Health Organization. Estimates of the global burden of foodborne diseases. 2015. Accessed August 25, 2021. https://www.who.int/en/news-room/detail/03-12-2015-who-s-first-ever-glob...

World Health Organization. Guidelines on the Management of Latent Tuberculosis Infection. [cited 2022 June 10]. Available from: https://www.who.int/publications/i/item/9789241548908. (n.d.). Retrieved December 14, 2022, from https://www.who.int/publications/i/item/9789241548908

World Health Organisation. WHO Estimates of the Global Burden of Foodborne Diseases: Foodborne Disease Burden Epidemiology Reference Group 2007-2015. World Health Organization. 2015. https://apps.who.int/iris/handle/10665/199350

Wu, G., Yuan, Q., Wang, L., Zhao, J., Chu, Z., Zhuang, M. et al. (2018). Epidemiology of foodborne disease outbreaks from 2011 to 2016 in Shandong province, China. *Medicine* 97, e13142. https://doi.org/10.1097%2FMD.0000000000013142