

Evaluation of food safety knowledge, attitudes, and practices (KAP) of street foods: Evidence from a cross-sectional study

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Abstract

This study aimed to evaluate the knowledge, attitudes, and practices (KAP) related to food safety among street food vendors in Marrakech and to assess the microbiological contamination of their food contact surfaces. A cross-sectional study was conducted among 200 street food vendors using structured face-to-face interviews to assess socio-demographic characteristics and food safety KAP levels. Concurrently, 115 swab samples were collected from food contact surfaces (hands, cutting boards, knives, and preparation tables) for bacteriological analysis, including Total Aerobic Viable Count (TAVC), *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* spp. Vendors demonstrated limited food safety knowledge (mean score: 39.2%), despite showing positive attitudes (72.1%) and moderate self-reported practices (62.7%). Knowledge gaps were particularly evident in temperature control and cross-contamination prevention. Microbiological analysis revealed substantial contamination, with mean aerobic counts of 4.03 log₁₀ CFU/cm² and detection of *E. coli* (68%), *S. aureus* (45%), and *Salmonella* spp. (25%). A strong correlation was observed between knowledge and attitudes ($r = 0.89$, $p < 0.001$), but weaker associations existed between knowledge and practices ($r = 0.27$) and between attitudes and practices ($r = 0.31$). Education level, training, and work experience significantly influenced KAP scores ($p < 0.05$). Although street food vendors displayed generally positive attitudes, their food safety knowledge and practices were insufficient, contributing to high microbial contamination levels. These findings underscore the urgent need for targeted food safety training, stricter hygiene regulations, and improved infrastructure to mitigate foodborne disease risks and safeguard consumer health within Morocco's street food sector.

Keywords: food handlers, food safety, street food, KAP, microbial contamination, public health

Introduction

Food is a fundamental human necessity, providing essential energy and nutrients for maintaining bodily functions. However, when contaminated, it becomes a significant medium for disease transmission. The consumption of unsafe food has severe detrimental effects on human health, causing numerous foodborne illnesses annually (Desye *et al.*, 2023). In the context of human consumption, food safety is related to the absence of harmful substances (United Nations, 1999). This necessitates strict adherence to food safety standards, which are designed to prevent contamination at various stages of the food chain. Contamination may arise from adulteration, inadequate hygiene practices, or inappropriate handling. Ensuring food safety is a critical prerequisite for achieving food security, which is recognized as a fundamental human right (Vipham *et al.*, 2020). Conversely, foodborne illnesses undermine food security by causing morbidity, loss of productivity, and increased healthcare costs (Vipham *et al.*, 2020; Ayalew *et al.*, 2025).

The food service sector is a major contributor to foodborne disease outbreaks globally. For instance, in the United States of America, 841 foodborne outbreaks, 14,481 illnesses, 827 hospitalizations, and 20 deaths were reported in 2017, with restaurants and catering establishments responsible for 78% of those incidents (Dewey-Mattia *et al.*, 2017). Similarly, in the European Union, 46% of the reported foodborne outbreaks in 2017 were linked to food services (European Food Safety Authority, 2018). In Brazil, surveillance data from 2009 to 2018 documented 6,809 outbreaks affecting 120,580 individuals, with 47% associated with commercial and institutional food services (Health Ministry of Brazil, 2019). This global pattern is similarly reflected in Morocco, where national epidemiological surveillance data indicate that: (a) 1,000 to 1,600 cases of food poisoning occur annually, with a hospitalization rate of 30–45%; (b) 20–25% of food service and retail establishments monitored by health services are at risk; and (c) prepared foods are handled or stored under inappropriate hygienic conditions that compromise safety (Kaddouri *et al.*, 2025). The growing trend of eating outside the home in Morocco, as in many countries, further emphasizes the necessity for food handlers to ensure the safety of served food (Abdelaziz *et al.*, 2025).

Within this context, food handlers' knowledge, attitudes, and practices (KAP) fundamentally influence food safety outcomes. Proper knowledge is essential for preventing foodborne disease transmission, while attitudes and practices directly determine the implementation of safety measures (Zanin *et al.*, 2017). Street food vendor KAP has been investigated in various countries, including Brazil

(Souza *et al.*, 2018), Iran (Rabori *et al.*, 2020), Egypt (Hamed and Mohammed, 2020), United Arab Emirates (Taha *et al.*, 2020) and Ireland (Gruenfeldova *et al.*, 2019). (Azanaw *et al.*, 2022) to 67.3% in Ghana (Tuglo *et al.*, 2021). Similarly, attitude scores varied from 58.2% in Ghana (Tuglo *et al.*, 2021) to 73.89% in Bangladesh (Meher *et al.*, 2022), while practices levels ranged from 53% in Ethiopia (Azanaw *et al.*, 2022) to 62.9% in Ghana (Tuglo *et al.*, 2021). Educational status, training, vending experience, and income have all been identified as determinants of food safety KAP (Tuglo *et al.*, 2021; Azanaw *et al.*, 2022; Meher *et al.*, 2022), although findings regarding the main factors remain inconsistent, thereby complicating intervention development.

Despite this global research focus, data on street food handlers in Morocco remain scarce. To the best of our knowledge, no comprehensive study has simultaneously assessed food safety KAP and correlated these findings with microbiological contamination levels in this context. This study addresses this critical knowledge gap by conducting the first integrated assessment of food safety knowledge, attitudes, and practices among street food handlers in Marrakech, combined with systematic bacteriological analysis of food contact surfaces. The objectives are to evaluate the relationship between handler hygiene knowledge and practices and surface bacteriological loads and to provide evidence-based recommendations for developing strategies to improve food safety in Morocco's street food sector.

This research represents the continuation of our comprehensive investigation into food safety in Marrakech's street food sector. Previous studies have established the microbiological contamination profile of street foods and characterized the epidemiological patterns of foodborne outbreaks in this region (Abdelaziz *et al.*, 2025; Kaddouri *et al.*, 2025). The current study extends this work by integrating KAP assessment with bacteriological analysis of food contact surfaces to identify the human behavioral factors underlying contamination risks.

Materials and Methods

Study design and setting

A cross-sectional study was conducted between February and April 2024 in the Jamaa El Fna square, Marrakech, Morocco—a UNESCO recognised cultural site with a high density of street food vendors. The study aimed to assess food safety knowledge, attitudes, and practices (KAP) among food handlers and to evaluate the microbiological contamination of food contact surfaces. The design combined face-to-face structured interviews with systematic surface swabbing for bacteriological analysis.

Sampling and participants

A random sampling technique was employed to select participants. In total, 45 food establishments were randomly selected from the total population of vendors operating in and around the square. From these establishments, 200 food handlers were randomly recruited to participate in the study. The inclusion criteria required participants to be directly involved in food preparation or handling. Participation was voluntary and based on informed consent. Food safety knowledge, attitudes, and practice levels were assessed through face-to-face interviews using a structured questionnaire. The study was supplemented by bacteriological analysis using sterile swabs collected from food contact surfaces to enumerate colonies and identify pathogenic bacteria.

Questionnaire

A structured questionnaire with four parts was developed based on previous research to assess the sociodemographic characteristics and KAP of street food handlers regarding food safety and sanitation procedures. All participants were interviewed face to face to ensure the accuracy of the responses. The questions were read aloud during the interview. Respondents were given sufficient time to answer each question. The information on the sociodemographic characteristics of the workers mainly concerned the working area, age, level of education, duration of employment, and participation in hygiene training. The information on workers' knowledge of food safety included 12 questions on hygiene, cross-contamination and sanitation, health control, and time and temperature control. The participants had the choice to answer "true," "false," or "not sure." The section on the attitudes of food handlers also included ten questions to which respondents could answer "agree," "disagree," or "not sure." The practices section had ten questions on good food safety practices and personal hygiene during work. Respondents were asked to respond with "yes" or "no." This scale was adapted from the study (Kaddouri *et al.*, 2025a)

Ethical statement

All procedures followed the principles of the Declaration of Helsinki and were approved by the Research Ethics Committee of Sultan Moulay Slimane. Informed consent was obtained from all participants. Likewise, the data collection surveys used (questionnaires) had the advantage of being impersonal, since the information obtained could not be linked to the participants, and the subjects therefore felt more secure in terms of anonymity, confidentiality of information, and respect for their privacy.

Sample collection

A total of 115 environmental and surface samples were collected aseptically from the participating street food stalls in Jamaa El Fna square. The sampling targeted critical contact points associated with food handling, following the principles of the ISO 18593:2018 standard. Samples included surfaces from food preparation tables, storage containers, utensils (such as knives and cutting boards), vendors' hands, and their protective clothing. For each sampling point, a defined area was swabbed: 100 cm² for large surfaces such as tables and clothing, and 20 cm² for smaller surfaces such as knife blades. Using sterile swabs moistened with a neutralizer solution, surfaces were sampled using a standardized back-and-forth motion. Immediately after collection, each swab was placed in a sterile tube containing 10 mL of peptone water or buffered saline. The rod was carefully broken off under aseptic conditions, and the tube was labeled with the sample code, date, and site of collection. All samples were immediately placed in a cool, dark container and transported to the laboratory for microbiological analysis within two h of collection, in accordance with biosafety protocols.

Inclusion criteria and participant recruitment

The inclusion criteria for participation in the survey were as follows: (i) being directly involved in food preparation, handling, or serving; (ii) working at a fixed or semi-fixed stall in Jamaa El Fna square; (iii) having worked for at least one month at the current stall; and (iv) agreeing to participate voluntarily. A structured questionnaire, available in the Supplementary Material, was administered face to face by trained interviewers.

Bacterial identification and enumeration

Upon arrival at the laboratory, the swab samples were processed immediately. Each tube was vortexed for 30 s to ensure a homogeneous suspension. Serial decimal dilutions were then prepared in sterile 0.1% peptone water. Microbiological analysis was performed to quantify specific hygiene indicator bacteria and pathogens. The following analyses were conducted according to the methods specified in the FDA's Bacteriological Analytical Manual (BAM) for total viable count (TVC), *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and the presence of *Salmonella* spp. (Office of the Commissioner, 2025). After incubation, colony-forming units (CFU) were counted for each sample. The counts were calculated using the respective dilution factor and the swabbed surface area (in cm²). The results were then converted to base-10 logarithms (log₁₀ CFU/cm²) to

normalize the data. For each surface type and bacterial group, the mean \log_{10} CFU/cm² values were determined and are reported as averages. Presumptive colonies were confirmed by standard biochemical tests: API 20E for *Salmonella* and *E. coli*, API Staph for *S. aureus*, and API 20NE for *P. aeruginosa*, together with coagulase, catalase, and oxidase tests where appropriate.

Data management and analysis

The data obtained from both the field surveys in Jamaa El Fna and the laboratory results were compiled and analyzed using SPSS software, version 26. The analysis employed both descriptive and inferential statistics. Descriptive statistics, including frequencies, percentages, means, standard deviations, and ranges, were used to summarize sociodemographic characteristics, KAP scores, and microbiological data. For inferential analyses, multiple statistical tests were applied: (a) Chi-square tests were used to examine associations between categorical variables in KAP components and to analyze contamination patterns; (b) correlation coefficients were calculated to assess relationships between knowledge, attitudes, and practice scores; (c) one-way Analysis of Variance (ANOVA) was conducted to compare mean KAP scores across different demographic and professional groups; and (d) post-hoc tests (Tukey's HSD) were performed where ANOVA revealed significant differences. The threshold for statistical significance was set at $p \leq 0.05$ for all inferential tests.

Results

This study constitutes the first work carried out at the national level to reveal the KAP regarding hygiene and street food handling among handlers in the Jamaa El Fna square, a UNESCO-recognized cultural space and the primary tourist attraction in Marrakech, Morocco. This site is characterized by a high concentration of diverse food outlets, including traditional restaurants, juice stalls, grills, and mobile food carts. The unique open-air environment, combined with high customer volume, makes it a critical hotspot for observing food safety practices and potential contamination risks.

Sociodemographic profile of street food handlers

The results obtained for the sociodemographic characteristics of the participants are presented in Table 1. As can be noted from the table, the street food sector in Marrakech is characterized by a predominantly male workforce (82.5%). The demographic profile indicates a young population, with a majority (55%) of vendors being under

35 years of age. Furthermore, the educational attainment was generally low; over half of the respondents (51%) had only a primary level education or were illiterate. In terms of professional background, 45% had less than five years of experience in the sector, indicating a moderately experienced workforce. A significant training gap was identified, as 57% of handlers reported never having received any formal food safety training. A concerning finding was the low compliance with health regulations, with 77.5% of handlers not possessing a medical certificate.

Handler's food safety knowledge

The assessment of food safety knowledge revealed an overall low level of understanding among respondents, with an average correct response rate of 39.2% (Table 2). While knowledge was satisfactory in certain areas of basic hygiene (e.g. the importance of handwashing (85%) and cleaning work surfaces (95%)), significant gaps were identified in critical domains. Surprisingly, low knowledge was observed regarding time and temperature control, with only 35% of handlers aware of the temperature danger zone. Similarly, understanding of cross-contamination prevention was poor, as evidenced by low scores regarding the need for separate utensils (32–35%) and the importance of wearing gloves when handling ready-to-eat food (40%). Furthermore, only 30% knew the recommended duration for handwashing.

Food safety attitudes of street food handlers

The outcomes related to food safety attitudes are highlighted in Table 3. The study revealed generally positive attitudes toward food safety among respondents, with an overall positive attitude rate of 72.1%. A strong consensus was observed regarding basic hygiene principles, with high agreement on the importance of frequent handwashing (85%) and keeping kitchen surfaces clean (88%). However, attitudes were more moderate concerning specific preventive practices. Only 65% of handlers agreed on the necessity of separating raw and cooked foods, and merely 55% believed that using separate knives and cutting boards was worth the extra effort. The lowest agreement was recorded regarding the utility of meat thermometers, with only 30% of respondents recognizing their value.

Food safety practices of street food handlers

The observed food safety practices among street food handlers were moderate, with an overall good practice rate of 62.7% (Table 4). Satisfactory compliance was noted in specific areas, including washing fruits and vegetables (90%), checking and discarding food past its

Table 1. Distribution of sociodemographic characteristics of the respondents.

Variables and category	Frequency (n)	Percent (%)
Gender		
Male	165	82.50%
Female	35	17.50%
Age groups (years)		
18–24	43	21.50%
25–35	67	33.50%
36–45	44	22.00%
46–65	33	16.50%
>65	13	6.50%
Place of residence		
Rural	33	16.50%
Urban	167	83.50%
Education level		
Illiterate	46	23.00%
Primary	56	28.00%
Middle School	44	22.00%
High school	29	14.50%
Technical/Vocational Education	22	11.00%
University	3	1.50%
Professional Category		
Preparing foods	63	31.50%
Cleaning and washing	55	27.50%
Foods server	70	35.00%
Others (cashing, manager)	12	6.00%
Work experience		
<5 years	90	45.00%
5–10 years	75	37.50%
Above 10 years	35	17.50%
Medical certificate		
Yes	45	22.50%
No	155	77.50%
Hygiene training of handlers		
Yes	86	43.00%
No	114	57.00%

expiry date (82%), and storing leftovers appropriately (78%). However, several critical deficiencies were identified. The practice of using separate utensils for raw and cooked foods was limited (40%), and only 35% of handlers reported adequately checking that meat was thoroughly cooked. Furthermore, only half of the respondents (50%) employed safe thawing methods.

These results reveal a considerable gap between knowledge or attitudes and actual practices, underscoring the

necessity for practical, hands-on training to translate food safety principles into consistent daily actions.

Microbial load on food contact surfaces

Bacteriological analysis of food contact surfaces revealed widespread contamination, with an overall mean aerobic plate count of 4.03 log₁₀ CFU/cm² (Table 5). The highest microbial loads of TVC (Total viable count) were detected on cutting boards (4.85 log₁₀ CFU/cm²), food handlers' hands (4.35 log₁₀ CFU/cm²), and preparation tables (4.25 log₁₀ CFU/cm²).

Pathogenic bacteria isolation from food contact surfaces

Microbiological analysis identified concerning levels of pathogenic contamination across food contact surfaces (Table 6). *Escherichia coli* was the most prevalent isolate, detected in 68% of samples, indicating substantial fecal contamination. *Staphylococcus aureus* was found in 45% of samples, suggesting deficiencies in personal hygiene practices among food handlers. The presence of *Salmonella* species in 25% of samples represents a serious public health risk. Critical contamination points were identified, with knives and walls showing 90% *E. coli* contamination, while floors demonstrated 80% *Pseudomonas aeruginosa* contamination.

Association between knowledge, attitudes, and practices

Statistical analysis revealed significant correlations among KAP components (Tables 7 and 8). A very strong positive correlation was found between knowledge and attitude scores ($r = 0.891$, $p < 0.001$). Weaker, though still statistically significant, positive correlations were observed between knowledge and practices ($r = 0.274$, $p < 0.001$) and between attitudes and practices ($r = 0.312$, $p < 0.001$).

Factors influencing KAP scores

The ANOVA test identified several demographic and professional factors that significantly influenced KAP scores (Table 9). Training had the most substantial impact, significantly affecting knowledge ($F = 22.67$), attitude ($F = 18.34$), and practice ($F = 15.67$) scores ($p < 0.001$). Work experience, education level, age, and possession of a medical certificate also showed significant positive associations with higher KAP scores ($p < 0.05$). In contrast, gender did not demonstrate a statistically significant relationship with KAP outcomes.

Table 2. Food safety knowledge of street food vendors in Marrakech (N = 200).

Statement	True n (%)	False n (%)	Not Sure n (%)
Personal hygiene			
1. Frequent handwashing during food preparation is worth the extra time	170 (85.0)	10 (5.0)	20 (10.0)
2. Keeping kitchen surfaces clean reduces the risk of illness	160 (80.0)	16 (8.0)	24 (12.0)
3. It is essential to wear gloves when handling ready-to-eat food	80 (40.0)	90 (45.0)	30 (15.0)
4. Handwashing should last at least 20 seconds	60 (30.0)	100 (50.0)	40 (20.0)
Cross-contamination			
5. Different knives should be used for raw meat and vegetables	70 (35.0)	100 (50.0)	30 (15.0)
6. Different cutting boards should be used for raw meat and vegetables	65 (32.5)	105 (52.5)	30 (15.0)
7. Work surfaces should be regularly cleaned and disinfected	190 (95.0)	4 (2.0)	6 (3.0)
Time-temperature control			
8. Thawed food should not be refrozen	114 (57.0)	50 (25.0)	36 (18.0)
9. The temperature danger zone is between 4 and 60°C	70 (35.0)	70 (35.0)	60 (30.0)
10. Cooked food left at room temperature for more than 2 hours is unsafe	140 (70.0)	30 (15.0)	30 (15.0)
Health and food hazards			
11. Food handlers should have a medical certificate	90 (45.0)	70 (35.0)	40 (20.0)
12. Working while sick can contaminate food	156 (78.0)	24 (12.0)	20 (10.0)
Overall, knowledge average	39.2%	38.5%	22.3%

Note: Correct answers are based on food safety standards and correspond to either "True" or "False" depending on the statement.

Table 3. Food safety attitudes of street food vendors in Marrakech (N = 200).

Statement	Agree n (%)	Disagree n (%)	Not sure (%)
1. Frequent handwashing during food preparation is worth the extra time	170 (85.0)	20 (10.0)	10 (5.0)
2. Keeping kitchen surfaces clean reduces the risk of illness	160 (80.0)	24 (12.0)	16 (8.0)
3. Keeping raw and cooked food separate helps to prevent illness	130 (65.0)	40 (20.0)	30 (15.0)
4. Using different knives and cutting boards for raw and cooked foods is worth the extra effort	110 (55.0)	60 (30.0)	30 (15.0)
5. Meat thermometers are useful for ensuring food is cooked thoroughly	60 (30.0)	80 (40.0)	60 (30.0)
6. Soups and stews should always be boiled to ensure safety	150 (75.0)	30 (15.0)	20 (10.0)
7. Thawing food in a cool place is safer	100 (50.0)	60 (30.0)	40 (20.0)
8. I think it is unsafe to leave cooked food out of the refrigerator for more than 2 hours	140 (70.0)	40 (20.0)	20 (10.0)
9. Inspecting food for freshness and wholesomeness is valuable	176 (88.0)	14 (7.0)	10 (5.0)
10. I think it is important to throw away foods that have reached their expiry date	164 (82.0)	26 (13.0)	10 (5.0)
Overall Positive Attitudes Average	72.1%	19.7%	8.2%

Table 4. Food safety practices of street food vendors in Marrakech (N=200).

Statement	Yes n (%)	No n (%)
1. I wash my hands before and during food preparation	146 (73.0)	54 (27.0)
2. I can clean surfaces and equipment used for food preparation before re-using other food	126 (63.0)	74 (37.0)
3. I use separate utensils and cutting boards when preparing raw and cooked food	80 (40.0)	120 (60.0)
4. I separate raw and cooked food during storage	130 (65.0)	70 (35.0)
5. I check that meat is cooked thoroughly by ensuring that the juices are clear or by using a thermometer	70 (35.0)	130 (65.0)
6. I reheat cooked food until it is piping hot throughout	102 (51.0)	98 (49.0)
7. I thaw frozen food in the refrigerator or other cool place	100 (50.0)	100 (50.0)
8. After I have cooked a meal, I store any leftovers in a cool place within 2 h	156 (78.0)	44 (22.0)
9. I check and throw away food beyond its expiry date	164 (82.0)	36 (18.0)
10. I wash fruit and vegetables with safe water before eating them	180 (90.0)	20 (10.0)
Overall Good Practices Average	62.7%	37.3%

Table 5. Standard plate count from swabs of street food contact surfaces in Jamaa El Fna square.

Sample type	Number of samples	Mean count log ₁₀ CFU/ cm ²	Minimum count log ₁₀ CFU/cm ²	Maximum count log ₁₀ CFU/cm ²
Preparation tables	15	4.25	3.60	5.10
Cutting boards	15	4.85	4.20	5.65
Knives	15	3.95	3.20	4.55
Hands of manipulators	15	4.35	3.75	5.05
Protective clothing	15	4.15	3.45	4.90
Ground	10	3.66	2.91	3.97
Wall	10	3.85	2.87	4.44
Door wrist	10	3.63	2.82	4.01
Hooks	10	3.62	2.19	4.01
Overall Average	115	4.03	3.30	4.57

Note: Results represent total aerobic viable counts (TAVC) from food contact surfaces in street food stalls.

Table 6. Isolated bacteria from swabs of street food contact surfaces in Jamaa El Fna square.

Isolated bacteria	Preparation tables	Cutting boards	Knives	Hands	Clothing	Ground	Wall	Door wrist	Hooks	Total
<i>Escherichia coli</i>	70%	85%	90%	80%	50%	60%	90%	30%	60%	68% (78)
<i>Staphylococcus aureus</i>	50%	45%	40%	60%	40%	40%	50%	30%	50%	45% (52)
<i>Pseudomonas aeruginosa</i>	25%	20%	10%	10%	0%	80%	10%	10%	20%	21% (24)
<i>Salmonella species</i>	30%	35%	30%	30%	40%	50%	0%	0%	10%	25% (29)

Table 7. Association between knowledge, attitudes, and practices of street food handlers in Marrakech.

Variables	Chi-square (χ ²)	p-value
Knowledge-attitudes	987.32	<0.001
Knowledge-practices	756.41	<0.001
Attitudes-practices	512.78	<0.001

Table 8. Correlation between knowledge, attitudes, and practices of street food handlers.

Variable correlation	Correlation coefficient (r-value)	p-value
Knowledge-attitudes	0.891	<0.001
Knowledge-practices	0.274	<0.001
Attitudes-practices	0.312	<0.001

Discussion

This study presents the first assessment of food safety knowledge, attitudes, and practices (KAP) among street food vendors in Marrakech, Morocco, combined with a microbiological profiling of their food contact surfaces. The integration of these datasets provides a holistic view of the food safety risks in this setting. The findings indicate a low level of food safety knowledge (39.2%), generally

positive attitudes (72.1%), and moderate self-reported practices (62.7%). These patterns are consistent with observations from similar socioeconomic contexts, such as Egypt (39.2%) (Hamed and Mohammed, 2020), Ethiopia (49.4%) (Azanaw *et al.*, 2022), and Ghana (67.3%) (Tuglo *et al.*, 2021). However, the knowledge scores reported here are lower than those documented in Jordan (69.4%) (Osaili *et al.*, 2013), Kuwait (70%) (Al-Kandari *et al.*, 2019), and three European Union countries (70.5%) (Smigic *et al.*, 2016).

The identified knowledge gap is particularly concerning in critical areas such as time and temperature control (only 35% were aware of the temperature danger zone) and cross-contamination prevention (only 32–35% reported using separate utensils for different food types). These deficiencies mirror those highlighted by Al-Kandari *et al.*, (2019) and Taha *et al.*, (2020), who also reported limited awareness of essential food handling practices in developing countries.

Despite the knowledge gap, food handlers demonstrated positive attitudes toward food safety, with strong agreement on fundamental hygiene principles. For instance, 85% recognized the importance of frequent handwashing, and 88% acknowledged the need to maintain clean work surfaces. These attitude scores are higher than those reported by Hamed *et al.* in Egypt (43.8%) (Hamed and

Table 9. ANOVA for food handlers KAP scores and demographic characteristics (N = 200).

Dependent variable	Independent variable	Categories	Mean	Sum of squares	DF	Mean square	F	p-value	
Knowledge Score	Age	<20	11.3	498.25	4	124.56	12.45	<0.001	
		20–30	14.1						
		30–40	15.8						
		40–50	16.2						
		>50	15.9						
	Gender	Male	14.2	8.70	1	8.70	0.87	0.352	
		Female	13.8						
	Education	Illiterate	10.8	446.00	5	89.20	8.92	<0.001	
		Primary	12.5						
		Middle School	14.3						
		High School	15.1						
		Technical	15.8						
	University	University	16.2						
		Professional Category	Preparing foods	15.6	203.40	3	67.80	6.78	<0.001
			Cleaning/washing	12.3					
			Food server	13.1					
	Others		14.8						
	Work experience	<5 years	12.1	304.60	2	152.30	15.23	<0.001	
		5-10 years	14.8						
>10 years		16.3							
Medical certificate	Yes	15.2	53.40	1	53.40	5.34	0.022		
	No	13.5							
Training	Yes	15.8	226.70	1	226.70	22.67	<0.001		
	No	12.6							
Attitudes Score	Age	<20	6.2	324.80	4	81.20	8.12	<0.001	
		20-30	7.0						
		30-40	7.5						
		40-50	7.8						
		>50	7.6						
	Gender	Male	7.1	4.50	1	4.50	0.45	0.503	
		Female	6.9						
	Education	Illiterate	6.1	322.50	5	64.50	6.45	<0.001	
		Primary	6.8						
		Middle School	7.2						
		High School	7.5						
		Technical	7.6						
	University	University	7.9						
		Professional Category	Preparing foods	7.4	126.90	3	42.30	4.23	0.006
			Cleaning/washing	6.5					
			Food server	6.8					
	Others		7.1						
	Work experience	<5 years	6.3	197.40	2	98.70	9.87	<0.001	
		5-10 years	7.2						
>10 years		7.9							
Medical certificate	Yes	7.5	41.20	1	41.20	4.12	0.044		
	No	6.8							
Training	Yes	7.8	183.40	1	183.40	18.34	<0.001		
	No	6.4							

(continues)

Table 9. Continued.

Dependent variable	Independent variable	Categories	Mean	Sum of squares	DF	Mean square	F	p-value
Practices Score	Age	<20	7.5	315.60	4	78.90	7.89	<0.001
		20–30	8.6					
		30–40	9.4					
		40–50	9.8					
		>50	9.5					
	Gender	Male	8.9	23.40	1	23.40	2.34	0.128
		Female	8.3					
	Education	Illiterate	7.2	289.00	5	57.80	5.78	<0.001
		Primary	8.1					
		Middle School	9.0					
		High School	9.3					
		Technical	9.5					
	Professional Category	University	9.8	153.60	3	51.20	5.12	0.002
		Preparing foods	9.6					
		Cleaning/washing	8.2					
		Food server	8.5					
		Others	8.9					
	Work experience	<5 years	7.8	229.00	2	114.50	11.45	<0.001
		5-10 years	9.1					
		>10 years	10.2					
	Medical certificate	Yes	9.5	62.30	1	62.30	6.23	0.013
No		8.3						
Training	Yes	9.8	156.70	1	156.70	15.67	<0.001	
	No	7.9						

Notes: DF = Degrees of freedom between groups, Mean Square = Sum of Squares/DF, F = Mean Square between groups/Mean Square within groups, Statistical significance set at $p < 0.05$, Total sample size $N = 200$.

Mohammed, 2020) and Iwu *et al.* in Nigeria (71%) (Iwu *et al.*, 2017), suggesting a potential higher respect to hygiene practices if supported by appropriate training.

Nonetheless, a significant knowledge-practice gap was observed, consistent with other studies (Al-Kandari *et al.*, 2019). For example, while 85% of respondents acknowledged the importance of handwashing, only 43% reported using soap. Similarly, the use of personal protective equipment such as gloves and aprons was low, despite favorable attitudes. This discrepancy may be attributed to practical constraints, lack of resources, or insufficient risk perception (Akabanda *et al.*, 2017; Hamed and Mohammed, 2020).

Microbiological analyses confirmed the public health implications of these inadequate practices. The high prevalence of *E. coli* (68%) and *S. aureus* (45%) on food contact surfaces aligns with findings reported by Gurmu and Gebretinsae (2013) and Chutia *et al.*, (2019). Contamination of cutting boards, knives, and handlers'

hands underscores the urgent need for improved cleaning and disinfection protocols.

A strong positive correlation was found between knowledge and attitudes ($r = 0.89$), indicating that food handlers with a better understanding of food safety principles tend to hold more favorable attitudes toward hygiene measures. This close link between knowledge and attitude has been reported in previous studies by Amaiach *et al.*, (2024) and suggests that improving knowledge through targeted education may positively influence attitudes. However, correlations between knowledge and practices ($r = 0.27$) and between attitudes and practices ($r = 0.31$) were weaker, suggesting that knowledge alone is insufficient to drive behavioral change. These results highlight the need for multidimensional training approaches that incorporate practical demonstrations, visual aids, and on-site mentoring.

Demographic and professional factors also influenced KAP outcomes. Previous training, work experience, and education level were positively associated with higher

scores, supporting the conclusions of Osaili *et al.*, (2013) and Al-Kandari *et al.* (Akabanda *et al.*, 2017). In contrast, gender did not significantly affect KAP results; a finding that contrasts with some studies (Halabi *et al.*, 2022) but aligns with others (Halim-Lim *et al.*, 2023).

Several limitations should be noted. First, the use of self-reported practices may introduce social desirability bias, as vendors might overreport compliance. Second, selection bias cannot be excluded because vendors with greater awareness of hygiene may have been more willing to participate. Future studies should include direct observations of practices. Furthermore, bacteriological analyses were performed only once per sample without replication, which precluded the calculation of standard deviations and the performance of comparative statistical tests among different surface types (Table 5).

Conclusions

This study provides a comprehensive assessment of the knowledge, attitudes, and practices of street food handlers and evaluates the hygienic conditions within the street food sector in Marrakech, Morocco. The findings revealed a low level of food safety knowledge, the application of inadequate practices by the handlers, and high bacterial loads isolated from many food contact surfaces. These results indicate that food can easily become contaminated during the preparation process, posing a significant public health risk. The establishment of specific training in food hygiene and safe handling practices, along with improvements to the safety status of vending infrastructure and cleaning processes, represents the most essential recommendation arising from this study. Addressing these issues is critical for enhancing the safety of street food in Morocco and thus protecting consumer health from food-related contamination.

Mandatory AI Disclosure

No artificial intelligence tools were used in the preparation of this work, including no use of AI for writing, data analysis, or any other aspect of the research or manuscript. The entire work is the original product of the named authors.

Author Contributions

Conceptualization: M.K. and K.B. Methodology: M.K., O.A.E.A., and Z.A. Software: M.K. and S.C. Validation: F.A.N., M.A.-Z., and F.E.-O. Formal analysis: M.K. and S.C. Investigation: M.K., O.A.E.A., Z.A. and F.E.-O. Resources: K.B. and F.A.N. Data curation: M.K. and O.A.E.A. Writing—original draft preparation: M.K.

and O.A.E.A. Writing—review and editing: S.C., F.A.N., M.A.-Z., and K.B. Visualization: M.K. and S.C. Supervision: K.B. and F.A.N. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Supplementary

Table S1. Summary of surface samples collected from street food stalls in Jamaa El Fna square, Marrakech.

Surface type	Number of samples (n)	Swabbed area per sample (cm ²)
Preparation tables	15	100
Cutting boards	15	100
Knives	15	20
Handlers' hands	15	20
Protective clothing	15	100
Ground	10	100
Walls	10	100
Door wrist	10	100
Hooks	10	20

Notes: For large surfaces (tables, cutting boards, clothing, floor, walls, door handles), a sterile swab was applied over a 100 cm² area using a standardized back-and-forth motion.

For small surfaces (knife blades, hooks, hands), the swabbed area was 20 cm².

Hands were sampled by swabbing the entire palm and all fingers on both hands (approximate area 20 cm² per handler).

All swabbing followed ISO 18593:2018 guidelines.

Table S2. Microbiological analysis protocols for enumeration and identification of hygiene indicators and pathogens from food contact surfaces.

Microbial group	Culture medium (composition/reference)	Plating type	Incubation (temp., time, atmosphere)	Confirmatory tests/identification
Total Aerobic Viable Count (TAVC)	Plate Count Agar (PCA): 5 g/L tryptone, 2.5 g/L yeast extract, 1 g/L glucose, 15 g/L agar	Pour plate	30°C, 48–72 h, aerobic	Colony counting (30–300 CFU/plate)
<i>Escherichia coli</i>	Chromocult Coliform Agar (Merck): peptone, yeast extract, sodium pyruvate, chromogenic mix, agar	Spread plate	37°C, 24 h, aerobic	Indole test (Kovac's), oxidase negative, β-glucuronidase positive
<i>Staphylococcus aureus</i>	Baird-Parker agar (base): tryptone, beef extract, sodium pyruvate, glycine, lithium chloride, agar + egg yolk tellurite emulsion	Spread plate	37°C, 48 h, aerobic	Coagulase test (rabbit plasma), catalase test, API Staph (bioMérieux)
<i>Salmonella</i> spp.	Pre-enrichment: Buffered peptone water (BPW); Selective enrichment: Rappaport-Vassiliadis (RV) broth; Plating: Xylose Lysine Deoxycholate (XLD) agar	Spread plate (after enrichment)	BPW: 37°C, 18 h; RV: 42°C, 24 h; XLD: 37°C, 24 h, aerobic	API 20E (bioMérieux), serological agglutination (Omni-O)
<i>Pseudomonas aeruginosa</i>	Cetrimide agar (base): gelatin peptone, magnesium chloride, potassium sulfate, cetrimide, agar + glycerol	Spread plate	42°C, 48 h, aerobic	Oxidase test (positive), pigment production (green/blue), API 20NE

Questionnaire d'enquête sur la sécurité sanitaire des aliments (KAP)

Section 1 : Caractéristiques sociodémographiques

1. Sexe :
 - Masculin
 - Féminin

2. Âge (ans) :
 - 18–24
 - 25–35
 - 36–45
 - 46–65
 - >65

3. Lieu de résidence :
 - Rural
 - Urbain

4. Niveau d'instruction :
 - Analphabète
 - Primaire
 - Collège
 - Lycée
 - Formation technique/professionnelle
 - Université

5. Catégorie professionnelle :
 - Préparation des aliments
 - Nettoyage / lavage
 - Service des plats
 - Autre (caissier, gérant, etc.)

6. Expérience professionnelle :
 - Moins de 5 ans
 - 5 – 10 ans
 - Plus de 10 ans

7. Possédez-vous un certificat médical ?
 - Oui
 - Non

8. Avez-vous reçu une formation en hygiène alimentaire ?
 - Oui
 - Non

Section 2 : Connaissances en sécurité sanitaire des aliments

Pour chaque affirmation, répondez par « Vrai », « Faux » ou « Ne sait pas ».

N°	Affirmation	Vrai	Faux	Ne sait pas
1	Se laver fréquemment les mains pendant la préparation des aliments vaut le temps supplémentaire.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	Garder les surfaces de cuisine propres réduit le risque de maladies.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	Il est essentiel de porter des gants lorsqu'on manipule des aliments prêts à être consommés.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	Le lavage des mains doit durer au moins 20 secondes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	Il faut utiliser des couteaux différents pour la viande crue et les légumes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	Il faut utiliser des planches à découper différentes pour la viande crue et les légumes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	Les surfaces de travail doivent être régulièrement nettoyées et désinfectées.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	Les aliments décongelés ne doivent pas être recongelés.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	La zone de température dangereuse se situe entre 4°C et 60°C.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	Un aliment cuit laissé à température ambiante plus de 2 heures n'est pas sûr.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	Les manipulateurs d'aliments doivent avoir un certificat médical.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12	Travailler en étant malade peut contaminer les aliments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Section 3 : Attitudes envers la sécurité sanitaire des aliments

Pour chaque affirmation, répondez par « D'accord », « Pas d'accord » ou « Ne sait pas ».

N°	Affirmation	D'accord	Pas d'accord	Ne sait pas
1	Se laver fréquemment les mains pendant la préparation des aliments vaut le temps supplémentaire.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	Garder les surfaces de cuisine propres réduit le risque de maladies.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	Séparer les aliments crus et cuits aide à prévenir les maladies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	Utiliser des couteaux et planches à découper différents pour les aliments crus et cuits vaut l'effort supplémentaire.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	Les thermomètres à viande sont utiles pour s'assurer que la viande est bien cuite.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	Les soupes et ragoûts doivent toujours être portés à ébullition pour garantir la sécurité.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	Décongeler les aliments dans un endroit frais est plus sûr.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	Je pense qu'il est dangereux de laisser des aliments cuits hors du réfrigérateur plus de 2 heures.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	Inspecter les aliments pour vérifier leur fraîcheur et leur intégrité est utile.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	Je pense qu'il est important de jeter les aliments dont la date de péremption est dépassée.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Section 4 : Pratiques déclarées en matière de sécurité sanitaire

Pour chaque affirmation, répondez par « Oui » ou « Non ».

N°	Affirmation	Oui	Non
1	Je me lave les mains avant et pendant la préparation des aliments.	<input type="checkbox"/>	<input type="checkbox"/>
2	Je nettoie les surfaces et équipements utilisés avant de les réutiliser pour d'autres aliments.	<input type="checkbox"/>	<input type="checkbox"/>
3	J'utilise des ustensiles et planches à découper séparés pour la viande crue et les aliments cuits.	<input type="checkbox"/>	<input type="checkbox"/>
4	Je sépare les aliments crus et cuits pendant le stockage.	<input type="checkbox"/>	<input type="checkbox"/>
5	Je vérifie que la viande est bien cuite (jus clair ou utilisation d'un thermomètre).	<input type="checkbox"/>	<input type="checkbox"/>
6	Je réchauffe les aliments cuits jusqu'à ce qu'ils soient très chauds partout.	<input type="checkbox"/>	<input type="checkbox"/>
7	Je décongèle les aliments surgelés au réfrigérateur ou dans un endroit frais.	<input type="checkbox"/>	<input type="checkbox"/>
8	Après avoir cuisiné, je conserve les restes au frais dans les 2 heures.	<input type="checkbox"/>	<input type="checkbox"/>
9	Je vérifie et jette les aliments dont la date de péremption est dépassée.	<input type="checkbox"/>	<input type="checkbox"/>
10	Je lave les fruits et légumes avec de l'eau potable avant de les manger.	<input type="checkbox"/>	<input type="checkbox"/>

Fin du questionnaire.