Assessment of Hazard Analysis and Critical Control Point (HACCP) Implementation and Associated Challenges among Food Handlers in Selected Food Establishments in Ikorodu, Lagos State, Nigeria

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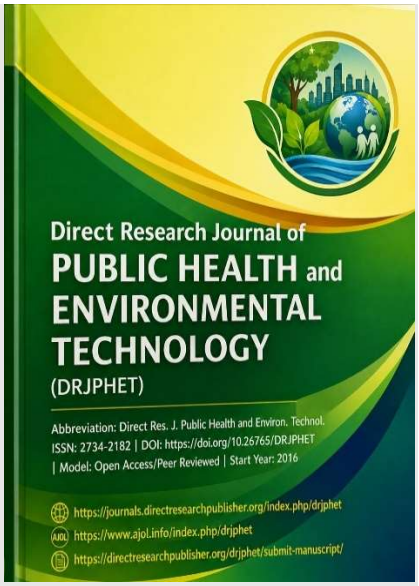
ABSTRACT

Background: *Food safety remains a public health concern, particularly in rapidly urbanizing settings where reliance on ready-to-eat meals increases the responsibility on food handlers to implement Hazard Analysis and Critical Control Point (HACCP) principles consistently. Despite national and international food safety standards, gaps in implementation and compliance persist, elevating the risk of foodborne illnesses; this study assessed the HACCP-based food safety practices and identified implementation challenges among food handlers in selected food establishments in Ikorodu, Lagos State.* ***Objective:*** *To assess the level of implementation of HACCP-based food safety practices among food handlers and identify the challenges influencing effective implementation of HACCP principles in selected food establishments in Ikorodu, Lagos State.* ***Methods:*** *A cross-sectional design was adopted, involving 424 food handlers selected through a multi-stage sampling technique from 46 registered establishments comprising 18 eateries and 28 restaurants across the Ikorodu metropolis of Lagos State. Data were collected using a validated questionnaire based on HACCP principles and food safety standards and analyzed using descriptive statistics, modified Poisson regression with robust standard errors, and independent-samples t-test at a 5% level of significance.* ***Results:*** *The findings showed a high level of self-reported HACCP implementation, with an overall mean score of above 4.87 on a five-point scale. Modified Poisson regression showed that food handlers aged 24 years or younger had a significantly lower prevalence of high HCCP implementation than those aged 45 years or older (aPR = 0.70; 95% CI: 0.51-0.97; p=0.032), while those aged 25-34 years also had a lower prevalence of implementation (aPR = 0.90; 95% CI: 0.83-0.97; p=0.005). Food handlers working in eateries had a significantly higher prevalence of implementation than those in restaurants (aPR = 1.09; 95% CI: 1.02-1.16; p=0.008). Training and capacity building were positively associated with adherence to HACCP-based practices. Structural challenge scores did not differ significantly between eateries and restaurants (p=0.224); however, operational challenge scores were significantly higher in eateries than in restaurants (4.71±0.46 versus 4.14±0.86; p<0.001).* ***Conclusion****: The study concluded that HACCP implementation was high but varied by age and establishment type and was constrained by operational pressures. It is recommended that regulatory authorities and establishment managers strengthen practical training, age-sensitive mentoring, supportive supervision, staffing, and establishment-specific operational controls to sustain verifiable food safety implementation.*

Keywords: *Hazard Analysis and Critical Control Point (HACCP), Food Safety, Food Handlers, Food Hygiene, Structural and Operational Challenges.*



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INTRODUCTION

Global Burden of Food Safety and the Need for Preventive Risk Management

Food safety is a critical component of public health, sustainable development, and global food security, as access to safe food is essential for preventing disease, protecting livelihoods, and supporting socioeconomic development (WHO, 2024). Increasing globalization, urbanization, industrialization, and international food trade have transformed food systems into highly interconnected networks, allowing biological, chemical, and physical hazards to spread rapidly across geographical boundaries. Consequently, food safety has evolved from a local public health concern into a global governance priority requiring coordinated, science-based, and risk-oriented management approaches (FAO & WHO, 2024; WHO, 2022; Macheka et al., 2025).

Despite advances in food production technologies, hazard surveillance, microbiological detection, and regulatory systems, foodborne diseases remain a substantial global health challenge. The World Health Organization estimates that approximately 600 million people worldwide suffer from foodborne illnesses annually, resulting in about 420,000 deaths and nearly 33 million disability-adjusted life years (DALYs) lost (WHO, 2023). Children under five years of age experience a disproportionate burden, accounting for a significant proportion of foodborne disease-related mortality. The burden is particularly severe in low- and middle-income countries (LMICs), where inadequate food control systems, limited surveillance capacity, insufficient laboratory infrastructure, and weak regulatory enforcement increase vulnerability to preventable foodborne hazards (FAO & WHO, 2024; GBD 2021 Diarrheal Diseases Collaborators, 2025).

Beyond health consequences, unsafe food imposes considerable economic costs through increased healthcare expenditure, reduced productivity, disrupted food supply chains, and diminished consumer confidence. In LMICs, foodborne diseases contribute substantially to productivity losses and healthcare costs, thereby limiting economic development and reinforcing existing inequalities (Jaffee et al., 2019).

Furthermore, emerging challenges such as antimicrobial resistance, climate change, changing food production systems, and transboundary foodborne outbreaks have intensified the need for resilient food safety systems based on prevention rather than reliance on corrective actions after contamination occurs.

Climate change is increasingly recognized as a driver of microbial proliferation, mycotoxin contamination, altered pest ecology, and disruptions in food production and distribution systems, thereby increasing food safety risks globally (Mirón et al., 2023; Grace, 2023; Kwoba et al., 2023).

Hazard Analysis and Critical Control Point (HACCP) as a Preventive Food Safety Framework

The Hazard Analysis and Critical Control Point (HACCP) system represents the internationally accepted framework for preventive food safety management. Developed initially to ensure the safety of food supplied during space missions, HACCP has evolved into a globally recognized approach applied across food manufacturing, hospitality, catering, and food service sectors (Codex Alimentarius Commission, 2023). Unlike traditional inspection-based approaches that primarily identify problems after production, HACCP adopts a proactive strategy by systematically identifying biological, chemical, and physical hazards and establishing Critical Control Points (CCPs) where effective control measures can be implemented. The effectiveness of the Hazard Analysis and Critical Control Point (HACCP) system depends on continuous monitoring, verification, documentation, corrective actions, and process validation to ensure that food safety hazards are prevented, eliminated, or reduced to acceptable levels throughout the food production process (Codex Alimentarius Commission, 2022). Recent evidence further demonstrates that preventive food safety principles are increasingly being embedded into process design, shifting the focus from end-product inspection to proactive hazard identification and control across the entire food supply chain, thereby reinforcing HACCP as the cornerstone of modern food safety management (Gregory et al., 2025). Accordingly, HACCP forms the foundation of the Codex General Principles of Food Hygiene and has been adopted as a central component of international food safety strategies, including the WHO Global Strategy for Food Safety 2022–2030, which advocates risk-based approaches to reduce foodborne diseases, strengthen food system resilience, and enhance consumer confidence (WHO, 2022). However, growing evidence indicates that successful HACCP implementation extends beyond the technical application of its principles and requires a comprehensive organizational approach. Sustainable implementation is influenced by leadership commitment, employee engagement, food safety culture, adequate infrastructure, prerequisite programs, and effective regulatory oversight (Uyttendaele et al., 2021; FDA, 2022; Ze et al., 2024). Systematic reviews have identified organizational deficiencies, including inadequate documentation, weak management commitment, insufficient employee training, and inconsistent inspection systems, as major contributors to food safety failures in food business operations (Ze et al., 2024). Moreover, essential operational resources such as reliable water supply, refrigeration, sanitation facilities, equipment maintenance, robust documentation systems, and routine verification are indispensable for maintaining HACCP effectiveness (Aslani et al., 2024). Collectively, these findings underscore that HACCP implementation is not merely a technical or regulatory requirement, but a multidimensional organizational process shaped by

interactions among individual competencies, institutional capacity, organizational culture, and regulatory governance, thereby necessitating integrated systems-based interventions to achieve sustainable food safety performance.

Food Safety Challenges in Sub-Saharan Africa

Although food safety regulations and training initiatives have expanded across Sub-Saharan Africa (SSA), effective implementation remains challenging. Rapid urbanization, population growth, expansion of informal food markets, inadequate infrastructure, and limited regulatory capacity continue to increase risks associated with commercially prepared foods. The increasing dependence on restaurants, catering services, fast-food outlets, and street food vendors has improved food accessibility but has also created new challenges regarding hygiene practices and compliance with preventive food safety requirements (WHO, 2022). Evidence from Sub-Saharan Africa (SSA) and other low- and middle-income countries (LMICs) consistently demonstrates a substantial gap between food safety policies and their effective implementation. A recent hybrid systematic and scoping review identified inadequate infrastructure, weak regulatory systems, insufficient laboratory capacity, limited financial resources, and poor interagency coordination as persistent barriers to effective food safety management across Africa, Asia, and Latin America (Macheka et al., 2025). These systemic constraints are reflected at the operational level, where food safety awareness often fails to translate into consistent hygienic practices. Supporting this observation, a recent systematic review and meta-analysis involving more than 12,000 food handlers reported that only about half demonstrated acceptable food hygiene practices, highlighting that knowledge alone is insufficient to ensure safe food handling behaviors (Atalay et al., 2025). Furthermore, studies across African countries have identified multiple organizational and environmental barriers, including inadequate water supply, poor sanitation facilities, unreliable refrigeration, weak documentation systems, limited managerial commitment, and inconsistent regulatory inspections that collectively hinder the effective implementation and sustainability of preventive food safety systems such as Hazard Analysis and Critical Control Point (HACCP).

These findings indicate that improving food safety outcomes requires interventions beyond food handler education alone. Sustainable improvements depend on strengthening institutional capacity, fostering supportive leadership and a positive food safety culture, improving infrastructure, and enhancing regulatory oversight. Contemporary evidence indicates that effective food safety management is achieved through integrated food control systems that combine workforce development, laboratory capacity, surveillance, risk-based inspection, infrastructure investment, and multisectoral collaboration, rather than relying solely on individual behavioral change (Codex Alimentarius Commission, 2022; WHO, 2022; Ze et al., 2024; Macheka et al., 2025; Gregory et al., 2025).

Food Safety Governance and HACCP Implementation Challenges in Nigeria

Nigeria has made important progress; nevertheless, food safety culture remains uneven across Nigerian food establishments. A recent review concluded that weak organizational commitment, inconsistent enforcement of food safety regulations, inadequate training, and poor institutional food safety culture continue to limit effective implementation of preventive food safety systems in Nigeria (Adebayo & Ojo, 2021). In strengthening food safety governance through national policies and regulatory reforms designed to align with international standards. The National Policy on Food Safety and Quality established a multisectoral framework involving agencies such as the Federal Ministry of Health, the National Agency for Food and Drug Administration and Control (NAFDAC), the Standards Organization of Nigeria (SON), and state-level authorities. Recent regulatory reforms have further emphasized preventive approaches, including improved sanitation requirements, food handler hygiene standards, documentation, environmental monitoring, and inspection procedures (NAFDAC, 2025).

Despite these developments, implementation challenges remain substantial. Differences in regulatory capacity, inspection frequency, laboratory availability, infrastructure quality, and organizational resources continue to limit effective adoption of preventive food safety systems, particularly among small and medium-sized food establishments. Barriers, including unreliable electricity, inadequate refrigeration, insufficient sanitation facilities, limited documentation practices, and weak management commitment, remain important constraints to HACCP implementation. Existing Nigerian food safety research has largely focused on food handlers' knowledge, attitudes, and self-reported practices using the Knowledge, Attitudes, and Practices (KAP) framework. Although these studies have demonstrated important gaps between food safety knowledge and observed behaviors, they provide limited understanding of how organizational and environmental factors influence the implementation of preventive food safety systems. Recent evidence from Nigerian food establishments indicates that positive attitudes and knowledge do not consistently translate into appropriate food safety practices, highlighting the importance of workplace conditions, supervisory support, and organizational commitment (Bakare et al., 2021; Barnabas et al., 2024). Consequently, there is increasing recognition that food safety performance is an organizational outcome shaped by leadership commitment, employee engagement, communication systems, availability of resources, and regulatory support. However, empirical evidence examining these determinants within Nigerian food establishments remains limited. Recent international evidence also suggests that sustainable HACCP implementation requires integrated

organizational, regulatory, and systems-level interventions rather than isolated food handler training, particularly in rapidly urbanizing low- and middle-income country (LMIC) settings, where infrastructural constraints, institutional capacity, and governance systems collectively influence food safety outcomes (Gregory et al., 2025; Macheka et al., 2025; Ze et al., 2024). Despite progress in food safety governance, significant gaps remain regarding the extent of HACCP implementation and the organizational factors that influence its sustainability in Nigeria. Existing studies have provided a limited objective assessment of HACCP compliance and have rarely examined the interaction between food handler competence, organizational support, infrastructure availability, food safety culture, and regulatory oversight. These gaps are particularly relevant in rapidly urbanizing areas such as the Ikorodu Local Government Area of Lagos State, where population growth, commercial expansion, and increasing numbers of restaurants, catering businesses, and informal food establishments have increased demand for effective food safety management systems. However, evidence regarding HACCP implementation within food establishments in Ikorodu remains scarce.

Guided by the Social Ecological Model, this study conceptualizes HACCP implementation as a multilevel process influenced by individual, organizational, and policy-level factors. By examining these determinants within food establishments in Ikorodu, Lagos State, this study aims to generate context-specific evidence to support regulatory improvement, strengthen organizational food safety practices, and contribute to sustainable HACCP implementation in Nigeria and other rapidly urbanizing LMIC settings. Specifically, this study aims to assess the application of Hazard Analysis and Critical Control Point (HACCP) principles and food safety compliance among food handlers in selected food establishments in Ikorodu, Lagos State. The objectives of the study are to (i) assess the level of implementation of HACCP-based food safety practices among food handlers and (ii) determine the challenges affecting effective HACCP implementation and food safety compliance among food handlers in selected food establishments.

MATERIAL AND METHODS

Study Area

Ikorodu Local Government Area (LGA), located between latitude 6°37′0.714″ N and longitude 3°30′29.059″ E in the north-eastern part of Lagos State, is one of the fastest-growing urban centres within the Lagos metropolitan region (Figure 1). It shares boundaries with Kosofe and Epe Local Government Areas, Ogun State, and the Lagos Lagoon. With an estimated population exceeding one million residents (NPC, 2019), Ikorodu has experienced rapid urbanization accompanied by a substantial expansion of restaurants, fast-food outlets, informal food vendors, and small-scale eateries that serve its growing residential and working population.

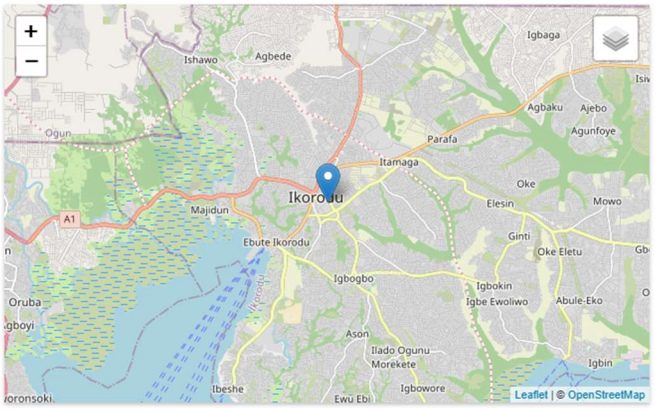

Figure 1: Satellite Map of Ikorodu, Lagos, Nigeria (Google Maps 2025)

The selection of Ikorodu was informed by its demographic and public health significance. Rapid urban growth has increased pressure on water, sanitation, and hygiene (WASH) infrastructure, creating conditions that may heighten the risk of food contamination and other enteric diseases. This concern is consistent with the 2024 cholera outbreak in Nigeria, during which Lagos State recorded 691 suspected cases by epidemiological week 34, the highest among affected states, underscoring the need to strengthen preventive food safety measures (NCDC, 2024). Moreover, a study involving 302 food vendors in Ikorodu reported high food hygiene awareness but recommended strengthened regulatory monitoring to ensure sustained compliance with safe food handling practices (Abusomwan, 2024). Given these characteristics and the ongoing implementation of food safety initiatives in Lagos State, Ikorodu provides an appropriate setting for assessing HACCP implementation and food safety compliance among food handlers.

Study Design

The study employed a cross-sectional design and was conducted in Ikorodu Local Government Area, Lagos State. This design was selected because it enables simultaneous assessment of HACCP implementation, food safety compliance, and associated factors among food handlers at a single point in time. It is particularly appropriate for HACCP compliance studies as it provides reliable estimates of the prevalence of compliance and identifies factors associated with implementation under routine operational conditions without manipulating study variables. However, because exposure and outcome are measured concurrently, the design does not establish temporal relationships and, therefore, cannot be used to infer causality.

Study Population

The study population comprised 424 food handlers employed in the selected registered eateries and restaurants across Ikorodu. Eligible participants included male and female workers actively engaged in food

handling, regardless of age, experience, or education. Food handlers were defined as individuals involved in food preparation, cooking, serving, storage, or handling of food for public consumption, including cooks, kitchen assistants, servers, and supervisors.

Sampling Techniques

A multi-stage sampling technique was employed to select participants for the study. First, a comprehensive sampling frame of all registered food service establishments was obtained from the Directorate of Environmental/Occupational Health and Safety and the Ikorodu Revenue Office (2025). The sampling frame comprised 76 registered food service establishments, including 18 eateries and 58 restaurants.
In the first stage, all 18 registered eateries were included through total enumeration because of their relatively small number, ensuring complete representation of this category. In the second stage, 28 of the 58 registered restaurants were selected using simple random sampling (balloting without replacement). Each restaurant was assigned a unique identification number, which was written on identical pieces of paper, folded uniformly, thoroughly mixed in a container, and drawn blindly. This procedure ensured that every restaurant had an equal probability of selection, thereby minimizing selection bias. In the final stage, food handlers directly involved in food preparation who met the study's inclusion criteria were selected from the 46 participating establishments using simple random sampling until the required sample size of 424 respondents was achieved. Informal food vendors were excluded because they lack a verifiable sampling frame, operate with high mobility, and are not routinely regulated or inspected by the relevant authorities, making probability-based sampling infeasible. Consequently, the findings apply only to registered food service establishments and should not be generalized to informal food vendors.

Sample size determination

The minimum sample size for this study was determined using Cochran's formula for single-proportion estimates:

$$n_0 = \frac{Z^2 \times p(1-p)}{e^2}$$

Where:

- n_0= minimum required sample size (for large populations)
- Z= standard normal deviate at 95% confidence level = 1.96
- p= estimated prevalence of food hygiene practices (50.68%) by Atalay et al., 2025.
- e= margin of error (precision) = 0.05

Choosing p From a Previous Study

To obtain a realistic and defensible prevalence value, p was drawn from a recent systematic review and meta-analysis conducted among food handlers in Sub-Saharan Africa, which reported that the pooled prevalence of good food hygiene practice was 50.68% (Atalay et al., 2025).

Step 1: Determine the Minimum Sample Size

Cochran's formula:

$$n_0 = \frac{Z^2 \times p(1-p)}{e^2}, \quad =$$

$$n_0 = \frac{1.96^2 \times 0.5068\ (1 - 0.5068)}{0.05^2}$$

$$= 384.09 \approx 384$$

Therefore, the initial minimum sample size = 384 respondents.

Step 2: Adjustment for Non-response

The formula used is

$$n_a = \frac{n_f}{1 - r}$$

Where

n_f = 384 (initial sample size), r = 10% = 0.10
So, substituting it into the formula, it will be

$$n_a = \frac{384}{0.90}$$

= 426.66, = approximately 427 respondents. When the questionnaires were returned, reviewed, and cleaned, 3 were rejected because they were not properly filled out, and therefore, the final sample size used for the study was 424 respondents.

Inclusion Criteria

Food handlers in the selected registered eateries and restaurants, who are directly involved in food preparation, cooking, serving, storage, packaging, and handling of food-contact surfaces in 46 registered establishments. Eligible participants were male and female workers aged 18 years and above, with a minimum of 6 months' work experience, who were present and actively engaged in their duties during data collection.

Exclusion Criteria

Cashiers, cleaners, and administrative staff who were not directly involved in food handling or food preparation; workers employed in unregistered food service establishments; and personnel working in large-scale food processing industries with highly formalized Hazard Analysis and Critical Control Point (HACCP) systems.

Research Instrument

Data were collected using a structured questionnaire developed through an extensive review of internationally recognized food safety frameworks, including the World Health Organization (WHO) Five Keys to Safer Food, the Codex Alimentarius Hazard Analysis and Critical Control Point (HACCP) Principles, Food and Agriculture Organization (FAO) food hygiene guidelines, and relevant Nigerian food safety regulations. The questionnaire was adapted from previously validated instruments used in similar studies and organized into sections assessing respondents' socio-demographic characteristics, HACCP knowledge, implementation practices, compliance, influencing factors, and barriers to implementation. To ensure contextual relevance and clarity, the draft instrument underwent expert review, and recommended revisions were incorporated to improve the wording, readability, and appropriateness of the items.

The validity of the instrument was established through face, content, and construct validity. Face validity was assessed by experts in the Office of Environmental Services, Lagos State Ministry of Environment and Water Resources, who evaluated the questionnaire for clarity, relevance, and suitability for the target population. Content validity was ensured by aligning the questionnaire with internationally recognized food safety standards and confirming that all domains relevant to the study objectives were adequately represented. Construct validity was strengthened by mapping questionnaire items to the Socio-Ecological Model, thereby enabling systematic assessment of individual, interpersonal, organizational, and policy-related determinants of HACCP implementation. Although a quantitative Content Validity Index (CVI) was not computed, expert consensus confirmed that the instrument adequately measured the intended constructs.

The reliability of the instrument was enhanced through the adaptation of items from previously validated food safety questionnaires that have demonstrated acceptable internal consistency (Cronbach's $\alpha \geq 0.70$) in comparable studies. Standardization was further achieved using structured closed-ended questions, uniform questionnaire administration, and immediate retrieval of completed questionnaires to minimize response bias and improve consistency. Although Cronbach's alpha was not calculated for the present study, this has been acknowledged as a limitation. Nevertheless, the use of internationally recognized frameworks, validated source instruments, expert review, and standardized data collection procedures supports the reliability and consistency of the measurement tool.

Method of data collection

Data was collected using a structured electronic questionnaire administered through the Kobo Collect mobile data collection platform. The survey was conducted by the researcher with the assistance of 9 trained research assistants. Before fieldwork commenced, the research assistants received one-day training covering the study objectives, participant eligibility criteria, ethical considerations, standardized questionnaire administration, informed consent procedures, and the use of the Kobo Collect application. This training ensured consistency in data collection across all selected food service establishments. Data collection was carried out over five consecutive days under the direct supervision of the researcher. Eligible food handlers who provided informed consent completed the questionnaire electronically using smartphones. Where necessary, the research assistants provided clarification to enhance respondents' understanding of the questionnaire without influencing their responses. Completed questionnaires were uploaded in real time to a secure cloud-based server through the Kobo Collect platform, enabling continuous monitoring of data submission and minimizing data loss. To ensure data quality, the researcher reviewed all submitted questionnaires daily for completeness, consistency, and adherence to the study protocol. Built-in validation features within Kobo Collect minimized entry errors during data collection, while an additional data cleaning process was undertaken before analysis. Questionnaires containing incomplete or inconsistent responses were excluded from the final dataset. The use of trained research assistants, standardized data collection procedures, electronic data capture, real-time supervision, and systematic quality assurance enhanced the completeness, accuracy, and reliability of the study data.

Ethical Considerations

Ethical approval for this study was obtained from the Faculty of Basic Medical Sciences, Rivers State University (Ethics Approval No. RSU/FBMS/REC/26/494) before the commencement of data collection. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and complied with institutional guidelines for research involving human participants. Administrative permission to conduct the study was also obtained from the management of the selected registered food service establishments in Ikorodu. Eligible food handlers were informed about the purpose, objectives, procedures, potential benefits, and minimal risks of the study before participation. Written informed consent was obtained from all participants before questionnaire administration. Participation was entirely voluntary, and respondents were informed of their right to decline participation or withdraw from the study at any stage without penalty or adverse consequences. Participants' privacy was protected by ensuring anonymity and confidentiality throughout the study. No personally identifiable information, such as names or identification numbers, was collected. All responses were coded and stored securely in a password-protected database

accessible only to the principal investigator and supervisory team. Data were analyzed and reported in aggregate form to prevent the identification of individual participants or food establishments and were used solely for research purposes.

Methods of Data Analysis

Data collected from the study were checked for completeness, coded, and entered into the Statistical Package for the Social Sciences (SPSS) version 25.0 for analysis. Descriptive statistics comprising frequencies, percentages, means, and standard deviations were used to summarize the socio-demographic characteristics of respondents and to describe the major study variables. Composite mean scores were computed for all multi-item constructs, and the results were interpreted using a five-point Likert scale, where higher mean scores indicated greater levels of agreement or implementation. Statistical significance was determined at a 5% level ($p < 0.05$).
Responses to the eight items measuring HACCP implementation were scored on a five-point Likert scale ranging from Never (1) to Always (5)**.** Mean scores and standard deviations were computed for each item and for the overall implementation score, after which the items were ranked according to their mean values to identify the most and least frequently implemented HACCP practices. The overall implementation score was subsequently categorized into low**,** moderate, and high levels of implementation using predetermined cut-off values.

To identify socio-demographic and occupational factors independently associated with the implementation of HACCP-based food safety practices, Modified Poisson Regression with Robust Standard Errors was performed. This analytical approach was adopted because the outcome variable (high implementation of HACCP practices) was highly prevalent among the study population, making Modified Poisson regression more appropriate than conventional logistic regression for estimating prevalence ratios in cross-sectional studies. Predictor variables entered into the model included respondents' age, sex, educational level, job role, years of work experience, previous food safety training, type of training received, time since last training, type of food establishment, and employment status. Regression coefficients (B), 95% Wald confidence intervals, Wald Chi-square statistics, and p-values were reported, with statistical significance established at $p < 0.05$.

Challenges affecting HACCP implementation and food safety compliance were grouped into structural and operational domains. Mean scores and standard deviations were computed for each challenge item and for the composite domain scores, after which the challenges were ranked according to their severity as perceived by respondents. To determine whether perceived challenges differ according to the type of food establishment, an independent samples t-test was conducted to compare the mean structural and operational challenge scores between respondents working in eateries and those working in restaurants. The test was considered appropriate because it compared the mean scores of two independent groups. The analysis was performed using the t-statistic and corresponding p-value, with statistical significance established at $p < 0.05$.

RESULTS

Socio-Demographic Distribution

The study sample comprised 424 food handlers recruited from various food service establishments. The participants had a mean age of 33.8 years (± 0.30 SE; 95% CI: 33.2–34.4 years). The age distribution showed a clear concentration in the economically active young-to-middle adulthood range: half of the respondents (50.2%) were aged 25–34 years, while nearly 40% (39.9%) fell in the 35–44-year bracket. Only 4.2% were 24 years or younger, and 5.7% were 45 years or older. The sample was markedly female-dominated, with women constituting 76.7% (n=325) of the participants and men 23.3% (n=99). Educational attainment was relatively high for this occupational group: almost half the respondents (49.3%) had completed secondary education, and a further 46.7% held higher (tertiary) qualifications. Only 3.8% reported primary-level education as their highest attainment, and one individual (0.2%) had no formal education. In terms of job roles, cooks formed the largest single group (46.2%), followed by servers (22.6%), kitchen assistants (16.0%), and supervisors (15.1%). Work experience in food handling was predominantly short to moderate: the majority (61.3%) had 1–5 years of experience, while 22.4% reported 6–10 years. Fourteen percent had less than one year of experience, and only 1.4% had 11 or more years. Self-reported exposure to food safety training was extremely high, with 99.5% of participants (n=424) indicating they had received such training at some point; only two individuals reported never having been trained. Among those trained, the most common type of training was food hygiene (61.6%), followed by combined food hygiene and HACCP instruction (36.3%). Only five respondents (1.2%) reported HACCP-specific training alone, and four (0.9%) indicated no specific type. Timing of the most recent training was generally recent: 65.8% had attended training within the last 1–3 years, and 31.1% within the preceding 12 months. Only 3.1% reported their last training as four or more years ago. Slightly more than half of the participants (54.5%) worked in restaurants, while 45.5% were employed in eateries (small, informal, or quick-service outlets). Employment was overwhelmingly full-time, with 96.2% of respondents in permanent positions and only 3.8% working part-time (Table 1 and Figures 2-3). Generally, these food handlers were predominantly young to middle-aged women with secondary or higher education, moderate work experience, near-universal exposure to food safety training (mostly within the last three years), and stable full-time employment in restaurant or eatery settings.

Table 1: Socio-Demographic Distribution

Variable	Category	Frequency	Percentages (%)
Age	≤ 24	18	4.2
Mean ± Std. Error: 33.79 ± 0.30	25 – 34	213	50.2
(C.I: 33.20, 34.38)	35 – 44	169	39.9
	≥45	24	5.7
Gender	Female	325	76.7
	Male	99	23.3
Educational Level	None	1	0.2
	Primary	16	3.8
	Secondary	209	49.3
	Higher	198	46.7
Job Role	Cook	196	46.2
	Kitchen Assistant	68	16.0
	Server	96	22.6
	Supervisor	64	15.1
Work experience (Years)	<1	63	14.9
	1-5	260	61.3
	6-10	95	22.4
	≥11	6	1.4
Previous food safety training	No	2	0.5
	Yes	424	99.5
Type of training received	Both	154	36.3
	Food hygiene	261	61.6
	HACCP	5	1.2
	None	4	0.9
Last training attended (Years)	<1	132	31.1
	1-3	279	65.8
	≥4	13	3.1
Type of establishment	Eatery	193	45.5
	Restaurant	231	54.5
Employment status	Full-time	408	96.2
	Part-time	16	3.8

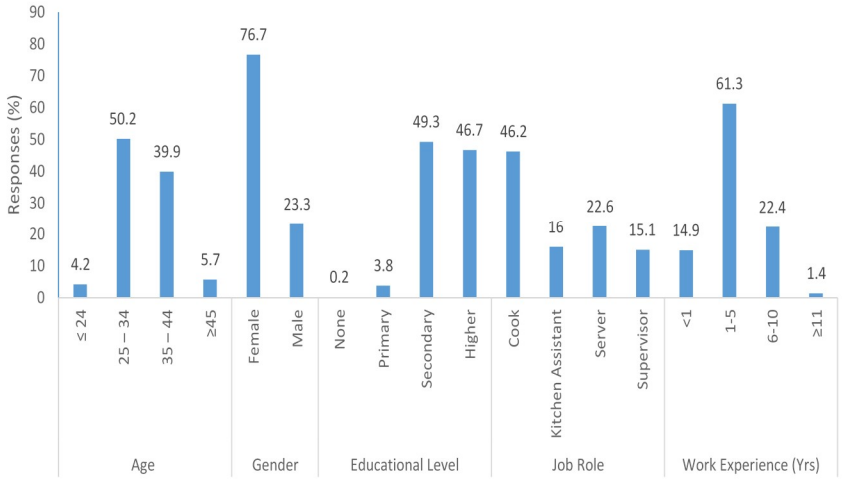

Figure 2: Socio-Demographic Distribution

Figure 3: Job Distribution

Table 2: Implementation of HACCP-Based Practices

S/N	Statement (n=424)	Rarely (%)	Sometimes (%)	Often (%)	Always (%)	Mean
1	Raw and cooked foods are separated	1(0.2)	1(0.2)	50(11.8)	372(87.7)	4.87*
2	Food temperatures are monitored	1(0.2)	6(1.4)	52(12.3)	365(86.1)	4.84*
3	Equipment is cleaned after use	0(0)	0(0)	47(11.1)	377(88.9)	4.89*
4	Handwashing is done before food handling	1(0.2)	1(0.2)	48(11.3)	374(88.2)	4.88*
5	Unsafe food is discarded	2(0.5)	0(0)	52(12.3)	370(87.3)	4.86*
6	Protective clothing is used	0(0)	3(0.7)	45(10.6)	376(88.7)	4.88*
7	Food is stored properly	0(0)	0(0)	49(11.6)	375(88.4)	4.88*
8	Pest control measures are observed	1(0.2)	11(2.6)	44(10.4)	368(86.8)	4.84*
	Total	6(0.2)	22(0.6)	387(11.4)	2977(87.8)	4.87*

(-) indicate no response and *indicate significance agreement

Assessment of the level of implementation of HACCP-based food safety practices among food handlers in selected food establishments

The food handlers surveyed demonstrated exceptionally high levels (99.1%) of self-reported adherence to core HACCP-based food safety practices, as summarized in (Table 2). Across the eight key statements, an overwhelming 87.8% of responses indicated that the practices were performed always, with only 0.2% reported as “rarely” and 0.6% as “sometimes,” yielding an overall mean score of 4.87 out of a possible 4.0 and confirming statistically significant implementation. Equipment cleaning after use emerged as the most consistently applied practice (mean = 4.89; 88.9% always), followed closely by proper food storage (mean = 4.88; 88.4% always), handwashing before handling food (mean = 4.88; 88.2% always), and use of protective clothing (mean = 4.88; 88.7% always). Separation of raw and cooked foods (mean = 4.87; 87.7% always) and discarding of unsafe food (mean = 4.86; 87.3% always) also showed very strong compliance. Slightly lower, though still markedly high, adherence was observed for monitoring food temperatures (mean = 4.84; 86.1% always) and observing pest control measures (mean = 4.84; 86.8% always), the latter recording the highest proportion of “sometimes” responses (2.6%).

The findings indicate that fundamental food safety controls are almost universally followed daily, with very few and infrequent departures from recommended standards. Also, results indicate that structured, ongoing training and capacity-building significantly influence food safety practices among handlers, explaining over 40% of the variance in adherence. Table 3 and Figure 4 present the results of a modified Poisson regression with robust standard errors, examining predictors of implementation of HACCP-based practices among food handlers, with reference categories set at Age group 4, Male sex, Secondary education, Supervisor job role, 6–10 years' experience, having received prior food safety training (PF=Yes), no training type (TT=None), 1–3 years since last training, Restaurant establishment type, and Part-time employment status.

Among all predictors examined, only three variables

Table 3: Parameter Estimates based on Modified Poisson Regression with Robust Standard Errors

Parameter	B	95% Wald Confidence Interval		Hypothesis Test	
		Lower	Upper	Wald Chi-Square	p-value
(Intercept)	-0.362	-1.059	0.336	1.034	0.309
[<24 yrs]	-0.353	-0.675	-0.03	4.591	0.032
[25-34yrs]	-0.107	-0.181	-0.032	7.932	0.005
[35-44 yrs]	-0.05	-0.116	0.017	2.14	0.144
[≥45 yrs]	0[a]	.	.	.	.
[Sex=Female]	-0.021	-0.076	0.035	0.529	0.467
[Sex=Male]	0[a]	.	.	.	.
[Edu=Higher]	0.053	-0.008	0.115	2.877	0.09
[Edu=None]	-4.95E-05	-0.052	0.052	0	0.999
[Edu=Primary]	-0.173	-0.383	0.038	2.575	0.109
[Edu=Secondary]	0[a]	.	.	.	.
[JR=Cook]	0.039	-0.023	0.1	1.488	0.223
[JR=Kitchen Assistant]	-0.084	-0.205	0.036	1.893	0.169
[JR=Server]	0.006	-0.08	0.092	0.02	0.888
[JR=Supervisor]	0[a]	.	.	.	.
[EXP=<1]	0.091	-0.024	0.207	2.388	0.122
[EXP=>10]	-0.245	-0.759	0.268	0.877	0.349
[EXP=1–5]	0.05	-0.024	0.125	1.764	0.184
[EXP=6–10]	0[a]	.	.	.	.
[PF=No]	-0.544	-1.956	0.868	0.57	0.45
[PF=Yes]	0[a]	.	.	.	.
[TT=Both]	0.119	-0.509	0.747	0.138	0.711
[TT=Food hygiene]	0.078	-0.547	0.702	0.059	0.808
[TT=HACCP]	0.153	-0.462	0.769	0.238	0.625
[TT=None]	0[a]	.	.	.	.
[LT raining=<1 year]	0.019	-0.049	0.087	0.293	0.588
[LT raining=>3 years]	0.012	-0.165	0.189	0.018	0.893
[LT raining=1–3 years]	0[a]	.	.	.	.
[TE=Eatery]	0.087	0.023	0.152	7.066	0.008
[TE=Restaurant]	0[a]	.	.	.	.
[ES=Full-time]	0.178	-0.083	0.44	1.785	0.182
[ES=Part-time]	0[a]	.	.	.	.
(Scale)	1[b]				

Dependent Variable: Implementation of HACCP-Based Practices
Model: (Intercept), Age, Sex, Edu, JR, EXP, PF, TT, LT raining, TE, ES

a. Set to zero because this parameter is redundant.
b. Fixed at the displayed value.

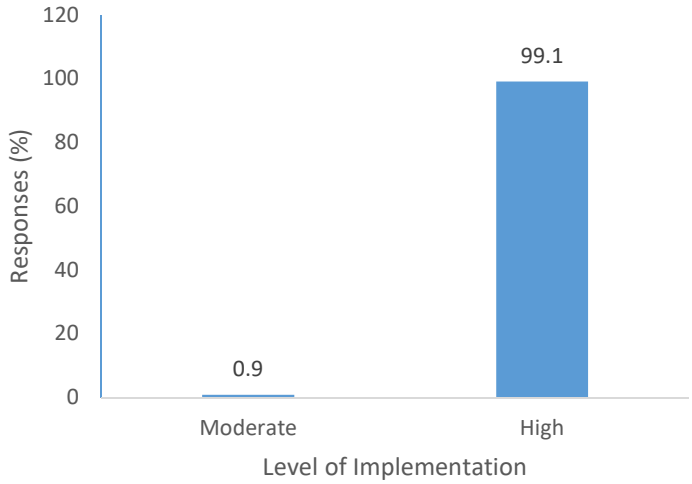

Figure 4: Level of Implementation of HACCP-Based Practices

Table 4: Challenges to HACCP Implementation & Food Safety Compliance.

S/N	Structural Challenges (n=424)	SD (%)	D (%)	N (%)	A (%)	SA (%)	Mean
1	Inadequate kitchen space affects food safety practices	0(0)	2(0.5)	3(0.7)	116(27.4)	303(71.5)	4.70*
2	Poor water supply limits hygiene compliance	1(0.2)	1(0.2)	0(0)	109(25.7)	313(73.8)	4.73*
3	Lack of refrigeration facilities affects safe food storage	1(0.2)	0(0)	0(0)	110(25.9)	313(73.8)	4.73*
4	Inadequate water disposal facilities affect hygiene	0(0)	0(0)	3(0.7)	102(24.1)	319(75.2)	4.75*
5	Poor ventilation affects food handling conditions	0(0)	1(0.2)	9(2.1)	102(24.1)	312(73.6)	4.71*
6	An unreliable electricity supply affects food safety practices	1(0.2)	0(0)	3(0.7)	116(27.4)	304(71.7)	4.70*
	Sub-Total	3(0.1)	4(0.2)	18(0.7)	655(25.7)	1864(73.3)	4.72*
	Operational Challenges	**SD (%)**	**D (%)**	**N (%)**	**A (%)**	**SA (%)**	
7	High workload limits adherence to food safety practices	13(3.1)	72(17)	14(3.3)	66(15.6)	259(61.1)	4.15*
8	Time pressure leads to shortcuts in hygiene practices	22(5.2)	67(15.8)	23(5.4)	61(14.4)	251(59.2)	4.07*
9	Staff shortages affect proper food handling	27(6.4)	57(13.4)	10(2.4)	78(18.4)	252(59.4)	4.11*
10	Lack of clear SOPs affects HACCP implementation	3(0.7)	2(0.5)	11(2.6)	98(23.1)	310(73.1)	4.67*
11	Poor supervision affects food safety compliance	1(0.2)	1(0.2)	6(1.4)	106(25)	310(73.1)	4.71*
12	Irregular internal monitoring affects adherence	1(0.2)	2(0.5)	7(1.7)	109(25.7)	305(71.9)	4.69*
	Sub-Total	67(2.6)	201(7.9)	71(2.8)	518(20.4)	1687(66.3)	4.40*

(-) indicate no response and *indicate significance agreement

emerged as statistically significant. Age category 1 was significantly negatively associated with HACCP implementation relative to the reference age group (B=-0.353, 95% CI: -0.675 to -0.03, Wald χ^2=4.591, p=0.032), as was age category 2 (B=-0.107, 95% CI: -0.181 to -0.032, Wald χ^2=7.932, p=0.005), indicating that younger age groups implemented HACCP-based practices to a significantly lesser extent than the reference (oldest) age group, with the effect being more precisely estimated for age category 2. Age category 3 did not differ significantly from the reference group (B=-0.05, p=0.144). The type of establishment also emerged as a significant predictor, with eateries showing significantly higher implementation of HACCP-based practices compared to restaurants (B=0.087, 95% CI: 0.023 to 0.152, Wald χ^2=7.066, p=0.008).

None of the remaining predictors reached statistical significance, including sex (p=0.467), educational level (Higher: p=0.09; None: p=0.999; Primary: p=0.109), job role (Cook: p=0.223; Kitchen Assistant: p=0.169; Server: p=0.888), years of experience (<1 year: p=0.122; >10 years: p=0.349; 1–5 years: p=0.184), prior food safety training received (p=0.45), type of training received (Both: p=0.711; Food hygiene: p=0.808; HACCP: p=0.625), time since last training (<1 year: p=0.588; >3 years: p=0.893), and employment status (Full-time: p=0.182). The intercept was also not statistically significant (B=-0.362, p=0.309).

These findings suggest that among the wide range of socio-demographic, occupational, and training-related factors examined, only age and establishment type were significant predictors of HACCP-based practice implementation. The consistent negative association between younger age and implementation suggests that older, potentially more experienced food handlers may adhere more closely to HACCP protocols, possibly reflecting accumulated on-the-job learning or greater risk awareness over time. Notably, training-related variables (whether training was received, the type, or recency) did not significantly predict implementation in this multivariate model, which may indicate that training alone, without reinforcement through supervision, organizational culture, or repeated practice, may be insufficient to drive consistent HACCP compliance. This warrants further investigation, possibly through qualitative exploration of the practical barriers food handlers face in translating safety knowledge into consistent practice.

Perceived challenges to an effective implementation of HACCP and food safety compliance among food handlers in selected food establishments.

The effective implementation of HACCP (Hazard Analysis and Critical Control Point) among food handlers in the selected establishments faces notable challenges, primarily in structural and operational domains, as detailed in (Table 4). Respondents rated these barriers with higher means, indicating greater perceived hindrance (all statistically significant). Structural challenges emerged as the most pronounced barriers (subtotal mean = 4.72; 73.3% strongly agree overall), reflecting pervasive infrastructural limitations that undermine core HACCP prerequisites such as safe storage, hygiene, and environmental control. Inadequate waste (water) disposal facilities ranked highest (mean = 4.75; 75.2% strongly agree), followed closely by poor water supply (mean = 4.73; 73.8% strongly agree) and lack of refrigeration facilities (mean = 4.73; 73.8% strongly agree), both impeding temperature control and safe storage of perishable foods. Poor ventilation (mean = 4.71; 73.6% strongly agree), unreliable electricity supply (mean = 4.70; 71.7% strongly agree), and inadequate kitchen space (mean = 4.70; 71.5% strongly agree) were similarly viewed as major constraints, creating conditions that favor contamination, bacterial growth, and inconsistent application of critical controls. Operational challenges presented a more mixed but still substantial profile (subtotal mean = 4.40; 66.3% strongly agree), highlighting day-to-day workplace dynamics that can compromise adherence. Poor supervision (mean = 4.71; 73.1% strongly agree) and lack of clear SOPs (mean = 4.67; 73.1% strongly agree) were perceived as significant hindrances to consistent HACCP execution, alongside

Table 5: Mean Difference between Establishments on Challenges to HACCP Implementation & Food Safety Compliance

Challenges	Establishment	n	Mean	Std. Dev.	t-statistic	p-value
Structural	Eatery	193	4.7451	0.38162	1.219	0.224
	Restaurant	231	4.6967	0.42828		
Operational	Eatery	193	4.7062	0.46231	8.198	0.000
	Restaurant	231	4.1407	0.85991		

irregular internal monitoring (mean = 4.69; 71.9% strongly agree). Workload-related issues were also prominent: high workload limiting adherence (mean = 4.15; 61.1% strongly agree), time pressure prompting hygiene shortcuts (mean = 4.07; 59.2% strongly agree), and staff shortages affecting proper handling (mean = 4.11; 59.4% strongly agree). These operational pressures align with broader patterns observed in resource-constrained settings, where peak demands can erode even well-intentioned practices. Addressing these structural and operational hurdles would likely yield the greatest gains in sustaining HACCP-aligned practices and reducing food safety risks.

Table 5 presents the results of independent samples t-tests comparing eateries and restaurants on structural and operational challenges to HACCP implementation and food safety compliance. With respect to structural challenges, eateries recorded a slightly higher mean score (4.74±0.38) than restaurants (4.69±0.42); however, this difference was not statistically significant ($t=1.219$, $p=0.224$), indicating that both types of establishments experienced structural challenges to HACCP implementation to a broadly similar extent. In contrast, a statistically significant difference was found between the two establishment types with respect to operational challenges ($t=8.198$, $p<0.001$). Eateries reported a notably higher mean score (4.70±0.46) compared to restaurants (4.14±0.85), indicating that eateries experienced operational challenges to HACCP implementation and food safety compliance to a significantly greater degree than restaurants.

The considerably larger standard deviation observed among restaurants (0.85 vs. 0.46) also suggests greater variability in how restaurant staff perceived operational challenges, compared to the more consistent perception reported among eatery staff. Generally, these findings suggest that while both establishment types face comparable structural barriers to HACCP implementation (e.g., infrastructure, resources, facility design), eateries appear to face substantially greater day-to-day operational difficulties (e.g., staff practices, process consistency, supervision) in maintaining food safety compliance than restaurants.

This distinction may have practical implications for targeting intervention strategies, suggesting that operational-level support, such as staff training, process standardization, and on-site supervision, may be particularly beneficial for eateries, whereas structural improvements may be similarly relevant across both establishment types.

DISCUSSION

The present study revealed that food handlers were predominantly young-to-middle-aged adults, female, relatively well educated, and largely employed on a full-time basis. The predominance of respondents aged 25-44 years suggests that food service establishments in Ikorodu rely heavily on an economically active workforce capable of meeting the physical and operational demands of commercial food handling. Younger workers may also demonstrate greater adaptability to contemporary food safety procedures, digital documentation systems, and structured HACCP protocols, particularly where regular workplace training is provided. Similar workforce demographics have been reported among food handlers in Nigeria, Ethiopia, Ghana, and other low- and middle-income countries (LMICs), where the food service sector is largely sustained by young adults with secondary or post-secondary education (Insfran-Rivarola et al., 2020; Kwol et al., 2020; Atalay et al., 2025). Nevertheless, age alone should not be interpreted as a predictor of food safety performance. Recent systematic evidence indicates that although younger workers often demonstrate better knowledge acquisition following training, sustained compliance is more strongly influenced by organizational culture, supervision, and workplace support than by demographic characteristics alone (Ze et al., 2024; Gregory et al., 2025).

The predominance of female respondents is consistent with findings from Nigeria and several African countries, where women constitute many workers engaged in food preparation and hospitality services because of prevailing sociocultural and economic labor patterns (Nordhagen, 2022; Atalay et al., 2025). However, this demographic pattern contrasts with reports from parts of Europe and the Middle East, where commercial catering and industrial food production employ relatively higher proportions of male workers, reflecting differences in labor market structures and food service organization (Insfran-Rivarola et al., 2020). Educational attainment was notably high among participants, with nearly all respondents having completed at least secondary education. This finding is encouraging because educational attainment enhances comprehension of food safety principles, risk communication, record keeping, and HACCP documentation requirements. Nonetheless, contemporary evidence suggests that education alone is insufficient to ensure sustained food safety compliance; rather, its effectiveness depends on continuous professional

development, supportive leadership, and reinforcement through organizational food safety culture (Insfran-Rivarola et al., 2020; Ze et al., 2024; Gregory et al., 2025). Consequently, policy interventions should extend beyond initial training by institutionalizing periodic refresher programs, competency-based certification, supportive supervision, and regulatory enforcement to sustain HACCP implementation and improve food safety performance within the food service sector. The study further demonstrated a remarkably high level of implementation of HACCP-based food safety practices among food handlers in the participating establishments. Core preventive behaviors, including regular hand hygiene, equipment sanitation, use of protective clothing, and appropriate food storage, were reportedly practiced consistently, suggesting that fundamental food hygiene principles have become integrated into routine operations. This finding is encouraging because it suggests that many formal food establishments in the study area have begun to integrate food safety practices into their daily operations. The high level of implementation may be due to the formal and registered nature of the establishments included in the study. Such establishments are likely to interact with Environmental Health Officers, undergo inspections, provide some form of staff training, and operate under greater pressure to protect their reputation and retain customers. The findings may also reflect growing awareness of foodborne diseases and increased attention to hygiene following the COVID-19 period. These findings are consistent with the Codex Alimentarius Commission, which emphasizes that effective HACCP implementation depends on strong prerequisite programs, including Good Hygiene Practices (GHPs), sanitation, employee training, and effective supervision (Codex Alimentarius Commission, 2023).

Similarly, a comprehensive systematic review and meta-analysis concluded that food safety training significantly improves food handlers' knowledge and self-reported hygienic practices, particularly when training is continuous and supported by workplace monitoring (Insfran-Rivarola et al., 2020). Nigerian studies conducted in hospitality establishments and institutional food service settings have likewise reported positive associations between food safety knowledge, attitudes, training, and hygienic practices (Kwol et al., 2020; Arole et al., 2026).

However, recent literature also cautions that improvements in knowledge and self-reported practices do not necessarily translate into sustained behavioral compliance. Systematic reviews have demonstrated that organizational leadership, food safety culture, management commitment, availability of resources, and continuous verification exert a greater influence on long-term HACCP compliance than training alone (Ze et al., 2024; Gregory et al., 2025). Consequently, the high implementation compliance observed in the present study may reflect not only effective workforce training but also supportive organizational environments within the selected establishments.

Despite the generally high implementation levels, relatively weaker performance was observed in system-dependent practices such as temperature monitoring and pest control. Unlike visible hygiene behaviors that can be readily supervised, these technical controls require functional infrastructure, calibrated equipment, comprehensive documentation systems, effective managerial oversight, and regular verification. This finding is consistent with studies showing that food handlers generally achieve higher compliance with observable personal hygiene behaviors than with technical HACCP requirements involving routine monitoring and documentation (De Boeck et al., 2018; Ze et al., 2024). Nevertheless, the exceptionally high self-reported compliance observed in the present study differs from broader evidence across sub-Saharan Africa, where only moderate levels of good food hygiene practice have generally been documented among food handlers (Atalay et al., 2025; Macheka et al., 2025). This discrepancy may partly reflect the structured nature of the participating establishments or the inherent limitations of self-reported data, including social desirability bias and selective reporting (Nordhagen, 2022).

Consequently, self-reported implementation compliance should be interpreted cautiously unless supported by direct observational assessments or objective verification records. These findings reinforce recent recommendations advocating stronger verification systems, including routine observational audits, digital temperature monitoring, mandatory record keeping, documented pest control programs, and risk-based regulatory inspections to ensure that reported practices translate into sustained operational food safety performance (WHO, 2022; Ze et al., 2024).

The modified Poisson regression provided additional insight by showing that age and type of establishment remained independently associated with HACCP implementation. The younger food handlers had a much lower prevalence of high implementation compared to the older food handlers. This pattern may indicate that older food handlers possess greater practical experience, have held food safety responsibilities for longer periods, or occupy positions in which they are more accountable for maintaining hygiene procedures.

However, work experience was not statistically significant after adjustment. This implies that the association with age may also reflect maturity, risk perception, professional responsibility, or other unmeasured characteristics rather than length of employment alone. Recent evidence supports the view that individual characteristics and work roles can influence food safety practices. In Jimma City, Ethiopia, Tesso et al. (2025) found that working position, knowledge, and attitude were significantly related to good food hygiene practices. The study also observed that bacterial contamination was higher among workers with poorer hygiene practices, demonstrating that differences in reported or observed practices may have real microbiological implications. The significantly higher

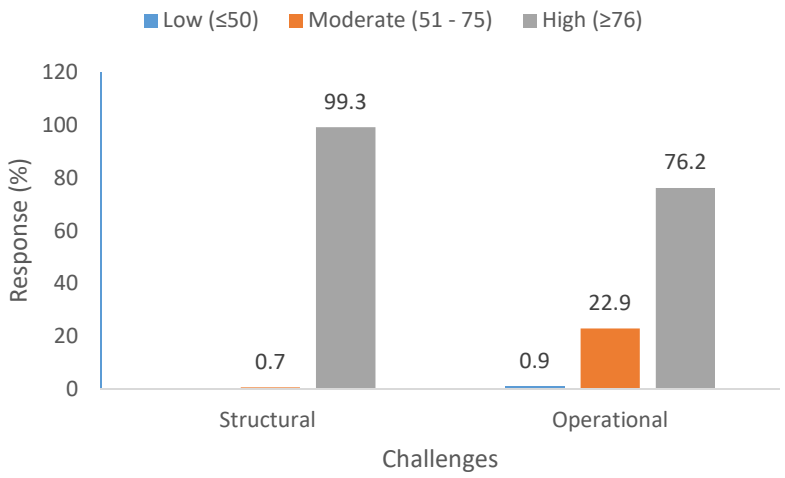

Figure 5: Challenges to HACCP Implementation & Food Safety Compliance

implementation among workers in eateries compared with restaurants was an unexpected but important result. Food handlers in eateries recorded approximately 9% higher prevalence of high implementation after adjustment for respondents' personal and occupational characteristics. One possible explanation is that eateries may have simpler menus, shorter production chains and more direct supervision, making routine hygiene procedures easier to observe. In contrast, restaurants may have more complex food preparation processes, larger menus, higher customer volumes, and more divided responsibilities. The result does not necessarily mean that eateries possess more advanced or fully documented HACCP systems; rather, workers in eateries reported more consistent performance of the specific HACCP-based practices measured in the study. The finding that establishment type influenced implementation agrees with Tesso et al. (2025), who found that food handlers working in snack houses were less likely to demonstrate good hygiene practices than workers in hotels. Although the direction of the association differs from the present study, both findings show that operational characteristics of food establishments matter and that food safety behavior cannot be explained solely by individual knowledge. The high level of implementation found in Ikorodu contrasts with much of the recent evidence from Sub-Saharan Africa (SSA). Atalay et al. (2025), in a systematic review and meta-analysis involving 42 studies and 12, 367 food handlers, estimated that only 50.68% of food handlers in SSA demonstrated good food hygiene practices. Food safety training, favorable attitudes, and regular medical examinations were among the factors associated with better practice; similarly, Tesso et al. (2025) reported that only 28.4% of food handlers in Jimma City had good hygiene practices, while 45.2% had one or more bacterial contaminants isolated from their hands. The differences between these studies and the present findings may be due to variations in the measurements, cut-off points, regulatory environments, and types of establishments studied. The current research assessed registered eateries and restaurants through self-reported questionnaire responses, whereas the Jimma study incorporated hand-swab testing and classified practice using a more restrictive binary outcome. Consequently, the very high implementation scores in Ikorodu may partly reflect social desirability bias, especially because respondents might have been concerned about the regulatory consequences of admitting unsafe practices. This interpretation is consistent with food safety culture literature. Pia et al. (2024) emphasized that sustainable food safety behavior depends on leadership, organizational commitment, communication, employee engagement, and the availability of appropriate resources, rather than on isolated training activities alone. Fekadu et al. (2024) also found that food safety knowledge, attitudes, and practices do not always improve uniformly, supporting the need to move beyond knowledge-based interventions towards workplace systems that reinforce safe behavior.

The study also identified significant infrastructural and operational barriers that threaten the sustainability of HACCP implementation (Figure 5). The most frequently reported constraints included unstable electricity supply, inadequate access to potable water, poor waste management systems, limited refrigeration capacity, insufficient ventilation, and constrained workspace. These deficiencies compromise prerequisite programs that underpin HACCP, particularly sanitation, environmental hygiene, and temperature control. The Codex Alimentarius Commission emphasizes that HACCP systems can function effectively only when supported by adequate infrastructure and well-established prerequisite programs (Codex Alimentarius Commission, 2023). Likewise, the WHO Global Strategy for Food Safety 2022–2030 identifies reliable infrastructure, laboratory capacity, surveillance systems, and effective governance as essential components of resilient food safety systems (WHO, 2022). Similar infrastructural constraints have been widely reported across LMICs, where unreliable utilities

and weak institutional capacity undermine food safety performance despite adequate worker knowledge and training (Nordhagen, 2022; Macheka et al., 2025). Beyond infrastructural limitations, the present study identified several organizational challenges, including unclear Standard Operating Procedures, inconsistent supervision, inadequate staffing, and workload pressures during peak service periods. These findings are consistent with studies demonstrating that operational stress, excessive workload, and weak managerial oversight increase deviations from hygiene protocols and reduce compliance with HACCP requirements (De Boeck et al., 2018; Arole et al., 2026). More recent systematic evidence similarly identifies inadequate management commitment, poor documentation systems, limited organizational support, and weak regulatory inspection as major determinants of food safety failures in commercial food establishments (Ze et al., 2024). In contrast, studies conducted in highly regulated food industries in high-income countries report substantially fewer implementation barriers because of stronger institutional governance, stable infrastructure, effective inspection systems, and well-developed food safety cultures (Gregory et al., 2025; Ze et al., 2024).

The independent samples t-test showed no significant difference in structural challenges between eateries and restaurants. Although the mean structural-challenge score was marginally higher in eateries, the difference was small and could have occurred by chance. This suggests that infrastructural problems within the study setting were not confined to a particular category of establishments. Both eateries and restaurants appeared to operate within the same broader environment of unstable public utilities, costly alternative power sources, equipment limitations, and challenges in maintaining adequate facilities. These findings agree with the review by Tohonon et al. (2025), which reported persistent gaps between international prerequisite-program requirements and actual practices in catering establishments across Sub-Saharan Africa. The review concluded that many catering services in the region do not meet critical hygiene requirements and emphasized capacity development, context-appropriate regulation and stronger institutional cooperation. The absence of a difference between eateries and restaurants in the current study, therefore, suggests that structural barriers may reflect wider environmental and system-level conditions rather than the management of individual establishments alone.

A markedly different pattern emerged for operational challenges. Food handlers working in eateries had significantly higher operational challenge scores than those working in restaurants. The estimated effect size was large, indicating that the difference was not only statistically significant but also practically meaningful. This finding suggests that eateries may experience greater difficulties in relation to staff shortages, workload, time pressure, irregular supervision, and maintaining food safety procedures during busy service periods. The higher level of operational challenges in eateries appears particularly important when considered alongside the Modified Poisson finding that eateries reported higher HACCP implementation. These two results may indicate that food handlers in eateries continue to report frequent performance of basic HACCP-based activities despite working under greater operational pressure. It is also possible that the smaller and more direct work structure of eateries makes basic practices easier to supervise, while simultaneously increasing individual workload. Another possibility is that workers over reported desirable practices while accurately acknowledging the operational difficulties they faced. This reinforces the need for future studies to combine self-reported responses with direct observation, review of HACCP records, temperature logs, and microbiological testing. The operational barriers identified in the present study agree with those of Dzwolak and Amin (2025), who found that small food businesses experienced multiple difficulties in maintaining HACCP-based food safety management systems. Their reported barriers included employee-related problems, weaknesses in the food safety management system operation, burdensome production processes, documentation demands, financial limitations, management-related difficulties, and poor infrastructure. The finding demonstrates that food businesses that have established HACCP-based systems may struggle to maintain them during routine operations. The present findings also align with Pai et al. (2024), who concluded that management commitment, leadership, communication, employee involvement and resource availability are central to a strong food safety culture. Where these organizational conditions are weak, workers may understand the required procedures but remain unable to perform them consistently. Similarly, the barriers identified by Dzwolak and Amin (2025) show that HACCP maintenance is affected by operational production demands and human factors rather than by technical knowledge alone. However, the current findings differ from settings where more formal or larger establishments have reported greater difficulties because of complex documentation, audits, and extensive food production processes. Dzwolaak and Amin (2025), for example, identified burdensome documentation and faults in formal food safety management systems as barriers within small businesses, but they were already maintaining standardized private food safety systems. In the present study, the greater operational burden was reported by eateries rather than restaurants. This difference may arise because the Ikorodu establishments were assessed mainly on routine operational challenges, whereas the Polish study focused on maintaining formally standardized and privately certified food safety systems. The findings demonstrate that interventions should be tailored to the establishment.

Overall, these findings suggest that barriers to sustainable HACCP implementation are predominantly structural and organizational rather than knowledge-based. Accordingly, effective food safety implementation compliance requires considerably more than individual

awareness or periodic training. Sustainable implementation depends on sustained investment in infrastructure, supportive leadership, robust food safety culture, effective supervision, continuous verification, and strong regulatory governance. These conclusions are consistent with contemporary international evidence advocating integrated food control systems that combine workforce development, institutional capacity, surveillance, infrastructure investment, risk-based inspection, and multisectoral collaboration to achieve lasting improvements in food safety (WHO, 2022; Macheka et al., 2025; Gregory et al., 2025; Ze et al., 2024). The study concludes that food handlers in selected food establishments in Ikorodu demonstrated a high level of self-reported HACCP implementation compliance with food safety standards; however, implementation varied with age and type of establishment, while operational challenges remained a significant barrier to sustaining effective HACCP practices, particularly in eateries. It is further recommended that regulatory agencies and food establishment managers should strengthen continuous practical HACCP training, supportive supervision, and routine monitoring, while addressing operational constraints such as workload, staffing, and workflow management to sustain effective food safety compliance.

Limitations of the Study

i. The study relied on self-reported questionnaire data, which may have been subject to social desirability bias, leading respondents to overstate their compliance with HACCP requirements and recommended food safety practices.

ii. The study was conducted among selected registered food establishments in Ikorodu, Lagos State; therefore, the findings may not be generalizable to informal food vendors or food service establishments in other geographical settings.

iii. The study did not incorporate direct observational assessments or microbiological analyses to independently verify reported food safety practices and HACCP compliance.

iv. Infrastructural factors, including electricity and water supply, were assessed based on respondents' perceptions rather than objective measurements, which may have influenced the accuracy of the findings.

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