

# **Food safety knowledge, practices, and microbial hand hygiene of food handlers in public primary schools in Gaborone Botswana**

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Dissertation submitted in fulfilment of the requirements for the Degree

**MAGISTER TECHNOLOGIAE:  
ENVIRONMENTAL HEALTH**

in the  
Department of Life Sciences  
at the  
Central University of Technology, Free State

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**BLOEMFONTEIN**

**November 2025**

## DECLARATION OF INDEPENDENT WORK

### DECLARATION WITH REGARD TO INDEPENDENT WORK

I, **ONALETHATA MASOLE**, identity number \_\_\_\_\_ and student number \_\_\_\_\_, do hereby declare that this research project submitted to the Central University of Technology, Free State for the Master of Environmental Health Science, is my own independent work; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State; and has not been submitted before to any institution by myself or any other person in fulfilment (or partial fulfilment) of the requirements for the attainment of any qualification.

**23/11/2025**

**SIGNATURE OF STUDENT**

**DATE**

## DEDICATIONS

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This work is dedicated to my late parents, Thaloso and Masole Sethare. Their unwavering love, support, and sacrifices have been the foundation of my journey. Through their guidance and strength, they instilled in me the values of perseverance, resilience, and the importance of education. Although they are no longer with me, their memory continues to inspire and guide me every day. This paper is a testament to their enduring influence in shaping the person I am today.

## ACKNOWLEDGEMENTS

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I would like to express my deepest gratitude to my husband, **Mr. Daniel Onyach**, for his unwavering support, love, and understanding throughout this entire journey. His constant encouragement and belief in me have been a source of great strength and motivation.

My heartfelt appreciation also goes to my best friend, **Ms. Mingie Itumeleng**, for her endless encouragement and for always being there to uplift me during challenging moments. Your friendship, positivity, and belief in me have been truly invaluable.

I am sincerely grateful to my entire family for their unconditional love, patience, and continuous support. I would like to thank my sister, **Ms. Phanano Masole**, for her immense encouragement and belief in my abilities. Your guidance, reassurance, and presence have made this journey much lighter and more meaningful.

I extend my sincere appreciation to the **Ministry of Health** for granting me permission to undertake this study and for supporting my academic and professional development. I am equally thankful to the **Botswana National Food Laboratory** for providing access to their facilities, which were essential for the successful completion of my research. My special thanks also go to **Mr. Allam Chivunga Mphande and Mr. Kenanao Kgalemang**, as well as the entire laboratory staff, for their invaluable assistance, technical expertise, and willingness to help throughout the research process.

I would also like to extend my deepest gratitude to my supervisors for their exceptional guidance and mentorship. My sincere thanks to **Prof. Jane Nkhebenyane** for her professionalism, patience, and insightful feedback, which continuously shaped and strengthened this work. I am profoundly thankful to my co-supervisor, **Dr. Tsepo Ramatla**, whose dedication, expertise, and tireless support have been instrumental in helping me complete this study efficiently. His consistent feedback, encouragement, and professionalism greatly enhanced the quality of my research, and I have learned so much under his guidance.



Finally, I would like to express my appreciation to all the participants who took part in this study. Your time, effort, and willingness to contribute made this research possible.

Once again, my heartfelt thanks to everyone who has contributed in one way or another to the completion of this work. Your support, encouragement, and belief in me will always be remembered with deep gratitude.

## ABSTRACT

### Background

Foodborne illnesses remain a persistent challenge in Botswana, and schools are particularly vulnerable because many children rely on on-site meals. Despite national food-safety standards, outbreaks linked to poor hygiene and inadequate food-handling practices continue to be reported in school environments. International studies show that food handlers often act as sources of contamination due to insufficient knowledge and poor personal hygiene. Given the scale of Botswana's school feeding program and the vulnerability of young children to foodborne diseases, there is a critical need to assess whether food safety knowledge and reported practices among school food handlers align with actual behavior and microbial hygiene outcomes. This gap underscores the importance of evaluating both behavioural and microbial indicators to strengthen food safety within school kitchens.

### Methods:

A mixed-methods design was employed involving questionnaires, direct observations, and laboratory analysis of hand swab samples. Seventy-seven food handlers from ten randomly selected schools participated. Quantitative data were analysed using EPI Info 7 and Stata 14, while qualitative observations were thematically analysed. Hand swab samples were cultured on selective chromogenic media, enabling simultaneous detection and differentiation of *Escherichia coli* and total coliforms. Contamination was categorised as none, low (1–49 CFU), moderate (50–99 CFU), or high ( $\geq 100$  CFU). Comparative and regression analyses were conducted to explore associations between demographic factors, knowledge, practices, and microbial outcomes.

### Results:

Participants demonstrated high self-reported practice scores (89.37%), moderate knowledge levels (79.7%), and lower observed practice performance (75.75%). Despite strong awareness in areas such as hand hygiene, knowledge gaps persisted, particularly in temperature control: 37.66% of food handlers had misconception that freezing food eliminates or destroy bacteria completely, and only 35.06% recognised the existence of heat-resistant toxins. Only 55.8% had received formal food safety

training, and none had undergone HACCP training. Mask usage during food preparation was low (22.08%), and 12.99% indicated willingness to work while ill.

Demographic factors, including age, gender, education, employment status, and work experience, were not significantly associated with food safety knowledge ( $p > 0.05$ ). However, hygiene practice scores were significantly higher among older handlers, those with longer work experience, permanent employees, and individuals with prior food safety training ( $p < 0.05$ ). Knowledge significantly predicted practice ( $F(1,75) = 5.29$ ,  $p = 0.024$ ;  $R^2 = 0.066$ ), though the effect was weak.

Microbial assessments revealed that *E. coli* was absent in all 77 samples, while total coliform bacteria were detected in 32.47%. Contamination varied across schools, with School 2 displaying the highest prevalence. Knowledge and practice scores did not significantly predict microbial contamination. However, handwashing technique was strongly associated with contamination levels ( $\chi^2(4) = 13.53$ ,  $p = 0.009$ ), indicating that specific behavioural competencies rather than general knowledge are most influential in determining microbial outcomes.

### **Conclusion:**

Although food handlers demonstrated moderate to high knowledge and self-reported practices, substantial behavioural gaps persisted, particularly in temperature control, mask use, and handwashing technique. Demographic characteristics were not reliable predictors of knowledge, though practical experience, employment stability, and training significantly influenced hygiene practices. The absence of *E. coli* indicates acceptable baseline hygiene, yet the presence of coliforms in one-third of handlers highlights continued risks. These findings emphasise that knowledge alone does not ensure food safety compliance; rather, hands-on training, continuous supervision, improved hygiene infrastructure, and institutional support are essential for strengthening food safety culture in school kitchens and protecting the health of children.

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## LIST OF ACRONYMS

|          |                                                      |
|----------|------------------------------------------------------|
| AfFSA    | Africa Food Safety Agency                            |
| AU       | African Union                                        |
| CFAPs    | charitable food assistance programmes                |
| CFUs     | Colony-forming units                                 |
| CI       | Confidence interval                                  |
| FAO      | Food and Agriculture Organization                    |
| FBDs     | Foodborne diseases                                   |
| FSANZ    | Food Standards Australia New Zealand                 |
| HACCP    | Hazard Analysis and Critical Control Points          |
| HUS      | haemolytic uremic syndrome                           |
| IQR      | interquartile range                                  |
| MDR      | multidrug-resistant                                  |
| MRSA     | Methicillin-resistant <i>Staphylococcus aureus</i>   |
| NSFP     | National School Feeding Programme                    |
| PPE      | Personal protective equipment                        |
| RTE      | Ready-to-eat                                         |
| SHP      | School Health Programme                              |
| STEC     | Shiga toxin-producing <i>E. coli</i>                 |
| WFP      | World Food Programme                                 |
| WHO      | World Health Organization                            |
| WHO AFRO | World Health Organization Regional Office for Africa |

## CHAPTER ONE:

# GENERAL INTRODUCTION AND BACKGROUND

---

### 1.1 Background

Foodborne illnesses remain a significant public health concern worldwide. According to the World Health Organization (WHO), nearly one in ten people falls ill every year from consuming contaminated food, approximately 600 million individuals with around 420,000 deaths, of which nearly 30% are children under the age of five (WHO, 2024). The highest incidence and mortality rates occur in the African and South-East Asian regions, where surveillance and control systems are often limited (FAO & WHO, 2020; WHO Regional Office for Africa [AFRO], 2024). In Africa alone, over 91 million people are estimated to suffer from foodborne diseases annually, leading to approximately 137,000 deaths (WHO AFRO, 2024).

Foodborne diseases are primarily caused by biological agents such as bacteria, viruses, and parasites, as well as by chemical contaminants, including heavy metals and pesticide residues (FAO & WHO, 2020). These diseases disproportionately affect low- and middle-income countries, particularly among children under five, where poverty and inadequate sanitation contribute to increased vulnerability (WHO, 2024; Masia et al., 2023). Weak surveillance systems and under-reporting of cases further obscure the true burden of foodborne diseases in many African nations, including Botswana (WHO AFRO, 2024).

In Botswana, ensuring food safety is critical within institutional settings such as the National School Feeding Programme (NSFP), which provides daily meals to over 330,000 primary-school children nationwide (NEPAD & Government of Botswana, 2022). This programme, one of the oldest in Africa, plays a key role in supporting nutrition, reducing hunger, and improving school attendance (Khama, 2022). However, as foodborne diseases continue to emerge globally, maintaining the safety and hygiene of meals prepared within school environments remains a pressing concern. Poor food-handling practices, inadequate sanitation facilities, and limited

food-safety training among food handlers have been identified as significant contributors to contamination risks in institutional meal programmes (Masia et al., 2023; WHO, 2024).

To safeguard children's health, Botswana has enacted food-safety standards and legislation, including the Food Control Act of 1993 and the National Food Safety Policy, which aim to strengthen regulatory oversight and ensure the delivery of safe, nutritious food in public institutions (Government of Botswana, 2023). Nonetheless, continuous capacity-building, regular monitoring, and adherence to hygiene standards remain essential for effective prevention of foodborne outbreaks within school feeding programmes (Botswana Youth Magazine, 2023).

Understanding food safety knowledge and practices is essential; a gap between knowledge and safe food handling can still result in contamination and illness. This study aims to assess the knowledge and practices of food handlers in schools through questionnaires and observations. The findings help identify gaps leading to outbreaks and inform targeted interventions for improvement.

### **1.1.1 Background of School Feeding Programme in Botswana**

#### **1.1.1.1 Health and education in Botswana**

Education in Botswana is provided by both public and private schools, with governance falling under the Ministry of Education and Skills Development. Education is compulsory for children within a specific age range, typically from five to eight and continuing until 16 to 18. The education system consists of seven years of primary education, three years of junior secondary education, and two years of senior secondary education. Approximately 87% of school-age children attend public schools, while 10% attend private institutions, and around 3% are homeschooled.

Health and education are fundamental pillars of human capital and crucial for an individual's economic productivity (WHO, 2001). In Botswana, health has long been a priority, closely tied to the country's Vision 2016 policy initiative, which aims to foster a healthy, compassionate population that is well-informed and actively contributing to the nation's development (Presidential Task Force, 1997). To support this vision, the

health and well-being of schoolchildren have been deemed essential, with the school health initiative first introduced in 1972 by Botswana's first community nurses. In 1999, the Ministry of Health (MOH), the Ministry of Education, and the Ministry of Local Government and Rural Development collaborated to develop the Botswana School Health Policy and Procedures Manual (MOH, 2006). This policy was designed to promote highlighting schoolchildren's health and the importance of health in the school environment.

A retrospective review by Kasule and Malungu (2009) highlighted the prevalence of acute poisoning, which primarily affected young children and accounted for an incidence rate of 3.8 cases per 100 and 1.5% of deaths over a two-year period. This emphasises the necessity of a school health programme to ensure that the school feeding initiative achieves its intended goals.

#### **1.1.1.2 School feeding programme**

The history of school feeding schemes dates to the 1930s, originating in the United Kingdom and the United States, where the aim was to provide balanced diets to children during school hours to combat hunger and improve attendance (Richter, Griesel, & Rose, 2000). Free milk has been historically offered in schools in the United Kingdom, with full subsidies introduced in 1944. Although universal access was reduced in the 1970s, free milk is still provided to children under five and those eligible for free school meals (Department for Education, 2024; Rural Payments Agency, 2024).

#### **1.1.1.3 Botswana primary school feeding programme**

Botswana's school feeding programme is recognised as one of the oldest in Africa, having been initiated by the country's first president, Sir Seretse Khama, in response to the severe famine of 1965. At that time, widespread poverty and long walking distances left many children attending school without adequate food. In April 1966, with assistance from the World Food Programme (WFP) and the United Nations, food commodities were distributed to schools and health facilities to support children's nutrition and attendance. As Botswana's economy grew, particularly following the discovery and development of diamond resources, the government progressively

assumed full responsibility for the programme between 1979 and 1987, incorporating locally sourced foods into school menus. This transition marked a shift from donor dependency to a nationally owned and sustainable initiative, which remains a cornerstone of Botswana's social protection and education policies today (Botswana Institute for Development Policy Analysis, Partnership for Child Development, & NEPAD Agency, 2013; FAO, 2013; Global Child Nutrition Foundation, 2021).

In 2008, the Letlhafula initiative was introduced, initially as a presidential directive to provide watermelon to schools during harvest seasons. By 2009, procurement guidelines were established to facilitate the supply of more agricultural produce to the school feeding programme (BAMB, 2011).

The Ministry of Local Government and Rural Development oversees the programme, collaborating with various partners, including the Ministry of Finance and Development Planning, Ministry of Education and Skills Development, Ministry of Health, Ministry of Agriculture, and the Partnership for Child Development. Despite these good intentions, the programme faces several challenges, notably the increasing incidence of foodborne illnesses in schools. Such diseases undermine the programme's goal of providing high-quality, safe food to students (Nhlapo et al.2014),

The overarching objectives of the school feeding programme include increasing primary school enrolment, alleviating short-term hunger, and ensuring every child has access to basic education. However, the government faces several challenges in achieving these goals. A study by Peter (2011) identified key barriers, such as insufficient resources to test all workers biannually, unclear roles in food safety, and gaps in microbial and chemical testing protocols. Additionally, irregular food supply, inadequate kitchen infrastructure, and insufficient food handling and preparation skills contribute to the programme's difficulties. The study also noted that the use of lead and aluminium pots, which pose health risks, including the contamination of food with toxic metals that may cause neurological damages developmental delays and adverse health effects. The lack of proper cooking areas, as well as staff shortages, further exacerbate the challenges.

### 1.1.2 Overview of foodborne illnesses in Botswana schools

Foodborne illnesses have become a significant issue in Botswana schools, frequently making headlines in local media. While it is challenging to establish an accurate picture of the situation due to underreporting, data from the *Food Control* Unit of the Ministry of Health between 1999 and 2004 indicated that 355 cases of food poisoning were reported in various parts of Botswana, including schools (Mbogeni, 2015). The continued occurrence of foodborne diseases in schools underscores the importance of improving food safety practices within the school feeding programme

**Table 1: Reported food-poisoning cases from 1999 to 2004**

| Year  | Total no of reported cases | Places                                                                                               |
|-------|----------------------------|------------------------------------------------------------------------------------------------------|
| 1999  | 355                        | Monnathoko CJSS, fast food outlet GC, Thalogang CJSS, University of Botswana, Moshupa                |
| 2000  | 485                        | Gaborone supermarket, Mamphitshane Primary School, prison, Francistown Senior                        |
| 20001 | 107                        | Bobirwa Sub District, fast food outlet Gaborone, Letlhakane, Goodhope, Taumanthe Primary School      |
| 2002  | 499                        | Naledi Secondary School, Makoba Primary School, Phatshimo CJSS, GTC, Mmashoro CJSS, Day Care Palapye |
| 2003  | 57                         | Sebele, Lobatse College                                                                              |
| 2004  | 50                         | BIAC                                                                                                 |

The above cases indicate that most incidents occurred in schools, from primary to college, underscoring the importance of focusing on this aspect in the study. There is evidence of foodborne illness in schools. A study conducted in Botswana on acute poisoning stated that food poisoning mostly involved children under the age of five at 32.9% and adults 30 years and above with 27.1%, particularly in the Gaborone health district, 44.7% followed by the southeast district, with 37.6%. According to the findings of the study, all cases were accidental, with more than 60% requiring hospitalisation. This study also revealed that food toxins contribute to 14.4% of cases of acute poisoning (Kasule & Malangu, 2009).

### **1.1.3 Food safety measures and strategies in Botswana**

Botswana has established a comprehensive food safety framework through national legislation and standards to protect consumers and support fair trade practices. The primary legal instrument governing food safety is the Food Control Act of 1993, which outlines requirements for regulating, monitoring, and enforcing food safety standards nationwide (Food Control Act, 1993). Under this Act, *authorised officers* are empowered to collect food samples from various sources including schools and submit them to designated laboratories for analysis to ensure compliance with safety regulations. The National Food Control Laboratory, operating under the Ministry of Health and Wellness, provides analytical services to both government and private stakeholders, supporting the enforcement of national standards and surveillance of food quality (World Health Organization, 2018; Republic of Botswana, 2023). In addition, the Botswana Bureau of Standards (BOBS) develops and maintains national food standards, which guide safety practices across the food sector (Botswana Bureau of Standards, 2024).

In addition to these legal and institutional measures, the Government of Botswana has implemented a School Health Programme aimed at safeguarding the health and well-being of schoolchildren (MOH, 2006). This initiative plays a key role in promoting public health, particularly in relation to food safety in educational settings.

#### **1.1.3.1 Food Control act and regulations**

The *Food Control* Act of 1993 is one of the cornerstone pieces of legislation that governs food safety in Botswana. It mandates the provision of clean, safe, and wholesome food for consumers. Complementing this Act is the Public Health Act of 2013, which grants environmental health officers the power to conduct inspections and enforce food safety regulations. These officers are authorised to enter and inspect food premises, including school kitchens, to ensure compliance with health and safety standards.

The Public Health Regulations (Part IV, Sections 18-36) provide detailed guidelines on food handler hygiene standards, which are critical for preventing foodborne illnesses. These regulations specify requirements for personal hygiene, protective clothing, and the prevention of communicable diseases within food preparation areas.



In addition to these standards, the regulations outline protocols for cleaning and maintaining food-handling equipment, as well as guidelines for storing materials and waste. The regulations also cover the storage of hazardous cleaning agents, waste management, proper refrigeration of food, and safe storage of raw materials to prevent contamination. Together, these measures form a robust framework that aims to protect public health by ensuring safe food-handling practices across sectors, including educational institutions. These food safety strategies, reinforced by regular inspections and adherence to stringent standards, are central to ensuring that the food provided in schools and other food service establishments remains safe for consumption and free from harmful contaminants.

## **1.2 Problem statement**

Foodborne illnesses are a significant public health concern worldwide and remain a persistent challenge in developing countries, including Botswana. Although many foodborne illness cases reported in Botswana are classified as mild or acute food poisoning, it is believed that a substantial proportion of cases remain unreported due to limited awareness and understanding of foodborne diseases among the population. The risk of foodborne illness is particularly concerning in school environments, where large numbers of learners depend on meals prepared and served through the Primary School Feeding Programme (PSFP).

The PSFP was established to alleviate short-term hunger, improve nutritional status, enhance school attendance, and support educational outcomes among primary school children. However, the success of the programme depends not only on the availability of food but also on the safety of the food provided. Foodborne diseases can negatively affect learners' health, growth, cognitive development, school attendance, and academic performance, thereby undermining the intended benefits of the programme. Previous studies in Botswana have identified several challenges affecting food safety within school feeding programmes, including inadequate food safety training, insufficient resources for routine health screening of food handlers, unclear food safety responsibilities, inadequate kitchen infrastructure, irregular food supply, and shortages of trained personnel (Peter, 2011). These challenges may increase the risk of food contamination and foodborne disease transmission within school kitchens.

Food handlers play a critical role in maintaining food safety, as improper food handling practices, poor personal hygiene, and cross-contamination have been identified as major contributors to foodborne disease outbreaks (World Health Organization [WHO], 2024). While several studies have investigated food handlers' food safety knowledge and self-reported practices, evidence suggests that possessing food safety knowledge does not necessarily translate into safe food handling behaviour. Consequently, there may be differences between what food handlers know about food safety, what they report doing, and what they actually do during food preparation and service. International studies have shown that poor personal hygiene, inadequate food safety knowledge, and unsafe food handling practices among food handlers contribute significantly to foodborne disease outbreaks in institutional settings, including schools (Scarborough et al., 2002; Mohammed et al., 2009; Millezi et al., 2011; Hui et al., 2017). However, many of these studies relied primarily on self-reported knowledge and practices and did not simultaneously assess actual food handling behaviours and microbiological contamination. Consequently, evidence remains limited regarding the relationship between food handlers' knowledge, reported practices, observed behaviours, and microbial contamination, particularly in school kitchen settings.

Despite the importance of food safety in school feeding programmes, there is limited evidence in Botswana regarding the relationship between food handlers' food safety knowledge, attitudes, reported practices, observed practices, and microbiological contamination in school kitchens. Existing studies have largely focused on programme implementation challenges and food safety knowledge but have not examined whether food handlers' knowledge and attitudes are reflected in their actual practices, nor have they objectively assessed how these practices relate to microbial contamination of food-contact surfaces and food handlers' hands. To the best of current knowledge, no study in Botswana has simultaneously assessed food handlers' knowledge, attitudes, and practices, directly observed food handling behaviours, and measured microbiological contamination in primary school kitchens.

There is therefore a critical gap in understanding the relationship between what food handlers know about food safety, what they claim to know and do, what they actually do during food preparation and service, and how these behaviours are linked to measurable microbiological contamination. In particular, Botswana lacks studies that

integrate assessments of food handlers' knowledge, attitudes, and practices with direct observational methods and microbiological investigations to objectively evaluate food safety risks in school kitchens. The absence of such evidence limits the ability of policymakers, school administrators, and public health practitioners to identify the specific behavioural and environmental factors contributing to food contamination and foodborne disease risks. Consequently, interventions may fail to address the actual drivers of contamination and may be less effective in improving food safety within school feeding programmes.

Therefore, this study seeks to address this gap by assessing food handlers' food safety knowledge, attitudes, and practices; evaluating food handling behaviours through direct observation; and determining the microbiological quality of food handlers' hands and selected food-contact surfaces in primary school kitchens. The findings will provide evidence on the relationship between food safety knowledge, attitudes, reported and observed practices, and microbiological contamination, thereby informing targeted interventions, training programmes, and policy decisions aimed at improving food safety and protecting the health of schoolchildren in Botswana.

### **1.3 Significance of this study**

The investigation into food safety knowledge and practices among food handlers in Botswana's primary schools is of paramount importance, given the critical role that safe food handling plays in safeguarding public health and enhancing educational outcomes.

The significance of this study lies in its potential to identify critical knowledge gaps and behavioural patterns that may be contributing to the persistence of foodborne illness outbreaks. Although foodborne diseases are preventable, they remain a significant public health concern globally, with food handlers as a primary vector of contamination. Prior research has consistently highlighted a deficit in food safety knowledge and practices among food handlers, particularly regarding microbiological hazards, food storage temperatures, cross-contamination prevention, and personal hygiene (Bas et al., 2006; Yand et al., 2000). As foodborne illness outbreaks often stem from lapses in these areas, addressing these gaps could substantially reduce the incidence of foodborne diseases.

The role of education and training in food safety cannot be overstated. The relationship between knowledge acquisition and behaviour change in food handlers has been widely documented. Yand et al. (2000) demonstrated that comprehensive customer and food handler education programmes were effective in decreasing the incidence of foodborne infections by enhancing awareness of safe food handling practices. Furthermore, studies have indicated that when food handlers are provided with ongoing, rigorous training that emphasises the practical application of food safety principles, they are more likely to internalise the information and adopt safer behaviours in the workplace (Al-Haddad et al., 2019). Given the dynamic nature of foodborne pathogens and the evolving understanding of food safety science, continuous education is critical for maintaining high standards of food safety in food service environments.

In addition, empirical evidence suggests that food handlers often have insufficient knowledge of critical food safety practices, including the correct storage temperatures for perishable foods, prevention of cross-contamination, and proper hand hygiene, all of which contribute to the occurrence of foodborne disease outbreaks (Lee et al., 2017; Zanin et al., 2017). This study builds on these findings by exploring specific areas where knowledge deficiencies exist, such as the safe use of food thermometers, understanding the temperature danger zone, and the importance of effective hand hygiene. Additionally, this study investigates how food handlers' attitudes toward food safety influence their adherence to recommended food safety protocols. Research has demonstrated that attitudes such as complacency or a lack of awareness of the severity of foodborne risks often act as barriers to the implementation of safe food-handling practices (Teffo & Tabit, 2020).

Another key element of this study is the investigation of systemic factors that influence food handlers' knowledge and behaviour. These factors include organisational culture, the availability of resources such as training, infrastructure, and protective equipment, and the regulatory environment in which food handlers operate. As noted by Pai et al. (2024), organisational dynamics such as management commitment, leadership practices, and the overall food safety culture play a crucial role in shaping food handlers' ability and motivation to implement safe food handling practices. Even well-trained food handlers may struggle to comply with safety standards when working in

environments characterised by inadequate facilities, limited supervisory support, or inconsistent enforcement of hygiene protocols. Therefore, this study also examines how contextual and institutional factors shape food safety practices and identifies opportunities for systemic improvement.

This research is significant as it adds to the body of food safety knowledge in Botswana, which has mainly relied on self-reported knowledge and practices of food handlers, through the use of behavioural and microbiological studies to assess hygiene practices in school feeding schemes. Although existing research has primarily emphasised self-reported awareness and practices, this study extends this by comparing these with observed practices and linking them to quantitative microbial contamination markers. This multi-dimensional approach offers a better understanding of food safety hazards in school canteens. The insights will inform evidence-based strategies by pinpointing the key behavioural and environmental factors contributing to contamination, and thus assist in the design of targeted training, enhanced hygiene monitoring and improved policies for food safety that will help ensure the health of school children.

### **Research aim**

To evaluate the relationship between food safety knowledge reported and observed practices on food handling and preparation, and microbial hand contamination as an indicator of hygiene practices among food handlers in public primary school kitchens in Gaborone city.

### **Other objectives**

To determine the level of food safety knowledge among food handlers in public primary school kitchens.

To evaluate self-reported and observed food safety practices among food handlers within the selected study area; To compare self-reported practices with observed ones to identify behavioural gaps among.

To determine the prevalence and levels of microbial contamination such as *E. Coli* and total coliforms on the food handlers' hand.

### **Structure of the study report**

This report is presented in chapters that comprise the following information:

**Chapter 1:** General introduction and outline of the school feeding programme in Botswana, statement of the problem, and study aim and objectives

**Chapter 2:** A review of the related literature that was consulted

**Chapter 3:** Study methodology, design, and results: Food safety knowledge and practices of food handlers in public primary schools in Botswana

**Chapter 4:** Study methodology, design and results: Assessment of hand hygiene among food handlers in public primary school. A microbial evaluation of using *E. coli* and total coliform bacteria.

**Chapter 5** General conclusion, summative remarks, and recommendations for future research.

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## **CHAPTER TWO: LITERATURE REVIEW – FOOD SAFETY KNOWLEDGE, PRACTICES, AND MICROBIAL HAND HYGIENE OF FOOD HANDLERS**

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### **2.1 Introduction**

Food hygiene and hand hygiene practices are the two most critical factors ensuring food safety. According to Murwira et al. (2015), personal hygiene and health surveillance play a significant role in ensuring the wholesomeness of food, as each aspect contributes to the overall quality. It was reported that half of foodborne-related diseases from the early 1990s were associated with outbreaks in institutions and schools, mostly due to unhygienic procedures (Soon et al., 2011).

### **2.2 Food poisoning**

Food poisoning is a gastrointestinal disorder that occurs when individuals consume food or drink contaminated with harmful substances, including bacteria, viruses, pesticides, or toxins (Unnevehr et al., 2000; WHO, 2015). The condition arises from exposure to these toxic agents, with the severity of the effects depending on the body's reaction to the contaminants and the type of food consumed. Exposure to foodborne toxins can occur via ingestion, direct skin contact (transdermal), or inhalation (Montville & Matthews, 2008). Such exposure may be either accidental or intentional (Persson et al., 1998).

Deliberate food poisoning, also known as food terrorism, occurs when an individual intentionally contaminates food or drink with toxic substances to cause harm or attract attention (Woolf & Maxey, 2007). Such incidents have been documented globally, ranging from targeted acts against individuals to broader public contamination events. Several published risk assessments describe cases where chemicals or toxic agents were deliberately added to food products in retail environments, highlighting the vulnerability of the food system to intentional adulteration (Gale, 2015).

In contrast, accidental food poisoning occurs when individuals unknowingly ingest contaminated food or drink, without any intention to harm themselves (Meyer et al., 2007). A study by Kasule (2009) found that all foodborne illness cases identified were

accidental. Poverty was identified as a significant factor contributing to the unintentional consumption of unsafe food, which increases the risk of foodborne diseases. Additionally, food safety challenges are often exacerbated by unsanitary living conditions in rapidly growing urban areas, lack of access to clean water, inadequate food storage and transport practices, and low levels of education among both consumers and food handlers (Mensah et al., 2012).

### **2.3 Microorganisms of concern in the food industry**

Bacteria are among the most prevalent microorganisms responsible for food poisoning. Notable pathogens include *Bacillus cereus*, *Clostridium botulinum*, *Vibrio cholera*, *Escherichia coli*, and *Shigella* species, among others, which produce toxins that lead to foodborne intoxication. Even if these bacteria do not proliferate in food, they can still be present and contribute to outbreaks of diseases such as dysentery (Iwamoto et al., 2019; Weiler et al., 2011). The most common symptom of food poisoning is diarrhoea, which affects approximately 550 million people annually and causes around 230,000 deaths worldwide (WHO, 2015).

Botswana, known for its strong beef industry, is largely free from many tropical diseases typically associated with heavy rainfall. However, foodborne illnesses in the country are primarily linked to poor food-handling practices and a lack of awareness of food safety (Urio, 2001).

#### **2.3.1 *Escherichia coli* (*E. coli*)**

*Escherichia coli* (*E. coli*) is a Gram-negative, facultative anaerobic bacterium naturally present in the gastrointestinal tracts of humans and warm-blooded animals. While many *E. coli* strains are harmless or even beneficial (when playing roles in vitamin K synthesis and competitive exclusion of pathogenic microbes), some strains are pathogenic and can cause significant illness. One of the most clinically significant groups of pathogenic *E. coli* is the Shiga toxin-producing *E. coli* (STEC), which produces potent cytotoxins known as Shiga toxins. Among STEC, *E. coli* O157:H7 is the best-known and most virulent serotype. It can cause severe gastrointestinal illness, including hemorrhagic colitis, and may lead to life-threatening complications such as

hemolytic uremic syndrome (HUS), particularly in young children, the elderly, and immunocompromised individuals.

*E. coli* contamination can occur at any stage of the food production chain from farm to fork and is often attributed to poor hygiene, inadequate food handling, or cross-contamination. Transmission to humans typically occurs through ingestion of faecally contaminated food or water, or via direct contact with infected animals or persons. High-risk foods include undercooked ground meat, raw milk, unpasteurised dairy products, and raw fruits and vegetables (Willshaw et al., 2000). Consequently, proper food handling, cooking, and sanitation practices are crucial in reducing the risk of infection.

Recent empirical studies in Botswana have shed light on the presence and characteristics of *E. coli* in local food systems, reinforcing concerns about its public health impact. A 2024 study conducted in the Chobe District examined 207 fresh produce samples from local markets and detected *E. coli* in 15.5% of the samples (Bywater et al., 2024). While classical Shiga toxin genes (*stx1*, *stx2*) were not detected, the *eae* gene, associated with the attaching and effacing phenotype of enteropathogenic *E. coli*, was detected in 1.5% of the isolates. Alarming, 72% of the *E. coli* isolates demonstrated resistance to at least one antibiotic, with 18% classified as multidrug-resistant (MDR), defined as resistance to three or more antimicrobial classes.

In a complementary study focusing on poultry in the same region, molecular characterisation revealed both virulence-associated genes and significant antimicrobial resistance in *E. coli* strains isolated from chicken meat and cloacal swabs (Yi et al., 2024). These findings position poultry as an additional reservoir and vector of potentially pathogenic, drug-resistant *E. coli* strains in the local food supply.

These results deepen the understanding of *E. coli*-related food safety risks in Botswana. Although classical STEC strains like O157:H7 were not detected in the analysed produce, the presence of virulence markers like *eae* and high levels of antimicrobial resistance present notable concerns. The combination of zoonotic transmission potential, food chain contamination, and therapeutic challenges underscores the importance of routine surveillance, food safety training for vendors

and handlers, and the implementation of antibiotic stewardship programmes. Together, these measures are critical in preventing the spread of pathogenic and resistant *E. coli* in both urban and rural communities.

### **2.3.2 *Listeria monocytogenes***

*Listeria monocytogenes* is a pathogen uniquely capable of multiplying at low temperatures (near refrigeration), surviving harsh conditions such as high salt, acidity, and even disinfectant exposure, as well as forming biofilms, all of which enable it to persist in food processing environments. Infection (listeriosis) poses serious risks to pregnant women (including miscarriage or neonatal infection), neonates, older adults, and immunocompromised persons. Common sources include ready-to-eat (RTE) meats, unpasteurised dairy, soft cheeses, and processed or cold meats.

A 2022 survey of ready-to-eat foods in the Eastern Cape province of South Africa collected 239 samples; *L. monocytogenes* was found in 44.77% of them. The most contaminated items included processed meat products such as Russian sausages (78.6%), sliced polony, muffins, and pies. Importantly, although prevalence was high, the bacterial loads were typically below 100 CFU/g. Molecular testing revealed extensive presence of virulence genes (such as *inlA*, *inlB*, *hlyA*, *plcA*, *actA*) and that approximately 69.1% of isolates were capable of forming biofilms (varying from weak to strong) (Kayode & Okoh, 2022). Another recent study in South Africa's beef product sector found *L. monocytogenes* in 9.3% of beef and beef-derived products, including 6.9% of ready-to-eat items, highlighting that the risk remains post-processing and at the retail level (Food Safety News, 2023; University of Pretoria, 2023). In fresh produce and food processing environments in the Western Cape, *Listeria* isolates were predominantly lineages I and II, with 57% of isolates belonging to lineage I. There was also a statistically significant association between lineage I and fresh produce. Genetic characterization identified serotypes 1/2a, 1/2b, and 4b among the isolates (du Toit, Gouws & Rip, 2025).

### **2.3.3 *Salmonella* spp.**

*Salmonella* species are among the primary bacterial agents responsible for causing foodborne illness worldwide, leading to salmonellosis. Transmission typically occurs



through the consumption of undercooked meat, poultry, and eggs; however, raw fruits and vegetables can also serve as vectors, particularly when cross-contaminated or handled with unclean hands or surfaces. Contamination risk increases when food is stored at ambient temperatures, hygiene is poor or slaughtering and processing facilities lack robust sanitation practices.

Recent regional data reinforce these concerns and refine the understanding of prevalence, virulence, and antimicrobial resistance profiles in Southern Africa. In Botswana, a 2022 study of 207 produce samples sourced from retail outlets in the Chobe District found *Salmonella enterica* in 3.4% of samples (7/207). Only one of those isolates displayed antibiotic resistance, indicating that while the prevalence is modest, there remains potential for resistant strains in produce consumed raw (Bywater et al., 2024). A related survey in the Chobe region, which sampled food, food waste, and water, similarly isolated *Salmonella* from produce at low rates, further highlighting that even low prevalence in raw foods can pose a risk, particularly in communities relying on fresh produce (Bywater, 2023).

In South Africa, studies focusing on poultry offal and informal market chickens provide more detailed evidence of both the prevalence and properties of *Salmonella* in commonly consumed meat products. A 2023 study of 446 retail poultry offal samples from KwaZulu-Natal province found *Salmonella* in 2.91% of the samples. Serovars identified included *S. Enteritidis*, *S. Heidelberg*, *S. Infantis*, *S. Mbandaka*, and *S. Typhimurium*. Notably, all isolates harboured several virulence genes (*invA*, *agfA*, *lpfA*, *sivH*), while resistance to amoxicillin, kanamycin, chloramphenicol, and oxytetracycline was observed in *S. Typhimurium* and *S. Mbandaka* isolates (Ndlovu et al., 2023). Parallel to this, a 2024 study from Gauteng informal markets assessed chickens using cloacal swabs, carcasses, and drips (n = 151 samples) and found *Salmonella* spp. with a range of virulence genes. The most common virulence genes were *invA* (100% of isolates), *shdA* (91%), *mgtB* (87.7%) and *sopE* (81%). Regarding resistance, genes conferring tetracycline resistance (*tetA*, *tetB*) were relatively common, while resistance to beta-lactams and quinolones was less frequent in that sample set (Mokgophi et al 2024).



#### **2.3.4 *Campylobacter* spp.**

*Campylobacter* spp., particularly *Campylobacter jejuni* and *Campylobacter coli*, are among the most common causes of bacterial gastroenteritis globally, including in sub-Saharan Africa. Transmission typically occurs through the consumption of undercooked poultry, unpasteurised dairy products, untreated water, or food contaminated during handling and preparation. Young children, immunocompromised individuals, and the elderly are particularly vulnerable to infection (Phosa et al., 2022). In Botswana, research on the burden of *Campylobacter* is limited but informative. A study by de Vries et al. (2018) found that approximately 14% of paediatric diarrhoeal cases were attributable to *Campylobacter* spp., with evidence pointing to both *C. jejuni* and *C. coli* as contributors. Molecular analysis in that study also showed genetic similarities between isolates from children and chickens, indicating zoonotic transmission, particularly from poultry. Regional data from South Africa support these findings. Phosa et al. (2022) conducted a study on informal poultry markets in Gauteng province and reported *Campylobacter* in 23.4% of samples using culture methods, and over 90% when tested by PCR. Isolates carried multiple virulence genes (e.g., *ciaB*, *flaA*, *racR*) and toxin genes (*cdtA*, *cdtB*, *cdtC*), and tetracycline resistance genes (*tetO*) were frequently detected, particularly in *C. coli*. This raises concerns regarding the therapeutic management of campylobacteriosis in humans. Similarly, a study conducted in the Northwest province of South Africa found *C. jejuni* in broiler chicken faecal samples collected from commercial abattoirs and confirmed varying degrees of antimicrobial resistance (Mileng et al., 2021). These findings underscore the public health threat posed by *Campylobacter*, particularly given the region's high poultry consumption and the emergence of antimicrobial-resistant strains. There is a clear need for improved surveillance, increased public awareness of safe food handling, and prudent antibiotic use in livestock production systems across Southern Africa.

#### **2.3.5 *Staphylococcus aureus***

*Staphylococcus aureus* is commonly found on the skin and in the respiratory tracts of healthy individuals. Although it is generally harmless, it can occasionally cause skin infections, such as acne or boils. This bacterium has also been detected in cows, dogs, and birds. Methicillin-resistant *Staphylococcus aureus* (MRSA) strains have been

identified in cases of skin and soft tissue infections (SSTIs) in Gaborone, raising concern in Botswana (Truong et al., 2011).

### **2.3.6 *Shigella* spp.**

*Shigella* species are the causative agents of shigellosis (bacillary dysentery), a highly contagious disease that can be transmitted through the ingestion of small amounts of bacteria via the fecal–oral route. Transmission commonly occurs through contaminated hands, food, water, or surfaces, particularly in settings with poor sanitation and suboptimal hygiene practices. Recent data continue to demonstrate a moderate but concerning prevalence of *Shigella* spp. across Africa. A systematic review and meta-analysis of studies from 2015 to 2022 in East Africa found a pooled prevalence of *Shigella* spp. of about 6.2% in various populations (children, diarrheal patients, asymptomatic food handlers), with some country-level variation (e.g., ~14.6% in Kenya, ~4.0% in Ethiopia, ~0.7% in Sudan) (Ayele, 2023).

Another broader meta-analysis focusing on the African continent estimated a pooled *Shigella* prevalence of 5.9% (95% CI: 4.9–7.0%) and also documented rising resistance to commonly used antibiotics such as ampicillin, trimethoprim-sulfamethoxazole, chloramphenicol, and tetracycline; however, resistance to drugs like ciprofloxacin and ceftriaxone was still relatively low in many settings (Africa pooled data) (Tadesse, 2017).

Studies among food handlers and in food establishments point to their role in transmission. For example, in Adigrat University (northern Ethiopia), 3.7% of food handlers were carriers of *Shigella* spp., and all *Shigella* isolates were resistant to ampicillin, while showing lower resistance to ceftriaxone and ciprofloxacin among other antibiotics (Legese et al., 2020). In another study in Yabelo Town, Southern Ethiopia, 3/396 food handlers (~0.76%) tested positive for *Shigella*, with the isolates susceptible to most drugs tested except ampicillin (which all were resistant to) (Gemuchu & Aliyo 2023).

These findings have several implications. First, even though prevalence in many settings is not extremely high, a public health risk. Second, high rates of resistance to first line and commonly used antimicrobials (ampicillin,

trimethoprim-sulfamethoxazole, etc.) limit treatment choices and increase the burden on healthcare systems. Third, the data show that food handlers are a significant potential source of transmission, particularly in institutions (schools, universities, cafeterias) and food service settings, underscoring the need for hygiene training, routine screening, and surveillance of antimicrobial resistance.

## **2.4 Chemical contaminants in food**

Food poisoning is not limited to microbial pathogens; it can also result from the ingestion of harmful chemical contaminants. These include agricultural chemicals such as pesticides, herbicides, and fungicides, as well as veterinary drug residues, food additives, colorants, preservatives, and heavy metals. Unlike bacterial food poisoning, which results from the ingestion and proliferation of pathogens in the gastrointestinal tract, chemically induced food poisoning occurs when toxic substances enter the body and disrupt physiological functions. Short-term (acute) exposure can lead to symptoms such as nausea, vomiting, abdominal pain, dizziness, and, in severe cases, neurological or cardiovascular impairment. Long-term (chronic) exposure, often due to cumulative ingestion of low-level contaminants, has been linked to cancers, endocrine disruption, reproductive disorders, and developmental toxicity (WHO, 2022; EFSA, 2020).

In some regions, intentional misuse of chemicals for food procurement further amplifies risks. For example, in Southern Africa, toxic organochlorine pesticides such as lindane and thiosulfan have been illegally used to catch fish in rivers, contaminating aquatic food sources and posing serious health risks to local communities (Bernett, 2005). Similarly, carbofuran, a highly toxic carbamate pesticide banned or restricted in many countries, has been used in East Africa to poison bushmeat for hunting purposes (Odino et al., 2008). These actions introduce potent neurotoxins into the food chain, endangering both consumers and ecosystems.

Additionally, contaminated irrigation water, polluted soils, and improper storage practices can lead to heavy metal contamination in fruits, vegetables, and grains. In urban and peri-urban agriculture, the use of untreated wastewater for irrigation can expose food to lead, arsenic, cadmium, and mercury, all known to cause serious health effects even at low exposure levels (FAO & WHO, 2019). Thus, chemical food

poisoning poses a multifaceted challenge, requiring regulatory oversight, public education, and ongoing monitoring throughout the food supply chain.

## **2.5 Prevalence and occurrence of foodborne poisoning and outbreaks**

### **2.5.1 Global perspective**

Foodborne diseases (FBDs) represent a significant global public health burden, affecting all regions and income levels. According to the WHO (2015), approximately 600 million people, or nearly 1 in 10 individuals worldwide, fall ill each year from contaminated food. Of these, an estimated 420,000 die annually, with children under five years old accounting for 125,000 deaths, almost 30% of the global mortality burden, despite representing only 9% of the global population. The burden is disproportionately concentrated in low- and middle-income regions, particularly in Africa and Southeast Asia, where both the incidence and fatality rates are highest (WHO, 2015).

The six WHO African regions bear the heaviest foodborne disease burden globally, with over 91 million illnesses and 137,000 deaths reported annually. Diarrhoeal diseases, largely caused by *non-typhoidal Salmonella*, *E. coli*, and *norovirus*, account for over 70% of this burden (WHO, 2015; PAHO, 2015). The Southeast Asia region follows closely, with more than 150 million cases and 175,000 deaths reported annually. Notably, 60 million children under five years old are estimated to be affected in this region alone, resulting in approximately 50,000 fatalities each year.

The Eastern Mediterranean region experiences over 100 million foodborne illnesses annually, with around 37,000 associated deaths, including a large proportion of children (WHO EMRO, 2015). In contrast, the region of the Americas, comprising both North and South America, shows a relatively lower burden with 77 million illnesses and 9,000 deaths annually. The European region, benefiting from robust surveillance and food safety systems, reports approximately 23 million illnesses and 5,000 deaths per year. Similarly, the Western Pacific region reports approximately 125 million illnesses and 50,000 deaths, with aflatoxin contamination of staple foods, such as maize and groundnuts, being a significant contributing factor (WHO, 2015).

In high-income countries, foodborne illness surveillance is more comprehensive. For example, in Australia, a national study identified 293 outbreaks between 1995 and 2000, of which 61% were bacterial, primarily *Salmonella*, resulting in 20 deaths (Craig et al., 2019). Likewise, in the United States, between 1998 and 2008, there were 13,405 reported outbreaks causing 273,120 illnesses, 9,109 hospitalisations, and 200 deaths. Viruses and bacteria each accounted for approximately 45% of these cases, while the remaining 10% were attributed to chemicals, parasites, and toxins (Gould et al., 2023).

Despite these figures, the true global burden of foodborne diseases is likely underestimated, particularly in low-income regions where surveillance, laboratory confirmation, and reporting systems are weak. Underreporting is a significant limitation, often driven by limited access to healthcare, insufficient diagnostic capacity, and the absence of national foodborne disease monitoring frameworks (Anelich & Lues, 2024; Jiya & Balogu, 2023). The COVID-19 pandemic has further strained food safety systems, impacting inspection, monitoring, and food supply chains globally, particularly in vulnerable economies.

Collectively, the global distribution of foodborne diseases underscores the urgent need for context-specific interventions, improved surveillance systems, and international cooperation to mitigate their burden. Strengthening food safety policies and enhancing awareness among food handlers, particularly in developing regions, remain key strategies to reducing illness and mortality associated with unsafe food.

### **2.5.2 African perspective**

Foodborne diseases and food poisoning represent a critical yet often underrecognised public health burden across Africa. According to the WHO (2023), the African region bears the highest global burden of foodborne diseases, with a mortality rate of 16 deaths per 100,000 population, which is 32 times higher than that of Europe. Each year, an estimated 137,000 deaths are attributed to foodborne illnesses across the continent, with diarrhoeal diseases alone causing up to 700,000 deaths annually, particularly affecting young children who may experience up to five episodes per year (WHO, 2023). Despite these alarming statistics, the actual prevalence remains largely

unknown due to widespread underreporting, inadequate surveillance systems, and the predominance of informal food markets (Anelich & Lues, 2024).

Africa's 55 countries exhibit vast cultural, infrastructural, and economic diversity, yet they share common systemic challenges that exacerbate food safety risks. Anelich & Lues (2024) identify *Salmonella spp.*, *Escherichia coli*, *Campylobacter*, and *Shigella* as significant microbial hazards, along with chemical contaminants such as mycotoxins and pesticide residues. The informal nature of many food systems, coupled with limited enforcement of food safety regulations, contributes to widespread contamination of food and water.

Jiya & Balogu (2023) describe food poisoning in Africa as a “silent epidemic”, driven by rapid urbanisation, population growth, weak institutional frameworks, and poorly regulated food imports. Their review highlights how infrastructural deficiencies and inadequate regulatory oversight create favourable conditions for both microbial and chemical contamination. A notable example is South Africa's 2017–2018 listeriosis outbreak, which affected 674 individuals and resulted in 183 deaths, with the majority of cases concentrated in the provinces of Gauteng, Western Cape, and KwaZulu-Natal. Additionally, outbreaks of *Vibrio cholerae*, *Shigella flexneri*, *Bacillus anthracis*, and *E. coli* O157:H7 have been documented across multiple African countries (Jiya & Balogu, 2023).

In Southern Africa, these trends are reflected in more localised and systematic studies. For instance, a review of foodborne outbreaks reported to South Africa's National Institute for Communicable Diseases documented 327 outbreaks between 2013 and 2017, affecting over 11,000 individuals and resulting in 49 deaths (Shonhiwa et al., 2018). These outbreaks were most common during warmer months and were frequently linked to *Salmonella* species found in stool and food samples. Similarly, Bisholo et al. (2018) reported a 27.3% prevalence of foodborne illness in rural households in the Eastern Cape, yet clinic records during the same period noted only four cases, underscoring the severe underreporting of foodborne diseases in public health records.

Other studies across the continent highlight the varied causes and outcomes of food poisoning incidents. Malangu (2011) examined acute poisoning patterns in Botswana,

South Africa, and Uganda, identifying household chemicals and agrichemicals as leading contributors to fatalities. While case fatality rates remained consistent across the three countries at around 2%, the demographic profiles and types of toxic agents varied significantly, reflecting contextual differences in exposure and risk.

Further north, a One Health study by Gobena et al. (2024) in Ethiopia linked foodborne pathogens to environmental and food contamination associated with child diarrheal cases. This study not only confirmed the presence of bacterial pathogens in food and environmental samples but also highlighted poor sanitation and hygiene practices as contributing factors. The economic implications are also stark; Ethiopia alone incurs an estimated USD 723 million in annual losses due to foodborne illnesses caused by three key pathogens (Food Business Africa, 2024).

Despite the severity of the issue, foodborne disease surveillance in Africa remains weak. Anelich & Lues (2024) emphasise that few countries maintain comprehensive and functioning food safety systems. There is a lack of reliable laboratory infrastructure, inconsistent outbreak reporting, and limited epidemiological data. Although food safety culture is beginning to emerge in some African countries, widespread gaps remain in public awareness, food legislation, and institutional enforcement capacity.

### **2.5.3 Southern African perspective**

Foodborne diseases and acute poisoning constitute significant public health challenges across Southern Africa, characterised by diverse aetiologies, varying exposure routes, and systemic weaknesses in surveillance and response mechanisms. Studies from South Africa, Botswana, Lesotho, Namibia, and Eswatini collectively highlight the multifaceted nature of these risks and their profound impacts on health systems and vulnerable populations.

In South Africa, surveillance data reported by Shonhiwa et al. (2018) documented 327 foodborne disease outbreaks between 2013 and 2017, involving over 11,000 illnesses, 494 hospital admissions, and 49 deaths. These outbreaks were predominantly reported in the provinces of KwaZulu-Natal, Gauteng, and Mpumalanga. Despite foodborne diseases being notifiable conditions, underreporting



and inconsistent outbreak investigations were evident, with *Salmonella* species frequently isolated but hindered by gaps in sample collection and record-keeping. Complementing these findings, Bisholo et al. (2018) found that in rural Eastern Cape, 27.3% of households experienced foodborne illness, yet official clinic registers recorded only four cases, underscoring significant under-detection and limited healthcare utilisation in rural settings.

Botswana and Uganda present distinct poisoning profiles. Malangu's (2011) comparative study of 1,780 poisoning cases across Botswana, South Africa, and Uganda revealed that most incidents in Botswana and South Africa were accidental, largely involving children under 12 years, whereas intentional poisonings were more common in Uganda. The case fatality rates were 2.6% in Botswana, 2.4% in South Africa, and 1.4% in Uganda. Toxic agents varied: household chemicals and pharmaceuticals predominated in Botswana and South Africa, while agrochemicals were more prevalent in Uganda, reflecting differing socioeconomic contexts and substance availability. Kaswa (2024) further emphasised the vulnerability of children under six in Botswana, where pharmaceuticals and natural toxins were leading causes of acute poisoning, highlighting the urgent need for improved emergency management and preventive strategies.

Expanding beyond these countries, recent studies from Lesotho, Namibia, and Eswatini reinforce the persistence of food safety risks throughout Southern Africa. In Lesotho's Leribe District, Ratsiu et al. (2025) investigated a 2021 outbreak linked to pork liver consumption, reporting symptoms including vomiting, dizziness, and confusion, with arsenic contamination confirmed in liver samples and one fatality among six cases. This outbreak underscores chemical poisoning risks associated with informal meat sources, a concern corroborated by Seeiso (2010) survey, which found elevated microbiological contamination in meat from informal slaughterhouses and butcheries.

Namibia faces similar challenges, particularly in urban food vending. Ndume et al. (2018) detected unsafe levels of *E. coli*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella*, and other pathogens in street-vended ready-to-eat meats in Windhoek. The prevalence of diarrheal diseases in children under five is also notable, with Mupambireyi & Moyo (2020) reporting that approximately 23.8% of



children in the Engela District experienced acute diarrhoea in the preceding two weeks, likely linked to poor water, sanitation, and food hygiene conditions. Additionally, Nauerby et al. (2012) reported *Salmonella* contamination in animal feed, indicating risks extending into the food production chain.

In Eswatini, while quantitative data on foodborne disease prevalence remain limited, ongoing initiatives reflect growing awareness of food safety risks. The Food and Agriculture Organization (FAO) and WHO have partnered with Eswatini's government to strengthen food safety governance, a priority given the country's high food insecurity levels that exacerbate exposure to unsafe food (FAO, 2025; WHO Africa, 2023; WFP, 2023).

Regional outbreaks of cholera further illustrate environmental and infrastructural vulnerabilities. Zambia experienced severe cholera outbreaks resulting in over 400 deaths and 10,000 infections, exacerbated by heavy rains and inadequate sanitation infrastructure (AP News, 2023). Similarly, Malawi's worst cholera outbreak in two decades caused 750 deaths and over 22,000 cases, driven by poor sanitation and climate change effects (AP News, 2023). South Africa's 2017 to 2018 listeriosis outbreak remains the deadliest globally, with 1,060 confirmed cases and 216 deaths, largely linked to contaminated processed meats.

Collectively, these studies reveal a consistent pattern: Southern Africa endures a substantial burden of foodborne diseases and poisoning amplified by underreporting, limited surveillance capacity, and socio-economic determinants such as informal food markets, inadequate infrastructure, and weak regulatory enforcement. Children and other vulnerable populations disproportionately bear this burden. There is a critical need for enhanced epidemiological surveillance, public health interventions, improved food safety education, and context-specific regulatory frameworks to mitigate these risks.

#### **2.5.4 Botswana context: Foodborne disease and acute poisoning**

Foodborne diseases in Botswana represent a growing public health concern, yet their true burden remains largely obscured by limited surveillance infrastructure, underreporting, and inadequate diagnostic capacity. While national health data

increasingly recognise the relevance of foodborne diseases, much of the available evidence suggests that cases remain clinically diagnosed without laboratory confirmation, contributing to gaps in both detection and response (Dargahi et al., 2024). From 2020 to 2022, reported foodborne outbreaks increased markedly from 12 to 73 outbreaks, with food consistently implicated as the primary source. However, in the absence of a dedicated national foodborne disease surveillance system and with minimal microbiological testing, these figures likely underestimate the actual burden (Dargahi et al., 2024).

Hospital-based studies offer further insight into foodborne illnesses and poisonings in Botswana. Malangu (2005) documented that food poisoning accounted for 8.5% of 116 acute poisoning cases admitted to referral hospitals in Gaborone and Francistown, with most incidents being accidental and involving children. Similarly, a retrospective review by Kasule & Malangu (2009) of 590 poisoning cases across three health districts found that food was the fourth most common toxic agent, implicated in 14.4% of cases, after pharmaceuticals (26.6%), natural toxins (25.6%), and household chemicals (14.6%). Children under 6 years old accounted for 33.4% of all cases, and ingestion was the predominant route of exposure. The overall case fatality rate was 3.8%, and intentional poisoning was found to be more prevalent among adolescent girls compared to boys (Malangu, 2005). These findings illustrate patterns of demographic vulnerability, particularly among young children, and highlight the need for age-specific public health interventions.

Despite the growing number of outbreaks, the episodic and poorly documented nature of foodborne incidents in Botswana has impeded systematic response efforts. Diagnostic testing is rarely conducted, and clinical records often lack sufficient detail to guide preventive strategies. Moreover, the country's surveillance systems for poisoning are not designed to track foodborne-specific toxic agents, making it difficult to assess trends or coordinate multisectoral responses (Kasule & Malangu, 2009; WHO, 2023).

The broader African context echoes many of these challenges. According to the WHO (2023), Africa bears the highest global mortality rate from foodborne illness, with an estimated 137,000 deaths annually, or 16 deaths per 100,000 people, a mortality rate 32 times higher than in Europe. This disproportionate burden is driven by weak food

safety systems, informal food markets, and environmental factors, including climate-related disruptions to water and sanitation infrastructure (Anelich & Lues, 2024; Jiya & Balogu, 2023). Studies across the continent, including in South Africa and Uganda, have demonstrated the role of both unintentional and intentional poisonings, often affecting vulnerable populations such as children and women (Malangu, 2011; Bisholo et al., 2018).

While Botswana's relative economic and infrastructural stability may shield it from some of the more severe outbreaks experienced in neighbouring countries, the lack of robust surveillance, public education on food safety, and limited laboratory capacity continue to hinder timely and effective responses. Targeted investments in diagnostic infrastructure, community awareness, and integrated food safety governance are urgently needed to better capture the burden of foodborne illness and reduce preventable morbidity and mortality, particularly among children under 12.

## **2.6 Role of food handlers in food safety**

### **2.6.1 Association of food handlers with foodborne disease outbreaks**

Food handlers play a vital role in safeguarding food safety, as their behaviours and hygiene practices directly influence the risk of food contamination and the transmission of foodborne pathogens. Improper handling, such as inadequate hand hygiene, cross-contamination through utensils or surfaces, and unsafe temperature control, can significantly contribute to foodborne disease outbreaks (Tadesse et al., 2020). Recent studies emphasise that lapses in personal hygiene and sanitation among food handlers remain a significant global concern, particularly in developing countries, where training and monitoring are often insufficient (Alemayehu et al., 2020; WHO, 2023).

Evidence shows that a substantial proportion of food handlers do not adhere to adequate hygiene practices. For instance, only about 50.7% of food handlers in sub-Saharan Africa demonstrated good hygiene practices, with lack of education, training, and medical screening identified as key barriers (Kibret et al., 2024). Alemayehu et al. (2020) found that fewer than half (46.7%) of Ethiopian food handlers practised proper food hygiene, with educational level and work experience significantly influencing

compliance. Training interventions have proven effective in improving food safety knowledge and practices, although behavioural change remains a challenge (Soon et al., 2020). Therefore, food handlers' adherence to personal hygiene, such as regular handwashing, the use of protective clothing, and avoidance of food preparation when ill, along with continuous food safety education and supervision, is a critical component in minimising the risk of foodborne disease outbreaks (WHO, 2023).

### **2.6.2 Personal hygiene**

Personal hygiene is a cornerstone of food safety and a crucial element in preventing the transmission of foodborne diseases in food service establishments. The increasing number of foodborne outbreaks globally underscores the crucial importance of maintaining proper hygiene among food handlers, as hands remain a primary vehicle for microbial contamination. Studies conducted across various regions have demonstrated that the prevalence of good hygiene practices among food handlers remains below optimal levels. For instance, a systematic review conducted in the Amhara region of Ethiopia reported that only 48% of food handlers practised proper hygiene, with poor access to handwashing facilities and lack of training being significant determinants (Fenta & Tadesse, 2022). Similarly, a meta-analysis across sub-Saharan Africa found that just over half (50.68%) of food handlers demonstrated satisfactory hygiene practices, emphasising the persistent challenge of limited training, negative hygiene attitudes, and inadequate medical screening (Kibret et al., 2024).

Personal hygiene in food handling encompasses practices such as regular handwashing, wearing clean protective clothing, maintaining short fingernails, avoiding jewellery, covering hair, and refraining from handling food when ill (Department of health Victoria, n.d.). Despite its apparent simplicity, hand hygiene remains one of the most critical yet often neglected practices. Recent evidence shows that even when knowledge is sufficient, compliance remains inconsistent. A multicountry European study observed substantial variations in handwashing frequency and technique among domestic and commercial food preparers (Mihalache et al., 2023). Furthermore, environmental and infrastructural factors play a vital role, as the absence of accessible handwashing stations increases the likelihood of poor hygiene behaviours by nearly fivefold (Berhanu et al., 2022). Structured and

continuous food safety training has been shown to significantly improve both knowledge and attitude toward hygiene, with training interventions producing notable improvements in understanding and compliance (Soon et al., 2020; Stedefeldt et al., 2024). However, sustaining these behavioural changes requires regular supervision, reinforcement, and the integration of hygiene culture into daily operational routines. From a regulatory standpoint, international standards such as the Codex Alimentarius General Principles of Food Hygiene (FAO & WHO, 2023) emphasise that personal hygiene is a shared responsibility among employers and employees and that food handlers must receive ongoing education and access to adequate facilities to uphold hygienic practices. Therefore, maintaining effective personal hygiene in food establishments is not only a matter of individual compliance but also reflects the organisational commitment to safeguarding public health and preventing foodborne illnesses.

In educational settings, the personal hygiene practices of food handlers have been identified as a crucial factor in mitigating the risk of foodborne illness. Studies indicate a substantial proportion of food service employees fail to adhere to recommended hand-washing protocols, thereby increasing the potential for pathogen transmission. For example, one study in Ethiopia found that 69% of food handlers worked under conditions where the microbial quality of the washing water was poor, and this directly correlated with high levels of bacterial contamination on their hands (Berhanu et al., 2021). Additional observational research in commercial food-service venues revealed that while soap was readily used, combined hand-hygiene regimens (soap and sanitiser) were the preferred protocol and the protocol was rarely followed, suggesting a gap between facility provision and actual behaviour (Schroeder et al., 2023). Bar soap and cloth towel systems have long been critiqued for providing reservoirs for microbial exchange between users; although the specific figure of 74.1% non-compliance in Brazilian schools (Campos, 2009) lies outside the ten-year window, the underlying finding is echoed by recent evidence: inadequate equipment (lack of antiseptics, soap, or disposable towels) remains a significant barrier to effective hygiene. Clearly, infrastructure and material provision (e.g., liquid soap dispensers, disposable paper towels) are foundational to enabling proper hygiene behaviour, particularly in busy school or institutional food-service settings. Beyond handwashing, regulatory frameworks emphasise that food handlers must be free from communicable

diseases, wear clean outer clothing, possess suitable hair restraints, and avoid wearing jewellery, all of which contribute to preventing contamination of food through carrier or contact routes. In the case of Botswana, national legislation mandates that food handlers must undergo a medical examination before employment and annually thereafter and prohibits the participation of individuals who are carriers of pathogens, such as *Salmonella* infection or Hepatitis A, in food-handling roles. These duties reflect a shift toward a 'from farm to fork' risk-based regulatory mindset. Taken together, improved infrastructure (hand-wash stations, liquid soap, and single-use towels), behavioural training, and regulatory oversight form a triad of interventions that is essential to reducing the incidence of foodborne outbreaks linked to poor personal hygiene among food handlers.

Part VI of the Public Health Regulations of 1983 for Botswana establishes essential hygiene and safety obligations for food handlers, employers and food premises, in order to protect public health and mitigate foodborne illness risk. Key provisions (e.g., Regulation 26) require food handlers to maintain short, clean fingernails, use clean washable caps where necessary, and refrain from handling food if they have open wounds, infections, or skin lesions. The regulation also prohibits improper behaviours such as spitting, smoking or using tobacco in food-handling areas, coughing or sneezing over unprotected food, placing utensils or fingers in the mouth, and mandates handwashing after nose-blowing or other contaminating acts. Further protective measures stipulate that food must be shielded from contamination by sweat, hair, cosmetics, medications, or jewelry. Regulation 28 places responsibility on employers, obliging them to provide suitable, light-coloured, washable protective clothing and headgear free of charge, to be worn by food handlers during working hours. This clothing and headgear must be stored in dedicated lockers away from food production or storage zones and not removed from the premises except for approved cleaning purposes. In addition, Regulation 26(2) emphasises the importance of proper solid-waste management procedures, requiring that waste storage and removal must not create nuisances or health hazards.

Collectively, these legal requirements form a comprehensive framework for personal hygiene, employer duties, and environmental cleanliness in food-handling settings in Botswana. While the legislation is foundational, recent evaluations of food safety

regulation implementation in Botswana indicate gaps in enforcement, training, and resource provision (Botswana Youth Magazine, 2023). The current international evidence highlights that food-handler knowledge, and practices remain sub-optimal and that regulatory mechanisms alone do not guarantee safe behaviour unless supported by infrastructure, education, and monitoring (Khan et al., 2021; Elshamy & Mahmoud, 2023). Accordingly, this Botswana regulatory context must be interpreted alongside contemporary global research, which emphasises that effective food-safety systems rest on the triad of robust regulation, continuous training, and enabling environmental conditions.

### **2.6.3 Food safety knowledge**

Food safety knowledge is a critical component of preventing foodborne illnesses and represents a primary responsibility of the foodservice industry (Cushman et al., 2011). Educating food handlers on food safety principles is essential not only for fostering behavioural changes but also for promoting positive attitudes toward hygienic practices (Coleman & Roberts, 2005). A lack of adequate knowledge of food hygiene can lead to improper handling, increasing the risk of contamination and subsequent foodborne disease outbreaks. Therefore, it is imperative to equip food handlers with the necessary knowledge and to establish monitoring systems that ensure compliance with safe practices (Kibret & Abera, 2012).

Empirical studies highlight gaps in food safety knowledge among food handlers across various contexts. In Ghana's Sagnarigu municipality, a study of street food vendors reported that 88.9% of participants demonstrated sufficient understanding of food hygiene practices, whereas 11.1% lacked essential knowledge. Notably, over half (51.1%) of the vendors had never undergone a medical examination to verify their fitness for food handling (Yakubu, 2021). In Malaysia, food handlers recognised the importance of proper handwashing to reduce bacterial transmission; however, many were unable to identify all pathogenic bacteria capable of causing foodborne illnesses. This deficiency underscores the need for targeted education on specific microorganisms and their associated risks (Nurul et al., 2017).

Similar knowledge gaps have been observed beyond food-handler populations. In Poland and Thailand, a study examining consumer food safety knowledge revealed



widespread misconceptions about the causes of food poisoning, with respondents demonstrating an incomplete understanding of basic food hygiene principles. None of the participants correctly identified all the causative agents of foodborne illness, highlighting the broader need for continuous education and awareness-raising campaigns in both professional and consumer settings (Marzena, 2017).

Collectively, these findings emphasise that food safety knowledge is foundational for effective hygiene practices but must be continuously reinforced through training, monitoring, and education. Aligning food-handler education with international standards, such as the WHO's Five Keys to Safer Food and Hazard Analysis and Critical Control Point (HACCP) principles, can help bridge the gap between knowledge and practice, thereby reducing the prevalence of foodborne illnesses (WHO, 2024).

#### **2.6.4 Food handlers' practices**

Awareness of food safety measures does not automatically ensure their consistent application, and lapses in hygiene practices can continue to pose significant risks of food contamination and foodborne illness. Several studies have examined the relationship between knowledge and practices among food handlers across diverse regions, highlighting persistent gaps between theoretical understanding and practical implementation. Research in Poland and Thailand revealed that, despite understanding the causes of foodborne illnesses, food handlers frequently demonstrated flawed hygiene practices during food preparation (Joanna & Wojcien, 2017). Similarly, studies conducted in hospital food service settings reported that most food handlers lacked adequate knowledge of essential food safety practices, and management systems often failed to detect or mitigate potential hazards (Adikari & Loken, 1995). These findings underscore the limitations of knowledge-based interventions when they are not regularly reinforced through monitoring, supervision, and supportive workplace infrastructure.

Nonetheless, improvements in food safety practices have been observed in some contexts. In Ghana, a study on institutional food handlers found that the majority possessed good knowledge of hygiene practices, including sanitation and cleaning procedures, with 97.7% recognising the importance of general sanitation. Many food handlers also wore gloves and cleaned surfaces appropriately using detergents.



Despite these positive outcomes, critical knowledge gaps remained, particularly regarding the impact of time and temperature on food safety (Annor, 2011). Insufficient understanding of cooking, holding, and storage temperatures has been identified as a recurring risk factor in multiple studies. For instance, research in Neuchatel restaurants demonstrated that inadequate knowledge of proper cooking temperatures contributed to foodborne outbreaks (Palak et al., 2001). Similarly, in the United States, 58% of food handlers were unaware of the temperature thresholds required to inhibit bacterial growth (Walker et al., 2002), and 22 foodborne disease outbreaks were directly linked to failures in temperature control (Summer et al., 2011). In Chicago, gaps in knowledge regarding the safe cooking, holding, and storage of foods were also observed among restaurant staff (Panchal et al., 2012).

These findings collectively emphasise that improving food-handling practices requires more than knowledge dissemination alone. Effective interventions must combine education with practical training, continuous supervision, robust management systems, and infrastructure that facilitates compliance, such as thermometers for monitoring food temperatures, adequate handwashing facilities, and standard operating procedures for hygiene and sanitation. Integrating these measures can help bridge the persistent gap between food safety knowledge and practice, ultimately reducing the risk of foodborne disease outbreaks.

## **2.7 Food safety measures**

### **2.7.1 Global food safety measures**

The increasing incidence of foodborne illnesses worldwide has emphasised the need for robust food safety strategies across all levels of food production and service (Mitchell et al., 2007). International standards, such as the Codex Alimentarius, provide evidence-based guidelines for hygiene, microbial limits, and safe food-handling procedures, serving as the benchmark for global food safety. One of the most widely adopted tools is the Hazard Analysis and Critical Control Points system, which focuses on identifying, evaluating, and controlling hazards to acceptable levels to prevent contamination (Kussaga et al., 2014).

Training programmes targeting food handlers have been shown to significantly improve food safety knowledge and practices. For example, Thelwell-Reid (2014) found that formally trained food handlers scored higher on both knowledge and the practical application of safe food-handling practices than untrained staff. Despite these advances, gaps in adherence to hygiene and safety measures persist, particularly in small-scale or informal foodservice settings, highlighting that regulation and training alone are insufficient without proper infrastructure and monitoring (Nee et al., 2011; Bas et al., 2006; Palak et al., 2001).

### **2.7.2 Food safety measures in Africa**

At the continental level, African countries have made progress in aligning with food safety regulations and promoting regional coordination. The African Union (AU) Statute for the Establishment of the Africa Food Safety Agency (AfFSA) aims to provide a unified framework for food safety management, including risk assessment, rapid alert systems, and alignment with national policies (African Union, 2025).

National legislation across African countries shares common principles, including hygiene standards, food handler requirements, and inspection protocols. Examples include Kenya's Food, Drugs and Chemical Substances Act (Cap 254) and Public and Ghana's Public Health Act (Act No. 851) and associated Food Safety Master Health Act (Cap 242), Kenya Law, 1970; Food and Drugs Authority, 2024). These laws are designed to reduce the risk of foodborne outbreaks through the structured regulation of food handling practices.

However, enforcement remains inconsistent across the continent due to limited resources, insufficient inspection personnel, and low compliance in the informal food sector (WHO Regional Office for Africa, 2024; Kimanya, 2024). Although many African countries have legal frameworks for food safety, their effectiveness depends on capacity-building, infrastructure development, and ongoing training of food handlers.

### **2.7.3 Food safety measures in Botswana**

Botswana has developed a comprehensive national framework for food safety through Part VI of the Public Health Regulations (1983) and related Food Safety Standards.

Key regulations (Regulations 26 and 28) focus on personal hygiene, protective clothing, proper waste management, and employer responsibilities in food establishments. Food handlers are required to maintain short, clean fingernails, wear washable caps, avoid handling food when injured or ill, and protect food from contamination by sweat, hair, cosmetics, medications, or jewellery (Botswana Youth Magazine, 2023).

Employers are obliged to provide light-coloured, washable protective clothing and headgear free of charge, ensure garments are stored properly, and maintain designated areas for solid waste management. These measures are aligned with international Hazard Analysis and Critical Control Points principles, ensuring systematic monitoring and hygiene protocols.

Despite these regulations, studies highlight implementation challenges, including gaps in staff training, supervision, and resources for enforcement (Khan et al., 2021; Elshamy & Mahmoud, 2023). Botswana's experience illustrates that legislation alone is insufficient, as effective food safety depends on the integration of regulation, continuous education, monitoring, and infrastructural support.

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## CHAPTER 3: FOOD SAFETY KNOWLEDGE AND PRACTICES OF FOOD HANDLERS IN PUBLIC PRIMARY SCHOOLS GABORONE, BOTSWANA

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### Abstract

**Background:** This study evaluated food safety knowledge, self-reported and observed practices, and microbial hygiene among food handlers in public primary schools in Gaborone, Botswana. Given the vulnerability of school-aged children to foodborne illnesses, understanding gaps between knowledge and behaviour is essential for developing effective interventions.

**Methods:** A mixed-methods approach was employed, involving structured questionnaires, direct observations, and hand-washing demonstrations. A total of 77 food handlers from ten randomly selected schools participated. Quantitative data were analysed using EPI Info 7 and Stata version 14, with descriptive and inferential statistics applied. Qualitative data from field notes were thematically analysed to explore contextual factors affecting compliance. In addition to descriptive findings, comparative statistical analyses were conducted to examine the influence of demographic factors on knowledge and practice scores.

**Results:** Food handlers demonstrated an average knowledge score of 79.7%, a self-reported practice score of 89.37%, and an observed practice score of 75.75%. While 55.84% used proper hand drying methods, 96.10% agreed on handwashing after sneezing or smoking, indicating a gap between knowledge and behaviour. Only 55.8% of food handlers had received formal food safety training, and none had Hazard Analysis and Critical Control Points training. Knowledge deficiencies were particularly evident in temperature control: 37.66% incorrectly believed freezing kills bacteria, and only 35.06% recognised heat-resistant toxins. Mask use during food preparation was low (22.08%), and 12.99% of food handlers reported being willing to work while vomiting. Handwashing compliance declined during later stages, particularly in fingertip and wrist cleaning.

Comparative analysis showed no significant differences in knowledge scores across demographic groups. However, practice scores were significantly higher among older food handlers, those with permanent employment, those with more years of experience, and those who had prior food safety training, indicating that practical experience and training, rather than demographic background alone, may be more predictive of hygienic behaviour.

**Conclusions:** Despite relatively high food safety knowledge, observed behaviours revealed significant gaps, underscoring the need for continuous, practical training, regular supervision, and institutional enforcement of food hygiene standards. These findings highlight the importance of strengthening food safety culture and systems in school environments to protect public health, particularly among children.

### 3.1 Introduction

Food safety is a critical public health concern, particularly in institutional settings such as schools, where large numbers of children rely on prepared meals for their daily nutrition. In Botswana, the national school feeding programme provides meals to approximately 365,288 primary-school learners, highlighting the scale and importance of institutional meals for child health, school attendance, and cognitive development (Global Child Nutrition Foundation, 2024).

Despite these benefits, foodborne diseases caused by bacteria, viruses, parasites, and chemical contaminants remain a significant risk. Globally, the WHO estimates that nearly 600 million people (almost one in ten) fall ill annually after consuming contaminated food, resulting in approximately 420,000 deaths. Children under five are particularly vulnerable, accounting for nearly one-third of all deaths from foodborne diseases, with around 125,000 children dying each year (WHO, 2015). The African and Southeast Asia regions experience the highest burden, with mortality far exceeding that in high-income regions. In Africa, foodborne disease mortality is estimated at 16 deaths per 100,000 population, approximately 32 times higher than in Europe. However, these figures are likely underreported due to weak surveillance systems, limited diagnostic capacity, and incomplete reporting (WHO, 2015; Akabanda et al., 2017).

Accurate reporting and surveillance of foodborne disease remain significant challenges, particularly in low- and middle-income countries such as Botswana. Limited laboratory capacity, underreporting from healthcare facilities, and weak health information systems contribute to an incomplete understanding of the true disease burden. Many mild or moderate cases go unreported, and diagnostic confirmation is often unavailable, which delays outbreak detection and public health response (Malangu, 2005; Mqgibandaba et al., 2020). Countries with robust surveillance systems, including the United States and European Union member states, demonstrate how coordinated laboratory networks and mandatory reporting can facilitate early detection, prompt intervention, and effective prevention of foodborne disease outbreaks (Crim et al., 2015; EFSA & ECDC, 2022). Strengthening surveillance, reporting, and diagnostic capacity in Botswana is therefore critical to better understand and manage foodborne diseases, particularly among vulnerable children under five.

Foodborne diseases are caused by more than 200 pathogens and chemicals, including norovirus, *Campylobacter*, non-typhoidal *Salmonella*, pathogenic *E. coli*, typhoid fever, aflatoxins, and other mycotoxins. While many foodborne diseases produce short-term symptoms such as vomiting, diarrhoea, and stomach pain, some can result in long-term health consequences, including delayed growth and cognitive development, kidney or liver failure, cancers, and neurological disorders, particularly in children, pregnant women, the elderly, and immunocompromised individuals (WHO Africa, 2016).

Institutional feeding programmes (such as school meal initiatives) introduce unique risks due to large-scale meal preparation, storage, and distribution. Hands serve as a primary vector for microbial transmission, making proper hand hygiene washing before and after handling food and after using the toilet critical to preventing outbreaks (WHO Africa, 2016; da Vitória et al., 2021). Even when bacteria do not proliferate in food, their presence can cause outbreaks of diarrhoea, dysentery, and acute poisoning. Inadequate personal hygiene, poor food handling practices, and a lack of proper training among food handlers are significant contributors to these outbreaks (Akabanda et al., 2017; Sibanyoni & Tabit, 2017). Emerging challenges, such as longer global food supply chains, technological changes, and antimicrobial resistance,

exacerbate these risks. Misuse or overuse of antibiotics contributes to the emergence of antibiotic-resistant bacteria, threatening the effectiveness of modern medicine and complicating the treatment of foodborne infections (WHO Africa, 2016).

Hospital-based studies provide critical insight into foodborne illness and poisoning patterns in Botswana. Malangu (2005) documented that food poisoning accounted for 8.5% of 116 acute poisoning cases admitted to referral hospitals in Gaborone and Francistown, with most incidents being accidental and involving children. Similarly, a retrospective review by Kasule & Malangu (2009) of 590 poisoning cases across three health districts found that food was the fourth most common toxic agent, implicated in 14.4% of cases after pharmaceuticals (26.6%), natural toxins (25.6%), and household chemicals (14.6%). Children under 6 years accounted for 33.4% of all cases, with ingestion as the predominant route of exposure. The overall case fatality rate was 3.8%, with intentional poisoning more common among adolescent girls than boys. These findings illustrate the demographic vulnerability of young children and underscore the need for age-specific food safety interventions.

In Botswana, legal frameworks such as the *Food Control Act* of 1993 and the Public Health Act of 2013 provide the foundation for ensuring food safety. However, compliance and enforcement at the institutional level remain inconsistent. Gaps in food handlers' knowledge, attitudes, and practices often undermine these regulatory safeguards, heightening the risk of foodborne diseases (Madilo & Mggibandaba, 2020). National and regional surveillance reports further indicate that foodborne outbreaks have shown an upward trend in recent years, reflecting both improved detection and persistent challenges in food safety management (WHO Africa, 2023; Ministry of Health Botswana, 2022).

Understanding food handlers' knowledge and practices is essential for safeguarding child health and ensuring the effectiveness of school feeding programmes. International studies consistently document inadequate knowledge and poor hygiene practices among school food handlers (Akabanda et al., 2017; da Vitória et al., 2021; Sibanyoni & Tabit, 2017), but research in the Botswana context remains limited. Factors such as age, employment status, work experience, and formal training may influence food safety practices, yet these relationships are underexplored.

This chapter forms part of a broader study assessing food safety knowledge, hygiene practices, and microbial hand contamination among food handlers in primary school kitchens in Gaborone. It evaluates food handlers' understanding of food safety principles, their observed and self-reported hygiene practices, and the influence of demographic and training-related factors. By identifying knowledge gaps and areas for improvement, this study aims to support targeted interventions that enhance food safety, protect children's health, and strengthen Botswana's school feeding programme.

## **3.2 Materials and methods**

### **3.2.1 Research design and rationale**

The study employed a mixed-methods cross-sectional design to assess food safety knowledge and practices among food handlers in public primary schools in Gaborone, Botswana. This design was justified as it provided a holistic understanding by combining quantitative data with qualitative insights from observations and handwashing demonstrations, ensuring both numerical trends and contextual behaviours were captured. Quantitative methods (structured questionnaires and statistical analysis) provided measurable data on knowledge and practices, while qualitative components (observations, handwashing demonstrations, and field notes) offered contextual understanding of compliance and behaviour. It was also practically relevant, allowing for cost-effective assessment at a single point in time within resource constraints. Furthermore, the study design closely aligned with the study objectives, enabling the identification of gaps between reported and actual practices, quantification of knowledge levels, and exploration of contextual issues affecting food safety.

### **3.2.2 Study setting/area**

This study was conducted in Gaborone, the capital city of Botswana (see Figure 3.1), focusing on public primary schools participating in the national school feeding programme. Botswana, a landlocked country in Southern Africa with a population of just over 2.5 million, has a youthful demographic, with more than one-third of its population under 15 (World Bank, 2021). The country has achieved significant

economic growth since its independence in 1966, largely driven by diamond mining, which accounts for approximately 35% of GDP, alongside modest contributions from agriculture, particularly beef exports (BBS, 2020). Despite political stability and good governance, Botswana faces persistent challenges, including poverty, inequality, unemployment, and the impacts of climate change on its arid environment (AfDB, 2021; World Bank, 2021). Gaborone, as the urban centre, was selected for this study due to its concentration of schools and representativeness of food handling practices in institutional settings.



**Figure 3.1:** Map of Botswana showing the Gaborone area of study

### 3.2.3 Study population and sampling procedure

#### 3.2.3.1 Population

The study population consisted of food handlers working in public primary school kitchens. Both permanent and temporary staff who were directly involved in food

preparation, cooking, serving, and cleaning was eligible. Administrative staff and teachers without direct food handling responsibilities were excluded.

### **3.2.3.2 Frame construction and Sampling strategy**

A multistage cluster sampling design with census sampling at the final stage was utilised in this study. The sampling process involved construction of the sampling frame, random selection of schools, and census inclusion of food handlers within the selected schools.

A sampling frame was constructed using a list of all public primary schools in Gaborone participating in the national school feeding programme. The list was obtained from the Ministry of Local Government, which oversees public primary schools in Botswana. A total of 13 schools met the eligibility criteria and formed the sampling frame for the study.

A simple *random* sampling strategy was utilised to select ten schools from the 13 schools under the school feeding programme. Schools were selected randomly from a list provided by the Ministry of Local Government to ensure representativeness at the institutional level.

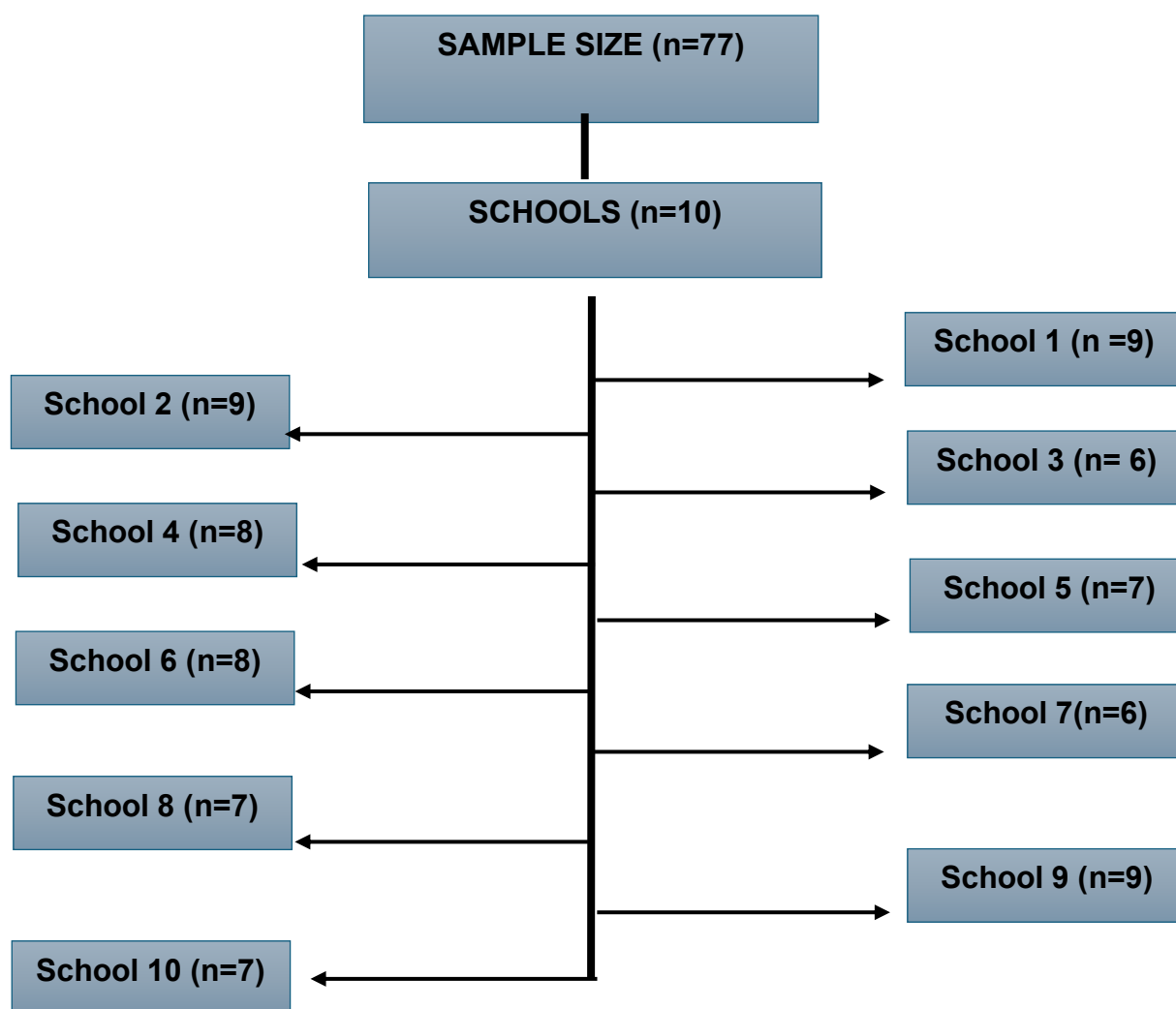
A *census* sampling strategy was utilised to include all food handlers in the selected schools. This approach was chosen over random sampling of individuals because the total number of food handlers per school was small, which maximised representation and reliability, and excluding some could omit important variations in practices.

### **3.2.3.3 Sample size**

A total of 77 food handlers participated in the study. The sample was derived through a multistage cluster sampling design, in which ten schools were randomly selected from the sampling frame of 13 eligible public primary schools participating in the national school feeding programme. All eligible food handlers within the selected schools were included using a census sampling approach. Of the 79 eligible food handlers identified in the selected schools, 77 participated in the study. Two food handlers did not participate, one due to sick leave and the other due to refusal to participate (see Figure 3.2).







**Figure 3.2:** Multistage sampling framework and distribution of food handlers across selected schools

#### 3.2.3.4 Inclusion criteria

Participants were eligible for the study if they met all the following criteria:

Food handlers and food service staff directly involved in food preparation, cooking, cleaning, or serving meals within the school kitchen

Male and female staff members working in food handling roles

Permanent and temporary employees were actively involved in daily food handling tasks during the study period

Staff working in public primary schools in Gaborone who participate in the national school feeding programme or provide meals to learners

Participants who voluntarily consented to participate after being fully informed about the purpose, procedures, and potential risks of the study.

### **3.2.3.5 Exclusion criteria**

Participants were excluded from the study if they met any of the following criteria:

Staff not directly involved in food handling activities, including administrative personnel, teachers, or general workers without food preparation or kitchen duties

Individuals who did not provide informed consent or who withdrew from the study at any stage

Staff employed at schools located outside the Gaborone area

Food handlers who were unavailable during the data collection period due to sick leave, official leave of absence, or other reasons that prevented their participation.

### **3.2.4 Procedures for recruitment, participation, and data collection**

Permission to conduct the study was obtained from the Ministry of Local Government and the school authorities. Food handlers were briefed on the objectives and procedures, and verbal informed consent was obtained because participants were uncomfortable signing forms.

#### **3.2.4.1 Data collection schedule and procedures**

Data collection was conducted over three structured visits to each participating school, with approximately one week allocated per school to allow for flexibility in coordination, thorough assessment, and laboratory procedures.

- **Day 1** involved introductory engagement with the school administration. The researcher visited each school to meet with the headmaster, submit the official approval letter, and formally request permission to conduct the study. During this visit, suitable dates were agreed upon for the subsequent data collection activities.
- **Day 2** focused on the administration of structured questionnaires to food handlers. These questionnaires were designed to assess their knowledge of food safety and self-reported hygiene practices. Observations were also conducted on the same

day, focusing on personal hygiene indicators such as handwashing behaviour, attire, and general cleanliness. All completed questionnaires were checked for completeness and retained for later data entry and analysis.

Throughout the data collection process, both overt and discreet observation techniques were employed to minimise the Hawthorne effect and capture more natural behaviours. All findings (including questionnaire responses and observation notes) were systematically documented and stored for subsequent analysis.

### 3.2.4.2 Instrumentation

#### Questionnaire

The questionnaire was adapted from previously validated studies (Nurul et al., 2017; Mustafa, 2017; Marzena et al., 2017) (Table 3.1). It assessed demographics, food safety knowledge (25 items), and self-reported practices. Reliability was pre-tested in a pilot study (Cronbach's  $\alpha > 0.7$ ). The questionnaire was available in both English (see Appendix 1) and Setswana (Appendix 2), allowing participants to respond in their preferred language. Food safety knowledge was evaluated through 25 questions covering various topics (Appendix 1). The closed-ended section of the questionnaire consisted of 20 binary (Yes/No) items. Each item was numerically encoded, with correct responses assigned a score of 1 and incorrect responses a score of 0. This binary scoring approach facilitated a straightforward quantification of knowledge levels. Open-ended responses from Questions 21 to 25 were thematically grouped using Epi Info™, then manually scored (1 = correct, 0.5 = partially correct, 0 = incorrect/missing). Scores were exported to Stata for analysis. The knowledge was assessed across four key areas.

**Table 3.1:** Specific questions used to assess each area of food safety knowledge

| Knowledge area                             | Questions                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Food contamination and cross-contamination | <ul style="list-style-type: none"> <li>Contaminated food always has some changes in colour, odour, and taste</li> <li>Expired food can be consumed as long as they do not look or taste bad</li> <li>Contact between cooked and raw food contributes to food poisoning</li> <li>Pathogens can be sourced from utensils</li> </ul> |

|                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                  | <ul style="list-style-type: none"> <li>• Cooked food which is stored incorrectly may contain germs that may make one sick</li> <li>• Pets in food premises can contaminate food</li> <li>• Is it safe to use the same knife for cooked and uncooked food</li> <li>• What are the causes of food contamination</li> <li>• How does improper waste storage contribute to food contamination</li> </ul>                                                                                                                                                                                      |
| Infection and disease prevention | <ul style="list-style-type: none"> <li>• Before jobs, the health condition of food handlers must be assessed</li> <li>• Food handlers with diseases such as diarrhoea, flu and throat infections pose a risk of food contamination</li> <li>• A healthy food handler can be a carrier of infectious foodborne disease</li> <li>• Food handlers with abrasions or cuts should not treat ready-to-eat food</li> <li>• List two signs of food poisoning</li> <li>• Why is it important to do a medical examination before jobs</li> </ul>                                                    |
| Temperature control              | <ul style="list-style-type: none"> <li>• Improper reheating of cooked food can contribute to food contamination</li> <li>• Refrigeration and freezing kill bacteria</li> <li>• Some toxins produced by microorganisms are resistant to heat during food heating</li> <li>• What is the right temperature for the storage of perishables</li> </ul>                                                                                                                                                                                                                                        |
| Personal and hand hygiene        | <ul style="list-style-type: none"> <li>• If hands are washed but not washed properly, they can pose a risk to food safety</li> <li>• Is it important to wash your hands after sneezing or smoking</li> <li>• Wearing gloves reduces the risk of food contamination</li> <li>• Long painted nails contribute to food contamination</li> <li>• Use of jewels such as rings, watches, and bracelets in food handling poses a risk to food contamination</li> <li>• Eating, drinking, talking, and smoking when preparing or serving food increases the risk of food contamination</li> </ul> |

### Observation checklist

Based on Zulkify (2013) and the *Food Control Act*, systematically assess hygiene practices. This observational checklist (see Appendix 4) covered personal hygiene and the overall health of the food handlers. Observations included various stages of food handling, such as preparation, cooking, serving, or distribution, as well as handwashing practices. Participants were also asked to demonstrate their handwashing techniques.

### Handwashing demonstration tool

Developed using WHO Guidelines on Hand Hygiene in Health Care (2009), focusing on the thoroughness of handwashing steps (see Appendix E). Food handlers were

asked to demonstrate their hand-washing techniques to assess their knowledge and adherence to recommended hand-washing procedures. The demonstration was designed to assess the accuracy and thoroughness of each participant's hand-washing routine.

### 3.2.5 Operationalization

The following framework was used to translate concepts into measurable indicators:

| Variable                | Indicator                               | Measurement tool      | Scale/Score     |
|-------------------------|-----------------------------------------|-----------------------|-----------------|
| Knowledge               | Correct responses to food safety items  | Questionnaire         | % score         |
| Self-reported practices | Reported compliance with hygiene rules  | Questionnaire         | % score         |
| Observed practices      | Direct adherence to food handling rules | Observation checklist | % compliance    |
| Hand hygiene            | Accuracy of handwashing steps           | Demonstration tool    | Checklist score |

### 3.2.6. Variables

- **Independent variables:** Age, gender, education, training, years of experience, status of employment
- **Dependent variables:** Knowledge score, self-reported practice score, and observed practice score

### 3.2.7 Data analysis

#### 3.2.7.1 Quantitative data analysis

Quantitative data were coded in EPI Info 7 and exported to Stata Version 14.

#### 3.2.7.2 Descriptive analysis

Descriptive statistics were used to summarise the participants' socio-demographic characteristics and to describe the distribution of knowledge and practice scores. Key measures included means and standard deviations (for continuous variables) and frequencies and percentages (for categorical variables). These descriptive summaries provided a clear overview of the characteristics and baseline knowledge/practices of the food handlers.

### 3.2.7.3 Inferential statistics

#### Qualitative data analysis

In order to test and establish relationships and differences between variables, suitable inferential statistical tests were used. Mean knowledge and practice scores were compared between two groups (e.g., gender and training status) using independent samples t-tests. Comparisons that involve more than two groups were done using one way analysis of variance (ANOVA). The chi-square tests were used to determine the relationship between categorical variables. To test the relationship between the knowledge and practice scores and predictors of food safety practices, linear regression analysis was performed. A significance level of  $p < 0.05$  was used to determine statistical significance. The analysis process was guided by statistical principles from *Basic Statistics and Epidemiology: A Practical Guide* by Anthony Stewart (2002), ensuring methodological rigour and appropriate test selection.

### 3.2.8 Threats to validity

Several potential threats to validity were considered in the design and execution of this study. Internal validity was addressed by using structured and standardised data collection tools to minimise observer bias; however, the use of self-reported questionnaires may have introduced social desirability bias, as participants might have provided responses they perceived as acceptable rather than truthful. In terms of external validity, the study's findings are primarily generalisable to similar urban public-school settings, as rural schools were not represented in the sample. Construct validity was strengthened by adapting instruments from previously validated tools, thereby ensuring that the measures accurately captured the intended concepts of food safety knowledge and hygiene practices. Lastly, reactivity bias, particularly the Hawthorne effect, where participants alter their behaviour due to being observed, was mitigated by using discreet observation methods to promote more natural behaviour during data collection.

### 3.2.9 Ethical considerations

The study proposal was approved by the Faculty Research Committee of Central University of Technology, Free State, South Africa. The ethical approval was obtained

from the Health Research and Development Division under the Ministry of Health and Wellness of Botswana, Reference Number HPRD: 6/14/1 (see Appendix 4), which was used to get permission to conduct research in schools from the Ministry of Local Government, Reference Number SER 1/15/2022 XVI (183) (see Appendix 5).

Informed consent was obtained from participants. The study topic and objectives were explained to the participants, along with the benefits of participating. The participants were assured of anonymity, and their names were neither used nor requested at any point. None of the participants were comfortable with signing, and verbal consent was accepted.

To ensure confidentiality and data security, pseudonyms/IDs were used in the data collection tools and reports. The linkage key was stored separately, and findings were reported in aggregate, with quotes being de-identified.

### 3.3 Results presentation and interpretation

This section presents the findings from the analysis of data collected to assess food handlers' knowledge of food safety in school kitchens. The results are categorised based on the types of questions used (closed-ended and open-ended) and the four thematic areas of food safety knowledge: food contamination and cross-contamination, infection and disease prevention, temperature control, and personal and hand hygiene.

#### 3.3.1 Demographic characteristics of respondents

As shown in Table 3.2, most food handlers were women (71.43%) and over the age of 35 (67.53%). A significant proportion (74.03%) had attained secondary education, with 15.58% having completed senior school, 9.09% having only primary education, and just 1.30% having received higher education.

**Table 3.2:** Socio-demographic characteristics of food handlers in primary school kitchens (n=77)

| Variable      | Frequency | Percentage (%) |
|---------------|-----------|----------------|
| <b>Gender</b> |           |                |
| Male          | 22        | 28.57          |

|                                                             |    |        |
|-------------------------------------------------------------|----|--------|
| Female                                                      | 55 | 71.43  |
| <b>Age</b>                                                  |    |        |
| 18-35                                                       | 25 | 32.47  |
| >35                                                         | 52 | 67.53  |
| <b>Educational level</b>                                    |    |        |
| Primary                                                     | 7  | 9.09   |
| Secondary                                                   | 57 | 74.03  |
| Senior                                                      | 12 | 15.58  |
| Higher                                                      | 1  | 1.30   |
| <b>Work experience (years)</b>                              |    |        |
| >5                                                          | 32 | 41.56  |
| 3-5                                                         | 13 | 16.88  |
| 0-3                                                         | 32 | 41.56  |
| <b>Employment status</b>                                    |    |        |
| Permanent                                                   | 49 | 63.64  |
| Temporal                                                    | 28 | 36.36  |
| <b>Training on food safety</b>                              |    |        |
| Formal                                                      | 45 | 58.44  |
| None                                                        | 32 | 41.56  |
| <b>Hazard Analysis and Critical Control Points Training</b> |    |        |
| Yes                                                         | 0  | 0      |
| No                                                          | 77 | 100.00 |

In terms of work experience, 41.56% of the participants had more than 5 years of experience, 41.56% had between 0 and 3 years, and 16.88% had between 3 and 5 years. Employment status data showed that 63.64% of the food handlers were permanently employed, while 36.36% held temporary positions.

Regarding food safety training, 58.44% of respondents had received formal training, while 41.56% had not. None (0%) of the food handlers had undergone training in Hazard Analysis and Critical Control Points, indicating a complete lack of exposure to this internationally recognised food safety framework.

### 3.3.2 Food safety knowledge among food handlers

The analysis of the food safety knowledge scores (see Table 3.3) revealed that, of 77 participants, the mean score was 19.92 (79.68%) of a possible maximum of 25 points,

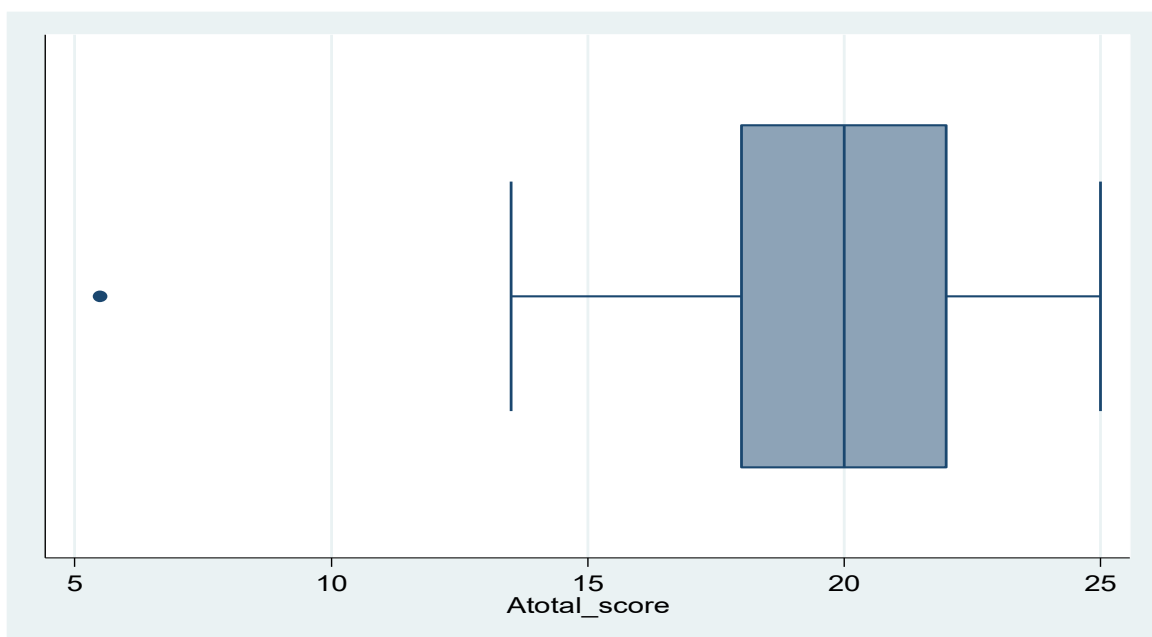


with a standard deviation of 3.25, indicating a generally moderate to high level of knowledge. The scores ranged from 5.5 to 25, indicating substantial variability in knowledge levels.

**Table 3.3:** Summary statistics of knowledge scores (STATA 14 output)

| Variable        | Obs | Mean     | Std. dev. | Min | Max |
|-----------------|-----|----------|-----------|-----|-----|
| Knowledge score | 77  | 19.91558 | 3.249901  | 5.5 | 25  |

While some food handlers demonstrated excellent knowledge by achieving a perfect score, others showed significant knowledge gaps. A box plot, created to further visualise the summary results, showed that one participant scored as low as 5.5/25, significantly lower than the rest of the participants, which is indicated as an outlier in the box plot (see Figure 3.3). This score lies well below the first quartile (Q1) and falls outside the interquartile range (IQR), indicating it is a statistical outlier. The presence of this outlier indicates that at least one participant had significantly lower knowledge of food safety practices than the others.



**Figure 3.3:** The distribution and spread of knowledge scores across participants

### 3.3.2.1. Part A: Closed-ended questions

The average correct score across all 20 questions was approximately 78.28%, indicating a moderate to high level of knowledge among respondents. However, the data also revealed notable gaps in specific areas such as temperature control and heat-resistant toxins, suggesting that while foundational awareness exists, targeted training is needed to address certain misconceptions and reinforce comprehensive food safety practices.

As shown in Table 3.4, the study revealed several areas of high awareness among food handlers. Most respondents (96.10%) recognised the importance of handwashing after sneezing or smoking, and 94.81% understood that improperly stored cooked food may harbour harmful germs. A similarly high proportion acknowledged the need for pre-employment health assessments, while 92.21% correctly identified utensils as a source of contamination.

However, notable knowledge gaps were also identified. Only 25.97% of respondents were aware that contaminated food does not always appear altered. Awareness that some toxins can withstand heat was limited to 35.06%, and only 38.96% correctly rejected the misconception that freezing kills bacteria. Just 44.16% recognised the risks associated with improper food reheating.

Some inconsistencies in knowledge emerged. While 80.52% knew that contact between raw and cooked food causes contamination, an equal proportion failed to recognise the risk of using the same knife for both. Moreover, 80.52% believed that glove use protects against contamination, suggesting a possible overreliance on gloves instead of proper hand hygiene.

On a positive note, over 85% of respondents demonstrated awareness of hygiene risks related to wearing jewelry, maintaining long nails, and engaging in improper behavior such as eating or smoking during food preparation. Despite none of the food handlers having received formal Hazard Analysis and Critical Control Points training, the relatively high scores in many areas suggest that informal or experiential learning plays a significant role in this group's food safety knowledge (see Table 3.4).

**Table 3.4: Part A:** Results on the knowledge of food handlers in school kitchens of primary schools (n=77)

| Variable                                                                                                         | Answered Yes |       | Answered No |       | Mean correct score |
|------------------------------------------------------------------------------------------------------------------|--------------|-------|-------------|-------|--------------------|
|                                                                                                                  | Frequency    | %     | F           | %     | %                  |
| Q1. Contaminated food always has some changes in colour, odour, and taste                                        | 20           | 25.97 | 57          | 74.03 | 74.03              |
| Q2. Expired food can be consumed as long as they do not look or taste bad                                        | 4            | 5.19  | 73          | 94.81 | 94.81              |
| Q3. Contact between cooked and raw food contributes to food poisoning                                            | 62           | 80.52 | 15          | 19.49 | 80.52              |
| Q4. If hands are washed but not washed properly, they can pose a risk to food safety                             | 65           | 84.42 | 12          | 15.58 | 84.42              |
| Q5. Is it important to wash your hands after sneezing or smoking                                                 | 74           | 96.10 | 3           | 3.90  | 96.10              |
| Q6. Wearing gloves reduces the risk of food contamination                                                        | 62           | 80.52 | 15          | 19.42 | 80.52              |
| Q7. Long painted nails contribute to food contamination                                                          | 67           | 87.01 | 10          | 12.99 | 87.01              |
| Q8. Use of jewels such as rings, watches, and bracelets in food handling poses a risk of food contamination      | 66           | 85.71 | 11          | 14.29 | 85.71              |
| Q9. Before jobs, the health condition of food handlers must be assessed                                          | 72           | 93.51 | 5           | 6.49  | 93.51              |
| Q10. Food handlers with diseases such as diarrhoea, flu, and throat infections pose a risk of food contamination | 67           | 87.01 | 10          | 12.99 | 87.01              |
| Q11. A healthy food handler can be a carrier of infectious foodborne disease                                     | 64           | 83.12 | 13          | 16.88 | 83.12              |
| Q12. Food handlers with abrasions or cuts should not treat ready-to-eat food                                     | 67           | 87.01 | 10          | 12.99 | 87.01              |
| Q13. Pathogens can be sourced from utensils                                                                      | 71           | 92.21 | 6           | 7.79  | 92.21              |
| Q14. Improper reheating of cooked food can contribute to food contamination                                      | 34           | 44.16 | 43          | 55.84 | 44.16              |

|                                                                                                                     |    |       |    |        |       |
|---------------------------------------------------------------------------------------------------------------------|----|-------|----|--------|-------|
| Q15. Refrigeration and freezing kill bacteria                                                                       | 30 | 38.96 | 47 | 61.04  | 64.94 |
| Q16. Cooked food which is stored incorrectly may contain germs that may make one sick                               | 73 | 94.81 | 4  | 5.19   | 94.81 |
| SK17. Some toxins produced by microorganisms are resistant to heat during food heating                              | 26 | 33.77 | 51 | 66.23  | 33.77 |
| Q18. Pets in food premises can contaminate food                                                                     | 67 | 87.01 | 10 | 12.99  | 87.01 |
| Q19. Is it safe to use the same knife for cooked and uncooked food                                                  | 20 | 25.97 | 57 | 74.03% | 74.03 |
| Q20. Eating, drinking, talking, and smoking when preparing or serving food increases the risk of food contamination | 68 | 88.31 | 9  | 11.69  | 88.31 |

### 3.3.2.2 Part B: Open-ended questions

The mean overall score across all five open-ended questions (see Table 3.4) was 74.81%, indicating a moderately high understanding. However, notable variations were observed across specific topics. Participants demonstrated excellent knowledge of certain core food safety concepts. For example, all respondents (100%) correctly answered the question regarding the signs of food poisoning, reflecting a universal awareness likely influenced by personal experience, health education campaigns, or routine exposure to discussions on food safety. Similarly, the effects of improper waste storage were well understood, with 96.10% accurately identifying how poor waste management can lead to contamination. This suggests a strong group understanding of environmental hygiene and the indirect risks associated with foodborne illness. Additionally, 94.81% of respondents correctly answered the question on the importance of undergoing medical examinations before employment, demonstrating their awareness of medical screening as a preventive measure to protect public health.

In contrast, the results pointed to moderate to low levels of understanding in more technical areas of food safety. For instance, only 58.44% of participants fully answered the question on the causes of food contamination correctly, with an additional 37.66% offering partially correct responses. This indicates that while many food handlers are aware of general contamination sources, such as dirty utensils or ill workers, they may lack a deeper understanding of microbial and environmental contributors. The most

pronounced gap emerged in responses to the question about the temperature for storing perishables. Only 20.78% of respondents provided the correct answer, reflecting a critical deficiency in technical knowledge. Proper temperature control is vital in preventing microbial growth, and failure to understand safe cold and hot holding ranges (typically below 5°C or above 60°C) significantly increases the risk of foodborne illnesses. This finding underscores the need for targeted training that emphasises practical, technical food safety principles in conjunction with basic hygiene practices (see Table 3.5).

**Table 3.5:** Part B results on Knowledge of food handlers in school kitchens of primary schools (n=77)

| Variable                                                              | Correct score=1 |       | Partially correct (0.5) |       | Incorrect score= 0 |       | >/=0.5 |
|-----------------------------------------------------------------------|-----------------|-------|-------------------------|-------|--------------------|-------|--------|
|                                                                       | F               | %     | F                       | %     | F                  | %     |        |
| Q21. What are the causes of food contamination                        | 45              | 58.44 | 29                      | 3.90  | 3                  | 3.90  | 62.34  |
| Q22. List two signs of food poisoning                                 | 77              | 100   | 0                       | 0     | 0                  | 0     | 100    |
| Q23. What is the right temperature for the storage of perishables     | 16              | 20.78 |                         |       | 61                 | 79.22 | 20.78  |
| Q24. How does improper waste storage contribute to food contamination | 74              | 96.10 | 0                       | 0     | 3                  | 3.90  | 96.10  |
| Q25. Why is it important to do a medical examination before jobs      | 63              | 81.82 | 10                      | 12.99 | 4                  | 5.19  | 94.81  |
| TOTALS                                                                |                 |       |                         |       |                    |       | 74.81  |

### 3.3.2.2.1 Insight into food handlers' understanding of causes of food contamination

Food contamination is a complex process involving multiple sources, including biological, chemical, and physical hazards. Biological contaminants such as *Salmonella*, *Listeria*, and *E. coli* are among the most common causes of foodborne illnesses globally (CDC, 2010). Additionally, environmental factors, including poor storage, pest infestations, and human handling practices, also play a significant role in contamination (Grondin et al., 2021).

Question 21 asked food handlers to identify the causes of food contamination. The results, presented in Table 3.5, reveal a mixed level of understanding, with some participants accurately identifying microbial causes, while others mentioned environmental or behavioural factors with varying specificity.

A large proportion of respondents correctly identified bacteria as a significant source of food contamination. This reflects a foundational awareness of biological hazards, which is consistent with public health messaging and basic food safety principles.

However, beyond bacteria, responses were diverse and fragmented, revealing partial knowledge of other critical contamination sources:

- Some participants recognised chemical contaminants (e.g., poisons or toxins), improper storage, and the presence of insects or rodents as risk factors, each of which is a valid and important contributor to contamination.
- A smaller number referenced behavioural risks, such as leaving food overnight, time-temperature abuse, and improper food handling. These are critical components of food safety but appear to be less consistently understood.

There were also a few uncommon or unclear responses, including references to long painted nails and general statements without microbial specificity, suggesting limited conceptual clarity among some participants.

Interestingly, very few respondents reported having no idea, indicating that most participants had at least some awareness of potential contamination sources, even if not fully informed by food safety science (see Table 3.6).

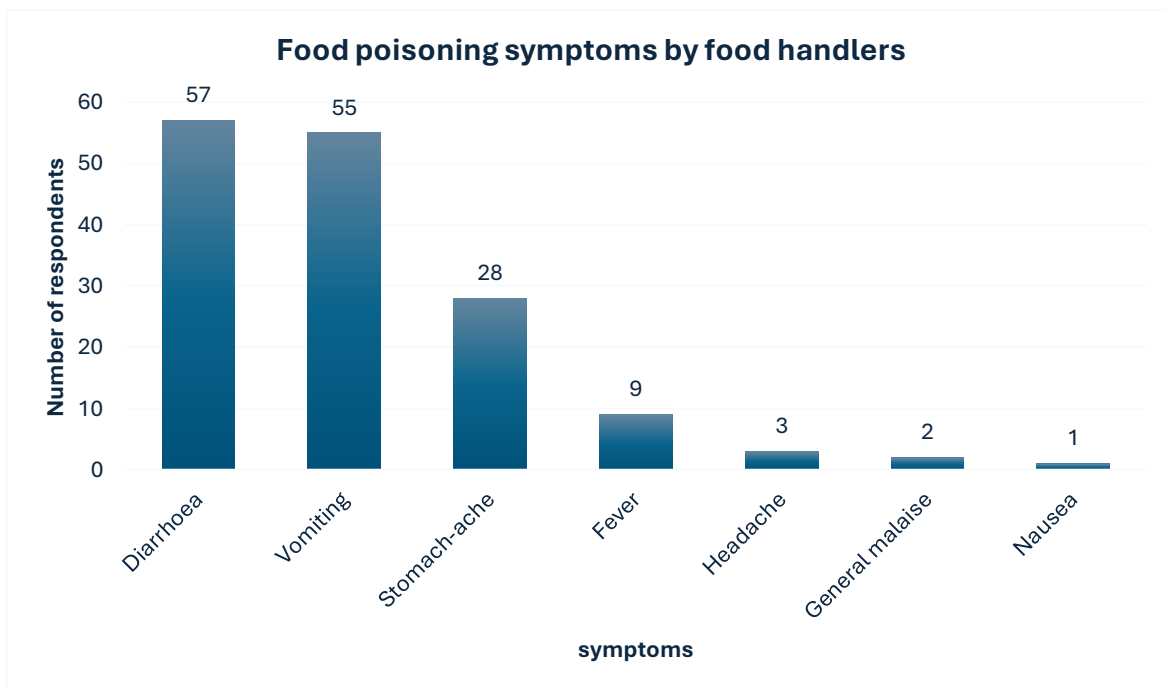
**Table 3.6:** Summary of themes from responses on causes of food poisoning

| Theme/Category              | Example responses                         | Implication                                                    |
|-----------------------------|-------------------------------------------|----------------------------------------------------------------|
| Biological hazards          | Bacteria, viruses                         | Most frequently recognised cause: basic awareness is strong    |
| Chemical hazards            | Chemicals, poisons                        | Present but less commonly identified                           |
| Environmental sources       | Insects, rodents, and poor storage        | Understood by some, though with varied terminology             |
| Improper practices          | Leaving food overnight, temperature abuse | Recognition exists, but is not consistently emphasised         |
| Behavioural/physical issues | Long painted nails, improper handling     | Rarely mentioned; may indicate overlooked aspects in training  |
| No knowledge stated         | “No idea”                                 | Very few, suggesting general exposure to food safety awareness |

### 3.3.2.2.2 Insight into food handlers' knowledge about food poisoning symptoms

Food poisoning can present a range of symptoms, typically including nausea and vomiting, diarrhoea (which may be bloody), abdominal cramps, mild fever, headaches, and muscle aches. (CDC, 2020). The most frequently recognised symptoms of food poisoning among food handlers were diarrhoea (74.03%) and vomiting (71.43%), followed by stomachache (36.36%). Least commonly mentioned symptoms included fever (11.69%), headache (3.90%), general malaise (2.60%), and nausea (1.30%) (see Figure 3.4). These results suggest that participants were generally more familiar with gastrointestinal manifestations of food poisoning than with systemic indicators.

The relatively high identification of stomachache aligns with the typical symptom profile of foodborne illness. However, the low recognition of fever, reported by only 9 participants, is notable. Fever often signals more severe infections and is a key indicator requiring medical attention. Fever's under recognition may reflect a lack of understanding of the full clinical spectrum of foodborne diseases.



**Figure 3.4:** Frequency of reported symptoms of food poisoning by food handlers

### **3.3.2.2.3 Insight into food handlers' understanding of proper storage temperatures**

Appropriate storage temperatures are a fundamental component of food safety. Refrigerated perishables should be kept at 4°C (40°F) or below, and frozen foods at –18°C (0°F) or below to minimise bacterial growth and prolong food quality (FDA, 2023; USDA, 2023).

The responses to this question, summarised in Table 3.6, reveal a significant lack of knowledge among food handlers regarding the correct storage temperature for perishables. The majority of respondents were unable to identify a correct or even approximate temperature range, indicating a serious gap in technical understanding.

Many food handlers expressed no knowledge at all, simply stating “no idea”. This group comprised well over half of all participants, suggesting that basic cold chain principles are not well understood or emphasised in their food safety practices or training.

Among the few who attempted to provide a specific temperature, many gave incorrect or dangerously high values, such as 27°C or 36°C temperatures far beyond the safe zone for perishable storage. These responses reflect misconceptions that could result in unsafe storage, accelerated microbial growth, and an increased risk of foodborne illness.

Only a small subset of 15 of the respondents identified 5°C as the correct or nearly correct temperature. While not fully precise, this figure is within an acceptable approximation range and suggests at least partial understanding among a minority of food handlers. According to Food Standards Australia New Zealand (FSANZ) guidelines, potentially hazardous foods must be kept at or below 5°C to prevent the rapid growth of pathogenic microorganisms, which can lead to foodborne illness if left uncontrolled (FSANZ, 2020, Appendix 2). The few who correctly referenced this temperature may have had some prior exposure to formal food safety training.

Other responses were scattered and inconsistent, ranging from 10°C to 20°C, further indicating a lack of standardised knowledge or formal training. No responses mentioned freezing temperatures, nor did any refer to temperature monitoring tools such as thermometers or cold storage guidelines.



#### 3.3.2.2.4 Insight into food handlers' understanding of waste-related contamination

Improper storage of waste is widely recognised as a significant contributor to food contamination, primarily through attracting pests and creating unsanitary conditions. In this question, food handlers were asked to explain how improper waste storage can lead to food contamination. The analysis of their responses reveals a range of understanding, with varying depth and accuracy.

The most cited mechanism involved flies being attracted to waste and subsequently transferring contaminants to food. This pathway was mentioned by most respondents, indicating a clear awareness of one of the most visible and intuitive contamination routes. This understanding is supported by recent studies showing that houseflies can carry *Salmonella*, Enterobacteriaceae, and other antimicrobial-resistant bacteria from waste to food-handling areas (Bertelloni et al., 2023; Rowe et al., 2023). Moreover, flies have been found to harbor coagulase-negative staphylococci with antimicrobial resistance, confirming their role as mechanical vectors in environments with poor sanitation (Bertelloni et al., 2023). These findings highlight the critical importance of waste management and vector control to prevent fly-mediated food contamination.

Other responses, while less frequent, suggested a partial or emerging understanding of additional contamination pathways. A few participants referred to airborne pathogens, the presence of insects and rodents, and the generation of foul odours as potential risks. Although foul smell is not a direct contaminant, its mention may reflect a sensory association with unhygienic conditions.

A small number of respondents referred to terms like 'bacteria and worms', 'dust', or 'germs', indicating a general awareness of contamination, but with limited specificity. These answers suggest gaps in microbiological knowledge and a need for more technical training on how environmental factors promote microbial proliferation and cross-contamination.

Only a few respondents were unable to articulate any connection between waste storage and contamination, suggesting that basic awareness of the issue is widespread, even if understanding of all mechanisms is incomplete.

### **3.3.2.2.5 Insight into food handlers' understanding of the importance of pre-employment medical examinations**

Medical examinations are a standard requirement in food-handling professions to safeguard the health of food workers and the safety of consumers. These screenings are designed to detect communicable diseases, assess overall fitness for work, and prevent the transmission of foodborne illness in food service settings (WHO, 2006).

The responses to this question, summarised in Table 3.5, provide valuable insight into how food handlers perceive the purpose of medical assessments. The data indicate a generally positive awareness, though with some misconceptions and areas for clarification.

Most respondents (over 50%) correctly stated that medical examinations are necessary to assess one's health status prior to starting work. This demonstrates a solid foundational understanding of the role of medical screening in preventing food contamination and protecting public health.

In addition, a significant number of respondents recognised the importance of identifying communicable diseases or infections, which can render food unsafe if the food handler is actively infected. This response directly reflects the core public health rationale for such screenings.

However, some responses reflected limited or misunderstood reasoning:

- A few respondents believed medical exams are for legal protection against employers, which misrepresents the actual intent of pre-employment health checks.
- Others associated medical checks with readiness to work in high-temperature environments or gauging general fitness for food handling, showing an incomplete grasp of the preventive health focus of such assessments.

Encouragingly, only 3.90% of participants expressed complete uncertainty, suggesting that most food handlers have at least a basic awareness of why medical screenings are required (see Table 3.7).

**Table 3.7:** Summary of thematic categories from responses to food handlers' understanding of the importance of pre-employment medical examinations

| Response theme                                                 | Interpretation                                                                    | Example phrases                                              |
|----------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------|
| Assessing general health status before food handling           | Most common and accurate understanding                                            | "To know your health status before you start work..."        |
| Identifying communicable diseases or infections                | Clear awareness of food safety implications                                       | "To know if you are suffering from communicable diseases..." |
| Misconceptions or misattributions (e.g. legal reasons)         | Minor confusion about the intent of screening                                     | "So, you can sue the government if you get sick at work"     |
| Environment- or task-specific reasons (e.g. high temperatures) | Limited focus on physical work conditions rather than hygiene and disease control | "To know if you can work in a high-temperature environment"  |
| Uncertainty or no idea                                         | Reflects a small knowledge gap                                                    | "No idea"                                                    |

### 3.3.3 Food safety practices among food handlers

The food safety practices were evaluated through a combination of self-reported methods and direct observation. Self-reported practices among food handlers indicated high levels of awareness in infection prevention, hand hygiene, and personal hygiene.

#### 3.3.3.1 Self-reported practices

Table 3.8 provides valuable insights into the hygiene and infection prevention practices reported by food handlers in the workplace. Overall, the data indicate strong adherence to proper hygiene and illness-prevention protocols. Most food handlers report taking time off when they exhibit symptoms of illness, such as fever, flu, or stomach cramps, with 100% stating they take a day off if they have a fever or the flu. This demonstrates a high level of awareness regarding the importance of not working while sick to prevent contamination. Additionally, most food handlers (92.21%) would refrain from working if they have a persistent cough, further emphasising their commitment to infection control. However, a concerning 15.58% of respondents reported they would continue working while experiencing stomach cramps, which presents a potential risk area and is inconsistent with established food safety guidelines (FDA, 2017).

Most food handlers demonstrated good hand hygiene habits, with all of them saying they wash their hands after using the toilet, before and after eating, and when preparing food. This shows a clear awareness of how important clean hands are in keeping food safe. However, a few gaps remain, as 6.5% of the respondents admitted they do not always wash their hands after handling unwashed vegetables, and around 2.6% said the same after sneezing or scratching. Another concern is that over a third (36.84%) reported using dish cloths to dry their hands, which can easily lead to cross-contamination (Sneed et al., 2015).

Personal hygiene standards are similarly high, with most food handlers consistently wearing clean aprons, ensuring their protective clothing is in good condition, and maintaining short, clean, and unpolished nails. However, 16.88% of respondents reported occasionally leaving the kitchen while wearing their protective clothing, which could pose a contamination risk. Regarding mask use, there is a noticeable gap: only 33.77% of food handlers wear masks when distributing or handling food. This indicates that while some recognise the importance of mask-wearing, it is not universally practised, and it could be a crucial area for improvement, particularly considering current health guidelines.

The data also reveals that food handlers generally report that they refrain from wearing jewellery or smoking while handling food, which are both essential practices for minimising contamination risk. While food handlers report strong adherence to hygiene and infection prevention practices overall, several areas require further attention. Specifically, mask use should be improved, and stricter controls on removing protective clothing outside the food preparation area could help mitigate contamination risks. These findings suggest that although food handlers exhibit strong self-reported compliance with hygiene practices, certain behaviours, such as continuing to work when experiencing stomach cramps and inconsistent hand drying practices, still need to be addressed to ensure the highest food safety standards (see Table 3.8).

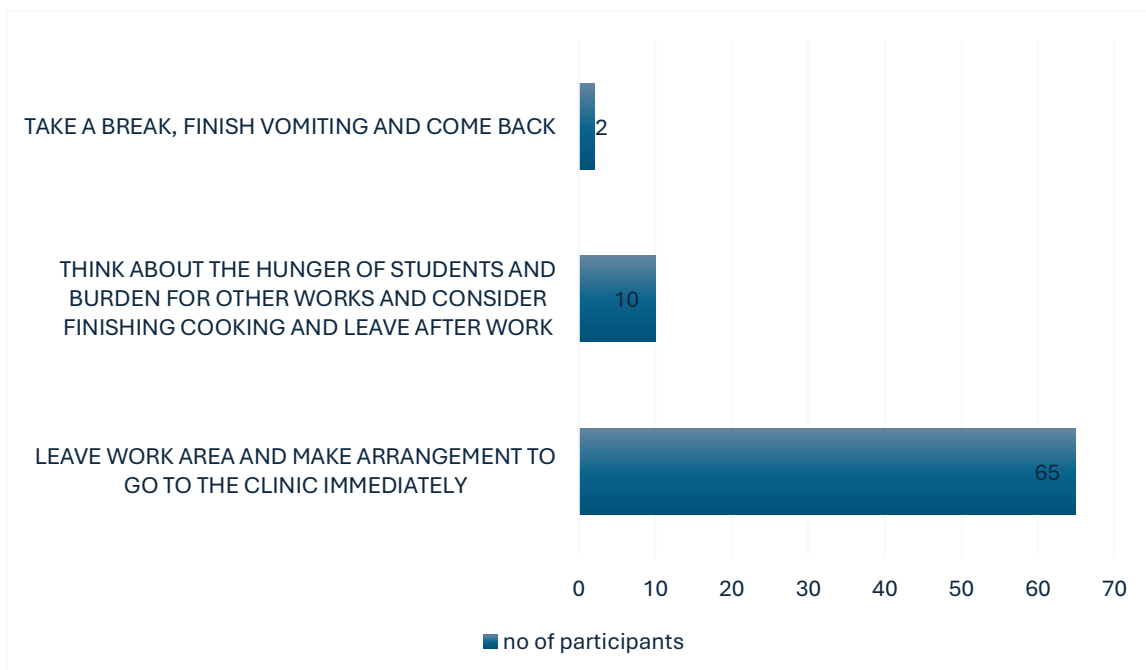
**Table 3.8:** Responses regarding self-reported practices by food handlers (N=77)

| Variable                    | Yes       |            | No        |            |
|-----------------------------|-----------|------------|-----------|------------|
|                             | Frequency | Percentage | Frequency | Percentage |
| <b>Infection prevention</b> |           |            |           |            |

|                                                                                                                            |    |       |    |       |
|----------------------------------------------------------------------------------------------------------------------------|----|-------|----|-------|
| I will take a day off if I continue coughing                                                                               | 71 | 92.21 | 6  | 7.79  |
| I will take a day off if I have a fever                                                                                    | 77 | 100   | 0  | 0     |
| I will take a day off if I have stomach cramps                                                                             | 65 | 84.42 | 12 | 15.58 |
| I will take a day off if I have flu                                                                                        | 77 | 100   | 0  | 0     |
| I only handle food when my medical aid has been done and is valid                                                          | 66 | 85.71 | 11 | 14.29 |
| I will not handle or come in contact with food and the food preparation area when I have a cut, injury, or skin infections | 69 | 90.79 | 7  | 9.21  |
| <b>Hand hygiene</b>                                                                                                        |    |       |    |       |
| I wash my hands after using the toilet                                                                                     | 73 | 94.81 | 4  | 5.19  |
| I wash my hands before and after eating                                                                                    | 75 | 97.40 | 2  |       |
| I wash my hands before and after preparing a meal                                                                          | 73 | 94.81 | 4  | 5.19  |
| I wash my hands after sneezing                                                                                             | 75 | 97.40 | 2  | 2.60  |
| I wash my hands after scratching                                                                                           | 75 | 97.40 | 2  |       |
| I wash my hands after handling unwashed vegetables                                                                         | 72 | 93.51 | 5  | 6.49  |
| I know the proper and effective way of hand washing                                                                        | 77 | 100   | 0  | 0     |
| I always wash my hands with soap or detergents                                                                             | 76 | 98.7  | 1  | 1.30  |
| <b>Personal hygiene</b>                                                                                                    |    |       |    |       |
| I always wear a clean apron in the food handling and preparation area                                                      | 72 | 98.51 | 5  | 6.49  |
| I always ensure that my protective clothing is in good condition, not worn out before use                                  | 77 | 100   | 0  | 0     |
| I always wear a hair restraint when handling and preparing food                                                            | 72 | 93.51 | 5  | 6.49  |
| I always ensure that I wear proper shoes which are fully enclosed and absorbent                                            | 73 | 94.81 | 4  | 5.19  |
| I keep my nails short, clean, and unpolished                                                                               | 77 | 100   | 0  | 0     |
| I do not leave the kitchen with protective clothing or take it outside the food preparation area                           | 64 | 83.12 | 13 | 16.88 |

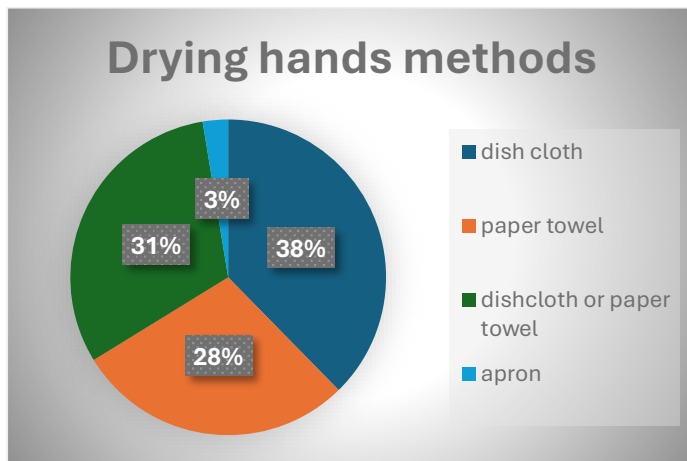
|                                                   |    |       |    |       |
|---------------------------------------------------|----|-------|----|-------|
| I wear a mask when distributing and handling food | 26 | 33.77 | 51 | 66.23 |
| I do not wear jewellery when handling food        | 72 | 93.51 | 5  | 6.49  |
| I do not smoke when handling food                 | 72 | 93.51 | 5  | 6.49  |

Figure 3.5 presents the responses to the question, "When you are at work and start vomiting, what do you do?". It reveals varied approaches to handling this situation. The majority of food handlers (84.42%) reported that they would leave the work area and decide to go to the clinic immediately. However, a concerning 12.99% of respondents indicated that they would continue working, given students' hunger and the burden on other workers, and would only leave after completing their cooking tasks. A small percentage (2.60%) reported that they would take a break, finish vomiting, and return to work, which also raises concerns regarding the potential for spreading illness in the workplace. These findings suggest that while the majority of food handlers recognise the importance of leaving work to seek medical attention when ill, there are still instances where the risks of continuing to work while unwell are not fully acknowledged.



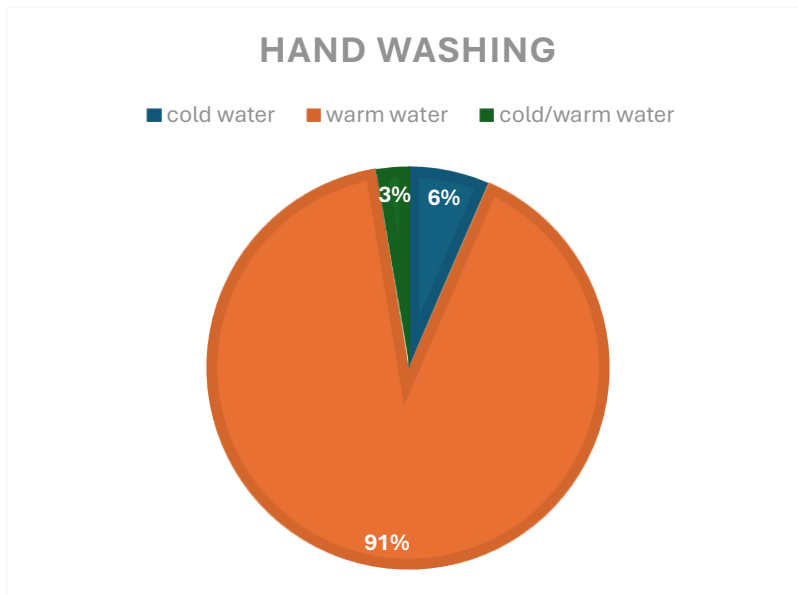
**Figure 3.5:** Response of food handlers on what they will do if they start vomiting while at work

Figure 3.6 illustrates the self-reported hand-drying practices of food handlers, highlighting the range of methods employed. There were 28 respondents (36.84%) who reported drying their hands with a dishcloth, 24 (31.58%) of the respondents reported using either a dishcloth or a paper towel, and 22 (28.95%) of the respondents indicated they use paper towels. A smaller portion of two respondents (2.60%) reported using an apron to dry their hands. The results indicate a mixed approach that combines both potentially unhygienic and hygienic methods.



**Figure 3.6:** Results food handlers reported on what they use to dry hands

Figure 3.7 presents handwashing practices. There were 70 food handlers (90.91%) who washed their hands with warm water. A smaller portion of five (6.49%) reported using cold water for handwashing, and two (2.60%) of respondents indicated they use either cold or warm water for handwashing, suggesting some inconsistency in practices.



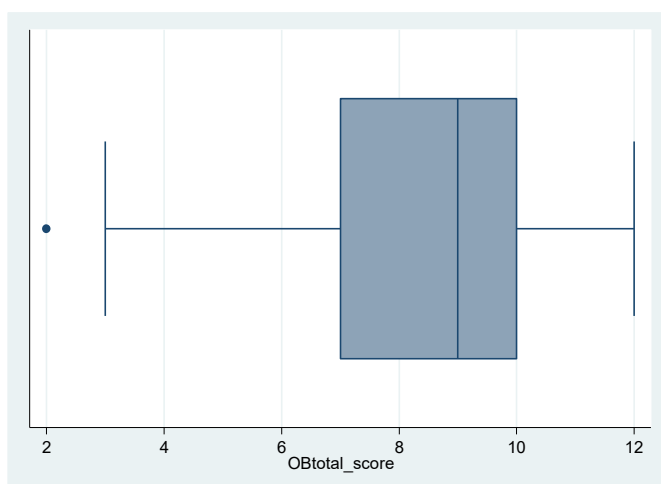
**Figure 3.7:** Self-reported response of what food handlers use to wash hands

### 3.3.3.2 Observed practices of food handlers

Food safety practices were assessed through direct observation using a checklist focused on personal hygiene behaviours. Among the 77 food handlers observed, the mean practice score was 8.62/12 (SD (standard deviation) = 2.31), representing approximately 71.8% compliance with recommended hygiene practices. Scores ranged from 2 to 12, indicating moderate overall adherence, with some handlers demonstrating excellent hygiene, while others showed considerable gaps in essential practices.

A box plot (see Figure 3.8) was used to visualise the distribution of scores from observed personal hygiene and food handling practices across 14 measured indicators. One outlier was identified, with a score of 2/14, significantly lower than the rest of the group. This outlier falls well below the lower bound of the distribution (below the whiskers), suggesting extremely poor hygiene compliance by that individual. Such a low score indicates widespread neglect or lack of adherence to essential personal hygiene and food handling practices such as wearing protective clothing, handwashing, nail hygiene, and avoiding contamination behaviours. The median score is approximately 9, indicating that half of the food handlers scored 9 or higher. The interquartile range (IQR) spans from about 7 to 10, suggesting that most scores are concentrated within this range and highlighting a moderate spread in performance.





**Figure 3.8:** Distribution and spread of knowledge scores across participants

Observing food handlers' actual practices and personal hygiene provides insight into their adherence to established food safety protocols. While there are encouraging signs of compliance, the findings also highlight several areas requiring attention (see Table 3.9).

**Table 3.9:** Food handlers observed practices and personal hygiene using a checklist (n=77)

| Variable                                                                                                                                                                | Yes       |            | No        |            |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|------------|-----------|------------|
|                                                                                                                                                                         | Frequency | Percentage | Frequency | Percentage |
| 1. Food handler appears to be in good health                                                                                                                            | 76        | 97.40      | 1         | 1.30       |
| 2. Not suffering from a cut, injury, or skin irritation                                                                                                                 | 75        | 97.40      | 2         | 2.60       |
| 3. Availability of a valid medical examination                                                                                                                          | 52        | 67.53      | 25        | 32.47      |
| 4. Frequent hand washing and washing between activities                                                                                                                 | 67        | 87.01      | 10        | 12.99      |
| 5. Hand-dried using proper methods                                                                                                                                      | 43        | 55.84      | 34        | 44.16      |
| 6. Apron worn and clean                                                                                                                                                 | 55        | 71.43      | 22        | 28.57      |
| 7. Protective clothing worn is of hygienic design, has no external pockets, is in good repair, and does not constitute any source of contamination to the food protects | 61        | 79.22      | 16        | 20.78      |
| 8. Hair restraint is worn and worn properly                                                                                                                             | 64        | 83.12      | 13        | 16.88      |

|                                                                                           |    |       |    |       |
|-------------------------------------------------------------------------------------------|----|-------|----|-------|
| 9. Nails kept short, clean, and no nail polish                                            | 49 | 63.64 | 28 | 36.36 |
| 10. Employee not removing protective clothing from the food preparation and handling area | 59 | 76.62 | 18 | 23.38 |
| 11. Employee wearing proper shoes that are fully enclosed and non-absorbent               | 70 | 90.91 | 7  | 9.21  |
| 12. Employee wears a mask when preparing or distributing food                             | 17 | 22.08 | 60 | 77.92 |
| 13. Not wearing jewellery when handling food                                              | 53 | 68.83 | 24 | 31.17 |
| 14. Not drinking, eating, or smoking in the food preparation area                         | 31 | 40.26 | 46 | 59.74 |

### 3.3.3.3 Positive practices

A high percentage of food handlers demonstrated compliance with essential health and hygiene requirements. Of the 77 participants, 97.40% of food handlers appeared to be in good health, and the same proportion reported no visible injuries, cuts, or skin conditions, both of which are crucial for reducing the risk of foodborne illness transmission (WHO, 2006). Furthermore, 90.91% were observed wearing fully enclosed, non-absorbent shoes, aligning with recommended occupational health and safety standards. Also, 87.01% of food handlers engaged in frequent handwashing, including between food-handling tasks, demonstrating good hygiene awareness in line with basic food safety protocols (FDA, 2017).

The use of hygienic protective clothing was moderately high, with 79.22% wearing attire that was appropriately designed (i.e., with no external pockets, in good repair, and unlikely to pose contamination risks). Hair restraint use was also observed in 83.12% of the food handlers, reflecting generally good practice in minimising the risk of physical contamination.

### 3.3.3.4 Areas of concern in observed food safety practices

Despite several strengths in food handlers' knowledge and reported practices, several critical gaps were observed in actual hygiene compliance. One of the most prominent

issues was inadequate hand drying, with only 55.84% of food handlers using proper drying methods. Additionally, face mask usage was alarmingly low; just 22.08% of food handlers were observed wearing masks during food preparation or distribution. This is particularly concerning, considering ongoing public health standards that emphasise mask-wearing to prevent respiratory contamination.

Another troubling finding was that 59.74% of employees were observed eating, drinking, or smoking in food preparation areas. Nail hygiene was also suboptimal, with only 63.64% maintaining short, clean, and unpolished nails, despite the known risk of pathogen harbouring under fingernails (Nee et al., 2011). Regarding medical screening compliance, only 67.53% of food handlers held valid medical certificates, indicating lapses in enforcing required health checks.

While most handlers wore aprons, only 71.43% wore clean aprons, suggesting inconsistent adherence to hygiene protocols. Jewellery removal during food handling was practised by only 68.83% of participants, and just 76.62% refrained from leaving the food preparation area while still wearing protective clothing, both of which are important practices for minimising physical and microbial contamination. These findings highlight key areas requiring immediate attention through targeted training, routine supervision, and stricter enforcement of existing food safety regulations.

Table 3.10 presents the distribution of observed practice scores among food handlers evaluated using a checklist based on 14 hygiene and food safety criteria. The scores ranged from 2 to 12, with most participants demonstrating moderate to high levels of compliance. The most frequently observed score was 10, recorded by 25.97% of participants, followed by scores of 8 (15.58%) and 11 (12.99%). Overall, 80.52% of food handlers scored between 7 and 12, indicating that a large majority adhered reasonably well to the expected hygiene standards.

**Table 3.10:** Distribution of scores on observed practices for food handlers

| Distribution of average score per participant |       |            |      |
|-----------------------------------------------|-------|------------|------|
| Score/14                                      | Freq. | Percentage | Cum. |
| 2                                             | 1     | 1.30       | 1.30 |
| 3                                             | 2     | 2.60       | 3.90 |
| 4                                             | 3     | 3.90       | 7.79 |

|       |    |        |        |
|-------|----|--------|--------|
| 5     | 2  | 2.60   | 10.39  |
| 6     | 4  | 5.19   | 15.58  |
| 7     | 9  | 11.69  | 27.27  |
| 8     | 12 | 15.58  | 42.86  |
| 9     | 9  | 11.69  | 54.55  |
| 10    | 20 | 25.97  | 80.52  |
| 11    | 10 | 12.99  | 93.51  |
| 12    | 5  | 6.49   | 100.00 |
| Total | 77 | 100.00 |        |

### 3.3.3.5 Comparison between self-reported practices and actual practices

A comparison between self-reported and observed food safety practices revealed notable discrepancies, suggesting a tendency among food handlers to over-report compliance. For instance, while 93.51% of participants claimed not to eat, drink, or smoke in food preparation areas, only 40.26% adhered to this during observation. This is a discrepancy of over 53%. Similarly, although 100% reported maintaining short, clean, unpolished nails, only 63.64% met this standard. Proper hand drying was observed in just 55.84% of cases, despite 98.7% claiming to always follow hand hygiene protocols.

Other inconsistencies included apron cleanliness (98.51% self-reported vs. 71.43% observed) and the avoidance of jewelry (93.51% vs. 68.83%). These gaps likely reflect social desirability bias, where respondents report ideal behaviour rather than actual practice. In contrast, greater alignment was seen in more visible or enforceable areas, such as health, appearance, and footwear (see Table 3.11).

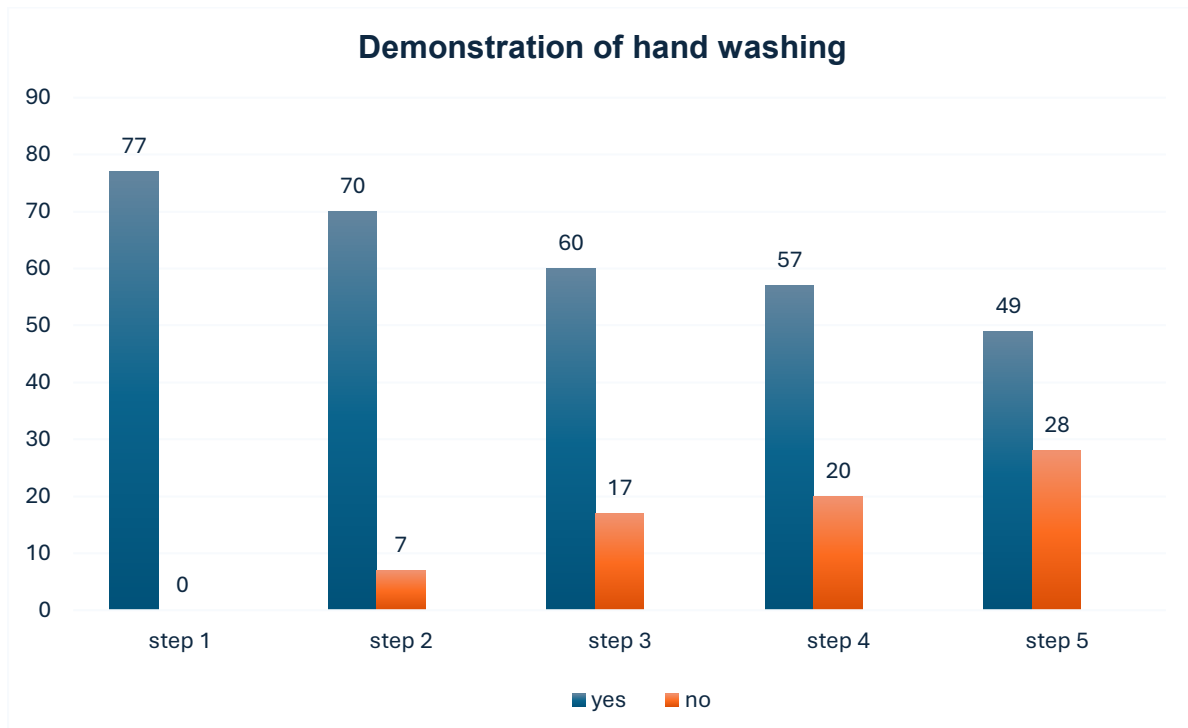
**Table 3.11:** Comparison of self-reported and observed food safety practices among food handlers (n=77)

| Practice area                         | Self-reported compliance (%) | Observed compliance (%) | Discrepancy (Gap %)  | Notes                                 |
|---------------------------------------|------------------------------|-------------------------|----------------------|---------------------------------------|
| Valid medical examination             | 85.71%                       | 67.53%                  | 18.18% over-reported | Suggests overestimation of compliance |
| Free from visible illness or injuries | 90.79%                       | 97.40%                  | 6.61% under-reported | Observation shows better              |

|                                                          |                                      |        |                      | actual compliance            |
|----------------------------------------------------------|--------------------------------------|--------|----------------------|------------------------------|
| Frequent handwashing, and between tasks                  | 94.81%                               | 87.01% | 7.8% over-reported   | Generally good alignment     |
| Proper hand drying methods                               | 98.7% (soap use as proxy)            | 55.84% | 42.86% over-reported | Major hygiene gap            |
| Wearing a clean apron                                    | 98.51%                               | 71.43% | 27.08% over-reported | One of the largest gaps      |
| Protective clothing in good condition                    | 100%                                 | 79.22% | 20.78% over-reported | Visual inspection disagrees  |
| Hair restraint is worn and worn properly                 | 93.51%                               | 83.12% | 10.39% over-reported | Slight but notable gap       |
| Wearing a mask while preparing/distributing food         | 33.77%                               | 22.08% | 11.69% over-reported | Both rates remain low        |
| Nails short, clean, unpolished                           | 100%                                 | 63.64% | 36.36% over-reported | Major personal hygiene gap   |
| Not removing protective clothing from the food prep area | 83.12%                               | 76.62% | 6.5% over-reported   | Modest discrepancy           |
| Wearing proper shoes (closed, non-absorbent)             | 94.81%                               | 90.91% | 3.9% over-reported   | High compliance              |
| Not wearing jewellery while handling food                | 93.51%                               | 68.83% | 24.68% over-reported | Personal hygiene concern     |
| Not eating, drinking, or smoking in the food prep area   | 93.51% (proxied from "do not smoke") | 40.26% | 53.25% over-reported | Largest discrepancy observed |

Figure 3.9 illustrates how food handlers performed across five key steps of proper handwashing technique. All 77 participants (100%) correctly carried out Step 1, wetting their hands with soap and rubbing the back of both hands, indicating a strong grasp of the basic starting point for hand hygiene. However, compliance gradually declined with each subsequent step. Approximately 90.9% of participants completed Step 2, which involves rubbing hands together with fingers interlaced. Step 3, which requires interlocking of fingers and rubbing the backs of the hands, saw correct performance drop to 77.9%. In Step 4, where the thumb and area between the thumb and index finger are rubbed in a rotating motion, only 74% of participants got it right. Step 5, the final step, which involved rubbing fingertips on the palms and rotating both wrists, had the lowest compliance, with only 63.6% performing it correctly. This

downward trend suggests that while basic handwashing practices are widely understood, more detailed or advanced techniques are less consistently followed.



**Figure 3.9:** Step-by-step compliance in handwashing demonstration

Table 3.12 presents the summary statistics of scores obtained during the handwashing demonstration. The results show a mean score of 3.86 with a standard deviation of 1.31, indicating moderate variation in performance across participants. The *minimum* score observed was 1, while the maximum was 5, suggesting that while some participants completed nearly all steps correctly, others missed several key components of the proper handwashing technique.

**Table 3.12:** Summary statistics for handwashing demonstration scores

| Variable | n | Mean | Standard deviation | minimum | Maximum |
|----------|---|------|--------------------|---------|---------|
|          |   |      |                    |         |         |

|                            |           |                 |                 |          |          |
|----------------------------|-----------|-----------------|-----------------|----------|----------|
| <b>Food handling score</b> | <b>77</b> | <b>4.064935</b> | <b>1.280806</b> | <b>1</b> | <b>5</b> |
|----------------------------|-----------|-----------------|-----------------|----------|----------|

Table 3.13 presents the distribution of scores from the handwashing demonstration conducted among 77 food handlers. The scores reflect the number of correct steps performed of a maximum of five, based on a standardised evaluation. The results indicate that the majority of participants (58.44%) achieved the highest possible score of 5, suggesting strong adherence to proper handwashing procedures among more than half of the sample. A smaller proportion of participants scored 4 (11.69%) and 3 (11.69%), while 14.29% scored 2 and 3.90% scored as low as 1.

These findings highlight a generally high level of compliance, with over 80% of participants scoring 3 or higher, but they also point to a minority (approximately 18%) who demonstrated insufficient or incomplete handwashing techniques. This variation highlights the importance of ongoing training and reinforcement of hand hygiene protocols, particularly for those with lower performance, to ensure that all food handlers consistently follow critical steps in handwashing.

**Table 3.13:** Frequency distribution of handwashing demonstration scores

| <b>Total score</b> | <b>Freq</b> | <b>Percentage</b> | <b>Cum</b> |
|--------------------|-------------|-------------------|------------|
| <b>1</b>           | 3           | 3.90              | 3.90       |
| <b>2</b>           | 11          | 14.29             | 18.18      |
| <b>3</b>           | 9           | 11.69             | 29.87      |
| <b>4</b>           | 9           | 11.69             | 41.56      |
| <b>5</b>           | 45          | 58.44             | 100        |

### 3.3.4 Relationship between demographics and knowledge scores

To explore potential influences on food safety knowledge, statistical tests were conducted comparing knowledge scores across several demographic and training variables. A summary of the comparative analysis is presented in Table 3.14. While male participants, permanent employees, and those who had received formal training showed slightly higher mean knowledge scores, none of these differences were statistically significant ( $p > 0.05$ ). Age group and work experience were also not significantly associated with knowledge scores. For the education level, both the ANOVA and Kruskal–Wallis tests confirmed no significant differences, although the ANOVA test violated the assumption of equal variances.

These results suggest that there were no statistically significant correlations between demographic variables and knowledge scores, but this does not rule out the possibility of underlying effects that could not be identified due to the limitation of the sample size. Full statistical outputs, including test statistics, assumption checks, and confidence intervals, are provided in Appendices 6 to 14.

**Table 3.14:** Statistical analysis of the relationship between knowledge scores and demographic variables

| Variable          | Test used              | Mean difference / F/ $\chi^2$ | p-Value       | Significant? | Direction / notes                      |
|-------------------|------------------------|-------------------------------|---------------|--------------|----------------------------------------|
| Gender            | Independent t-test     | t = -1.76                     | 0.0826        | No           | Men scored slightly higher             |
| Employment status | Independent t-test     | t = -1.37                     | 0.176         | No           | Permanent staff scored higher          |
| Training          | Independent t-test     | t = 1.13                      | 0.264         | No           | Trained workers scored slightly higher |
| Age group         | Independent t-test     | t = 0.045                     | 0.964         | No           | No meaningful difference               |
| Work experience   | One-way ANOVA          | F(2,74) = 0.36                | 0.697         | No           | No meaningful difference               |
| Education level   | ANOVA & Kruskal–Wallis | F = 0.08, $\chi^2$ = 0.616    | 0.968 / 0.893 | No           | No difference; violated assumptions    |



### 3.3.5 Relationship between demographics and food safety practice scores

Statistical analyses were conducted to examine the association between demographic variables and food safety practice scores. A summary of the findings is presented in Table 3.15. Full statistical test outputs, including means, confidence intervals, and post-hoc tests (where applicable), are provided in Appendices 15 to 21.

Results indicate that age, employment status, formal training, and work experience were significantly associated with practice scores. Older food handlers, those in permanent employment, individuals with prior training, and those with more years of experience demonstrated significantly better food safety practices ( $p < 0.05$ ). Gender and education level were not significantly associated with practice scores. Although male participants and participants with higher education levels had slightly higher mean scores in some cases, these differences were not statistically significant.

**Table 3.15:** Statistical analysis of the relationship between practice scores and demographic variables

| Variable          | Test used              | Statistic (t/F/ $\chi^2$ ) | p-Value         | Significant? | Comment                                             |
|-------------------|------------------------|----------------------------|-----------------|--------------|-----------------------------------------------------|
| Gender            | Independent t-test     | t = -0.79                  | 0.430           | No           | Male participants scored slightly higher            |
| Age group         | Independent t-test     | t = -2.94                  | 0.004           | Yes          | Older participants scored significantly higher      |
| Employment status | Independent t-test     | t = -5.65                  | <0.001          | Yes          | Permanent staff scored significantly higher         |
| Training          | Independent t-test     | t = 3.17                   | 0.002           | Yes          | Trained individuals scored significantly higher     |
| Work experience   | ANOVA + Kruskal-Wallis | F = 9.22; $\chi^2$ = 13.55 | 0.0003 / 0.0011 | Yes          | More experience is associated with better practices |
| Education level   | ANOVA + Kruskal-Wallis | F = 0.58; $\chi^2$ = 3.03  | 0.627 / 0.387   | No           | No significant effect                               |

### 3.3.6 Relationship between knowledge scores and practice scores

A simple linear regression was conducted to examine whether food handlers' hygiene practice scores significantly predicted their knowledge scores. The model was

statistically significant,  $F(1,75) = 5.29$ ,  $p = 0.024$ , and explained approximately 6.6% of the variance in knowledge scores ( $R^2 = 0.066$ ). Practice scores were a significant predictor of knowledge ( $\beta = 0.361$ ,  $p = 0.024$ ), indicating that for each one-point increase in practice score, the knowledge score increased by approximately 0.36 points. This suggests a weak but meaningful positive relationship between hygiene practices and food safety knowledge among food handlers. Full regression outputs are presented in Appendices 22 and 23 and Table 3.16.

**Table 3.16:** Linear regression results for the effect of practice on knowledge scores

| Predictor variable | Outcome variable | $R^2$ | F(df)            | B coefficient   | p-Value | Significant? | Interpretation                             |
|--------------------|------------------|-------|------------------|-----------------|---------|--------------|--------------------------------------------|
| Practice score     | Knowledge score  | 0.066 | $F(1,75) = 5.29$ | $\beta = 0.361$ | 0.024   | Yes          | Weak but significant positive relationship |

### 3.4 Discussion

#### 3.4.1 Demographic characteristics

The majority of the participants were female food handlers (71.43%) and over 35 years old (67.53%). These findings are consistent with other studies. For instance, Siew et al. (2014) reported that 84.7% of the participants were female food handlers, with over 55.5% having completed secondary education. Similarly, Vitoria et al. (2021) found that female participants predominated (96.5%) in Brazil, with 57.9% having attained high school education, 39.5% having more than 5 years of experience, and 74.4% having received formal training. In Ethiopia, Shifare (2024) reported that 89.5% of the participants were female food handlers, and the majority had only primary education. This study found that 74.03% of participants had secondary education, with only 9.09% having completed primary education.

Comparing these demographics internationally reveals both parallels and distinctions. Gameda et al. (2024), studying food handlers in Adama town, Ethiopia, found that 63% were female, with a mean age of 30.2 years ( $\pm 6.36$ ), compared to a larger proportion aged 35 or older in my study. Employment stability was slightly higher in my cohort, with 63.64% of individuals permanently employed, compared to 65.8% on

monthly contracts in Adama. Educational attainment and formal training were also more prevalent in my sample.

Bangladesh presents a different demographic profile; a systematic review of 12 studies reported a male majority of food handlers, with 41% to 52% lacking formal education (Farhana et al., 2020; Al Mamun et al., 2013; Nizame et al., 2019; Al Banna et al., 2021). Five studies included only male participants, in stark contrast to the female predominance in my study. Tarannum (2021) noted that higher education is more prevalent among household food handlers compared to street vendors or restaurant workers.

In Somaliland, Abdilahi et al. (2025) surveyed 306 food handlers, of whom 85.3% were male, 76.8% were aged 20 to 29 years, and over 84% lacked formal education. Only 30% were married, highlighting differences in age, gender, and education compared to my predominantly older, female participants and better-educated cohort employed in formal school settings.

Similarly, Mathenge et al. (2018) reported that 80% of participants in Nairobi were male food handlers, with a median age of 30.5 years, in contrast to the older, predominantly female participants in my study. Although 36% of those in Nairobi completed secondary school and 34% had post-secondary education, my study showed a higher proportion with secondary education (74.03%), but fewer with post-secondary qualifications. Formal training was more widespread in Nairobi (64%) than in my study (58.44%). These differences may influence food safety behaviours and highlight contextual variation in workforce profiles.

In South Africa, Makhunga et al. (2023) examined food handlers in charitable food assistance programmes (CFAPs) within the eThekweni District. They found 94% female participants, with 49.2% aged 50 or older, indicating an older workforce than in my study. Educational levels were relatively high, with 40.5% having Grade 12 certificates and 59.1% having post-matric qualifications. Most participants, at 72.2% had over ten years of experience, and 60.7% were directly engaged in food service. Despite this, only 12.3% had received formal food hygiene training in the past five years. Compared to my study, participants were older and female predominated, with lower educational attainment at 1.30% and, somewhat higher formal training at

58.44%, and excluding Hazard Analysis and Critical Control Points. These differences underscore the variability in demographic and educational profiles across settings, with implications for food safety practices.

Amaich & Art El (2024) surveyed 282 food handlers in central Morocco, revealing that most were men (86.88%), predominantly aged 20 to 30 years (41.13%), followed by 30 to 40 years (25.53%). Education varied, with 56.38% attaining secondary education and 26.95% attaining only primary education, similar to my sample's educational profile. Most participants (61.70%) had 1–5 years of experience, with 45.74% in food service roles and 34% in preparer roles. Over 60% had no formal food safety training, and work schedules varied between afternoon, morning, and rotating shifts. These findings highlight the heterogeneity in workforce composition and training across geographical and operational contexts.

In my study, 55.8% of food handlers had formal food safety training, and the average knowledge score was 79%. However, none had received Hazard Analysis and Critical Control Points training, and self-reported practices may not fully reflect actual behaviours. Aljasir (2023) reviewed 37 studies across Gulf countries and found that food safety knowledge was generally low to moderate, often failing to translate into proper food handling behaviours. Training and education were key predictors of both knowledge and practice; however, even trained individuals inconsistently implemented safety measures. These persistent gaps underline the necessity for continuous education, supervision, and practical reinforcement to mitigate foodborne disease risks effectively. Work experience in this study varied: 41.56% had over 5 years, 41.56% had 0 to 3 years, and 16.88% had 3 to 5 years. This distribution suggests the need for ongoing professional development and refresher training to sustain safe food handling practices.

### **3.4.2 Knowledge of food handlers on food safety**

The findings of this study indicate that food handlers in primary schools possess an above-average level of food safety knowledge, demonstrating a commendable understanding of the essential principles of food safety. The average knowledge score was 79.7%. Despite this generally positive outcome, notable gaps persist, signaling opportunities for further educational interventions. Comparable studies reinforce these

results within educational settings. For example, Smith et al. (2020) reported an average knowledge score of 76.5% among food handlers in secondary schools, while Johnson and Lee (2019) found a score of 73.8% in childcare centres. Similarly, Garcia et al. (2021) observed a 75.2% knowledge score among food service workers in community colleges.

These results contrast with lower levels of knowledge observed in other global studies. Rifat et al. (2022) found that 62.5% of food handlers in Bangladesh had poor food safety knowledge. In Somaliland, Abdilahi et al. (2025) reported that only 11.8% of food handlers had formal food safety training, and 64.7% demonstrated poor food safety knowledge. Similarly, Nasir & Ezzaddin (2025) in Iraq and Makhunga et al. (2023) in South Africa reported low levels of food safety knowledge, particularly in charitable food settings. In comparison, Gebru et al. (2024) in Ethiopia reported that 79.5% of food handlers had good knowledge, but only 37.7% adhered to safe practices. Sezer (2024) in Türkiye found moderate knowledge (68.03%) among handlers, but significant gaps in their understanding of foodborne disease risks and reheating practices.

These international comparisons reinforce the relatively strong performance of school-based food handlers in this study, which is likely due to institutional support, access to training, and routine oversight. However, the persistent gaps observed across all settings indicate a universal need for continuous, context-specific food safety education.

The data also reveal a strong awareness of food contamination, with an average of 81.53% of food handlers recognising factors contributing to foodborne illnesses. This knowledge is crucial, as contamination can occur at multiple stages, including preparation, cooking, and serving (Fitzgerald et al., 2019).

However, 74.03% of food handlers in this study acknowledged that contaminated food may not exhibit changes in colour, odour, or taste, a vital but often misunderstood concept. This finding is consistent with the CDC (2023) and WHO (2020) guidelines, which emphasise that many pathogens do not alter sensory qualities. In similar studies, only 35.06% of food handlers in Türkiye recognised the risks posed by heat-

resistant toxins (Sezer, 2024), while time and temperature abuse were minimally recognised in Ethiopia and Bangladesh (Gebru et al., 2024; Rifat et al., 2022).

While 80.52% recognised the danger of cross-contamination from raw to cooked foods, and 92.21% identified risks related to utensil transfer, these numbers, although high, still suggest room for improvement. For instance, in Somaliland, knowledge of contamination routes was significantly lower (Yusuf et al., 2023). Similarly, recognition of less obvious contamination sources, such as viruses (1.30%) and chemicals (7.79%), remains alarmingly low in this study and aligns with findings from Bangladesh and Iraq, where awareness of microbial and chemical contamination was lacking (Rifat et al., 2022; Nasir & Ezzaddin, 2025).

Food handlers demonstrated commendable awareness of personal and hand hygiene, with an average score of 88.53%. Proper hygiene is crucial in preventing the transmission of foodborne pathogens, primarily through effective handwashing and maintaining cleanliness (López-Gálvez et al., 2020).

Despite this, other studies have reported a gap between knowledge of hygiene and its application. Moyo & Okafor (2017) found that while 65% of food handlers understood hygiene practices, only 50% adhered to them. Similarly, Gebru et al. (2024) observed poor hygiene behaviour despite good theoretical knowledge. The present study echoes this tension: although 85.42% recognised improper handwashing risks, and 96.10% agreed on the importance of handwashing after sneezing or smoking, the real-world implementation of these practices may vary.

The use of gloves (80.52%) and recognition of long, painted nails as a risk factor (87.01%) reflect a solid conceptual understanding, consistent with findings by Sezer (2024) and Makhunga et al. (2023); however, actual compliance with these practices in other studies has been mixed.

The study's findings reflect a proactive stance on infection prevention. Their participants recognised that the link between *Food Safety and Public Health* fosters safer food service behaviours, including illness reporting and adherence to sick leave policies (Al-Shabib et al., 2017; Matsheka & Lembede, 2019).

Most respondents (93.51%) acknowledged the importance of health screening before employment, a higher rate than the 67.53% observed in this study's direct observations. In Ethiopia, only 45% of food handlers had undergone medical examinations (Gebru et al., 2024), and in Saudi Arabia, the rate was 70% (Al-Haddad et al., 2017).

Recognition of symptoms and illness-related risks was generally high, with 87.01% understanding the danger of working while ill, and 83.12% acknowledging that asymptomatic individuals can still transmit pathogens. These findings align with global health recommendations and further underscore the importance of institutional enforcement of health screening policies.

A significant knowledge gap was identified in temperature control, a fundamental aspect of food safety. Similar shortcomings have been widely documented in previous research. For instance, Teffo & Tabit (2020) found that fewer than one-third of hospital food handlers correctly identified the safe method for thawing frozen foods, highlighting limited understanding of basic temperature requirements. Likewise, a study in São Paulo found that many food handlers held “diverse and erroneous” beliefs about safe food temperatures, including misconceptions about refrigeration, freezing, and defrosting (da Silva Cota et al., 2023). Consistent with these findings, Ncube et al. (2020) observed that a substantial proportion of restaurant food handlers believed that refrigeration and freezing kill bacteria, demonstrating a persistent misunderstanding of how pathogens survive under cold conditions. Collectively, these studies reinforce the conclusion that gaps in temperature-control knowledge such as failing to recognise the presence of heat-resistant toxins or assuming visual cues signal contamination remain common across diverse food service environments.

These results align with those of Walker et al. (2003), Palak et al. (2001), and Bas et al. (2006), as well as recent data from Türkiye and Ethiopia, where a poor understanding of temperature-related hazards was prevalent (Sezer, 2024; Gebru et al., 2024). This knowledge gap is particularly concerning in school settings, where vulnerable populations are served, and highlights an urgent need for targeted training.



### 3.4.3 Assessment of food safety practices among food handlers

The assessment of food safety practices among food handlers in public schools using both self-reported data and direct observation provides critical insights into the alignment between knowledge and actual behaviours. Although food handlers demonstrated high levels of self-reported compliance in key food safety domains, observable practices revealed notable discrepancies. This disconnect suggests a need for more rigorous training, practical supervision, and reinforcement of workplace accountability measures. Food handlers reported high compliance with essential food safety practices, with self-reported adherence rates of 90.91% for infection prevention, 89.9% for hand hygiene, and 87.3% for personal hygiene. This yielded an overall average of 89.37%, suggesting a strong theoretical understanding and a generally positive safety culture. These findings align with studies such as Seaman & Eves (2010) and Bas et al. (2006), which similarly reported high self-declared adherence among food service workers.

However, these self-reports may be influenced by social desirability bias, as suggested by Nee et al. (2011), where food handlers may overstate their compliance to meet perceived expectations. For instance, some food handlers in this study admitted willingness to work while experiencing symptoms like vomiting, a behaviour that contradicts public health guidelines and represents a critical risk for pathogen transmission. This inconsistency between knowledge and practice reflects an area of concern that must be addressed through policy enforcement and behavioural training.

Another divergence was observed in the low rate of mask usage during food distribution and preparation, a particularly important issue considering recent global health crises. Despite heightened awareness, only 22.08% of food handlers used masks, contrasting with 55% reported in a study among street food vendors in Pakistan (Niaz et al., 2021). This gap highlights the need for updated training modules that emphasise emerging food safety threats, including the transmission of respiratory pathogens.

In conclusion, while self-reported practices indicate a commendable level of food safety awareness, actual behaviour suggests otherwise, necessitating ongoing education, policy enforcement, and workplace audits to bridge the gap between



knowledge and its effective implementation. These recommendations align with findings from recent studies, such as Al-Mamun et al. (2013), which emphasise the importance of continuous, practical, and context-relevant food safety education to enhance compliance and mitigate risks.

The direct observation of food handlers revealed a more nuanced and concerning picture. While the observed compliance rate was 70.13%, the overall average score was 75.75%, which is significantly lower than the self-reported figures. This discrepancy mirrors findings by Makhunga et al. (2023), who documented similar knowledge-practice gaps among institutional food handlers in Southern Africa.

A key concern is that only 67.53% of food handlers had valid medical examinations, a critical safeguard for public health. This figure reflects similar concerns raised by Al-Haddad et al. (2017) in Saudi Arabia, where only 70% of food handlers had recent health checks, potentially exposing consumers to undiagnosed foodborne risks.

In terms of hygiene practices, 87.01% reportedly washed their hands frequently, but only 55.84% used proper hand-drying methods, a vital step for preventing microbial contamination. This pattern is consistent with findings from Kumar & Mishra (2019) in India, who noted that although 75% of food handlers washed their hands regularly, only 50% used appropriate drying techniques.

Use of personal protective equipment was inconsistent. Although 71.43% wore clean aprons and 79.22% wore hygienically appropriate clothing, the extremely low mask usage (22.08%) is a significant lapse. In comparison, street vendors in some regions reported better compliance, such as the 55% of food handlers wearing hygienically appropriate clothing in Pakistan (Niaz et al., 2021).

Positive behaviours were noted in 63.64% of food handlers, who kept their nails short and clean, and 68.83% avoided wearing jewellery, both practices essential in reducing the risk of microbial harbourage and physical contamination. These figures align with the results from Basha et al. (2020) in Bangladesh, where 65% of food handlers maintained nail hygiene and 72% refrained from wearing jewellery.

Despite these positive indicators, the overall picture reveals an implementation gap. Food handlers may know what is required, but resource constraints, lack of monitoring, or cultural practices could hinder consistent adherence.

#### **3.4.4 Demonstration of hand-washing technique**

The findings from this study indicate a clear and consistent pattern: as the handwashing process progresses through its more detailed stages, there is a steady decline in the proper execution of technique among food handlers. While initial steps such as wetting hands and applying soap were generally well adhered to, significant lapses occurred during the latter, more intricate stages, particularly cleaning of fingertips and wrists.

This pattern aligns with previous research, including Pragle et al. (2007), Green et al. (2006), and Strohbehn et al. (2008), who reported that food handlers often rushed through or omitted key steps in the handwashing process, performing only simplified versions of the recommended technique. Similarly, Sezer (2024) documented low compliance with detailed hand hygiene practices among food handlers in Türkiye, reinforcing that this issue is not location-specific but a broader training and behaviour challenge.

The particularly sharp drop observed in this study during the final steps, particularly in wrist and fingertip cleaning, represents a notable and novel finding, suggesting either a lack of training emphasis on these steps or a limited understanding of their importance in pathogen removal. These results highlight a critical training gap, where food handlers may be aware of the general need for handwashing but lack clarity or skill in executing the full procedure correctly.

To address this issue, comprehensive and repeated training is recommended, focusing not only on the steps of handwashing but also on the rationale behind each step, particularly the less intuitive steps. Visual aids, demonstrations, and behaviour modelling could be effective in reinforcing correct techniques. These strategies are supported by Bas et al. (2006) and Seaman & Eves (2010), who emphasised the importance of practical, hands-on instruction in food safety programmes.

In conclusion, while compliance with basic handwashing steps is relatively high, the drop in adherence to more complex or final steps indicates a targeted area for improvement. Strengthening food handlers' understanding and adherence to complete hand hygiene practices is essential for minimising foodborne illness risks and ensuring overall food safety in institutional settings.

### **3.4.5 Influence of demographic factors on food safety knowledge and practices**

The study found no statistically significant association between food safety knowledge and demographic characteristics, including gender, age, education level, work experience, employment status, or food safety training. While groups such as trained food handlers, permanent employees, and male participants had slightly higher mean knowledge scores, these differences were not statistically meaningful ( $p > 0.05$ ). This finding is consistent with research by Teffo & Tabit (2020) and Baldeh et al. (2020), which showed that demographic variables and formal education alone are not reliable predictors of food safety knowledge.

The lack of a significant relationship between knowledge and educational level challenges common assumptions that formal education enhances food safety competence. This supports the findings by Baldeh et al. (2020), who reported no meaningful correlation between academic qualifications and food safety knowledge. These results emphasise the importance of hands-on, targeted training that addresses food safety concepts in a practical and accessible manner for all education levels.

Similarly, no significant differences in knowledge were observed based on age or work experience. While it is often assumed that older and more experienced individuals possess greater knowledge, this study, along with others (Redmond & Griffith, 2003; Berger et al., 2022), suggests that without structured, ongoing training, knowledge may remain static or decline over time.

Food safety practice scores were significantly associated with several demographic variables, including age, employment status, work experience, and training. Older food handlers, those employed permanently, individuals with longer job experience, and those who had received formal food safety training demonstrated significantly better hygiene practices ( $p < 0.05$ ). These results align with findings from studies conducted in Ethiopia and Pakistan (Asmelash et al., 2021; Tessema et al., 2022; Ali et al., 2022),

which highlighted that practical experience, job security, and training play critical roles in shaping positive food safety behaviours.

Gender and education level were not significantly associated with food safety practices, mirroring the lack of association between these demographic factors and food safety knowledge. In fact, Teffo & Tabit (2020) found that hospital food handlers with higher academic qualifications and more work experience did not have significantly better food safety knowledge than those with lower education or experience, suggesting that formal education alone may not be sufficient to improve food safety competence.

### **3.4.6 Relationship between knowledge and practice**

A simple linear regression analysis revealed a significant but weak positive relationship between food safety practice and knowledge scores ( $\beta = 0.361$ ,  $p = 0.024$ ;  $R^2 = 0.066$ ). This suggests that while better hygiene practices are associated with higher food safety knowledge, the strength of the relationship is modest.

This finding aligns with previous research suggesting that knowledge is a necessary but not sufficient condition for good food safety behaviour. Even with adequate knowledge, other factors such as workplace culture, motivation, monitoring, and available resources can influence whether food handlers apply that knowledge effectively (Berger et al., 2022; Redmond & Griffith, 2003).

These results highlight the importance of reinforcing knowledge with practical training and behaviour-based interventions. While knowledge provides the foundation, practice is shaped more strongly by experiential and environmental factors, including support from management and the frequency of hands-on food safety education.

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## CHAPTER 4: ASSESSMENT OF HAND HYGIENE PRACTICES AMONG FOOD HANDLERS IN PUBLIC PRIMARY SCHOOLS: A MICROBIOLOGICAL EVALUATION OF *ESCHERICHIA. COLI* AND TOTAL COLIFORM CONTAMINATION

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### Abstract

**Background:** Hand hygiene among food handlers is pivotal in preventing foodborne diseases, particularly in school settings where children are more vulnerable to infections. This study evaluated the prevalence and levels of total coliforms and *Escherichia coli* (*E. coli*) on the hands of food handlers at 10 public primary schools in Gaborone, Botswana, in 2022.

**Methods:** A total of 77 hand swab samples were collected from food handlers using sterile swabs. Samples were directly streaked onto chromogenic media that support the simultaneous detection of total coliforms and *E. coli*. Plates were incubated at 37°C for 24 hours, after which colony growth was assessed based on characteristic colour development and morphology. Bacterial counts were categorised into four contamination levels: none, low (1–49 CFU), moderate (50–99 CFU), and high ( $\geq 100$  CFU).

**Results:** Of the 77 samples, 32.47% (25/77) tested positive for total coliforms, while 67.53% showed no detectable contamination. Among the positive samples, 31.17% exhibited low-level contamination, and 1.3% showed moderate contamination. No high-level contamination was observed. Importantly, *E. coli* was not detected in any of the samples, indicating an absence of direct faecal contamination. Variation in contamination levels was observed between schools, with School 2 showing the highest prevalence (77.8%) and the highest average CFU count (15.4), followed by Schools 5 and 7.

**Conclusion:** The presence of total coliforms on nearly one-third of food handlers' hands suggests persistent lapses in hand hygiene practices, although the absence of *E. coli* indicates a lack of recent faecal contamination. These findings underscore the need for strengthened hygiene education, improved sanitation facilities, and ongoing

monitoring programmes to ensure food safety in school environments. Enhanced hand hygiene compliance among food handlers is essential to minimise the risk of foodborne disease transmission and safeguard the health of schoolchildren.

#### 4.1 Introduction

Food handlers' hands represent a crucial point of potential contamination in institutional food preparation settings such as school kitchens. Inadequate hand hygiene can transfer pathogenic microorganisms to food, leading to foodborne illnesses, particularly among vulnerable populations, such as schoolchildren (WHO, 2020; Amoah et al., 2021). *Escherichia coli* (*E. coli*) and total coliforms are widely recognised as indicators of faecal contamination and poor sanitary practices; their presence on hands signals a failure in fundamental hygiene procedures (Lambrechts et al., 2014). The WHO (2020) emphasises that unwashed or improperly washed hands are among the leading contributors to foodborne disease outbreaks, particularly in low-resource settings.

Globally, foodborne pathogens remain a significant public health concern, with bacteria such as *E. coli*, *Salmonella* spp., *Listeria monocytogenes*, *Campylobacter* spp., and *Shigella* spp. contributing to diarrhoea, gastroenteritis, and other serious illnesses (Iwamoto et al., 2019; Weiler et al., 2011). Approximately 550 million cases of foodborne disease occur annually worldwide, resulting in over 230,000 deaths, highlighting the scale of the problem (WHO, 2015). In Botswana, although many tropical diseases are uncommon, foodborne illnesses are primarily linked to suboptimal food handling and inadequate hygiene awareness (Urio, 2001). Studies in the Chobe District have detected *E. coli* in fresh produce at 15.5%, with 72% of isolates resistant to at least one antibiotic, raising concerns about contamination and antimicrobial resistance (Bywater et al., 2024). Complementary studies in poultry also revealed virulence genes and resistance in *E. coli*, indicating potential transmission risks along the food supply chain (Yi et al., 2024).

Research from other African contexts highlights the role of food handlers in the transmission of microbes. In Ethiopia, Assefa et al. (2015) reported significant contamination of food handlers' hands with pathogenic bacteria, while a recent study in Côte d'Ivoire showed the presence of *E. coli* and *Staphylococcus aureus* on hands

during the COVID-19 pandemic, underscoring the persistent risks in both rural and urban settings (Traoré et al., 2024). These findings collectively demonstrate that microbial contamination on hands is a substantial risk factor for foodborne disease, with implications for both local and regional public health.

This chapter presents the microbiological findings of the study, specifically examining the detection and levels of *E. coli* and total coliforms on the hands of food handlers working in selected public primary school kitchens in Gaborone, Botswana. The study aims to describe the extent of microbial contamination, identify patterns across schools and individuals, and interpret the public health implications. Findings are compared with those from similar studies in the region and internationally to contextualise hygiene practices and provide evidence-based recommendations for improving food safety in school feeding programmes.

## **4.2 Methodology**

### **4.2.1 Study design**

This study employed a cross-sectional descriptive design to assess hand hygiene practices among food handlers in public primary schools in Gaborone. The primary objective was to determine the presence and level of microbial contamination on the hands of food handlers, with a specific focus on *E. coli* and total coliform bacteria. Data collection was conducted using a microbiological hand swab analysis.

### **4.2.2 Study population**

The study population consisted of all food handlers who participated in both the questionnaire survey and observational assessment, as detailed in Chapter 3: Methodology. These individuals were drawn from the same study area and under the same ethical approval framework established for the research. The inclusion of this population ensured consistency in data collection and alignment with the study's objectives.



### 4.2.3 Data collection procedures

Hand swabbing was performed using sterile cotton swabs that were pre-packaged with transport media, eliminating the need for additional preparation. The hands of each participant were swabbed, with attention given to the fingertips, palm, areas between the fingers, and underneath the fingernails. The swab was gently rotated across these areas for approximately 10 to 15 seconds. After collection, the swabs were returned to their original transport tubes and securely sealed. Each sample was labelled with the corresponding participant code. All swabs were then stored in a cooler box with ice packs and transported to the microbiology laboratory within 30 minutes of collection. The researcher adhered to strict hand hygiene and aseptic procedures throughout the sampling, transport, and analysis processes to minimise the risk of cross-contamination and protect laboratory personnel. Improper handling of specimens can pose significant infection risks; therefore, all activities were conducted in accordance with established laboratory biosafety guidelines (WHO, 2004).

### 4.2.4 Laboratory analysis

BILL Brilliant™ *E. coli*/ coliform Medium was prepared in advance according to the manufacturer's instructions to ensure it was ready for immediate use upon sample collection. This allowed for the prompt processing of the hand swab samples upon arrival at the laboratory.

Upon receipt of the swabs, the laboratory workstation was cleaned and disinfected using 70% ethanol, and a Bunsen burner was used to maintain a sterile environment during handling. Using aseptic techniques, each swab was streaked onto the prepared medium employing the streak plate method to isolate bacterial colonies.

Each Petri dish was labelled with the corresponding sample code and incubated at 37°C for 24 hours. After incubation, plates were examined for bacterial growth. Colony-forming units (CFUs) were manually counted to quantify the microbial load present on each hand swab.

All laboratory procedures were conducted by the researcher, ensuring consistency in the handling of all samples. These analyses were conducted in the presence of an official from the Botswana National Food Laboratory, who supervised the process and



verified that all procedures were carried out according to national standards. This oversight added a layer of credibility and quality assurance to the microbiological findings.

### **1.1.1 Interpretation of *E. Coli* and total coliform results from hand swabs**

After 24 hours of incubation at 37°C, Petri dishes inoculated with hand swab samples were removed and first examined for any visible microbial growth. Before interpreting the test samples, a negative swab control was prepared using an unused, sterile swab that was transported and handled alongside the actual samples. This control underwent all stages of handling, including transportation, exposure during streaking, and incubation, but not direct contact with participants' hands. The control ensured that no contamination occurred at any point during sample collection, handling, or laboratory processing. The absence of growth on the control confirmed the sterility of the materials and procedures used.

For plates showing growth, colony identification was based on chromogenic colour differentiation, as per the enzymatic reactions defined in the manufacturer's protocol for BILL Brilliant™ *E. coli*/ coliform Medium and aligned with ISO 9308-1:2014 standards.

- Colonies exhibiting a dark blue to violet colour, due to a positive reaction for both  $\beta$ -D-galactosidase and  $\beta$ -D-glucuronidase, were identified as *E. coli*.
- Colonies that appeared pink to red, indicating a positive  $\beta$ -D-galactosidase reaction only, were classified as presumptive total coliforms (excluding *E. coli*).

Only colonies displaying these defined characteristics were considered valid for enumeration. The number of CFUs was manually counted using a magnifying glass to enhance visibility. As each sample was analysed using a single Petri dish, the result was reported directly as CFU per hand swab, representing the microbial load on the swabbed hand surface area.

### **1.1.2 Quality control measures**

To ensure the reliability and validity of the study findings, strict quality control protocols were followed throughout the research process. Swab collection was conducted solely

by the researcher using a standardised procedure across all schools. All microbiological media and laboratory reagents were sourced from accredited suppliers and stored according to manufacturer guidelines. Laboratory equipment was routinely calibrated, and standard quality control strains were used to verify the accuracy of culture media and incubation conditions. These measures helped to ensure that results were both reproducible and scientifically sound.

To ensure the reliability of the microbial analysis and to rule out any external sources of contamination, three types of negative controls were incorporated into the study:

- **Swab control:** This control was used to detect any contamination originating from the sterile swab itself. An unused sterile swab was directly streaked onto an agar plate without contacting any surface. The plate was then incubated under the same conditions as the test samples. As expected, no microbial growth was observed, confirming the sterility of the swab material.
- **Media control:** This control aimed to verify the sterility of the culture media and the incubation environment. Uninoculated agar plates were incubated without any exposure to biological material. These plates also showed no microbial growth, confirming that the culture medium and incubation conditions were not sources of contamination.
- **Field negative control:** For each sampling session, one unused sterile swab from the same batch used for hand swabbing was transported alongside the actual samples. This swab was exposed to the same handling, environmental conditions, and laboratory procedures as the test swabs but was not used to swab any surface. It was streaked onto an agar plate and incubated identically to the test samples. The absence of microbial growth on this plate confirmed that contamination did not occur during sample transport, handling, or laboratory processing.

The absence of growth in these controls confirmed that observed colonies on participant swabs were due to contamination from the participants' hands rather than external sources.

#### 4.2.5 Data analysis

Microbial contamination data were recorded as reported as CFU per hand swab for each hand swab sample. For ease of interpretation and comparison, CFU values were also categorised based on numerical ranges into defined contamination levels: low, moderate, and high. Additionally, binary classifications were applied to indicate the presence or absence of *E. coli* and total coliforms.

Descriptive analysis was performed using Stata software, with results presented in tables and figures that show the distribution of contamination levels by school and participant characteristics. This chapter focuses on the presentation of these descriptive distributions.

### 4.3 Results

#### 1.1.3 Detection of *Escherichia coli*

All 77 hand swab samples collected from food handlers across the ten public primary schools in Gaborone tested negative for *E. coli*. No colonies indicative of *E. coli* were observed on the culture media used during laboratory analysis.

#### 1.1.4 Detection of total coliforms

The microbiological analysis of hand swab samples in Table 4.1 shows that total coliforms were detected in a notable proportion of food handlers. Of the 77 hand swabs collected from food handlers across ten public primary schools in Gaborone, 25 samples (32.47%) tested positive for total coliform contamination, while 52 samples (67.53%) showed no detectable coliforms.

**Table 4.1:** Total coliforms detected in hand swab samples (n = 77)

| Total coliforms | Frequency | Percentage (%) | Cumulative percentage (%) |
|-----------------|-----------|----------------|---------------------------|
| Detected        | 25        | 32.47%         | 32.47%                    |
| Not detected    | 52        | 67.53%         | 100.00%                   |
| Total           | 77        | 100.00%        | 100.00%                   |

The exact 95% confidence interval (CI) for the proportion of positive results is estimated to be between 22.23% and 44.10%, while the CI for the negative results

ranges from 55.90% to 77.77%. These intervals provide a statistical estimate of the expected range within the general population of food handlers in similar settings.

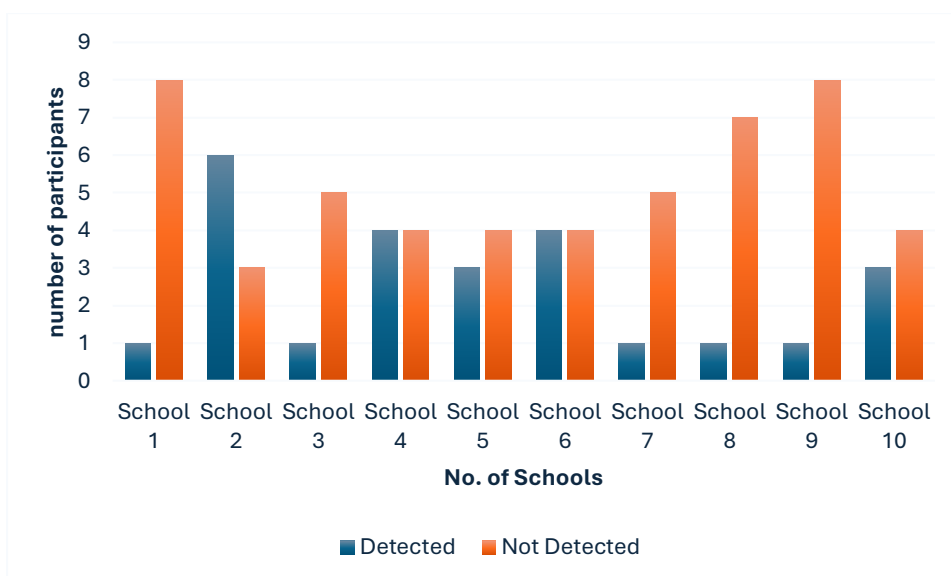
The detection of coliforms in nearly one-third of hand swab samples raises significant food safety concerns.

#### **1.1.5 Total coliform detection per school**

The results in Figure 4.1 revealed notable differences in the presence of total coliforms among the ten participating schools. School 2 recorded the highest rate of total coliform detection, with 77.8% (7/9) of its food handlers testing positive. This high prevalence suggests potential issues related to inadequate hand hygiene practices or environmental contamination within the school's food handling areas.

Other schools with elevated contamination rates included School 4 (50.0%), School 6 (50.0%), and School 5 (42.9%), indicating potential lapses in handwashing compliance or deficiencies in sanitation infrastructure. These findings point to a need for targeted interventions in those schools, such as improved hygiene education and enhanced access to handwashing stations.

In contrast, School 1 (11.1%), School 9 (11.1%), and School 10 (42.9%) showed lower detection rates, suggesting comparatively better adherence to hand hygiene protocols among their food handlers. These schools may benefit from maintaining and reinforcing their current hygiene practices and infrastructure.



**Figure 4.1:** Total coliform detection per school

### 1.1.6 Categorised total coliform results

As shown in Table 4.2, 68.8% of food handlers had no detectable coliforms, which is a positive indication of generally good hand hygiene practices among the majority of participants. However, 28.6% of food handlers had low levels of total coliforms (ranging from 1 to 49 CFU), suggesting the presence of minor contamination. While these levels are not alarmingly high, they are still concerning, as even small amounts of contamination can reflect inadequate handwashing or environmental exposure.

Only 1.3% of participants (1/77) showed moderate contamination, with a total coliform count of 64 CFU. Importantly, no food handler exceeded 100 CFU, meaning there were no cases of high-level contamination recorded in this study.

Overall, while most participants maintained acceptable hygiene, the detection of coliforms in a significant minority highlights the need for continued emphasis on consistent and effective hand hygiene practices in school food handling environments.

**Table 4.2:** Categorised total coliform results

| Coliform category | Range (CFU) | Frequency (n) | Percentage (%) | Participant codes                                                                                                                                                                                                                                                                                        |
|-------------------|-------------|---------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| None detected     | 0           | 52            | 67.53%         | S1P1, S1P2, S1P3, S1P4, S1P6, S1P7, S1P8, S1P9, S2P2, S2P7, S3P1, S3P2, S3P3, S3P4, S3P6, S4P1, S4P2, S4P7, S4P8, S5P1, S5P5, S5P6, S5P7, S6P3, S6P4, S6P6, S6P8, S7P1, S7P2, S7P4, S7P5, S7P6, S8P2, S8P4, S8P6, S8P7, S8P8, S9P1, S9P2, S9P3, S9P4, S9P5, S9P6, S9P7, S9P8, S10P2, S10P4, S10P6, S10P7 |
| Low               | 1–49        | 24            | 31.17%         | S1P5, S2P1, S2P3, S2P4, S2P5, S2P6, S2P8, S3P5, S4P3, S4P4, S4P5, S4P6, S5P2, S5P3, S5P4, S6P2, S6P5, S6P7, S7P3, S8P1, S8P3, S8P5, S9P9, S10P1, S10P3                                                                                                                                                   |
| Moderate          | 50–99       | 1             | 1.3%           | S2P9                                                                                                                                                                                                                                                                                                     |
| High              | ≥100        | 0             | 0%             | –                                                                                                                                                                                                                                                                                                        |
| Total             | –           | <b>77</b>     | <b>100%</b>    | –                                                                                                                                                                                                                                                                                                        |

### 1.1.7 Summary of total coliform CFU levels by school

The analysis of total coliform contamination across the ten participating public primary schools revealed notable variation in both the frequency and intensity of microbial presence on the hands of food handlers. School 2 had the highest number of positive cases, with 7/9 participants testing positive for total coliforms. It also recorded the highest maximum CFU count (64) and an average of 15.4 CFU among those who tested positive. This suggests that School 2 may be facing systemic hygiene challenges, possibly due to inconsistent handwashing, limited access to sanitation facilities, or environmental contamination in food handling areas. School 5 also showed notable contamination, with 3/7 positive participants. One food handler recorded 41 CFU, contributing to an average of 14.7 CFU among positives. Similarly, School 7 had only one positive case, but the detected CFU was 22, which is relatively high for a single sample, highlighting potential localised risk despite low detection numbers.

Other schools, such as School 1, School 3, and School 4, reported low levels of contamination. For example, School 1 had just one positive case with a low count of

2 CFU, and School 3 reported a single detection of 1 CFU. These minimal counts may reflect better hygiene behaviour or more effective handwashing practices.

Schools 9 and 10, each with one positive case at 8 CFU, fall in the mid-range of contamination severity. Notably, School 6 had four detected cases (not two as originally noted), with CFU values of 1, 1, 16, and 0 (excluded), yielding a corrected average of 6.0 CFU.

When comparing average CFU levels, Schools 2, 5, and 7 had the highest microbial loads, signalling a need for targeted hygiene interventions. Schools with lower average CFUs and fewer detections may reflect more consistent hygiene compliance.

Overall, while most schools had relatively low contamination levels, the presence of total coliforms in 25/77 participants (32.47%) emphasises the ongoing need for regular hygiene training, improved sanitation infrastructure, and strict adherence to food safety practices among school food handlers.

**Table 4.3:** Summary of total coliform CFU levels by school

| School    | No. of participants | No. detected | Min CFU | Max CFU | Average CFU (detected only) |
|-----------|---------------------|--------------|---------|---------|-----------------------------|
| School 1  | 9                   | 1            | 2       | 2       | 2.0                         |
| School 2  | 9                   | 7            | 3       | 64      | 15.4                        |
| School 3  | 6                   | 1            | 1       | 1       | 1.0                         |
| School 4  | 8                   | 4            | 1       | 5       | 2.8                         |
| School 5  | 7                   | 3            | 1       | 41      | 14.7                        |
| School 6  | 8                   | 4            | 1       | 16      | 6.0                         |
| School 7  | 6                   | 1            | 22      | 22      | 22.0                        |
| School 8  | 8                   | 1            | 8       | 8       | 8.0                         |
| School 9  | 9                   | 1            | 8       | 8       | 8.0                         |
| School 10 | 7                   | 2            | 4       | 8       | 6.0                         |
| Total     | <b>77</b>           | <b>25</b>    | —       | —       | —                           |

## 1.2 Discussion

This study evaluated the microbiological quality of food handlers' hands across ten public primary schools in Gaborone, Botswana, focusing on the presence of *E. coli* and total coliforms as indicators of hand hygiene efficacy and potential food safety

risks. The findings offer insight into both strengths and gaps in hygiene practices within structured school environments.

The complete absence of *E. coli* across all 77 hand swab samples is a good and encouraging public health outcome. *E. coli* is a widely recognised indicator of faecal contamination and a known cause of foodborne disease outbreaks (Hassan et al., 2016). Its absence suggests relatively effective hygiene practices among food handlers in the surveyed schools. This contrasts with studies in other African countries such as Sudan, where 87% of hand swabs showed bacterial contamination, including *E. coli* (Honua, 2018), and Ethiopia, where 10.9% of food handlers tested positive for *E. coli* (Assefa et al., 2015). Several factors could explain the absence of *E. coli* in the current study. Structured hygiene interventions, such as handwashing education, access to clean water, and consistent enforcement of hygiene protocols, may have contributed significantly (Heath et al., 2014; WHO, 2009). Schools, being formal institutions, may have better oversight compared to informal food handling environments, such as street vendors or small eateries, where hygiene practices are often poorly regulated.

The absence of *E. coli* in this study, despite the presence of total coliforms, may also reflect effective hygiene practices, particularly hand hygiene, among food handlers. This aligns with the WHO (2020), which identifies contaminated hands as one of the primary pathways for foodborne pathogens like *E. coli* and coliforms. The presence of total coliforms typically indicates poor sanitation, inadequate handwashing, and faecal contamination (Todd et al., 2007). However, *E. coli* was not detected in my samples, suggesting that the handlers in these school kitchens may have consistently practised adequate hygiene, such as proper handwashing with soap and water or the use of alcohol-based hand sanitisers (Hassan et al., 2016). As noted by Heath et al. (2014), food safety training and regular hygiene education can significantly reduce the risk of pathogen transmission.

This interpretation is consistent with Traoré et al. (2024), who found *E. coli* only in rural communities in Côte d'Ivoire but not in urban schools, linking its absence to structured environments with access to clean water and sanitation. Likewise, Palupi et al. (2024) detected *E. coli* in only one of many food samples in Indonesian catering services, even though most food handlers lacked formal training. This suggests that specific



food handling behaviours (e.g., raw food contact or improper storage) may trigger *E. coli* contamination more than general knowledge alone. In contrast, Abidin et al. (2021) found *E. coli* in 9.1% of Warmindo food stalls, directly tied to poor waste disposal, inconsistent PPE use, and informal food prep spaces. These discrepancies highlight that structured environments such as school kitchens may inherently reduce risk.

Further evidence from Mohamed et al. (2024) in Egypt's ready-to-eat food sector showed *E. coli* present in 22.22% of food samples, 12.19% of surface swabs, and 9.38% of hand swabs, revealing a strong link between surface contamination, hand hygiene failures, and foodborne pathogen transmission. Their study emphasised how surfaces like benchtops and cutting boards, when poorly sanitised, promote biofilm formation and serve as reservoirs for *E. coli* and *S. aureus*, thereby increasing the risk of cross-contamination. The lack of *E. coli* in my study may be attributed to effective surface cleaning, reduced biofilm presence, and better personal hygiene, key control measures also highlighted in Mohamed et al.'s (2024) findings.

While the absence of *E. coli* is promising, it should not be taken as evidence of a pathogen-free environment. The detection of coliforms in nearly one-third of hand swabs suggests ongoing hygiene issues, as the presence of coliforms may indicate inadequate hygiene practices or environmental contamination. sanitation failure (Martin et al., 2016). Moreover, structured food preparation settings, such as school kitchens, may inherently carry lower microbial risks compared to informal environments, like street vendors, markets, or restaurants with high food volume and turnover (Hassan et al., 2016). In Botswana, the School Health Programme (SHP) is an established initiative created by the Ministries of Health, Education, and Local Government, which includes environmental health assessments as a core component. Under the School Health Programme, school teams, when fully functional, are expected to include environmental health officers who participate in routine inspections of school facilities, such as sanitation, water supply, and the overall hygiene environment of schools (Shaibu & Phaladze, 2010). The health promotion structures, such as the Health Education and Promotion Unit, coordinate school health services nationally, integrating environmental health, health education, and hygiene oversight (Tapera et al, 2018). This institutional framework likely contributes to the relatively good hygiene practices observed in this study, possibly helping explain why

*E. coli* was not found on any hand swab samples. Despite this, the literature also notes that the implementation of the School Health Programme is uneven, as some schools face difficulties with supplies, resources, and consistent oversight (Shaibu & Phaladze, 2010), which may explain why total coliforms were still present in a sizable minority of samples. However, this should not lead to complacency. As *E. coli* contamination may be episodic or missed due to sampling limitations, continuous monitoring, proper handwashing, surface sanitation, and annual food safety training remain essential (WHO, 2009; Heath et al., 2014). Ultimately, while *E. coli* was not found, the presence of indicator organisms signals the need for sustained vigilance in hygiene practices to protect against broader microbial risks.

Despite the absence of *E. coli*, total coliforms were found in 25/77 samples (32.47%), indicating lapses in hygiene that could still pose food safety risks. Coliform bacteria are widely used as indicator organisms to assess general hygiene and potential faecal contamination (He et al., 2020). Their presence suggests that some food handlers may not be consistently following proper hand hygiene procedures. When coliform levels were categorised, 68.8% of food handlers had no detectable coliforms, 28.6% showed low-level contamination (1-49 CFU), and 1.3% had moderate contamination (50–99 CFU). While no high-level contamination ( $\geq 100$  CFU) was observed, even low levels may contribute to foodborne illness, particularly in settings serving vulnerable populations like children. These findings align with those of Ahmednur et al. (2023), who found that microbial hand contamination can persist even after hand washing, particularly when water quality is compromised. Their study established a statistically significant correlation ( $r = 0.34$ ,  $P = 0.032$ ) between the presence of coliforms in water and contamination on hands, underlining the importance of both water infrastructure and behavioural hygiene (Ahmednur et al., 2023).

A significant outcome of this study was the significant variation in coliform contamination levels across the ten surveyed schools, highlighting the need for localised and tailored hygiene interventions. School 2 recorded the highest contamination rate, with 77.8% (7/9) of food handlers testing positive and the highest colony-forming unit (CFU) count at 64, averaging 15.4 CFUs among positive cases. These results suggest systemic hygiene challenges in this school, potentially stemming from limited access to handwashing facilities, ineffective hygiene training,

or poor sanitation practices overall. Similarly, School 5 had 3/7 positive participants, with a comparable average CFU of 14.7, indicating a notable contamination risk. School 7, although showing only one positive case, recorded a high individual count of 22 CFUs, which could indicate localised lapses in hygiene protocols. In contrast, Schools 1, 3, and 4 showed minimal contamination, with CFU counts ranging between 1 and 5, possibly reflecting more consistent adherence to proper hygiene practices and better infrastructure. School 6 exhibited a mixed contamination profile, whereas Schools 8, 9, and 10 demonstrated moderate contamination levels. These inter-school differences underscore that a one-size-fits-all approach to food hygiene is insufficient; instead, interventions must be context-specific, addressing each school's unique infrastructural, behavioural, and educational gaps. On a positive note, schools such as 1, 3, and 9, where minimal or no contamination was found, could serve as models for best practices. Understanding the specific interventions, infrastructure, or monitoring practices used in these schools may provide valuable lessons for improving hygiene in other settings.

This variability underscores that a one-size-fits-all intervention may not be effective. Instead, localised assessments and customised interventions are necessary to address the specific challenges of each school. Similar conclusions were drawn by Lambrechts et al. (2014) in South Africa and Allam et al. (2016) in Egypt, where site-specific education and interventions proved more effective than generic policies.

The presence of coliforms even in schools with hygiene programmes highlights the ongoing gap between knowledge and behaviour. Several African studies have noted this disconnection. For instance, Bojuwoye (2024) found that while 96.3% of food handlers in Nigeria were aware of hygiene practices, only 3.7% used soap consistently. Mohamed (2018) observed similar lapses in Sudan. Mafuyai (2004) noted high microbial contamination among untrained street vendors in Nigeria. These studies reinforce the idea that hygiene education alone is insufficient. Multifactorial approaches combining education, infrastructure, supervision, and behaviour reinforcement are essential to promote lasting change. The WHO (2009) emphasises that effective hand hygiene is dependent not only on behaviour but also on the availability of resources like soap and clean water.

This study's results align with global evidence that hand hygiene, when effectively implemented, significantly reduces foodborne disease transmission. According to WHO (2020), contaminated hands are among the leading contributors to the spread of pathogens such as *E. coli* and coliforms. The findings also support earlier reports by Todd et al. (2007) that identified poor hand hygiene as a significant route of faecal contamination in food environments.

### 1.3 Conclusion

This study contributes valuable insight into the microbiological safety of food handling practices within public primary schools in Gaborone, Botswana. The complete absence of *E. coli* across all hand swab samples is a positive finding, suggesting a commendable baseline of hygiene compliance. However, the detection of total coliforms in approximately one-third (32.47%) of food handlers indicates that hygiene practices are not uniformly adhered to, and latent risks to food safety persist.

Given the heightened vulnerability of school-aged children to foodborne illnesses, these findings underscore the critical importance of maintaining high standards of hygiene in school food environments. The variability in contamination levels across school's points to the influence of contextual factors such as infrastructure, staff training, access to clean water, and institutional oversight. Such disparities suggest that a one-size-fits-all approach to food safety may be inadequate and that localised, needs-based interventions are essential. Ultimately, sustainable improvements in food safety will depend not only on knowledge dissemination but also on the systemic capacity to enforce, support, and adapt hygiene practices within each school context.

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## CHAPTER 5: GENERAL DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

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### 5.1 General discussion

This study assessed the level of food safety knowledge, hygiene practices, and microbial hand contamination among food handlers working in ten public primary schools within Gaborone, Botswana. The aim of the study was to generate an evidence-based understanding of hygiene standards in institutional food service settings, particularly within school kitchens where the health of a vulnerable child population is at stake. In addition to evaluating knowledge and self-reported practices, the study conducted microbial hand assessments to determine the presence of bacterial contaminants as objective indicators of hygiene. A key component involved examining the bacterial profile of hand swabs, particularly the presence of *Escherichia coli* and total coliforms, which are indicators of general hygiene and possible environmental contamination, while *E. coli* is a stronger indicator of recent faecal contamination.

The study also explored the interrelationships between food safety knowledge, hygiene practices, and demographic characteristics. This included analysing whether knowledge translated into better practices and whether either of these elements contributed to measurable improvements in hand hygiene outcomes. These investigations provided deeper insights into the factors influencing food safety behaviour and the effectiveness of institutional hygiene protocols in structured environments like public schools.

The study revealed that, overall, food handlers in the surveyed schools demonstrated moderate levels of food safety knowledge. Knowledge questions addressed topics such as foodborne illnesses, temperature control, cross-contamination, and personal hygiene. While most participants demonstrated a basic understanding of food safety principles, critical knowledge gaps remained. For instance, several respondents noted misconceptions about the causes of food poisoning and safe food storage.

Despite these gaps, a key insight from the study is that demographic factors such as age, education, gender, employment status, and work experience were not significantly associated with food safety knowledge levels. This finding is consistent with prior studies Teffo & Tabit, 2020 that suggest knowledge does not automatically increase with academic background or tenure. These results underscore the need for contextual, skill-based training interventions rather than reliance on prior education or experience. Hygiene practice scores were significantly influenced by employment type, training, age, and years of work experience. Food handlers who had received formal food safety training, were permanently employed, and had more experience tended to demonstrate better hygiene behaviours. This suggests that institutional support, such as training opportunities and employment stability, plays a crucial role in shaping consistent hygiene behaviour.

Even though food handlers in this study reported high levels of hygiene practices, the observational assessment and microbiological findings suggested that actual practices were not always consistent with what participants reported. Similar discrepancies have been documented in previous studies, where self-reported food safety practices tended to overestimate actual behaviour because respondents often report practices they know are expected rather than those routinely performed (Clayton et al., 2002 and da Cunha et al., 2019). These findings highlight the importance of complementing questionnaire-based assessments with direct observation and microbiological verification to obtain a more accurate evaluation of hygiene practices among food handlers.

The microbiological analysis of hand swab samples provided objective evidence of the hygiene status of food handlers in the participating schools. A total of 77 hand swab samples were analysed for *Escherichia coli* and total coliforms. Notably, *E. coli* was not detected in any of the samples, suggesting that faecal contamination of food handlers' hands was effectively controlled at the time of sampling. This is an encouraging public health finding because *E. coli* is widely recognised as an indicator of faecal contamination and inadequate hand hygiene. In contrast, studies conducted in Ethiopia have reported the presence of *E. coli* and other bacterial contaminants on the hands of food handlers, highlighting the continued risk of food contamination where hygiene practices are inadequate (Assefa et al., 2015; Abdisa et al., 2025). The

absence of *E. coli* in the present study may reflect the relatively structured nature of school food service operations in Botswana, where routine environmental health inspections, implementation of the School Health Programme, and access to handwashing facilities, clean water and sanitation may contribute to improved hygiene standards. Nevertheless, the absence of *E. coli* should be interpreted alongside the detection of total coliforms and the observational findings, which indicate that opportunities remain to strengthen hand hygiene and food handling practices among school food handlers.

Total coliforms were present in 32.47% (25/77) of the hand swabs, suggesting that contamination risks remain. While coliforms are not necessarily harmful themselves, their presence is widely regarded as an indicator of poor hygiene or faecal contamination (He et al., 2020). Schools with the highest levels of contamination, such as School 2 (77.8% positive samples) and School 5, may be experiencing systemic issues related to inadequate handwashing facilities, poor sanitation, or limited access to training.

These findings suggest that knowledge alone is insufficient to ensure food safety outcomes, and that specific behavioural competencies, particularly correct handwashing, are the most reliable predictors of hygiene success. This supports a shift from general awareness campaigns to skill-based, hands-on training approaches in institutional food safety programmes.

#### **5.1.1 Relationships between knowledge, practice, and microbial contamination**

To determine whether food safety knowledge and hygiene practices translated into reduced microbial contamination, regression analyses and cross-tabulations were performed. Food safety knowledge showed a statistically significant but weak positive association with hygiene practice scores ( $\beta = 0.361$ ,  $p = 0.024$ ), explaining only 6.6% of the variation in hygiene practices ( $R^2 = 0.066$ ). This finding is consistent with previous studies, which have shown that although food safety knowledge contributes to better hygiene practices, it explains only a small proportion of actual behaviour because workplace conditions, attitudes and organisational factors also influence food handling practices (Ko, 2013; Annor & Baiden, 2011). In contrast, food safety

knowledge was not a significant predictor of microbial contamination in the present study ( $F(1,75) = 2.85$ ,  $p = 0.095$ ;  $R^2 = 0.037$ ). Likewise, hygiene practice scores did not significantly predict total coliform contamination ( $F(1,75) = 0.00$ ,  $p = 0.958$ ;  $R^2 = 0.000$ ). These findings suggest that higher knowledge scores and favourable self-reported hygiene practices do not necessarily translate into improved microbiological outcomes. Similar observations have been reported elsewhere, where food handlers demonstrated satisfactory knowledge and reported good hygiene practices, yet microbiological assessments and direct observations revealed evidence of contamination and inconsistencies between reported and actual practices (Lee et al., 2017; da Cunha et al., 2019).

### **5.1.2 Hand hygiene and microbial contamination**

While general hygiene practice scores were not predictive of microbial contamination, a specific focus on handwashing technique revealed a significant association. A cross-tabulation between total coliform detection on hands and handwashing technique scores showed a statistically significant relationship ( $\chi^2(4) = 13.53$ ,  $p = 0.009$ ). Among 77 food handlers, those with higher handwashing technique scores (4 or 5) were less likely to have coliform bacteria detected, while lower scores were associated with higher microbial presence.

The significant association between correct handwashing technique and lower microbial contamination observed in this study highlights the importance of practical hand hygiene skills in promoting food safety. Unlike general food safety knowledge or self-reported hygiene practices, correct execution of handwashing was associated with reduced coliform contamination, suggesting that the quality of hygiene practices is more important than simply knowing what should be done. Similar findings have been reported elsewhere, where effective handwashing techniques were shown to substantially reduce bacterial contamination on hands (Burton et al., 2011), and international guidelines continue to emphasise that proper hand hygiene requires correct technique and consistent practice rather than knowledge alone (WHO, 2009). These findings reinforce the need for practical, competency-based training that allows food handlers to demonstrate correct handwashing procedures and receive regular supervision and feedback to sustain good hygiene practices.

## 5.2 Conclusion

The findings presented in this chapter underscore the complexity of food safety behaviour among food handlers in primary school settings. While participants demonstrated moderate levels of food safety knowledge, this did not consistently translate into improved hygiene practices or reduced microbial contamination. A comparative analysis revealed that demographic factors, including age, gender, education, and work experience, were not significantly associated with knowledge scores. However, practice scores were notably influenced by formal training, employment type, age, and experience, indicating that institutional support and targeted training play a crucial role in shaping safe food handling behaviours.

Importantly, although *E. coli* was not detected in any hand swab samples, a positive indication of basic hygiene compliance was found in nearly a third of samples, pointing to gaps in hand hygiene, particularly in certain schools. These findings reinforce the need for practical, skill-based training programmes and robust hygiene monitoring systems rather than relying solely on theoretical knowledge or self-reported behaviours.

In conclusion, the chapter highlights that knowledge alone is not a reliable predictor of hygiene performance. Effective food safety interventions in school kitchens should therefore prioritise hands-on training, ongoing supervision, and the strengthening of structural supports such as sanitation infrastructure and job stability to ensure sustained improvements in food handling and hygiene practices.

In summary, this chapter demonstrates that demographic characteristics do not reliably predict food safety knowledge or microbial outcomes, whereas factors such as experience, training, and employment stability have a significant influence on hygiene practices. Crucially, proper handwashing technique demonstrated a clear protective effect against microbial contamination. Institutional support, including regular supervision and monitoring, promoted adherence to recommended food safety practices. These findings underscore the need for behaviour-focused interventions supported by training, monitoring, and institutional support to effectively improve food safety.

### 5.3 General Recommendations

**Improve practical hygiene training:** The Ministry of Local Government and Traditional Affairs, together with the Ministry of Health, should provide regular practical food safety training for school food handlers. The training should focus on areas where this study identified weaknesses, particularly correct handwashing techniques, appropriate glove use, and prevention of cross-contamination. Practical demonstrations and refresher sessions may be more effective than theory-based training alone. From time-to-time food handlers should be checked to ensure they still do the correct hand washing practice.

**Improve hygiene facilities in school kitchens:** Schools should ensure that food handlers have continuous access to clean running water, soap, hand-drying materials, and adequate personal protective equipment such as gloves and face masks. These resources are necessary to enable food handlers to consistently apply good hygiene practices during food preparation. Frequent inspections can be a great tool to ensure this.

**Strengthen hygiene monitoring:** Routine hygiene inspections should be complemented by periodic microbiological testing of food handlers' hands and selected food-contact surfaces. Such monitoring can identify contamination that may not be detected through visual inspection alone and help schools evaluate the effectiveness of hygiene practices.

**Strengthen supervision:** School management should regularly supervise food handlers using simple hygiene checklists during food preparation. Regular feedback and reminders may help improve compliance with established food safety procedures and encourage consistent good practices.

**Ensure regular food safety training for all food handlers:** Food safety training should be compulsory for all school food handlers, irrespective of their educational level, age, or years of work experience. The findings of this study suggest that these characteristics alone do not guarantee good hygiene practices. Newly recruited staff should also receive training before assuming food preparation duties.

**Strengthen the School Health Programme:** The School Health Programme should be supported to conduct regular inspections and provide technical support to schools. Since hygiene performance differed significantly between schools, interventions should be tailored to the needs of individual schools rather than applying the same approach to all schools.

#### **5.4 Recommendations for Future Research**

Future studies should include food handlers working in boarding schools. Unlike day schools, boarding schools prepare more meals each day and operate under different conditions, which may influence hygiene practices and microbial contamination.

Research is also needed to determine how kitchen infrastructure affects food safety. Factors such as the availability of handwashing facilities, water supply, kitchen design, food storage facilities, and ventilation should be examined because they may influence food handlers' ability to maintain good hygiene.

Further studies should investigate the role of school management in promoting food safety. Areas such as supervision, implementation of food safety policies, staffing levels, and availability of cleaning supplies should be explored to determine their influence on hygiene practices.

Intervention studies should be conducted to assess whether improvements in food safety training, supervision, and kitchen infrastructure lead to reductions in microbial contamination over time.

Future research should compare hygiene practices and microbial contamination between different categories of schools, including public and private schools, day and boarding schools, and schools of different sizes.

Longitudinal studies are also recommended to determine whether improvements in food safety practices are sustained over time rather than relying on findings from a single cross-sectional assessment.

Future studies should include additional sources of contamination, such as food-contact surfaces, kitchen utensils, food samples, and water to provide a more comprehensive assessment of food safety risks within school kitchens.

Finally, research should investigate whether poor hygiene practices and microbial contamination among food handlers are associated with student health outcomes, including diarrhoeal diseases, foodborne illnesses, and school absenteeism.

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## **APPENDICES**

### **Appendix 1: Questionnaire in English**

#### **QUESTIONNAIRE**

**Topic:** Food safety knowledge, practices and microbial hand hygiene of food handlers  
in public primary schools in Gaborone, Botswana

Date .....

School No.....

Participant No.....

### DEMOGRAPHIC CHARACTERISTICS

| Category                                                | Range                                            | Quantity | Percentage |
|---------------------------------------------------------|--------------------------------------------------|----------|------------|
| Age                                                     | 18-35<br>>35                                     |          |            |
| Gender                                                  | Male<br>Female                                   |          |            |
| Educational level                                       | None<br>Primary<br>Secondary<br>Senior<br>Higher |          |            |
| Experience                                              | 0-3<br>3-5<br>>5                                 |          |            |
| Status                                                  | Permanent<br>Temporal<br>Contract                |          |            |
| Training on food safety                                 | Formal<br>None                                   |          |            |
| Hazard analysis and critical<br>control points training | YES<br>NO                                        |          |            |

## **FOOD SAFETY KNOWLEDGE**

| <b>Item</b>                                                                                                       | <b>Yes</b> | <b>No</b> | <b>Comments</b> |
|-------------------------------------------------------------------------------------------------------------------|------------|-----------|-----------------|
| 1. Contaminated food always has some changes in colour, odour, and taste                                          |            |           |                 |
| 2. Expired food can be consumed as long as they do not look or taste bad.                                         |            |           |                 |
| 3. Contact between cooked and raw food contributes to food poisoning                                              |            |           |                 |
| 4. If hands are washed but not washed properly, they can pose a risk to food safety                               |            |           |                 |
| 5. Is it important to wash your hands after sneezing or smoking                                                   |            |           |                 |
| 6. Wearing gloves will reduce the risk of food contamination                                                      |            |           |                 |
| 7. Long painted nails contribute to food contamination                                                            |            |           |                 |
| 8. Use of jewels such as rings, watches, and bracelets in food handling poses a risk to food contamination        |            |           |                 |
| 9. Before jobs, the health condition of food handlers must be assessed                                            |            |           |                 |
| 10. Food handlers with diseases such as diarrhoea, flu, and throat infection pose a risk of food contamination    |            |           |                 |
| 11. A healthy food handler can be a carrier of infectious foodborne disease                                       |            |           |                 |
| 12. Food handlers with abrasions or cuts should not treat ready-to-eat food                                       |            |           |                 |
| 13. Pathogens can be sourced from utensils                                                                        |            |           |                 |
| 14. Reheating cooked food can contribute to food contamination                                                    |            |           |                 |
| 15. Refrigeration and freezing kill bacteria                                                                      |            |           |                 |
| 16. Cooked food which is stored incorrectly may contain germs that may make one sick                              |            |           |                 |
| 17. Some toxins produced by microorganisms are resistant to heat during food heating                              |            |           |                 |
| 18. Pets in food premises can contaminate food                                                                    |            |           |                 |
| 19. Is it safe to use the same knife for cooked and uncooked food                                                 |            |           |                 |
| 20. Eating, drinking, talking and smoking when preparing or serving food increases the risk of food contamination |            |           |                 |

What causes food contamination.....

Give two signs of food poisoning.....

What is the right temperature for storing perishables.....

How does improperly stored waste contribute to food contamination.....

Why is it important for food handlers to go for medical examination.....

## FOOD HANDLER'S SELF-REPORTED PRACTICES ON FOOD SAFETY AND HYGIENE

|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                            |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>I will take leave or a day off if</p> <ul style="list-style-type: none"> <li>• Continue coughing</li> <li>• Fever</li> <li>• Stomach ache cramps</li> <li>• Flu</li> </ul> | <p>I will not handle or come in contact with food and the food preparation area when I have a cut, injury or skin infection<br/>YES/NO</p>                                                                                                                                                                                                                                                 |
| <p>I only handle food when my medical exam has been done and is still valid<br/>YES/NO</p>                                                                                    | <p>When you are at work and start vomiting, what do you do</p> <ul style="list-style-type: none"> <li>• Leave the work area and make arrangements to go to the clinic immediately</li> <li>• Think about the hunger of students and the burden for other workers, and consider finishing cooking and leaving after work</li> <li>• Take a break, finish vomiting, and come back</li> </ul> |
| <p>I wash my hands with</p> <ul style="list-style-type: none"> <li>• Cold water</li> <li>• Warm water</li> <li>• Soap or any detergent</li> </ul>                             | <p>I wash my hands</p> <ul style="list-style-type: none"> <li>• After using the toilet</li> <li>• After eating</li> <li>• After handling unwashed fruits and vegetables</li> <li>• Before preparing a meal</li> <li>• After handling food</li> <li>• Before eating</li> <li>• After sneezing</li> <li>• Scratching</li> </ul>                                                              |
| <p>I dry my hands after washing with</p> <ul style="list-style-type: none"> <li>• my apron</li> <li>• dish cloth</li> <li>• paper towel</li> </ul>                            | <p>I wear a clean apron when in the food handling and preparation area<br/>YES NO</p>                                                                                                                                                                                                                                                                                                      |

|                                                                                                                      |                                                                                                            |
|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| I always ensure before using that my protective clothing is in good condition, like not worn out before using YES/NO | I always wear a hair restraint when handling and preparing food<br>YES NO                                  |
| I keep my nails short, clean, and unpolished<br>YES NO                                                               | I do not leave the kitchen with protective clothing or take it outside the food preparation area<br>YES/NO |
| I understand I should wear proper shoes, which are fully enclosed and absorbent, and do so all the time<br>YES/NO    | I wear a mask when distributing food<br>YES/ NO                                                            |
| I do not wear jewellery when handling food<br>YES/NO                                                                 | I do not eat or smoke when handling food<br>YES/NO                                                         |
| I know the proper and effective way of washing hands<br>YES NO                                                       |                                                                                                            |

## Appendix 2: Questionnaire in Setswana

**FOOD SAFETY KNOWLEDGE**

| DIPOTSO                                                                                                                                                                  | EE | NYAA | KAKGELO |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|------|---------|
| 1. Dijo tse di senyegileng ka nako tsothe di nna di nale monko, di fetogile mmala le tatso                                                                               |    |      |         |
| 2. Dijo tse di fetilweg ke nako (expired) dika jewa solanka di sa lebege di senyegile kana di sena tatso e e sa siamang                                                  |    |      |         |
| 3. Kamano fa gare ga dijo tse di apailweng le tse di sa apewang dika baka kgotelesego ya dijo                                                                            |    |      |         |
| 4. Fa matsogo a tlhapiwa mme asa tlhapiwe sentle go baka bodiphatsa mo tshireletsong ya dijo                                                                             |    |      |         |
| 5. Go botlokwa go thapa diata pele oja kana o sena go ithimola or o goga motsoko                                                                                         |    |      |         |
| 6. Go rwala dihenakausu "gloves" go fokotsa kgotelesego ya dijo                                                                                                          |    |      |         |
| 7. Dinala tse ditelele ebile di pentilwe dika thothetse kana tsa baka tshenyego ya dijo                                                                                  |    |      |         |
| 8. Tiriso ya maseka, dibaga, disupanako kana dipalamonwa hao amana le dijo dika nna le seabe mogo bakeng kgotelesego ya dijo                                             |    |      |         |
| 9. Pele tiro ya letsatsi e simolola seemo sa botsogo jwa moapei botshwanetse ja kanokiwa                                                                                 |    |      |         |
| 10. Moapei yoo naleng malwetse ago tshwana le letshololo, mohikela kana bolwetse ja magalapaga tshwanela go amana le ka se sedi tsenya mo diphatse tsa go ka kgotelesego |    |      |         |
| 11. Moapei kana yoo itekanetseng mogo tsa botsogo mm ease kebelelo fa a tshwere dijo oka dira gore megare e senyang dijo e tsene mo dijong kgotsa e senye dijo           |    |      |         |
| 12. Moapei yoo naleng dintho kana a golafetse mo matsogong ga a tshwanela go amana le dijo                                                                               |    |      |         |
| 13. Ditshidinyana tse di bakang kgotelesego ya dijo dika hithelwa lemo dijana, mantshwana kana dipitsa tse di dirisiwang mo go tsa kapei                                 |    |      |         |



|                                                                                                                                    |  |  |  |
|------------------------------------------------------------------------------------------------------------------------------------|--|--|--|
| 14. Go nyaosa kana go gatolosa dijo goka rotoetsa , ga baka kgothelesego ya dijo                                                   |  |  |  |
| 15. Go tsidifatsa kana go gatsetsa dijo ga go bolaye megare ee bakang kgotelesego ya dijo                                          |  |  |  |
| 16. Dijo tse di apeilwengmme disa beiwa kana disa khurumelwa sente dika nna le megare ee ka lwatsang                               |  |  |  |
| 17. Mengwe ya botholo jo bo bakiwang ke ditshidinyana mo dijong e kgona go seke e swe lee kopane le mogote oo ko godimo            |  |  |  |
| 18. Diruiwa tsa mo lapeng jaaka dikatse and dintsa dika baka kgotelesego ya dijo hadi ka letelelwa go tsena mo lefelong la boapelo |  |  |  |
| 19. Reka dirisa thipa ele ngwefela for dijo tse di boduleng letse di sa butswang                                                   |  |  |  |
| 20. Go ja kana gonwa, go goga le go bua o apeile , kana o tshwere dijo go baka lego rotoetsa kgotelesego ya dijo                   |  |  |  |

21. Ke eng sese bakang kgotelesego kana go senyega ga dijo

.....

22. Ntsha dikai tse pedi tse di kago bontshang dijo tseo di jeleng di ne di senyegile

.....

23. Ke sefe selekanyo sa mogote se se letelesegang go ka beela dijo tse di senyegang ka bonako jaakq merogoo,ditamati

.....

24. Matakala aa sa beiwang kana asa lathiwe sente a thothoetsa tshenyego ya dijo jang?

.....

25. Goreng go tamega gore baapei banne le setankana sa sesupo sa gore ba thathobilwe ke bongaka pele ba simolola mmereko

.....

### Appendix 3: Food safety checklist (personal hygiene and handwashing demonstration checklist)

#### ASSESSMENT OF PERSONAL HYGIENE AND PRACTICES

Date \_\_\_\_\_

Observer \_\_\_\_\_

| Item                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Yes | No | Comment |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|----|---------|
| 1. Food handler appear in good health                                                                                                                                                                                                                                                                                                                                                                                                                                                      |     |    |         |
| 2. Employee not suffering from a cut, an injury, or an infected skin irritation                                                                                                                                                                                                                                                                                                                                                                                                            |     |    |         |
| 3. Availability of a valid medical certificate                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |    |         |
| 4. Frequent hand washing and washing between activities were observed                                                                                                                                                                                                                                                                                                                                                                                                                      |     |    |         |
| 5. Hand-dried using the proper method                                                                                                                                                                                                                                                                                                                                                                                                                                                      |     |    |         |
| 6. Apron worn and clean                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     |    |         |
| 7. Protective clothing worn is of hygienic design, has no external pockets, is in good repair, and does not constitute any source of contamination to the food products                                                                                                                                                                                                                                                                                                                    |     |    |         |
| 8. Hair restraint is worn and worn properly                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |    |         |
| 9. Nails kept short, clean and no nail polish                                                                                                                                                                                                                                                                                                                                                                                                                                              |     |    |         |
| 10. Employee not removing protective clothing from food preparation and handling area                                                                                                                                                                                                                                                                                                                                                                                                      |     |    |         |
| 11. Employee wearing proper shoes which are fully enclosed and non-absorbent                                                                                                                                                                                                                                                                                                                                                                                                               |     |    |         |
| 12. Employee wears a mask when distributing food                                                                                                                                                                                                                                                                                                                                                                                                                                           |     |    |         |
| 13. No sign of jewellery when handling food                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |    |         |
| 14. Drinking, eating, or smoking in the food handling area                                                                                                                                                                                                                                                                                                                                                                                                                                 |     |    |         |
| 15. Demonstration of hand washing technique <ul style="list-style-type: none"> <li>• Wet hands with soap and rub the back of both hands together</li> <li>• Interlace and rub hands together</li> <li>• Interlock fingers and rub the back of both hands</li> <li>• Rub thumb in a rotating manner, followed by the area between the index finger and thumb</li> <li>• Rub fingertips on palm for both hands and rub both wrists in a rotating manner, rinse and dry thoroughly</li> </ul> |     |    |         |



## Appendix 4: Ministry of Health approval letter

|                                                                  |                                                                                                                                                   |                                                                                                       |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| <p>PRIVATE BAG 0038<br/>GABORONE<br/>BOTSWANA<br/>REFERENCE:</p> |  <p>REPUBLIC OF BOTSWANA<br/>MINISTRY OF HEALTH AND WELLNESS</p> | <p>TEL: (+267) 363 2500<br/>FAX: (+267) 391 0647<br/>TELEGRAMS: RABONGAKA<br/>TELEX: 2818 CARE BD</p> |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|

---

REFERENCE NO: HPRD: 6/14/1

16<sup>th</sup> June 2022

**Health Research & Development Committee**

**Principal Investigator:** Onalethata Onyach  
**Notification of IRB Review:** **Continuing Review**

**Protocol Title:** FOOD SAFETY KNOWLEDGE, PRACTICES AND MICROBIAL HAND HYGIENE OF FOOD HANDLERS IN PUBLIC PRIMARY SCHOOLS; GABORONE, BOTSWANA

|                         |              |
|-------------------------|--------------|
| <b>Review Type:</b>     | Expedited    |
| <b>Review Date:</b>     | 13 June 2022 |
| <b>Approved Date:</b>   | 16 June 2022 |
| <b>Effective Date:</b>  | 16 June 2022 |
| <b>Expiration Date:</b> | 15 June 2023 |

This certifies that the continuing review request for the protocol above was reviewed under expedited review procedures. The Approval is valid for a period of 1 year.

☒ Study is continuing.  
☐ Accrual complete with treatment intervention and /or participant interviews/surveys continuing.  
☐ Subject interventions/data collection ended on (date): \_\_\_\_\_  
☐ Open for analysis only. Expected end date : \_\_\_\_\_  
☐ Completed (including all analysis). Date completed: \_\_\_\_\_  
☐ Cooperative Review

If you have any questions please do not hesitate to contact Mr. K. Motlhanka at [kgmmotlhanka@gov.bw](mailto:kgmmotlhanka@gov.bw), Tel +267-3632751. Thank you for your cooperation and your commitment to the protection of human subjects in research.

Yours sincerely  
  
Mr. Kgomo Motlhanka  
**for /PERMANENT SECRETARY**



MINISTRY OF HEALTH  
RESEARCH DIVISION  
16 JUN 2022  
P/BAG 0038, GABORONE  
HEALTH POLICY RESEARCH & DEVELOPMENT

---

**Vision:** A Healthy Nation by 2036.  
**Values:** Botho, Equity, Timeliness, Customer Focus, Teamwork, Accountability



BOTSWANA  
the pride, your motivation

## Appendix 5: Ministry of Local Government approval letter

MINISTRY OF BASIC EDUCATION



TELEPHONE: (267) 3931851  
(267) 3972454  
FAX: (267) 3975899

Republic of Botswana

Director, Regional Operations  
South East  
Private Bag 00343  
GABORONE  
BOTSWANA

---

REF: SER 1/15/2022 XVI (183) 21 September 2022

Ms. Onalethata Onyach  
P.O. Box 20649  
MAHALAPYE

**EXTENSION OF PERMISSION TO CONDUCT A RESEARCH**

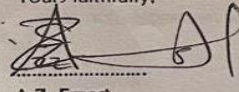
Reference is made to your dated 20 April 2022 letter requesting to carry out research in **South East Region** is here by granted. The research will be carried out **Primary Schools (see attached list)**. This permit is valid from the **September 2022 to July 2023**.

Your research is titled "**Food safety knowledge, practices and microbial hand hygiene of food handlers in public primary schools in Gaborone**". Permission is hereby granted for you to carry out your research as per your request. However, **Covid- 19 Protocols have to be strictly adhered to by yourself**.

NB: Furthermore, you are requested to submit at least one hardcopy and an electronic copy of the report to the South East Region, Ministry of Basic Education within 3 months of completion of the study. Approval is for academic fulfillment only. Copies should be submitted to all other relevant authorities.

Thank you.

Yours faithfully,



A.Z. Ernest  
For/ Director, Regional Operations, South East Region



PRIVATE BAG 0038  
GABORONE  
BOTSWANA  
REFERENCE:



REPUBLIC OF BOTSWANA  
MINISTRY OF HEALTH AND WELLNESS

FAX: (+267) 391 0547  
TELEGRAMS: RABONGAKA  
TELEX: 2818 CARE BD

REFERENCE NO: HPRD: 6/14/1

16<sup>th</sup> June 2022

**Health Research & Development Committee**

**Principal Investigator:** Onalethata Onyach  
**Notification of IRB Review:** **Continuing Review**

**Protocol Title:** FOOD SAFETY KNOWLEDGE, PRACTICES AND  
MICROBIAL HAND HYGIENE OF FOOD HANDLERS IN PUBLIC PRIMARY  
SCHOOLS: GABORONE, BOTSWANA

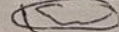
**Review Type:** Expedited  
**Review Date:** 13 June 2022  
**Approved Date:** 16 June 2022  
**Effective Date:** 16 June 2022  
**Expiration Date:** 15 June 2023

This certifies that the continuing review request for the protocol above was reviewed under expedited review procedures. The Approval is valid for a period of 1 year.

- ☒ Study is continuing.  
☐ Accrual complete with treatment intervention and /or participant interviews/surveys continuing.  
☐ Subject interventions/data collection ended on (date): \_\_\_\_\_  
☐ Open for analysis only. Expected end date : \_\_\_\_\_  
☐ Completed (including all analysis). Date completed: \_\_\_\_\_  
☐ Cooperative Review

If you have any questions please do not hesitate to contact Mr. K. Motlhanka at [kgmmotlhanka@gov.bw](mailto:kgmmotlhanka@gov.bw), Tel +267-3632751. Thank you for your cooperation and your commitment to the protection of human subjects in research.

Yours sincerely

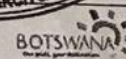


Mr. Kgomoiso Motlhanka  
**for /PERMANENT SECRETARY**



**Vision:** *A Healthy Nation by 2036.*

**Values:** *Botho, Equity, Timeliness, Customer Focus, Teamwork, Accountability*







## Appendix 11: STATA 14 output of one-way Anova comparing knowledge scores by education level

| Analysis of Variance |            |    |            |      |          |
|----------------------|------------|----|------------|------|----------|
| Source               | SS         | df | MS         | F    | Prob > F |
| Between groups       | 2.77539018 | 3  | .92513006  | 0.08 | 0.9683   |
| Within groups        | 799.925909 | 73 | 10.9578892 |      |          |
| Total                | 802.701299 | 76 | 10.5618592 |      |          |

Bartlett's test for equal variances:  $\chi^2(2) = 12.3655$  Prob> $\chi^2 = 0.002$

## Appendix 12: STATA 14 output of kruskal-wallis test comparing food safety knowledge scores by educational level

Kruskal-Wallis equality-of-populations rank test

| Educational | Obs | Rank Sum |
|-------------|-----|----------|
| Higher      | 1   | 30.50    |
| Primary     | 7   | 311.50   |
| Secondary   | 57  | 2208.00  |
| Senior      | 12  | 453.00   |

chi-squared = 0.613 with 3 d.f.  
probability = 0.8935

chi-squared with ties = 0.616 with 3 d.f.  
probability = 0.8928

## Appendix 13: STATA 14 independent samples t-test – gender and practice scores

Two-sample t test with equal variances

| Group    | Obs | Mean      | Std. Err. | Std. Dev. | [95% Conf. Interval] |          |
|----------|-----|-----------|-----------|-----------|----------------------|----------|
| female   | 55  | 8.490909  | .2991264  | 2.218381  | 7.891197             | 9.090621 |
| male     | 22  | 8.954545  | .5444616  | 2.553751  | 7.822276             | 10.08682 |
| combined | 77  | 8.623377  | .2634223  | 2.311521  | 8.098726             | 9.148028 |
| diff     |     | -.4636364 | .5845381  |           | -1.628096            | .7008233 |

diff = mean(female) - mean(male)      t = -0.7932  
Ho: diff = 0      degrees of freedom = 75

Ha: diff < 0      Ha: diff != 0      Ha: diff > 0  
Pr(T < t) = 0.2151      Pr(|T| > |t|) = 0.4302      Pr(T > t) = 0.7849

## Appendix 14: T-test – age and practice scores

Two-sample t test with equal variances

| Group    | Obs | Mean      | Std. Err. | Std. Dev. | [95% Conf. Interval] |           |
|----------|-----|-----------|-----------|-----------|----------------------|-----------|
| 18-35    | 25  | 7.56      | .586174   | 2.93087   | 6.350196             | 8.769804  |
| >35      | 52  | 9.134615  | .2441299  | 1.760446  | 8.644504             | 9.624727  |
| combined | 77  | 8.623377  | .2634223  | 2.311521  | 8.098726             | 9.148028  |
| diff     |     | -1.574615 | .5363195  |           | -2.643019            | -.5062122 |

diff = mean(18-35) - mean(>35)      t = -2.9360  
Ho: diff = 0      degrees of freedom = 75

Ha: diff < 0      Ha: diff != 0      Ha: diff > 0  
Pr(T < t) = 0.0022      Pr(|T| > |t|) = 0.0044      Pr(T > t) = 0.9978

## Appendix 15: T-test – employment status and practice

Two-sample t test with equal variances

| Group    | Obs | Mean      | Std. Err. | Std. Dev. | [95% Conf. Interval] |           |
|----------|-----|-----------|-----------|-----------|----------------------|-----------|
| temporal | 28  | 6.964286  | .4919515  | 2.603163  | 5.954885             | 7.973687  |
| permanen | 49  | 9.571429  | .2082483  | 1.457738  | 9.152717             | 9.99014   |
| combined | 77  | 8.623377  | .2634223  | 2.311521  | 8.098726             | 9.148028  |
| diff     |     | -2.607143 | .4617776  |           | -3.527051            | -1.687235 |

diff = mean(temporal) - mean(permanen)      t = -5.6459  
Ho: diff = 0      degrees of freedom = 75

Ha: diff < 0      Ha: diff != 0      Ha: diff > 0  
Pr(T < t) = 0.0000      Pr(|T| > |t|) = 0.0000      Pr(T > t) = 1.0000

## Appendix 16: T-test – training and practice

Two-sample t test with equal variances

| Group    | Obs | Mean     | Std. Err. | Std. Dev. | [95% Conf. Interval] |          |
|----------|-----|----------|-----------|-----------|----------------------|----------|
| formal   | 45  | 9.288889 | .2689715  | 1.804316  | 8.746812             | 9.830965 |
| none     | 32  | 7.6875   | .4654115  | 2.632765  | 6.738287             | 8.636713 |
| combined | 77  | 8.623377 | .2634223  | 2.311521  | 8.098726             | 9.148028 |
| diff     |     | 1.601389 | .5052978  |           | .594784              | 2.607994 |

diff = mean(formal) - mean(none)      t = 3.1692  
Ho: diff = 0      degrees of freedom = 75

Ha: diff < 0      Ha: diff != 0      Ha: diff > 0  
Pr(T < t) = 0.9989      Pr(|T| > |t|) = 0.0022      Pr(T > t) = 0.0011



## Appendix 17: ANOVA – work experience and practice

| Source         | Analysis of Variance |    |            | F    | Prob > F |
|----------------|----------------------|----|------------|------|----------|
|                | SS                   | df | MS         |      |          |
| Between groups | 81.000999            | 2  | 40.5004995 | 9.22 | 0.0003   |
| Within groups  | 325.076923           | 74 | 4.39293139 |      |          |
| Total          | 406.077922           | 76 | 5.34313055 |      |          |

Bartlett's test for equal variances:  $\chi^2(2) = 14.2688$  Prob> $\chi^2 = 0.001$

## Appendix 18: Kruskal-Wallis – work experience and practice

Kruskal-Wallis equality-of-populations rank test

| Work_e~e | Obs | Rank Sum |
|----------|-----|----------|
| 0-3      | 32  | 945.00   |
| 3-5      | 13  | 469.50   |
| >5       | 32  | 1588.50  |

chi-squared = 13.187 with 2 d.f.  
probability = 0.0014

chi-squared with ties = 13.554 with 2 d.f.  
probability = 0.0011

## Appendix 19: ANOVA and Kruskal-Wallis – education and practice

| Source         | Analysis of Variance |    |            | F    | Prob > F |
|----------------|----------------------|----|------------|------|----------|
|                | SS                   | df | MS         |      |          |
| Between groups | 9.51902483           | 3  | 3.17300828 | 0.58 | 0.6273   |
| Within groups  | 396.558897           | 73 | 5.43231366 |      |          |
| Total          | 406.077922           | 76 | 5.34313055 |      |          |

Bartlett's test for equal variances:  $\chi^2(2) = 0.0686$  Prob> $\chi^2 = 0.966$

Kruskal-Wallis equality-of-populations rank test

| Educati~l | Obs | Rank Sum |
|-----------|-----|----------|
| Higher    | 1   | 27.50    |
| Primary   | 7   | 281.50   |
| Secondary | 57  | 2340.50  |
| Senior    | 12  | 353.50   |

chi-squared = 2.952 with 3 d.f.  
probability = 0.3991

chi-squared with ties = 3.034 with 3 d.f.  
probability = 0.3865

## Appendix 20: Linear regression output – practice scores predicting knowledge scores

|          |            |    |            |               |   |        |
|----------|------------|----|------------|---------------|---|--------|
| Source   | SS         | df | MS         | Number of obs | = | 77     |
| Model    | 52.89003   | 1  | 52.89003   | F(1, 75)      | = | 5.29   |
| Residual | 749.811269 | 75 | 9.99748358 | Prob > F      | = | 0.0242 |
|          |            |    |            | R-squared     | = | 0.0659 |
|          |            |    |            | Adj R-squared | = | 0.0534 |
| Total    | 802.701299 | 76 | 10.5618592 | Root MSE      | = | 3.1619 |

|               |          |           |       |       |                      |          |
|---------------|----------|-----------|-------|-------|----------------------|----------|
| Atotal_score  | Coef.    | Std. Err. | t     | P> t  | [95% Conf. Interval] |          |
| OBtotal_score | .3608961 | .1569064  | 2.30  | 0.024 | .0483225             | .6734697 |
| _cons         | 16.80344 | 1.40022   | 12.00 | 0.000 | 14.01406             | 19.59282 |