QUALITY AND SAFETY OF READY-TO-EAT STREET-VENDED FOODS SOLD IN SELECTED LOCATIONS WITHIN THIKA TOWN, KIAMBU COUNTY, KENYA

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Quality and Safety of Ready-To-Eat Street-Vended Foods Sold in Selected Locations within Thika Town, Kiambu County, Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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This thesis has been submitted for examination with our approval as the university supervisors

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DEDICATION

I dedicate this work to my lovely wife Catherine Nzisa Mwangangi, my daughters Faith Mawia Kyalo and Isabell Mumbe Kyalo and my parents Mr. Christopher Mwove and Mrs. Mary Mwove. Thank you for being a source of strength and showing me that all dreams are achievable.

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ABBREVIATIONS AND ACRONYMS

FAO	Food and Agriculture
FSHAP	food safety, hygiene awareness, and practices
IARC	International Agency for Research on Cancer
MRL	Maximum Recommended Limit
NACOSTI	National Commission for Science and Technology
NLPCA	Nonlinear principal component analysis
CATPCA	Categorical principal component analysis
OR	Odds ratios
SFVs	street food vendors
SVFs	Street-vended foods
TCC	total coliform count
WHO	World Health Organization
YMC	yeast and molds count
$BMDL_{10}$	Benchmark dose for a 10% response
TDI	Tolerable Daily Intake level
ELISA	enzyme-linked immunosorbent assay

ABSTRACT

The safety of street foods remains a public health concern, especially in developing countries like Kenya where foodborne illnesses associated with these foods have often been reported. Their consumption has the potential to cause foodborne diseases due to contamination with pathogenic microorganisms as well as the presence of toxic chemical contaminants. The objective of this study was to determine the level of food safety knowledge and practice of street food vendors and to determine the microbial and chemical quality of ready-to-eat street-vended foods sold in selected locations within Thika Town of Kiambu County in Kenya. The study targeted 385 street food vendors in six locations including Thika town center, Ngoigwa, Juakali area, Makongeni, Kiandutu slums, and the area surrounding Thika Level 5 hospital. Data collection was accomplished through face-to-face interviews using structured questionnaires and observation using an assessment tool for observation of personal hygiene and food handling practices of SFVs and the condition of the vending environment. A total of 199 food samples consisting of cereals, sliced fruits, salads, groundnuts, tubers, fruit juices, boiled deshelled eggs, smokies, and sausages were randomly collected for microbial and chemical analysis. Determination of total viable counts, total coliform counts, yeast and molds counts, *Escherichia coli* counts, *Staphylococcus aureus* counts as well as the presence of *Salmonella* spp*.*, and *Listeria monocytogenes* were determined following standard microbiological methods. The concentrations of lead and cadmium were determined by atomic absorption spectrophotometry while acrylamide in french fries was determined using high-performance liquid chromatography. Total aflatoxins and aflatoxin B1 in cereal-based foods and groundnuts were determined using a competitive direct enzyme-linked immunosorbent assay. The results indicated that the majority of the street food vendors were male (63.2%) with 38.1% of them having attained secondary school education. About 93% of the SFVs had not received any formal training on food hygiene and safety. The majority of street food vendors handled food with bare hands (96.8%) or handled money while serving food without washing hands (86.1%). Few vendors appropriately preserved their food with 78.3% storing foodstuff that required refrigeration at ambient temperatures. Whereas public health officers' visits were found to significantly ($p<0.0001$) motivate street food vendors to obtain a food handler's medical certificate, only about 27% had obtained it. Good food safety and hygiene awareness scores were significantly ($p<0.05$) influenced by education level, food hygiene, and safety training, mobility of street food vendors, public health inspection, and the category of street food vendors. The levels of total viable counts, total coliform counts, yeast and mold counts, *Escherichia coli*, and *Staphylococcus aureus* ranged from 6.59 to 3.38, 5.57 to 1.59, 5.05 to 1.60, 2.03 to 0.00, and 5.97 to 1.89 Log_{10} CFU/g respectively. At least nine food samples were contaminated with *Escherichia coli* although the chance for contamination was significantly ($p = 0.0002$) higher (15 times) in plant-based foods compared to animal-based foods. At least one sample in each food type was contaminated with *Staphylococcus aureus* with contamination levels above 1.89±1.66 Log_{10} CFU/g. *Listeria monocytogenes* was not detected in any food sample. The level of lead contamination in street-vended foods ranged between 0.271±0.070 and 1.891±0.130 mg/Kg with groundnuts recording significantly higher ($p<0.0001$) mean levels (1.891 mg/Kg) than other food types. These concentrations exceeded the maximum allowable limits set by the Joint Food and Agriculture/ World Health Organization food standards program. The mean acrylamide level for the street-vended french fries in Thika town was 0.558±0.128 µg/g, higher than the European Union benchmark value of 0.5 µg/g. Total aflatoxin and aflatoxin B1 in street-vended groundnuts averaged between 4.4 - 14.2 µg/kg and 3.4-11.3 µg/kg, respectively. On average 16.7% and 44.4% of groundnut samples exceeded the total aflatoxin and aflatoxin B1 limits established by the Kenya Bureau of Standards, respectively. In addition, 72.2% and 100% of the groundnut samples exceeded the limits for total aflatoxin and aflatoxin B1 set by the European Union, respectively. These findings suggest that street-vended foods sold in this study area are of public health concern as they potentially can cause illnesses to consumers. Consequently, there is a need to regulate the informal food processing and marketing channels to enhance their quality and safety standards. The public health sector should enhance awareness among street food vendors and consumers on food hygiene and safety through training. In addition, the provision of basic infrastructure for enhancing hygiene among street food vendors, continuous monitoring of street-vended foods by the public health department to identify potential contaminants and the establishment and enforcement of policies to govern the street-vended food businesses may contribute to improved quality and safety of these foods.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Street foods are ready-to-eat foods (RTFs) and beverages that are mostly sold and sometimes prepared by vendors on the streets and in other public places. They are usually bought by consumers for immediate consumption or consumption at a later time without any further preparation or processing (Imathiu, 2017). The vast growing urban population in developing countries has stimulated a rise in the number of street food vendors in many cities to satisfy the demand for affordable and accessible ready-to-eat meals. Many of these people rely on street-vended foods for one or more of their daily meals (Moussavi, Liguori, & Mehta, 2016). Street foods are not only cheap and convenient to consumers but also a key contributor to income and nutrition for many people in the developing world (Choudhury *et al.*, 2011; IFRA, 2016; Micah *et al.*, 2012; Namugumya & Muyanja, 2011; Oyunga-Ogubi *et al.*, 2009; Steyn *et al.*, 2014). They are also potential channels for food fortification (Imathiu, 2017).

The safety of street-vended foods remains a public health concern, especially in developing countries like Kenya. Street vendors operate informally with minimal control since they are often unlicensed to handle food and are untrained in food hygiene and sanitation (IFRA, 2016; Imathiu, 2017; Muinde & Kuria, 2005). It has also been reported that food safety knowledge is low among street vendors (Bereda *et al.*, 2016). Due to the informal nature of these businesses, compliance with food laws as well as the enforcement of the same is not always possible. Without compliance, the possibility of food-borne diseases occurring in the population is very high. Furthermore, the chance of adulteration of food with unlicensed harmful substances or the sale of uncertified food substances is high. Since consumers do not always think of food safety when they purchase street-vended foods (Asiegbu, Lebelo, & Tabit, 2016; Sanlier *et al.*, 2018), the potential for these foods to cause harm is high. Billions of consumers are at high risk and millions contract foodborne diseases of both microbiological and chemical nature every year and as a result, many die from consuming these unsafe foods (WHO, 2015).

This has been majorly attributed to poor hygiene practices and inadequate safety knowledge by street food vendors resulting in contamination with pathogenic microorganisms. In Bharatpur, Nepal, a study on street-vended foods revealed contamination with 13 different bacterial pathogens of which *Escherichia coli, Staphylococcus aureus*, and *Citrobacter spp.* were most prevalent (Khadka *et al.*, 2018). In Africa, Isara *et al.* (2017) reported that poor handling practices amongst street vendors resulted in contamination with coliforms as well as *Staphylococcus aureus* in Benin City, Nigeria. In Ethiopia, Bereda *et al.* (2016), reported the presence of *Escherichia coli, Staphylococcus aureus,* and *Salmonella* species in street-vended foods. In Kenya, Muinde and Kuria (2005) reported that operators lacked hygiene training as well as safe food handling practices that are important in assuring the safety of foods in Nairobi, Kenya. Similar results were reported in Embu municipality, Kenya, in the case of food handlers in commercial eating places (Kariuki & Orago, 2017). In addition, Kariuki, Waithera Ng'ang'a, and Wanzala (2017) reported *Escherichia coli* and *Klebsiella pneumoniae* in a sample of boiled egg with a raw vegetable salad sold on the streets of Githurai and Gikomba markets in Kenya while Awino (2015) found street-vended foods to contain *Staphylococcus aureus*, *Escherichia coli,* and *Salmonella* in Kisumu, Western Kenya. Therefore, there is a need for research on street-vended foods to identify possible contaminants present to develop interventions to curb the spread of pathogenic microorganisms. For instance, a sanitation standard for street food vendors has potential to enhance the safety and quality of these foods (WHO, 2015). Efforts have been put in this direction in several countries around the world but very little has been done in Kenya (Rane, 2011).

Besides microbiological contaminants, street-vended foods are also key contributors to unsafe chemical contaminants in the diet. Various toxic chemical contaminants including acrylamide (Altissimi *et al.*, 2017; Ogolla *et al.*, 2015) and aflatoxins (Asemoloye *et al.*, 2017), as well as heavy metals (Chavez *et al.*, 2014; Ihsan & Edwin, 2018), have been reported in street-vended foods around the world. However, research in this area is very scanty. In Kenya, minimal research has been carried out on the chemical toxic constituents present in ready-to-eat street-vended foods. According to WHO (2015), the number and amount of these chemicals and toxins that make it into the food supply and eventually into ready-to-eat foods are unknown. Further worsening the situation is that the health effects of chemicals may not be observed for several years following exposure (WHO, 2015). Thus, cases of liver cancer and cardiovascular disease may be linked to toxic contaminants consumed through food over long periods (Koriech, 1994)**.** For instance, acrylamide and nitrosamines have been reported as potent human carcinogens (Tricker & Preussmann, 1991; Zyzak *et al.*, 2003). Consequently, there is a need to identify and quantify the types and amounts of toxic substances in ready-to eat-foods, the information of which can be used to guide the development of possible mitigation strategies to minimize risks associated with these contaminants.

Therefore, this study aimed to determine the quality and safety characteristics of ready-to-eat street-vended foods sold in selected locations within the Thika sub-County, Kiambu County, Kenya. A structured survey targeting street food vendors was administered to determine their safety knowledge and practices. In addition, street-vended foods were analyzed for possible microbial and chemical toxic contaminants.

1.2 Statement of the problem

Street food safety remains a public health concern, especially in developing countries like Kenya. According to the WHO (2015), consumers are potentially exposed to diseases from either microbiological or chemical contamination every time they consume such food. Many consumers are at high risk and millions contract foodborne diseases every year, as a result, many people die from consuming contaminated food. According to the WHO (2022), approximately 600 million individuals worldwide, become sick due to consumption of contaminated food. Tragically, this leads to approximately 420,000 deaths annually, resulting in a total loss of 33 million years of healthy life with children under 5 years of age carrying about 40% of the foodborne disease burden, with about 125,000 deaths occurring every year. Street foods have been thought to contribute a substantial proportion of these foodborne illnesses usually due to poor hygienic and sanitary conditions in which they are prepared and often sold. Street food vendors in Kenya operate informally with minimal regulation which poses a food safety concern considering the large number of consumers of these food products, most of whom are young adults and children (Imathiu, 2017). Furthermore, ensuring compliance with food handling practices and health measures is thus impossible since there are no established sanitation standards for street-vended foods. Due to the lack of regulation, the chances of adulteration of food with unlicensed harmful substances or the sale of uncertified food substances are high.

Previous research in Kenya has shown that street vendors lack training in food preparation, hygiene, and sanitation, and work under unsanitary conditions (Kimani, Kariuki, & Irungu, 2018; Muinde & Kuria, 2005). Furthermore, the storage conditions for street-vended foods are poor due to the lack of storage facilities to maintain the cold chain for highly perishable foods (Muinde & Kuria, 2005). This has resulted in the contamination of food with pathogenic microorganisms (Awino, 2015; Kariuki *et al.*, 2017) showing that food-borne diseases and poor hygiene practices are still a public health concern in Kenya. Nevertheless, reports on the microbial safety of street-vended foods are limited in Kenya. In particular, data for some common pathogenic microorganisms such as *Salmonella, Staphylococcus aureus,* and *Listeria monocytogenes* in street-vended food is very scanty or unavailable in Kenya. Chemical contaminants have also been reported contaminating street-vended foods. For instance, antibiotic and pesticide residues, heavy metals, acrylamide, and aflatoxins have been reported in street foods (Ahlberg *et al.*, 2016; Altissimi *et al.*, 2017; Ezekiel *et al.*, 2012; Kamika & Takoy, 2011; Ogolla *et al.*, 2015; Orwa *et al.*, 2017).

These contaminants have been linked to human diseases. For instance, acrylamide and nitrosamines have been reported as potent human carcinogens (Tricker & Preussmann, 1991; Zyzak *et al.*, 2003). Whereas process contaminants and chemical residues are of public health concern, limited research has been carried out to determine their presence and concentrations in street-vended foods sold in Kenya. Thus, there is a need for the analysis of street-vended foods to determine their quality and safety and therefore, compliance to food standards and to come up with policies that cover the entire chain of street food vending.

1.3 Justification

There has been a constant increase in the demand for convenient foods that are cheap and easily available to consumers. Street foods are consumed by most urban dwellers mostly because they are affordable and convenient. Every day, almost 2.5 billion individuals consume street food worldwide (Shehasen & Mohammed, 2020). In Kenya, many people consume street-vended foods. In their studies on street-vended foods, Moussavi *et al.* (2016) reported that there were over 95% of street food consumers in Central Kenya.

Besides their convenience and affordability, street-vended foods contribute to food nutrition security for many people in the developing world (Micah *et al.*, 2012; Namugumya & Muyanja, 2011; Oyunga-Ogubi *et al.*, 2009). Furthermore, owing to their huge consumption, they may be suitable channels for food fortification (Imathiu, 2017). However, street food vending is mostly done by the urban poor who are often uneducated or lack basic training on food hygiene and sanitation.

Unlike those well-established businesses that are licensed, street vendors are mobile and unregistered, with poor compliance with food handling practices and health measures in place (IFRA, 2016; Imathiu, 2017; Muinde & Kuria, 2005). This poses a safety health concern as contamination can easily occur in these foods affecting many people. Moreover, due to the lack of regulation, the chances of adulteration of food with unlicensed harmful substances or the sale of uncertified food substances that may be harmful to the unsuspecting public are high (Omemu & Aderoju, 2008). Considering that a substantial portion of street food consumers are children and young adults, who often indulge in such foods daily, the potential impact of contaminants is a pressing issue (Hill *et al.*, 2016).

Thika Town, a rapidly growing urban center in Kenya, is home to a population of approximately 251,407 (Kenya National Bureau of Statistics, 2019). Its proximity to Nairobi and its concentration of educational institutions contribute to its vibrant street food culture. As the population relying on street-vended foods continues to grow, the associated public health challenges are likely to escalate. Notably, reports of poor food hygiene and safety practices among street food vendors in Kiambu County, particularly in the Juja sub-County (Kimani *et al.*, 2018) adjacent to Thika town, further emphasize the need for a comprehensive study on the quality and safety of street-vended foods.

This study, focused on Thika town, aims to provide vital insights into the safety of street-vended foods and their implications for public health. The findings are expected to establish a valuable baseline for the development of effective food safety policies for street-vended foods in Kenya. By addressing existing gaps in understanding and highlighting critical issues, this research contributes to enhancing the overall quality of street food offerings, thus safeguarding the health and well-being of consumers. Furthermore, it opens avenues for future studies and interventions to address the challenges faced by this crucial sector.

1.4 Objectives

1.4.1 General objective

To determine the food safety knowledge and practice of street food vendors and the quality and safety of ready-to-eat street-vended foods sold in selected locations within Thika Town, Kiambu County, Kenya.

1.4.2 Specific objectives

1. To determine food safety knowledge and practice of street food vendors of ready-to-eat foods sold in selected locations within Thika Town.
2. To determine the categories of food hygiene and safety knowledge and practices and the factors influencing food safety, hygiene awareness, and practices among street food vendors in Thika Town.
3. To determine the microbial quality and safety of ready-to-eat street-vended foods sold in selected locations within Thika Town.

4. To determine the toxic chemical substances in ready-to-eat street-vended foods sold in selected locations within Thika Town.

1.5 Hypotheses

1. Ho: The practices and the level of safety knowledge of street food vendors in selected locations within Thika Town are adequate for ensuring food quality and safety.
2. Ho: There is no significant categorization of food hygiene and safety knowledge and practices among street food vendors, and there are no significant factors influencing food safety, hygiene awareness, and practices among street food vendors in Thika Town.
3. Ho: The microbial quality and safety characteristics of ready-to-eat street-vended foods sold in selected locations within Thika Town conform to the food quality and safety standards of Kenya.
4. Ho: There are no toxic chemical substances in ready-to-eat street-vended foods sold in selected locations within Thika Town.

CHAPTER TWO

LITERATURE REVIEW

2.1 Street-vended foods

Street foods are ready-to-eat beverages and foods that may be prepared and sold by street food vendors in the streets and other public places (Imathiu, 2017). They are usually bought by consumers for immediate consumption or consumption at a later time without any further preparation or processing (Imathiu, 2017; Winarno & Allain, 1991). Consumers are attracted to the seemingly nutritious low-cost foodstuffs that are ready-to-eat and available whenever they are needed (Winarno & Allain, 1991). Street-vended foods can be of animal or plant origin. Some of these foods may be already processed by established manufacturers, only requiring re-heating or prepared by the street vendors themselves either at their residential places or at the site of sale (Maroko, 2016). According to Imathiu (2017), street foods can be grouped into three categories; processed food sold by mobile vendors, food prepared at vendors' homes and sold to the public, and food prepared and sold on the street.

Since street food vending does not require huge capital investment to start (Verma *et al.*, 2023) and it lacks government regulation, it is attractive to many people, especially the urban poor and the unemployed (Khairuzzaman *et al.*, 2014). As a result, street food vendors have been reported to lack training in safe food preparation (Muinde & Kuria, 2005) which may result in public health issues concerning these foods. Poor preparation may also result in the formation of toxic process contaminants or the addition of harmful additives that may be injurious to the consumer. Moreover, other street-vended foods are minimally processed foods. For instance, fruits and vegetables that are sold as salads may only undergo preparation processes such as cutting or peeling which creates avenues for contamination (Carrasco, Morales-Rueda, & García-Gimeno, 2012). Consumers most often overlook hygiene and sanitation as well as the safety of street foods which may prove to be costly in the event contamination with pathogens or toxic chemical contaminants occurs.

2.2 Street food consumption

Almost 2.5 billion individuals consume street food daily around the world (Shehasen & Mohammed, 2020). In a study conducted by van't Riet *et al.* (2001) who surveyed 1011 households in the low-income areas of Korogocho and Dandora in Nairobi, Kenya, they reported that 78% and 53% of the respondents were street food consumers in Korogocho and Dandora, respectively. In a more recent study by Moussavi *et al.* (2016), which involved 50 respondents, it was found that in Nyeri town, over 95% of the population were consumers of street-vended foods.

This large number of street food consumers has stimulated an increase in the number of street food vendors in major towns in Kenya. This can also be attributed to the increase in poverty and the need to earn a living as well as the cheap nature of the business and the ease of access by consumers. As a result, street foods make up a significant proportion of the daily diet for many people (Muinde & Kuria, 2005; Steyn *et al.*, 2014). These foods are sold in populous areas including the markets, construction sites as well as bus stations where a large number of people frequent or work and are unable to prepare their food. Even though data on consumption patterns for street-vended foods is minimal, Hill *et al.* (2016) reported that consumption of street foods was high in South Africa as 43% of people were found to consume these foods 2 – 3 times a week, while 38.3% bought them almost every day showing the importance of these foods to the consumers. In this study, fruits had the highest consumption at 87.2% while cooked and/ or baked products followed closely at 72.1% (Hill *et al.*, 2016). Thus, regulation of this sector is important to ensure the safety of street food consumers. Since children are among the consumers of street-vended foods (Imathiu, 2017), care must be taken to enhance the safety of these foods since children are in the high-risk population bracket.

Besides their contribution to employment and income for many, street foods contribute to daily nutrient intake (Micah *et al.*, 2012; Namugumya & Muyanja, 2011). Oyunga-Ogubi *et al.* (2009) reported that street foods were good contributors to iron, zinc, and vitamin A in the diet. Thus, street-vended food may be crucial in the fight against food nutrition insecurity. Nevertheless, food safety awareness is low among both consumers as well as street food vendors. For consumers, accessibility, better taste, and affordability are some of the reasons for the purchase of street foods (Asiegbu *et al.*, 2016). Sanlier *et al.* (2018) reported that most consumers were aware that street foods could be contaminated with microorganisms and that sellers did not pay good attention to hygiene, and that those foods were raw or insufficiently cooked. Nonetheless, they still preferred them because they were cheap and delicious and there was variety and fast service. The chance of infection originating from contaminated street food is, therefore, very high. There is a need to enhance the safety of street-vended foods which will ultimately reduce the chance of infections originating from them.

2.3 Factors influencing the microbiological quality and safety of street-vended foods

2.3.1 Food safety knowledge among street vendors

Food safety is the practice of handling, preparing, and storing food in a way that minimizes the possibility that customers would contract a foodborne illness (WHO, 2022). To avoid food becoming contaminated and resulting in food poisoning, several rules must be followed. This is accomplished in several ways, some of which include maintaining a high standard of personal hygiene, properly storing food, heating food sufficiently, and thoroughly cleaning and sanitizing all surfaces, tools, and utensils (Uçar, Yilmaz, & Çakiroglu, 2016). Food safety knowledge encompasses understanding the potential hazards—whether chemical, microbial, or physical—that could contaminate food, along with the practices and measures necessary to ensure that food is safe for human consumption (Kamboj *et al.*, 2020; Uçar *et al.*, 2016).

Food safety knowledge is generally poor among street food vendors as not all of them are usually educated or trained in food handling (Omemu & Aderoju, 2008). On the other hand, having food safety knowledge may not assure safe food on the streets. For instance, in Benin City, food vendors had a high level of knowledge of food hygiene even though their food safety practices did not match their level of knowledge (Isara *et al.*, 2017). Similar observations were reported by (Bormann, Adzinyo, & Letsa, 2016) in street-vended foods in Ghana. Perhaps, enforcement of food laws may motivate street food vendors to adhere to good hygiene practices. According to Muinde and Kuria (2005), many street food vendors in Kenya had no food preparation skills as most gained knowledge through experience. Poor knowledge of food preparation as well as food safety has the potential to cause food contamination. This explains the need for policy formulation covering street food vending so as to regulate the sector to ensure public health safety.

2.3.2 Street food vendor's hygiene and sanitation

Sanitation includes all of the tools, practices, and services needed to stop diseases and disease-causing agents from spreading due to contact with human waste (WHO, 2018a). The term hygiene describes practices that enhance cleanliness and promote good health among people (Bartram & Cairncross, 2010). The safety and hygiene status of street-vended foods has been reported to be poor in Africa (Bormann, Adzinyo, & Letsa, 2016; Eliku, 2016; Muinde & Kuria, 2005; Omemu & Aderoju, 2008). Examples of poor hygiene and sanitation practices among vendors include not washing their hands or washing hands with dirty water. It has been reported as common vendor practice to directly touch ready-to-eat foods with unwashed hands, for instance during the slicing of meat products. In addition, most vendors may not wear protective attire such as sterile nylon gloves before handling ready-to-eat foods (Makinde *et al.*, 2020; Uçar *et al.*, 2016). According to Omemu and Aderoju (2008), street food vending sites in Abeokuta Nigeria lacked basic facilities such as water and toilets. In Ghana (Bormann *et al.*, 2016), inadequate sanitary facilities and poor personal hygiene practices were identified as responsible for the low safety and quality of street foods. In Ethiopia, Eliku (2016) reported that basic hygiene practices were overlooked. For instance, 88.6% of vendors did not have an apron on while 95% had uncovered hair. In addition, all street vendors handled money with bare hands while serving food. Similar results were reported by Muinde and Kuria (2005) in Kenya. Street vendors rarely have licenses to operate their businesses (Eliku, 2016). As a result, following the food hygiene and safety measures and follow-up by the public health inspectors are not possible. This leaves the safety of the consumers at the mercy of the street food vendors whose intention is to make a living.

2.3.3 Packaging and storage practices for street-vended foods

The packaging material comes into contact with food. Thus, any contamination on the packaging may end up in the food product. Poor packaging practices have been reported among street food vendors. For instance, in Ethiopia, Eliku (2016) reported that over 90% of street food vendors used recycled paper for packing food. In Kenya, due to the recent ban on plastic packaging materials that were cheap and available for packaging street-vended foods, vendors now use recycled paper or sell food that is not packed (Personal communication, February 8, 2019). The poor packaging materials used for food by street food vendors can release undesirable substances to food that are of safety concern to consumers (Proietti, Frazzoli, & Mantovani, 2014b). For instance, using paper packaging materials that were used to wrap other substances or using newspapers to wrap bakery products (Personal communication, February 8, 2019) may transfer contaminants to the food.

Besides the poor packaging practices, storage practices for street food vendors have also been reported to be inferior. This is due to a lack of storage facilities to maintain low temperatures for highly perishable foods that require refrigeration (Cortese *et al.*, 2016). In Ghana (Bormann *et al.*, 2016), temperature abuses and poor packaging were identified as responsible for the low safety and quality of street foods. In Kenya, Muinde and Kuria (2005) found out that cooked foods were stored at ambient temperatures and exposed to the environment during the sale which posed significant safety concerns. Exposing food to ambient temperatures encourages a wide range of microorganisms to proliferate. Some of those microorganisms may be pathogenic and able to cause infections and intoxications when consumed in the food.

2.3.4 Source of the raw materials or the food

The quality of raw materials always determines the quality of the end products. The quality of the raw materials depends on their source. For instance, due to the diverse treatment that animals undergo from different farms, some of which may use illegal drugs, the quality of meat and meat products from different sources may not be the same in terms of antibiotic residues (Proietti *et al.*, 2014b). According to Omemu and Aderoju (2008), the volume of raw materials and the price are considered more than the freshness and cleanliness when purchasing. Thus, vendors may choose to buy low-priced raw materials or use cheap additives that are illegal and unsuitable for human consumption to make a substantial profit from their ventures. This further worsens the already worse situation. Therefore, contaminants originally existing in raw materials end up in ready-to-eat products. Most processed foods are usually safe at dispatch from the manufacturers unlike those that are prepared by the street food vendors at their homes or the retail site. When processed foods require a short preparation before the sale, avenues of contamination are many. In addition, storage practices before preparation and after preparation will also determine the quality and safety of the foods (Proietti *et al.*, 2014b). Since street food vendors do not have sufficient storage facilities (Cortese *et al.*, 2016), mixing of raw and ready-to-eat products may occur which may result in contamination.

2.3.5 Food preparation environment

The hygiene and sanitation of vending sites have the potential to influence the quality and safety of street food. In Owerri, Nigeria, Chukuezi (2010) reported that street food vendors sold foodstuffs in unhygienic places. In Ghana, poor construction and the haphazard location of vending sites were identified as some of the factors contributing to the low safety and quality of street foods. In Kenya, Muinde and Kuria (2005) reported that street food vendors prepared the food either at home or at the stalls located by the roadsides. Exposure of food to such environments has the potential to influence its quality with a high chance that contamination with pathogenic microorganisms will occur. Therefore, there is a need to have street food selling zones that are designed to allow for the sale of safe food to consumers. Having a clear set, marked-out selling place fitted with adequate amenities to ensure the sale of safe food is one way in ensuring public safety (Muinde & Kuria, 2005).

2.4 Microorganisms commonly associated with street-vended food

Microbial foodborne diseases occur when pathogenic microorganisms are consumed through contaminated food. Even though the pathogen may be destroyed during food preparation, the toxins produced by some pathogens may remain to cause diseases when the food is consumed. Street-vended foods have been linked to causes of infections due to contamination with pathogenic microorganisms. Table 2.1 shows foodborne pathogens reported in street-vended food around the world. The commonly reported pathogens in street-vended foods include *Salmonella*, *Escherichia coli, Staphylococcus aureus*, and *Listeria monocytogenes*.

Table 2.1: Common pathogenic microorganisms reported in street-vended foods

Bacteria	Food studied	Country	Reference
Clostridium perfringens	Boiled eggs, beans and maize, sausages, smokies, Meats (Fried steaks, beef stews, and chicken stews), gravies, salads, rice, etc	Kenya, South Africa	Kariuki *et al.* (2017); Mosupye and von Holy (1999)
Escherichia coli	Ice cream, sandwiches, beverages, panipuri (masala, pani, and puri), pasta, boiled eggs with raw vegetable salad, deep-fried and fried snacks, buttermilk, salads, panipuri, juices, tamarind water, plain drinking water, bread, sugar cane juice, etc.	Nepal, Kenya, S. Africa*, Ghana, Bangladesh, Ethiopia, India, Kenya, Chad, Indonesia, Sudan, Dhaka City, Brazil,	Adzhani, Purwanta, and Rahmatullah (2018); Awino (2015); Bereda *et al.* (2016); Djibrine *et al.* (2018); Elfaki and Elhakim (2011); Guraza *et al.* (2018); Hossain *et al.* (2017); Islam *et al.* (2015); Jahan *et al.* (2018); Kariuki *et al.* (2017); Khadka *et al.* (2018); Mensah *et al.* (2002); Mohamed (2015); Mosupye and von Holy (1999); Rajan and Aruna (2017); Sachdev and Mathur (2017); Ferrari, Oliveira, and São josé (2021); Asiegbu, Lebelo, and Tabit (2020); Ghosh, Mitra, and Ali (2022)
Listeria monocytogenes	Dairy products, Fish and fish products, meat and meat products, spices, dried fruits, jellies, gingerbread, candies, etc	Romania, S. Africa, Pakistan, Chile	Ciolacu *et al.* (2016); Asiegbu *et al.* (2020); Khaliq *et al.* (2021); Nosheena *et al.* (2022); Bustamante *et al.* (2020)
Salmonella Enteritidis	Meat and meat products, egg and egg products, milk and milk products, burgers, *shawarma*, *pizza*, and sandwiches	India, Pakistan	Anukampa *et al.* (2017); Raza *et al.* (2021)
Salmonella Paratyphi	Panipuri (Masala, Pani and Puri)	Nepal, India	Khadka *et al.* (2018); Anukampa *et al.* (2017)
Salmonella Typhi $^{+}$	Panipuri (Masala, Pani and Puri)	Nepal, India	Anukampa *et al.* (2017); Kariuki and Orago (2017); Khadka *et al.* (2018)
Salmonella spp.	Vegetable Salad, mandazi (a form of fried bread), ice cream, deep fried and fried snacks, pickles, fruit chutney, baked items, Juices, tamarind water and plain drinking water, Pasta, sandwich, etc	Kenya, Bangladesh, Ethiopia, Minas Gerais, India, Sudan, Brazil, S. Africa	Awino (2015); Bereda *et al.* (2016); Elfaki and Elhakim (2011); Guraza *et al.* (2018); Imathiu (2018); Islam *et al.* (2015); Jahan *et al.* (2018); Kariuki *et al.* (2017); Kharel, Palni, and Tamang (2016); Magalhães Monteiro *et al.* (2017); Mohamed (2015); Nemo, Bacha, and Ketema (2017); Noor (2016); Rajan and Aruna (2017); Ferrari *et al.* (2021); Asiegbu *et al.* (2020)

Bacteria	Food studied	Country	Reference
Salmonella typhimurium	Buttermilk, salads, panipuri, burgers, *shawarma*, *pizza*, and sandwiches, etc	India, Pakistan	Anukampa *et al.* (2017); Guraza *et al.* (2018); Raza *et al.* (2021)
Staphylococcus aureus	Ice cream, egg burger, vegetable salad, packaged fried rice, pasta, meat and meat products, Sandwiches, buttermilk, meat, salads and vegetables portions, savory snacks, hot dogs, coconut water, meat barbecued on the skewer and boiled corn, bread, sugar cane juice, etc	Kenya, Romania, Ethiopia, South Africa, Ghana, India, Chad**, Minas Gerais, Botswana, Brazil	Akusu, Kiin-Kabari, and Wemedo (2016); Bereda *et al.* (2016); Ciolacu *et al.* (2016); Djibrine *et al.* (2018); Elfaki and Elhakim (2011); Guraza *et al.* (2018); Isara *et al.* (2017); Kariuki *et al.* (2017); Loeto *et al.* (2017); Mafune, Takalani, and Anyasi (2016); Magalhães Monteiro *et al.* (2017); Mensah *et al.* (2002); Nemo *et al.* (2017); Rajan and Aruna (2017); Sachdev and Mathur (2017); Tshipamba *et al.* (2018); Ferrari *et al.* (2021); Asiegbu *et al.* (2020); Ghosh *et al.* (2022)
Staphylococcus spp.	Egg burger, vegetable salad, packaged fried rice, meat pie, etc	Sudan, Ethiopia	Mohamed (2015) Kharel *et al.* (2016); Nemo *et al.* (2017)

***** *Escherichia coli* (non O157:H+), ****** Coagulase-positive staphylococci, + isolated from food handler

According to Rane (2011), microbial food safety issues involving street-vended foods are caused by microorganisms belonging to the genus *Clostridium*, *Bacillus*, *Listeria*, *Staphylococcus*, *Campylobacter*, *Salmonella*, and *Vibrio.* Food contamination is thought to cause the majority of diarrheal diseases globally (WHO, 2017). This is mainly due to poor hygiene and sanitary conditions, especially during the handling of ready-to-eat foods. Thus, street-vended food may be a significant contributor to diarrheal diseases due to poor sanitation and hygiene practices among food handlers (WHO, 2015).

In Kenya, diarrheal diseases rank high among the causes of death (MOH, 2014). Since the hygiene and sanitation of the surrounding environment influence the occurrence of pathogenic microorganisms and thus, diarrheal diseases in humans (Elmi & Dioso, 2017), considering the poor hygiene practices reported among street food vendors and the unhygienic vending environments where these foods are often sold, street-vended foods could therefore be potential sources of pathogenic microorganisms.

Escherichia coli and *Klebsiella pneumoniae* were detected in a sample of boiled egg with a raw vegetable salad in a study on the food-handling practices and environmental factors associated with food contamination among street food vendors in Nairobi County, Kenya (Kariuki *et al.*, 2017). In another study, Awino (2015) found street-vended foods to contain *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella* in a study investigating the prevalence of pathogenic microorganisms in Kisumu County, Western Kenya while Muendo, Kikuvi, and Mambo (2022) found *Escherichia coli* (51.7%), *Staphylococcus aureus* (34.4%) and *Salmonella* (15.2%) in street-vended cooked foods in Chuka town, Tharaka Nithi County. Therefore, the safety of street-vended foods in Kenya is still a public health concern. The presence of *Escherichia coli* which is an indicator of fecal contamination of food is a key indicator of the poor sanitation and hygiene practices of street food vendors. The global burden of foodborne illnesses is considerably high and affects people of all ages, particularly children under 5 years of age due to their weaker immunity (WHO, 2015). Considering that most consumers of these foods are children, there is a need to enhance the safety of street-vended foods.

Street foods are subjected to temperature abuse due to poor storage practices at the site of sale (Bormann *et al.*, 2016). For instance, animal-based products such as meat that require refrigeration during storage may be left at ambient temperatures during sales. Furthermore, leftovers of the same temperature-abused product may be stored and sold the following day. This presents an avenue for the proliferation of microorganisms including pathogenic bacteria which may produce toxins or increase in numbers to levels that are capable of causing diseases when the food is consumed. In street-vended foods, contamination of food with toxins has been reported. Pathogenic *Escherichia coli* toxin was detected in ethnic street foods including *samosa*, *kachori, puchkka, alu chop, and* vegetable *momo*, among others, from Gangtok in India (Kharel *et al.*, 2016). *Escherichia coli* toxins such as the Shiga toxin produced by *Escherichia coli* O157:H7 are associated with a hemolytic uremic syndrome that has been reported to be fatal to humans (Tarr, Gordon, & Chandler, 2005).

2.4.1 Key pathogenic microorganisms of interest in street-vended foods

2.4.1.1 *Salmonella*

Salmonella is a genus name that incorporates gram-negative rod-shaped bacilli that are part of the *Enterobacteriaceae* family. They are facultative anaerobic bacteria with two reported species that are further classified into many subspecies. These include *Salmonella enterica* and *Salmonella bongori* (Brenner *et al.*, 2000). *Salmonella* causes salmonellosis which is a major cause of enteric bacterial illnesses in both animals and humans (Antunes *et al.*, 2016; Brenner *et al.*, 2000; Gomez *et al.*, 1997). It usually results in gastroenteritis and bacteremia, affecting mostly immunocompromised individuals (Acheson & Hohmann, 2001; Chen *et al.*, 2013). Many serotypes have been found to cause salmonellosis. However, a few are associated with most human infections. For instance, *Salmonella enterica Enteritidis* is the most frequently associated serovar with human disease (Antunes *et al*., 2016). In healthy humans, the infective dose is 10^6 to 10^8 CFU, (Chen *et al.*, 2013), although counts as low as 10^3 CFU have been reported in outbreaks (Blaser & Newman, 1982). Most affected food products are those of animal origin including meat products and eggs (Antunes *et al.*, 2016; Hugas & Beloeil, 2014). In particular, poultry products have been more implicated in *Salmonella* outbreaks (Antunes *et al.*, 2016). These foods are some of the most commonly street-vended foods.

In street-vended ready-to-eat foodstuffs, *Salmonella* species have been reported. For instance, *Salmonella typhimurium* was reported in street-vended buttermilk, salads, sandwich, and *panipuri*, in India (Anukampa *et al.*, 2017; Guraza *et al.*, 2018). In Brazil, Ferrari *et al.* (2021) reported the presence of *Salmonella* spp. in savory snacks as well as hot-dog while in the Johannesburg Metropolis, South Africa, *Salmonella* spp. were reported in 21.8% of ready-to-eat starch-based, beef-based, poultry-based, fish-based, vegetable-based and sandwich-based (burgers, *samosa*, filled hotdogs, and *bunny chow*) street-vended foods (Asiegbu *et al.*, 2020). *Salmonella* spp. (*Salmonella enteritidis* and *Salmonella typhimurium*) were identified in 15.3% of ready-to-eat street-vended burgers, *shawarma*, *pizza*, and sandwiches in Pakistan (Raza *et al.*, 2021).

In Kenya, while studying the prevalence of pathogenic microorganisms in Kisumu, Western Kenya, Awino (2015) found street-vended foods to contain *Salmonella* while Muendo et al. (2022) reported *Salmonella* spp. in 15.2% of street-vended cooked foods sold in Chuka town, Tharaka Nithi County. Thus, street-vended foods can be a key contributor to *Salmonella* infections in Kenya. Such infections can be far-reaching and devastating because the consumers of street-vended foods are diverse. Considering that salmonellosis is severe in immunocompromised individuals including children who form a good proportion of street food consumers (Imathiu, 2017), infections may be exceedingly more severe. Since *Salmonella* is a virulent pathogen, there is a need to determine the prevalence of this pathogen in street-vended ready-to-eat foodstuffs to inform any reforms that may improve street food safety.

2.4.1.2 *Staphylococcus aureus*

Staphylococcus aureus remains a dangerous human pathogen. It is a gram-positive coccus belonging to the *Micrococcaceae* family. They have a distinguished gold pigmentation on colonies giving positive results in mannitol fermentation, and coagulase tests (Lowy, 1998). *Staphylococcus aureus* is commonly implicated in most infections in hospitalized patients. Due to its wide range of virulent factors, the pathogen can cause a wide range of infections. *Staphylococci* produce numerous toxins that may result in human illness (Archer, 1998; Lowy, 1998). It is a prominent factor in the occurrence of bacteremia and infective endocarditis, as well as infections related to the bones, joints, skin, soft tissues, and lungs (Tong *et al.*, 2015).In street-vended foods, *Staphylococcus aureus* has been reported. The pathogen has been reported in sandwiches and samosa in Sudan and Ethiopia (Kharel *et al.*, 2016; Mohamed, 2015; Nemo *et al.*, 2017). In Accra Ghana, Mensah *et al.* (2002) reported *Staphylococcus aureus* in 31.9% of 163 food samples. *Staphylococcus aureus* has also been reported in street-vended fresh salads from Quetta City, Pakistani (Saifullah *et al.*, 2018). In Brazil, Ferrari *et al.* (2021) reported the presence of *Staphylococcus aureus* in savory snacks, hot dogs, coconut water, meat barbecued on a skewer, and boiled corn while in the Johannesburg Metropolis, South Africa, it was reported in 31.8% of ready-to-eat starch-based, beef-based, poultry-based, fish-based, vegetable-based and sandwich-based street-vended foods (Asiegbu *et al.*, 2020).

While studying the prevalence of pathogenic microorganisms in Kisumu, Western Kenya, Awino (2015) found street-vended foods to contain *Staphylococcus species*. Similar results were reported by Kariuki *et al.* (2017) in a study on food-handling practices and environmental factors associated with food contamination among street food vendors in Nairobi County, Kenya, and Muendo *et al.* (2022) while studying microbial contamination levels in cooked street-vended foods sold in Chuka town, Tharaka Nithi County, Kenya. Thus, *Staphylococcus aureus* being a virulent pathogen, there is a need to determine the prevalence of this pathogen in street-vended ready-to-eat foodstuffs that are more prone to contamination and recontamination before consumption.

2.4.1.3 *Listeria monocytogenes*

Listeria monocytogenes is one of the 17 species of the genus *Listeria* (Molla, Yilma, & Alemayehu, 2004; Orsi & Wiedmann, 2016). Among the 17 species, only *Listeria monocytogenes* and *Listeria ivanovii* are considered pathogenic to humans (Orsi & Wiedmann, 2016). *Listeria monocytogenes* are gram-positive bacteria that are facultatively anaerobic, non-spore-forming rods. They exhibit flagella motility showing a positive Voges-Proskauer reaction. They give a positive catalase reaction, a negative oxidase test as well as a negative nitrate test (Orsi & Wiedmann, 2016). *Listeria monocytogenes* can grow at temperatures as low as 4 °C, making them a problem not only in foodstuffs stored at room temperature but also in those that are refrigerated.

Listeria monocytogenes cause listeriosis. Signs of listeriosis can manifest within 24 hours, and in individuals without underlying health issues, they may include joint pain, headaches, abdominal pain, diarrhea, nausea, vomiting, loss of appetite, fatigue, and drowsiness (Chlebicz & Śliżewska, 2018). Listeriosis outbreaks have been reported severally around the world involving ready-to-eat food products. Of particular mention is the outbreak that occurred in South Africa (WHO, 2018b) with a case fatality rate of 27%. This outbreak in South Africa was linked to a ready-to-eat processed meat product called "Polony". Researchers have reported fatalities ranging from 20-30% when listeria outbreaks occurred (Julian *et al.*, 2001; Swaminathan & Gerner-Smidt, 2007). The fatalities are even higher when the high-risk population is considered (Jackson, Iwamoto, & Swerdlow, 2010). This is because, even though uncommon in ready-to-eat foods, the infectious dose for *Listeria monocytogenes* is low. Farber, Ross, and Harwig (1996) estimated the infective dose of *Listeria monocytogenes* to be 10 - 100 million colony-forming units (CFU) in healthy hosts, and only 0.1 - 10 million CFU in individuals at high risk of infection. Thus, *Listeria monocytogenes* are dangerous even at very low levels in ready-to-eat foodstuffs.

The presence of *Listeria monocytogenes* in street-vended foods has been reported. In Egypt, it was isolated in 57% of street-vended sandwiches and dishes of traditional food (El-Shenawy *et al.*, 2011). In Malaysia, it was isolated in squids, prawns, chicken, cucumber (slices), and peanut sauce (Arumugaswamy, Ali, & Hamid, 1994). In Pakistan, Khaliq *et al.* (2021) reported a prevalence ranging from 37.5 – 62.5% in ready-to-eat street-vended salads from different zones within Faisalabad City while Nosheena *et al.* (2022) reported a prevalence of 2% in street-vended fresh salads in Quetta. *Listeria monocytogenes* was also detected in 7.5% of ready-to-eat artisanal foods in Chile (Bustamante *et al.*, 2020) and in 46.4% of ready-to-eat starch-based, beef-based, poultry-based, fish-based, vegetable-based and sandwich-based street-vended foods sold in the Johannesburg Metropolis, South Africa (Asiegbu *et al.*, 2020).

In Kenya, there is limited information on the prevalence of *Listeria monocytogenes* in ready-to-eat foodstuffs. Therefore, it is important to determine the prevalence of *Listeria monocytogenes* in especially ready-to-eat street-vended foods where contamination may easily occur.

2.5 The presence of toxic chemical substances in foods

Limited research has been reported on the level of contamination of street foods with chemical toxic contaminants. Table 2.2 shows toxic compounds reported in street-vended foods. Commonly reported toxins in street-vended foods include acrylamide, polycyclic aromatic hydrocarbons, aflatoxins, and heavy metals such as lead, mercury, antimony, manganese, and cadmium (Table 2.2). As shown in Table 2.2, these contaminants have been reported in many street-vended foodstuffs. These toxins may be categorized into four: environmental contaminants, processing contaminants, agricultural residues, and microbial toxins.

Table 2.2: Toxic chemical substances in street-vended foods

Chemical Residue	Foods Implicated	Food Category	Country	Reference
Acrylamide	Potato crisps	Plant origin	Kenya	Ogolla *et al.* (2015)
PAHs	Roasted yam, fried fish *	Animal and plant origin	Nigeria	Ekhator, Udowelle, and Igbiri (2018)
Lead (Pb)	Fried street food, rice, spaghetti, beans, roasted plantain, fried chicken, fried turkey, edible maggot, meat pie, fried plantain, white rice, stewed meat, salad, roasted yam, buns, fried meat, fried fish, doughnut, cake, sausage, etc.	Animal and plant origin	Indonesia, Nigeria, Philippines	Chavez *et al.* (2014); Ekhator *et al.* (2017); Ihsan and Edwin (2018); Solidum (2010)
Mercury (Hg)	Rice, spaghetti, beans, roasted yam, buns, fried plantain, white rice, roasted plantain, fried fish, doughnut, meat pie, edible maggot, stewed meat, salad, cake, sausage, fried chicken, fried turkey, fried meat, etc.	Animal and plant origin	Nigeria	Ekhator *et al.* (2017)
Antimony (Sb)	Rice, spaghetti, beans, roasted plantain, fried chicken, fried turkey, meat pie, roasted yam, buns, fried plantain, fried meat, fried fish, doughnut, white rice, stewed meat, salad, cake, sausage, etc.	Animal and plant origin	Nigeria	Ekhator *et al.* (2017)
Manganese (Mn)	Rice, spaghetti, beans, roasted plantain, fried chicken, fried turkey, fried meat, salad, cake, sausage, meat pie, edible maggot, roasted yam, buns, fried plantain, white rice, stewed meat, fried fish, doughnut, *	Animal and plant origin	Nigeria	Ekhator *et al.* (2017)
Aluminum (Al)	Rice, spaghetti, white rice, stewed meat, salad, fried chicken, fried turkey, fried meat, beans, roasted plantain, fried fish, doughnut, meat pie, edible maggot, roasted yam, buns, fried plantain, cake, sausage, *	Animal and plant origin	Nigeria	Ekhator *et al.* (2017)
Cadmium (Cd)	Deep-fried breaded quail, buns, fried plantain, white rice, steamed dumpling, grilled chicken's small intestine, rice, spaghetti, beans, fried chicken, fried turkey, meat pie, edible maggot, roasted yam, stewed meat, fried meat, fried *	Animal and plant origin	Philippines, Nigeria	Chavez *et al.* (2014); Ekhator *et al.* (2017)
Aflatoxins	Corn, groundnut, nuts (coconut, tiger nut, and walnut), and wheat snacks, *	Plant origin	Nigeria, Congo	Ezekiel *et al.* (2012); Kamika and Takoy (2011)

PAHs - polycyclic aromatic hydrocarbons, *and others

2.5.1 Environmental contaminants

Contamination of street-vended foods from the environment may occur at any step from the production of raw materials to street food preparation and eventual vending (Proietti *et al.*, 2014b). Raw materials such as the vegetables used for salads may already be contaminated with toxic substances especially if the vegetables were grown on contaminated soils (Osaili *et al.*, 2016). Street food is exposed to environmental pollutants since it is often cooked, served, and consumed in open areas without adequate shelter. The exposed food can be contaminated by airborne pollutants, car smoke, burning industrial gasses, insects, rats, and foul odors from garbage (Rakha *et al.*, 2022). Amongst the environmental contaminants of concern reported in street-vended foods are heavy metals including lead and mercury (Chavez *et al.*, 2014; Ekhator *et al.*, 2017; Ihsan & Edwin, 2018; Mohammed, 2010; Solidum, 2010).

In a study carried out in Jordan, Osaili *et al.* (2016) reported that the mean level of lead (0.15-1.15 mg/kg) in onions, exceeded the European Union set limits (0.1 mg/kg fresh weight). Ali and Al-Qahtani (2012) reported lead in both onions (3.52 – 4.28 mg/kg) and tomatoes (2.78 – 3.32 mg/kg) sold in Saudi Arabian markets. The presence of lead in onions and tomatoes that are used to prepare salads is an indication of the possibility of lead contamination in salads and other foods that are prepared using these vegetables. In Nigeria, Ogunkunle, Bello, and Ojofeitimi (2014) reported the presence of lead (0.07 – 1.93 mg/kg) and cadmium (0.00-0.09 mg/kg), in street-vended mangoes, pawpaw, and watermelons while Ekhator *et al.* (2017) reported the presence of lead (0.12 - 1.37 mg/kg) and cadmium (<0.001 – 0.0014 mg/kg)) in commonly consumed street-vended foods sold in Benin City and Umunede, Nigeria. In Kenya, research on heavy metals especially ready-to-eat food products is minimal. Kinyanjui (2009) reported lead levels ranging from 0.00 - 0.38 mg/100 g in fruits and vegetables sold in Kisumu County, Kenya. Tomno *et al.* (2020) reported contamination of kale and spinach cultivated and sold in Machakos Municipality, Kenya with cadmium levels ranging between 0.013 – 3.19 mg/kg and lead levels ranging between 0.02 – 0.368 mg/kg. Continuous ingestion of heavy metals such as lead and mercury has a damaging effect on humans (Jaishankar *et al.*, 2014). For instance, aluminum in large quantities interferes with physical and cellular processes in the body (Jaishankar *et al.*, 2014). Previous research has also linked heavy metals to the increasing cases of cancer in sub-Saharan Africa (Fasinu & Orisakwe, 2013).

Heavy metals may enter the food chain in many ways. The contamination of soils with toxic wastes laced with heavy metals as a result of poor waste disposal practices from some industries may result in the accumulation of these heavy metals in plants that grow in those soils. Thus, plant produce may contain some of these toxic heavy metals in varying concentrations. In addition, when animals consume these plants, animal products such as milk, eggs, and meat may in turn become contaminated with these toxic metals. The growing of vegetables in cities and near industrial places has been reported to yield foodstuffs contaminated with heavy metals (Ali & Al-Qahtani, 2012). For instance, Njagi *et al.* (2017) reported that vegetables grown around dumpsites in Nairobi City County, Kenya were heavily contaminated with mercury (0.38 to 2.68 mg/kg) and lead (0.39 to 1.59 mg/kg) above maximum allowable levels. Although the sources of raw materials for street-vended foods are not well established, it may be possible that some of these raw materials may be from small farms established in cities and near industrial places. Poor waste disposal systems constantly experienced in developing countries such as Kenya further enhance contamination of the environment and food with toxic substances (Fasinu & Orisakwe, 2013). It is usual practice for trash piles, fly-infested areas, and rat nests to gather close to street vending locations. Street food vendors often contribute to littering by discarding leftover food and non-food items in public spaces (Rakha *et al.*, 2022). Problems caused by these toxic contaminants may not be immediate but accumulation in the body may reach toxic levels causing health issues late in life.

2.5.2 Agricultural residues

2.5.2.1 Antibiotic residues

Antibiotics are used to treat or prevent animal diseases (Allen *et al.*, 2014). The presence of antibiotic residues in foods (Darwish *et al.*, 2013) is an indication of excessive, inappropriate, and unnecessary use and poor management of antibiotics (Beyene, 2016; HSCC, 2018). Despite the large amounts of antibiotics in use around the world, there are minimal reports on antibiotic residues in foods (WHO, 2015). There are also few reports documenting research on antibiotic residues in ready-to-eat foods (WHO, 2015).

Tetracycline and beta-lactams are among the most commonly used antibiotics. Tetracycline is a broad-spectrum antibiotic with bacteriostatic effects. They have been used in both human and animal disease management. Tetracyclines are predominantly the most prescribed antibiotics in Africa representing 41% of all antibiotic-associated residues in food (Darwish *et al.*, 2013).

The beta-lactams are characterized by a beta-lactam ring in their chemical structure that gives them their antibacterial activity (Donowitz & Mandell, 1988). Their activity against the microorganisms is based on their ability to inhibit cell wall synthesis in bacteria (Donowitz & Mandell, 1988; Macheboeuf *et al.*, 2006). Examples of beta-lactam antibiotics include penicillin, monobactams, carbapenems, and cephalosporins. Beta-lactams are also among the most common antibiotics that are used in the treatment of humans as well as animals (King et al., 2017). Beta-lactam antibiotics follow tetracyclines closely at 18% of all antibiotic-associated residues in foods (Darwish *et al.*, 2013). Indiscriminate and inappropriate use of antibiotics in the treatment of animals has been reported in Kenya (Roderick *et al.*, 2000). Thus, there is a high possibility for antibiotic residues to be found in animal-derived food products.

Antibiotic residues are the leading cause of antimicrobial resistance that is being reported around the world (Beyene, 2016; Omulo *et al.*, 2015). Antimicrobial-resistant bacterial infections currently claim at least 700,000 lives globally, and the numbers are expected to rise in the next 30 years (HSCC, 2018). According to Beyene (2016), the major public health concern of antibiotic residues is the development of drug resistance, carcinogenicity, hypersensitivity reaction, teratogenicity, mutagenicity, and disruption of intestinal normal microflora in the human gastrointestinal tract. According to Bacanlı and Başaran (2019), they can cause various side effects including the transmission of antibiotic-resistant bacteria to people, immunopathological effects, allergies, mutagenicity, nephropathy (from gentamicin), hepatotoxicity, reproductive problems, bone marrow toxicity (from chloramphenicol), and even carcinogenicity (oxytetracycline, furazolidone, sulphamethazine). Antimicrobial resistance of pathogenic bacteria isolated from street foods has been reported by other researchers (Anukampa *et al.*, 2017; Hossain *et al.*, 2017; Lin *et al.*, 2017; Nemo *et al.*, 2017; Ngangom, Tamunjoh, & Boyom, 2019).

Even though there is limited research on antibiotic residues in street-vended ready-to-eat foods, these residues have been reported in foodstuffs. For instance, Ahlberg *et al.* (2016) reported the presence of beta-lactams, sulfonamides, and tetracyclines in 24% of the milk samples tested in Kenya. Recently, Orwa *et al.* (2017) reported the presence of sulfonamides and tetracyclines antibiotic residues in raw milk from both rural (31.4%) and peri-urban (28.8%) dairy systems in Kenya. In another research, Kosgey, Shitandi, and Marion (2018) reported the presence of antibiotic residues in 24% of milk obtained from milk vending machines as well as 24% of street-vended, supposedly ready-to-drink milk samples. Similarly, Wanjala *et al.* (2018) reported antibiotic residues in ready-to-drink processed milk. Thus, there is the possibility of finding antibiotic residues, especially β-lactams and tetracyclines commonly used in disease management in Kenya in street-vended foods.

2.5.2.2 Pesticide residues

To manage weeds, insects, and diseases in a variety of fruits and vegetables, pesticides are used both pre-and post-harvest. Some types of pesticides include insecticides, herbicides, fungicides, nematicides, and avicides. The application of pesticides has enhanced agricultural production, crop yield, crop protection, the availability of inexpensive food, and farmers' income (Zikankuba *et al.*, 2019). However, their improper use and management result in residues in fruits and vegetables sold in many markets and streets. Pesticide residues have been shown to cause acute and chronic adverse health effects in humans. In particular, they have been implicated in endocrine disruption, genotoxicity, mutagenicity, chronic neurotoxicity, and carcinogenesis (Macharia, MithÃ, & Waibel, 2009). Many countries and health organizations such as the US, and WHO, have established the maximum residue limits (MRL) for pesticide residues in farm produce. Pesticide residues such as acephate, bifenthrin, chlorothalonil, chlorpyrifos, cyfluthrin, cyhalothrin, cypermethrin, deltamethrin, dichlorvos, dimethoate, fenitrothion, fenpropathrin, fenvalerate, isocarbophos, methamidophos, omethoate, phorate, parathion-methyl, parathion, permethrin, triadimefon, and triazophos have been reported in fruits and vegetables (C. Chen et al., 2011). Some of them have been found in cabbages, cucumber, eggplant, apples, broccoli, legumes, lettuce, oranges, cauliflower, celery, peach, pear, spinach, and tomatoes (Chen *et al.*, 2011).

In street-vended foods, pesticide residues at levels above maximum residue limits (MRLs) have been reported around the world (Bakırcı *et al.*, 2014; Chen *et al.*, 2011; Elgueta *et al.*, 2017; Łozowicka *et al.*, 2015; Lozowicka *et al.*, 2016; Mebdoua *et al.*, 2017; Struciński *et al.*, 2015; Szpyrka *et al.*, 2015; Yang *et al.*, 2016). Yang *et al.* (2016) reported 66.7% while Elgueta *et al.* (2017) reported 27% of fruit and vegetable samples contained pesticide levels above MRLs in China and Chile, respectively. In Algeria, Mebdoua *et al.* (2017) reported that 12.5% of food samples contained pesticide residues.

Carbamates and organophosphorus compounds are amongst the most commonly used pesticides in Kenya that have been reported to adversely affect human health (AIRS, 2017). Large exposures to organophosphates produce cholinesterase depression (Hardos *et al.*, 2020). Cholinesterase inhibition in turn results in an overstimulated nervous system which further results in nausea, dizziness, confusion, and eventually respiratory paralysis and death (AIRS, 2017). In the case of organophosphates, it is cumulative and longer-lasting, and therefore more dangerous (AIRS, 2017; Bosak, 2006). Although there has been research on pesticide residues around the world, little research has been done in Kenya. In particular, the levels of pesticide residues in street-vended foods are important.

Pesticide residues have been found in soil and water indicating the possible presence in food (Getenga, Keng'ara, & Wandiga, 2004).

2.5.3 Food processing contaminants in street-vended foods

Using heat to process food paves the way for chemical contamination of the food. Utilizing high cooking temperatures is the most common method of food processing in both homes and commercial settings. When combined with other factors, the use of high heat for cooking can lead to the production of dangerous compounds that affect the food's quality and safety. Toxic compounds such as nitrosamines, chloropropanols, acrylamide, furanes, or polycyclic aromatic hydrocarbons are produced during the heating, roasting, grilling, baking, canning, fermentation, or hydrolysis processes used to process food. During the process of preparing food, frying is most usually responsible for the production of a variety majority of dangerous substances (Rather *et al.*, 2017).

Due to a lack of adequate training in food preparation, most street food vendors heat foods for an extended period without the replacement of heating oils or fats (Abong & Kabira, 2015). This has the potential for the development of toxic compounds such as nitrosamines in the case of cured meat products containing nitrates or nitrites (Sen, 2018). Nitrosamines are formed by the reaction of secondary or tertiary amines with nitrosating agents such as nitrous anhydride, which is formed from nitrite in an acidic, aqueous solution. The nitrates and nitrites are used in cured meat products and can easily produce nitrous anhydride (Scanlan, 1983). The most common nitrosamines are N-nitroso dimethylamine, N-nitroso diethylamine, and N-nitroso pyrrolidine (Sen, 2018). On the other hand, acrylamide can be formed in starchy foods. When food is heated at typical cooking temperatures, the carbonyl-containing compounds may interact with amino groups, especially from amino acid asparagine to produce acrylamide. According to Zyzak *et al.* (2003), the formation process involves the formation of a Schiff base after which decarboxylation and subsequent elimination of either ammonia or a substituted imine under heat occur resulting in the formation of acrylamide.

Herrmann, Duedahl-Olesen, and Granby (2014) reported the formation of nitrosamines in cured meat products when heated. Ogolla *et al.* (2015) reported high levels of acrylamide (8556.8-9728.1 µg/kg) in especially street-vended potato crisps in Nairobi, Kenya. A study estimating acrylamide intake among young people found high contamination in French fries (Altissimi *et al.*, 2017). French fries are common street-vended foods that rank highest in consumption level amongst young people. Such toxicants have been linked to causes of non-communicable diseases such as cancer whose prevalence in Kenya is on the rise (Abong & Kabira, 2015) although their contribution to these diseases is unknown. Moreover, the number and amount of these chemicals and toxins that make it into the food supply and eventually into ready-to-eat foods are unknown (WHO, 2015).

Controlled food additives such as nitrites that are used to enhance specific food characteristics have also been abused and added in excess, especially for street-vended foods (Abong & Kabira, 2015; Lança de Morais *et al.*, 2018). This also has the potential to cause adverse health issues. A research study designed to study the effect of synthetic colour and flavor additives on rats revealed that brilliant blue (124 mg/kg diet), carmoisine (70 mg/kg diet), tartrazine (75 mg/kg diet), trans-anethole (4.5 g/kg diet), propylene glycol (0.25 g/kg diet), and vanillin (1.25 g/kg diet) significantly induced a decrease in hemoglobin concentration, body weight, and red blood cell count (El-Wahab & Moram, 2013). This shows that synthetic flavours and colours may have adverse health effects, especially if used in foods without regulation. Nevertheless, there is limited research on the compliance of street food vendors with food additive regulations.

2.5.4 Microbial toxins in street-vended foods

Besides the presence of bacterial pathogens in street-vended foods, mycotoxin-producing fungi have also been found. Oranusi and Olorunfemi (2011) reported the presence of *Penicillium* spp., *Aspergillus niger,* and *Mucor* spp. in street-vended foods. Under appropriate conditions, these fungi have been reported to produce toxins. Mycotoxins are the secondary metabolites of molds that produce adverse health effects on humans resulting mostly in illnesses. Mycotoxins of the greatest health and economic importance include aflatoxins, ochratoxins, zearalenone, trichothecenes, tremorgenic toxins, fumonisins, and ergot alkaloids (Hussein & Brasel, 2001).

Aflatoxins are mycotoxins produced by some strains of *Aspergillus flavus*, *Aspergillus parasiticus*, and *Aspergillus nomius*. There are four main aflatoxin types (B_1, B_2, G_1, G_2) and two more (M_1, M_2) that are produced through milk by animals that have metabolized the main four types. Aflatoxins are commonly found contaminating peanuts, maize, wheat, rice, nuts, milk, eggs, and cheese among other foods. In humans, they have been found to cause the following pathological effects: hepatotoxicity, bile-duct hyperplasia, hemorrhage in the Intestinal tract and the kidneys as well as carcinogenesis (Bullerman, 2003).

Fumonisins are mycotoxins produced primarily by *Fusarium verticillioides* and *Fusarium proliferatum*. There are three types of fumonisins (FB_1, FB_2, and FB_3). Fumonisins are commonly found in contaminated maize. In humans, they have been linked to esophageal cancer (Bullerman, 2003). Since they may be present in maize, they may also be found in maize-based food products. Since the storage of street-vended foods is poor, the fungus may grow and produce these mycotoxins.

Environmental conditions such as temperature and moisture are key factors in mycotoxin production (Daou *et al.*, 2021). Therefore, street-vended foods improperly stored may attract mold growth. Since some of these toxins are resistant to heat, the low heat treatments administered to re-heat street-vended foods on the street may not be sufficient to reduce the levels in foods. In street-vended foods, mycotoxins have been reported. For instance, aflatoxins were reported in corn, groundnut, nuts (coconut, tiger nut, and walnut), and wheat snacks among other street-vended products in Nigeria and Congo (Ezekiel *et al.*, 2012; Kamika & Takoy, 2011). In Kenya, there is limited research on mycotoxin contamination in street-vended ready-to-eat foodstuffs. Nevertheless, aflatoxins and fumonisins as well as aflatoxicosis incidences have been reported involving foodstuffs (Daniel *et al.*, 2011; Mutiga *et al.*, 2015; Probst, Njapau, & Cotty, 2007). Recently, aflatoxin was reported in ready-to-eat peanut butter in Kenya (Merab, 2019).

Thus, there is a need for the analysis of street-vended foods to identify contamination levels and avenues for the prevention of toxin formation.

CHAPTER THREE

DETERMINATION OF FOOD SAFETY KNOWLEDGE AND PRACTICES OF STREET FOOD VENDORS IN SELECTED LOCATIONS WITHIN THIKA TOWN, KIAMBU COUNTY, KENYA

3.1 Introduction

The growing urban population in developing countries has stimulated a rise in the number of street food vendors (SFVs) in many cities to satisfy the demand for affordable and readily accessible ready-to-eat (RTE) meals. Most of the town dwellers rely on such foods because they are convenient (Moussavi *et al.*, 2016). Not only are street foods valued for their convenience and affordability, but they also make a significant contribution to the country's economy, the preservation of society's cultural and social heritage, and maintaining and enhancing people's nutritional status (Hill *et al.*, 2019). Street food enterprises are distinguished by their low capital requirement, which makes it easier for SFVs to enter the market (Rane, 2011).

Food safety knowledge is generally low among street food vendors as not all of them are usually educated or trained on food handling and safety (Omemu & Aderoju, 2008; Omorodion & Ogunekum, 2022). In a study on the link between food safety knowledge and practices of food handlers in Kushtia, in Bangladesh, Aktar and Biswas (2022) reported that 47.8% of food handlers had not taken any training on food safety. In their study, 60.4% of the food handlers did not know that uncooked foods should be kept separate from ready-to-eat foods. Similar findings were reported in a study on food safety compliance among street food vendors in Can Tho City, Vietnam by Huynh-Van *et al.* (2022) who found that only 14% of street food vendors knew that raw food should be separated from ready-to-eat foods. In Kenya, Muendo *et al.* (2022) reported that 91.1% of street food vendors of cooked foods in Chuka town, Tharaka Nithi County, Kenya had not received any training on food safety. The lack of training on food safety as well as food preparation has been linked to poor hygiene practices among street food vendors (Huynh-Van *et al.*, 2022). Published reports, especially from developing countries generally indicate that SFVs primarily sell in crowded places such as open-air markets and bus terminus to attract consumers (Kariuki *et al.*, 2017). Thus, the vending sites are often lacking basic provisions such as toilets, potable water supply, handwashing facilities, waste disposal systems, and good drainage systems. Vending sites such as those close to waste disposal sites provide ideal breeding sites for rodents and insects which can easily contaminate the foods with food safety hazards (Imathiu, 2017). Similarly, foods sold on the roadsides which are often dusty and contaminated with exhaust fumes from vehicles may easily be contaminated with chemical food safety hazards such as polycyclic aromatic hydrocarbons, as well as lead and arsenic which are carcinogenic (Omari & Omari, 2019).

Due to the informal nature of these businesses, compliance with food laws as well as the enforcement of the same may not always be possible. Thus, the hygiene and sanitary condition of vending structures, as well as the vending environments, may be compromised with the possibility of foodborne diseases posing public health risks to the consumers of these foods (Okojie & Isah, 2014; WHO, 2015). In Kisumu County in Kenya, Ouma, Oyango, and Kakai (2019) reported the presence of *Staphylococcus aureus* in water used by SFVs. These deficiencies in street food vending environments have been linked to numerous foodborne disease outbreaks, especially microbial illnesses (Alimi, 2016; Cortese *et al.*, 2016). Therefore, the quality and safety of street-vended foods are of great concern to public health, as consumers are constantly exposed to the risk of illness every time they consume these foods.

Due to the unsafe practices reported among SFVs, the scarce funds in developing countries that could have been utilized for infrastructural growth are being harnessed to treat foodborne disease outbreaks that could have been prevented through the provision of safe foods (Alimi, 2016). However, there are minimal reports on the handling practices and the level of food safety knowledge among SFVs in Kenya, especially in fast-growing towns such as Thika town. On several occasions, especially through media, cases of microbial foodborne illnesses have been reported in these areas. Therefore, it is necessary to determine the food hygiene practices and food safety knowledge of SFVs to identify gaps where interventions can be recommended and/or applied to ensure the provision of quality and safe street-vended foods and help alleviate incidences of foodborne diseases.

3.2 Materials and methods

3.2.1 Study design and study site

A cross-sectional descriptive study was conducted on SFVs in six street food vending locations in Kiambu County, Kenya between June and July 2019. The study locations included the area surrounding Thika Level 5 Hospital, Juakali, Kiandutu, Makongeni, Ngoigwa, and Thika Town Center (Figure 3.1). These study areas are not administrative units but rather subdivisions of the town taken to ease the data collection and analysis process as shown in Table 3.1.

Table 3.1: Description of study locations within Thika town

Location	Description
Thika level 5 hospital area	This is the area surrounding the Thika Level 5 Hospital and Mount Kenya University.
Juakali area	The area comprises small-scale and informal businesses (*Juakali*) as well as manufacturing industries within Thika town.
Kiandutu area	The area hosts retail businesses and a slum hosting low-income earners within Thika town
Makongeni area	The area comprises retail businesses, an estate that hosts low to middle-income earners as well as some manufacturing industries.
Ngoigwa area	The area comprises retail businesses and hosts the Ngoigwa estate which is home to high-income earners in Thika town.
Thika town center	The area comprises the central business zone within Thika town. It hosts mainly retail businesses and the central bus terminus in Thika town.

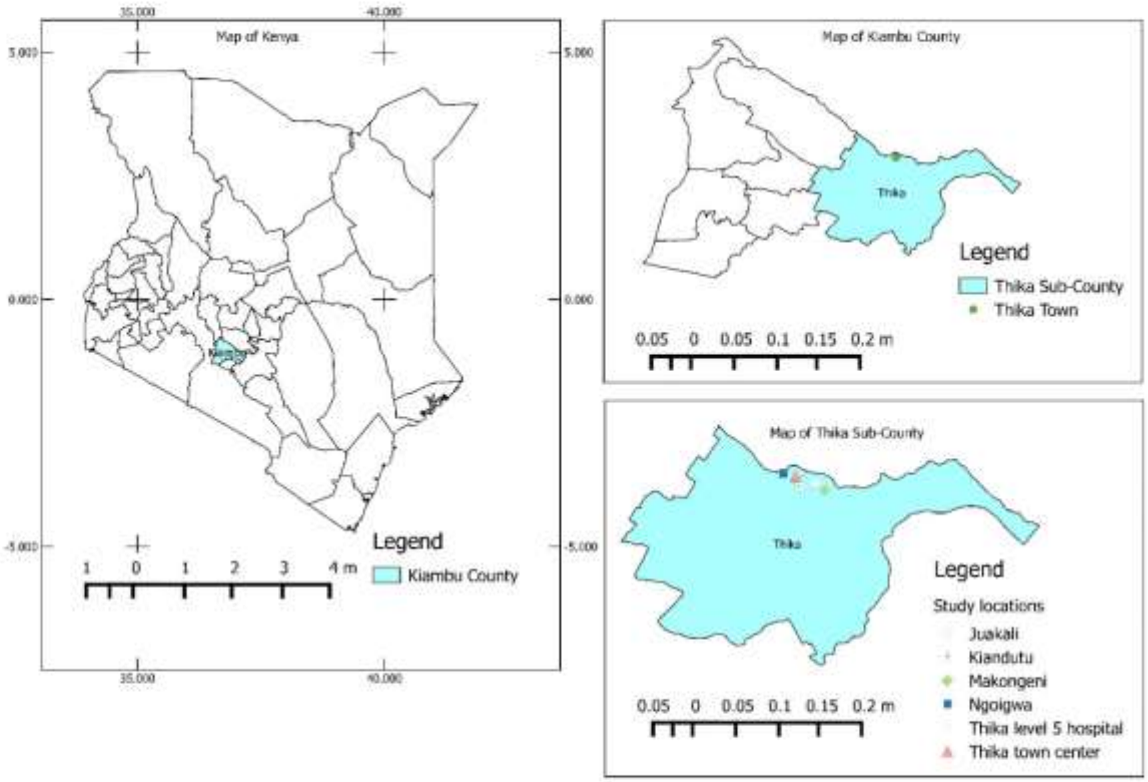


Figure 3.1: Map of the study area showing the study locations in Thika town.

3.2.2 Sampling procedure for street food vendors

Since the total population of SFVs in the study site was unknown, the determination of the number of SFVs to be used in this study was carried out using the formula described by Kothari (2004) (Equation 3.1). This equation yielded 385 SFVs. The SFVs were randomly selected from among the individuals who were found vending street foods at the time of data collection. No prior notification had been sent to the SFVs to inform them of the data collection exercise.

$$n = \frac{z^2 p(1-p)}{d^2} \quad \text{Equation 3.1}$$

Where: n is the sample size, z is the z statistic at a 95% confidence level (z = 1.96), p is the estimated population proportion, taken as p = 0.5 (maximum variability), d is the desired precision level of ±5% (0.05) at 95% confidence level.

In this study, street vendors were defined as individuals selling RTE foods in open places whether mobile or in stationary locations along the streets or in public places. The inclusion criteria were as follows: (a) vendors must be on the street, mobile, or located in standard locations with temporary structures and (b) vendors must be selling any RTE foodstuff that does not require further processing by the consumer before consumption. Out of 385 identified SFVs, only 345 consented to take part in the study.

3.2.3 Questionnaire design and SFV interviews

The questionnaire designing process was guided by relevant information from literature and the guidelines provided by WHO (1996) regarding street food vending hygiene and safety practices. The questions covered the sources of raw materials or RTE foodstuffs sold, storage and/or preservation of raw materials and RTE foodstuffs during the sale as well as food preparation and temperature control. In addition, the questions also covered hygiene and sanitation knowledge and practices, awareness of the potential food safety hazards in the food products, knowledge of food safety standards, and food contamination. The questionnaire was pre-tested among 19 street food vendors in Juja town, Kiambu County, Kenya, and administered through a face-to-face interview by six appointed individuals.

3.2.4 Assessment tool for observation of street food vendor practices

An assessment tool for observation of SFVs' practices was administered to each vendor to determine their compliance with the essential hygiene and safety requirements for SFVs outlined by WHO (1996). The checklist was used to collect information regarding personal hygiene practices, food handling practices, and the condition of the vending environment. For each vendor, the hygiene and sanitary status of the vending place, the garbage collecting bin, and the vending environment was determined subjectively using a 3-point rating scale as follows: "good" if it was found to be extremely clean, "average" if the place of vending was moderately clean with efforts put in place to clean the place and "poor" if the place of vending was dirty. The checklist was filled through observation by the six appointed data collectors immediately after the interview for each SFV was completed.

3.2.5 Consent to collect information from street food vendors

Permission to carry out this study was obtained from the National Commission for Science and Technology (NACOSTI) and the County Commissioner for Kiambu County, Kenya (Research permit number: NACOSTI/P/19/87469/31129). In the actual survey, the participants were notified of the objective of the study and that the information they were going to provide would be held confidential. They were further notified that participation was entirely voluntary and that they could opt out of the survey at any time during the interview.

3.2.6 Statistical analysis

The data obtained were analyzed using the statistical package for social sciences (SPSS) software version 25 (SAS Institute**)**. For categorical data, frequencies, and percentages of occurrence of responses were calculated while numerical data were summarized as means ± standard error. A Chi-square test of independence was used to test whether there were significant relationships between the categorical variables. All tests were carried out at a $p = 0.05$ level of significance.

3.3 Results and discussion

3.3.1 Socio-demographic characteristics of street food vendors

There were more male SFVs (63.2%) compared to female vendors (36.8%) (Table 3.2). Although food preparation is regarded in African society as the preserve of females, men are stepping up and picking up roles that were traditionally set aside for females, especially to gain income. This may explain the high proportion of male vendors in street food vending in this study. These results are in agreement with those of Cortese *et al.* (2016) who reported more males (58%) than females (42%) in the street food vending business in Brazil. However, contrary to this study, Odundo, Okemo, and Chege (2018) and Da

Silva *et al.* (2014) reported female dominance in street food vending at 60% and 55.9% in Kenya and Brazil, respectively. These variations underscore the complexity of socio-economic and cultural factors that shape gender roles in street food vending across different regions.

Table 3.2: Demographic characteristics of SFVs in selected locations in Thika town, Kiambu County, Kenya.

	Categories	Frequency	Percentage (%)
Gender	Female	127	36.8
	Male	218	63.2
	Total	345	100.0
Age category	Below 18 years	2	0.6
	Between 18 – 25 years	113	32.9
	Between 26 – 35 years	158	46.1
	Between 36 – 45 years	46	13.4
	Above 45 years	24	7.0
	Total	343‡	100.0
Education level	No formal education	10	2.9
	Incomplete primary school	26	7.7
	Completed primary school	78	23.0
	Incomplete secondary school	61	18.0
	Completed secondary school	129	38.1
	College education	27	8.0
	University education	8	2.4
	Total	339‡	100.0

Note: ‡ Some vendors did not reply to certain questions.

The male dominance observed in our study challenges traditional gender stereotypes associated with food preparation. This shift could be influenced by the changing landscape of income opportunities. The consistency of this pattern with findings from Brazil, along with the contrasts with other studies, underscores the need for a comprehensive exploration of socio-economic dynamics to fully understand gender distribution in street food vending.

About a third of the SFVs (32.9%) were between 18-25 years old (Table 3.2). This category constitutes the relatively young and economically vibrant workforce that may be able to cope with the laborious tasks involved in street food vending (Adama, 2020). Similar results were reported by Odundo *et al.* (2018) in Mombasa County, Kenya in a study investigating food safety practices among SFVs where the most predominant age group was found to be 19-28 years accounting for 49% of the SFVs.

The study revealed that 38.1% of the SFVs had obtained secondary school education with 10.4% having received college or university training. Only 10.6% of the vendors had not either completed primary school education or attained any formal education (Table 3.2). Having completed secondary education level as well as college and university training may imply that SFVs are offering better quality and safe food since the level of the SFVs' formal schooling is one of the factors that contribute to food safety (Rebouças *et al.*, 2017). Generally, higher levels of education are assumed to correlate with higher food hygiene and safety knowledge (Ma *et al.*, 2019). The findings of this study differed from those of Ma *et al.* (2019) who reported that the majority of SFVs (68%) in Handan, China, were either illiterate or had attained primary or middle school education (level of education between high school and primary school). This may be because most SFVs may lack the opportunity to pursue secondary, college, or university education for reasons such as lack of funds. Nevertheless, some vendors may consider street food vending as an opportunity to begin their entrepreneurial endeavors. This shows that street food vending is dynamic and may appeal not only to persons who are less educated but also to those who have attained college or university education. In addition, the limited availability of formal employment opportunities in Kenya may also serve as a motivating factor, compelling individuals with college or university education to engage in street food vending.

3.3.2 Length of time in street food vending business

The length of time spent in the street food vending business may positively correlate with the level of food hygiene and safety knowledge that the vendor has gathered over time. Vendors who have been in business for a long time are therefore expected to have better food hygiene and safety knowledge although this is not always the case (Gamieldien & Van Niekerk, 2017). The mean duration of time in business was 3.3±0.2 years with a median of 2 years. The median time of 2 years means that at least 50% of the vendors in this study had been in business for 2 years and below. Thus, there are many entrants into street food vending businesses in the study area, and this business may not be a permanent career for most SFVs. This is clearly shown by the large proportion of almost 40% of vendors who had been in business for one year and below (Figure 3.2). This differs from the findings of Da Silva *et al.* (2014) who reported the median time spent working in street food vending in their study investigating the socioeconomic and food safety perspectives of SFVs on the coast of Salvador, Bahia, Brazil to be 9 years. This meant that at least 50% of the vendors had been in business for at least 9 years which is higher than the median time reported in this study.

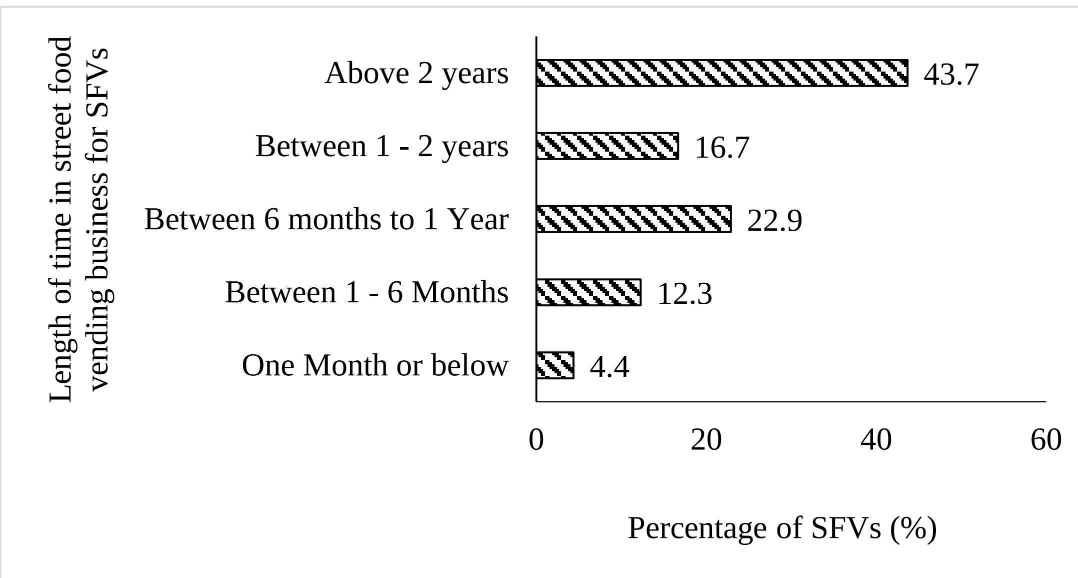


Figure 3.2: Street food vendors' length of time in street food vending business.

There were significantly ($p<0.001$) more vendors aged between 18 to 25 years who had been in business for one year and below as compared to those in the other age categories **Figure 3.3**. This age group comprises the young and most vibrant persons who may have probably completed their secondary or tertiary education and needed a job to earn a living.

Street food vending is an inexpensive venture to start. Thus, it presents an opportunity for this group of people to start earning a living.

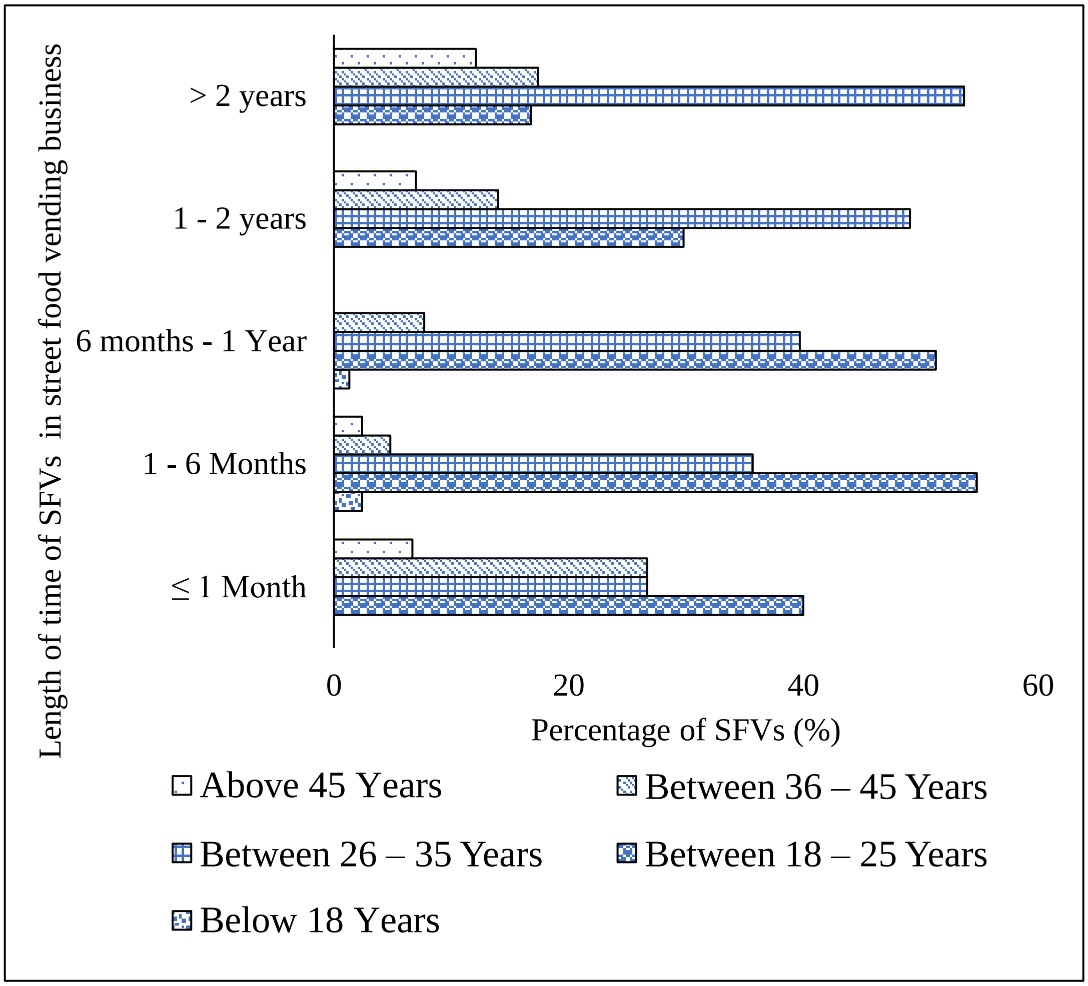


Figure 3.3: Relationship between age category and the duration of time in business.

3.3.3 Washing practices for hands, equipment, and utensils

Washing practices for hands, equipment, utensils, and foodstuff among the SFVs are shown in Figure 3.4. Most vendors (56.9%) washed their hands using cold water only. Only 40.8% used cold water with soap to wash their hands. Regarding washing equipment and utensils, 54.5% of SFVs washed them using cold water and soap, and only 20.1% used warm water with soap. According to the WHO (1996), essential food safety guidelines for SFVs, vendors should wash their hands with water and soap every time they engage in any activity that may introduce physical, biological, or chemical hazards to food. Thus, washing hands and utensils with cold water only may not be as sufficient in removing all food safety hazards as when washed with water and soap (Shukla *et al.*, 2019). This implies that there is a high potential for contamination of street-vended food due to insufficient hand and utensils washing practices. These results were consistent with the results reported by Muyanja *et al.* (2011) who studied the practices, knowledge, and risk factors of SFVs in Uganda where 76.9% of SFVs used cold water and soap, 7.6% used cold water only while 2.2% and 7.6% used hot water only or hot water with soap, respectively to wash their utensils. SFVs must possess good hand, equipment, and food washing practices involving the use of water and soap to ensure the safety of RTE food (Dudeja & Singh, 2017).

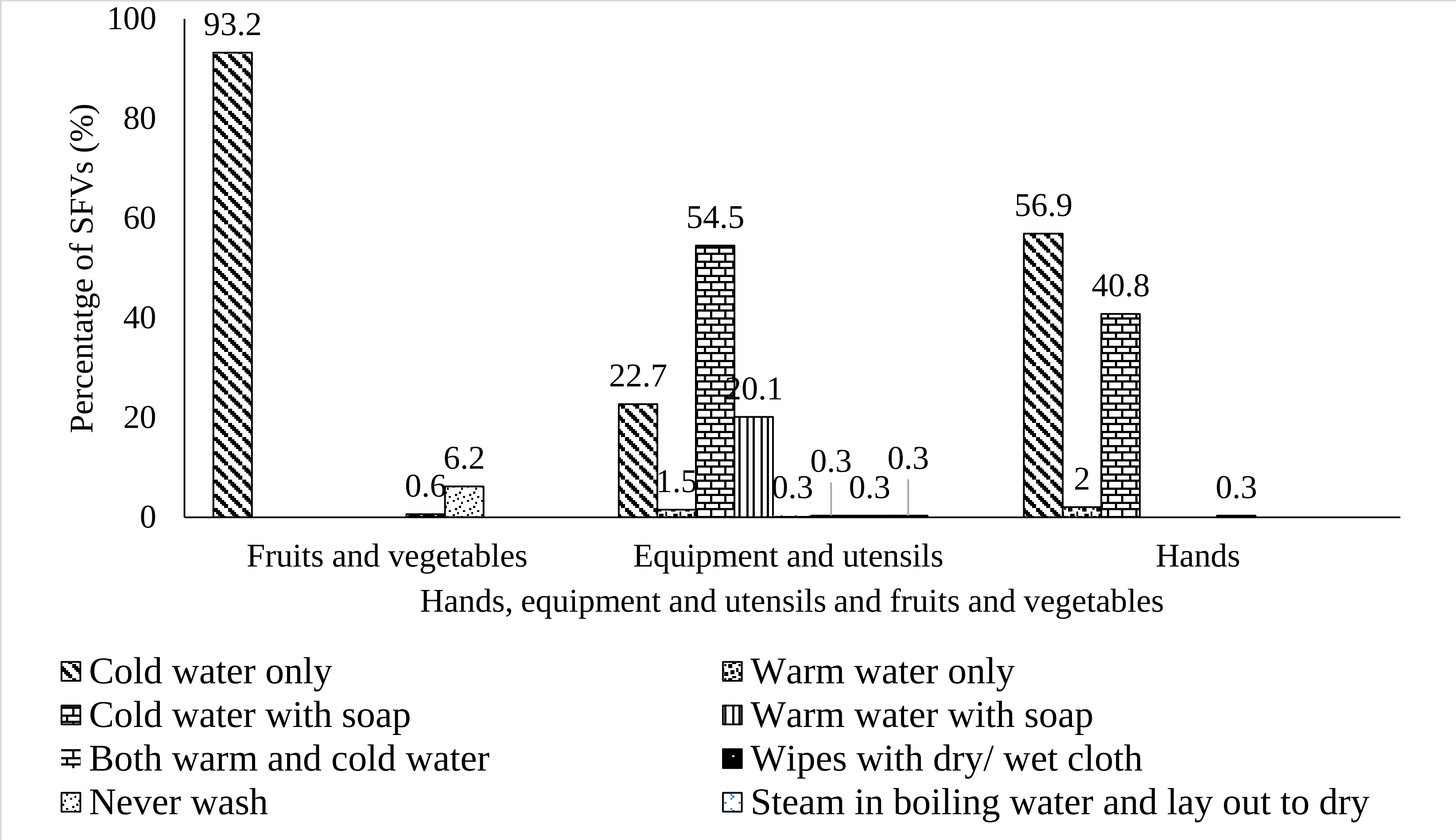
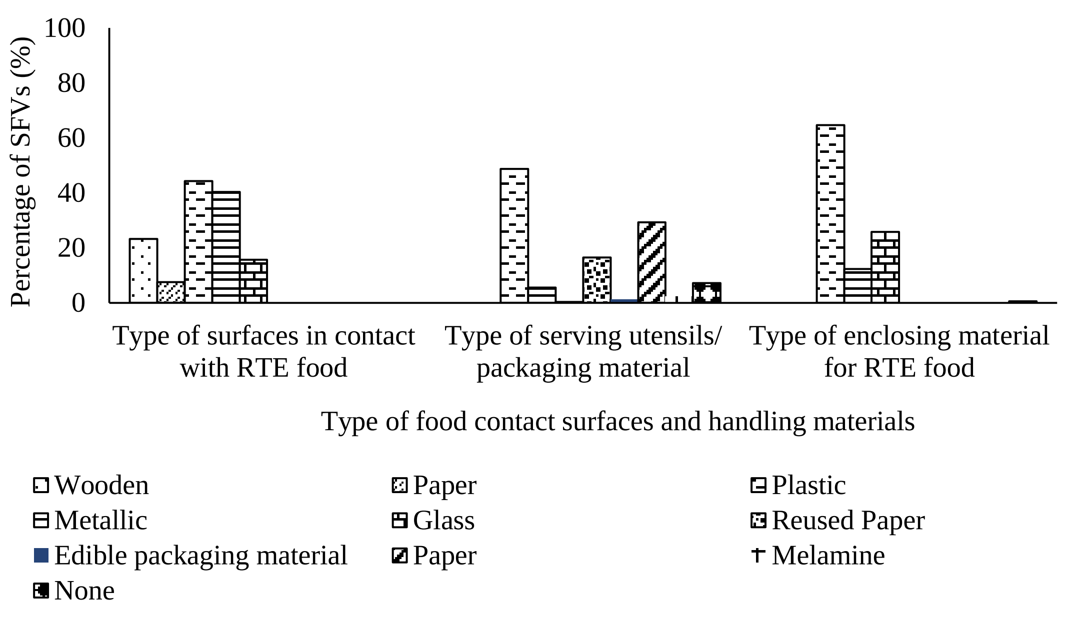


Figure 3.4: Washing practices for hands, equipment, and fruits and vegetables.

3.3.4 Handling of ready-to-eat food, utensils, and packaging materials by street food vendors

About 48.7% of the vendors had plastic serving utensils or packaging materials while 29.3% were found to be using paper. Reused papers such as those used to cover other food or non-food stuff were found to be used to wrap foodstuffs in 16.5% of the SFVs (Figure 3.5). The use of recycled packaging materials can contaminate food with hazards such as pathogenic microorganisms or chemical residues that may be injurious to people's health (Proietti *et al.*, 2014b). For instance, recycled paper has been reported to contribute to the exposure of consumers to thousands of toxicants including endocrine-disrupting chemicals such as bisphenol-A, and dibutyl phthalate, as well as di-2-ethylhexyl phthalate (Geueke, Groh, & Muncke, 2018; Lopez-Espinosa *et al.*, 2007). In Ethiopia, Eliku (2016) reported that over 90% of SFVs used recycled paper for packaging food.



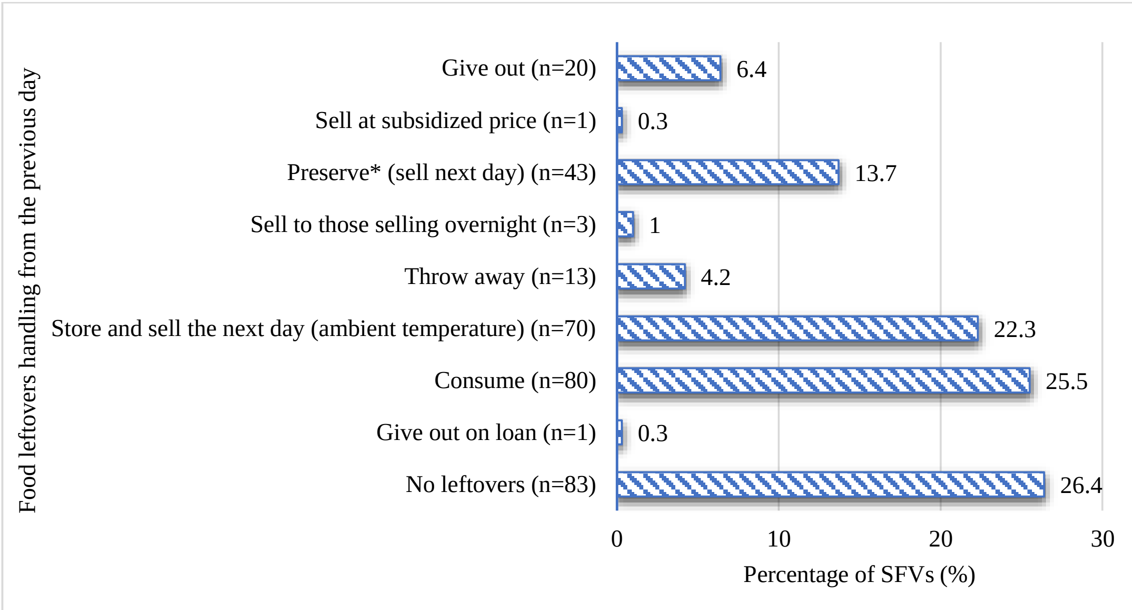
Note: Percentages are above 100% due to SFVs who used multiple packaging and food handling materials.

Figure 3.5: Type of materials used for working surfaces, closures, serving utensils, and/or packaging materials.

3.3.5 Storage and preservation practices of ready-to-eat food by street food vendors

It was found that most vendors would store their stock, including the foodstuff that required refrigeration at ambient temperatures (78.3%) awaiting preparation and eventual sale. Most RTE foods (38.6%) were also stored at ambient temperatures (20-25°C). Similar results were reported by Muhonja and Kimathi (2014) in Nakuru county, Kenya while assessing the hygiene and food handling practices among SFVs where cooked foods were stored at ambient temperatures exposed to the environment during the sale which posed significant safety concerns. Temperature abuse by exposing food to ambient conditions encourages a wide range of spoilage and pathogenic microorganisms to proliferate causing infections and intoxications when the food is consumed (Obaji *et al.*, 2018; Ouma *et al.*, 2019; Shiningeni *et al.*, 2019).

SFVs used various methods to handle leftover food from the day's sales as shown in **Figure 3.6**. About 25.5% of the vendors indicated that they would consume the leftovers while 22.3% stored the foodstuffs without any form of preservation and sold them the following day. Leftover food can easily be contaminated by especially pathogenic microorganisms when stored under ambient temperatures posing safety concerns to the consumers (Obaji *et al.*, 2018). This is worrying considering the poor handling and storage practices that the foods are exposed to during the day.



*Note: *Preservation was occasionally done through refrigeration. Some vendors indicated that they stored boiled eggs in cold salted water.*

Figure 3.6: Street food vendors' ways of handling leftovers from the previous day.

In case the food was contaminated with pathogens, storage at ambient temperatures allows the pathogens to proliferate to levels that can cause disease or produce toxins that cause disease when the food is consumed. Similar results were reported by Muhonja and Kimathi (2014) in Nakuru county, Kenya while studying the hygiene and food handling practices among SFVs who found out that SFVs mostly stored leftover foods at ambient temperatures.

3.3.6 Personal hygiene of street food vendors

Poor hygiene and sanitary practices were observed among most of the SFVs as shown in Figure 3.7. For instance, 86.1% of the vendors handled money while serving food without washing their hands.

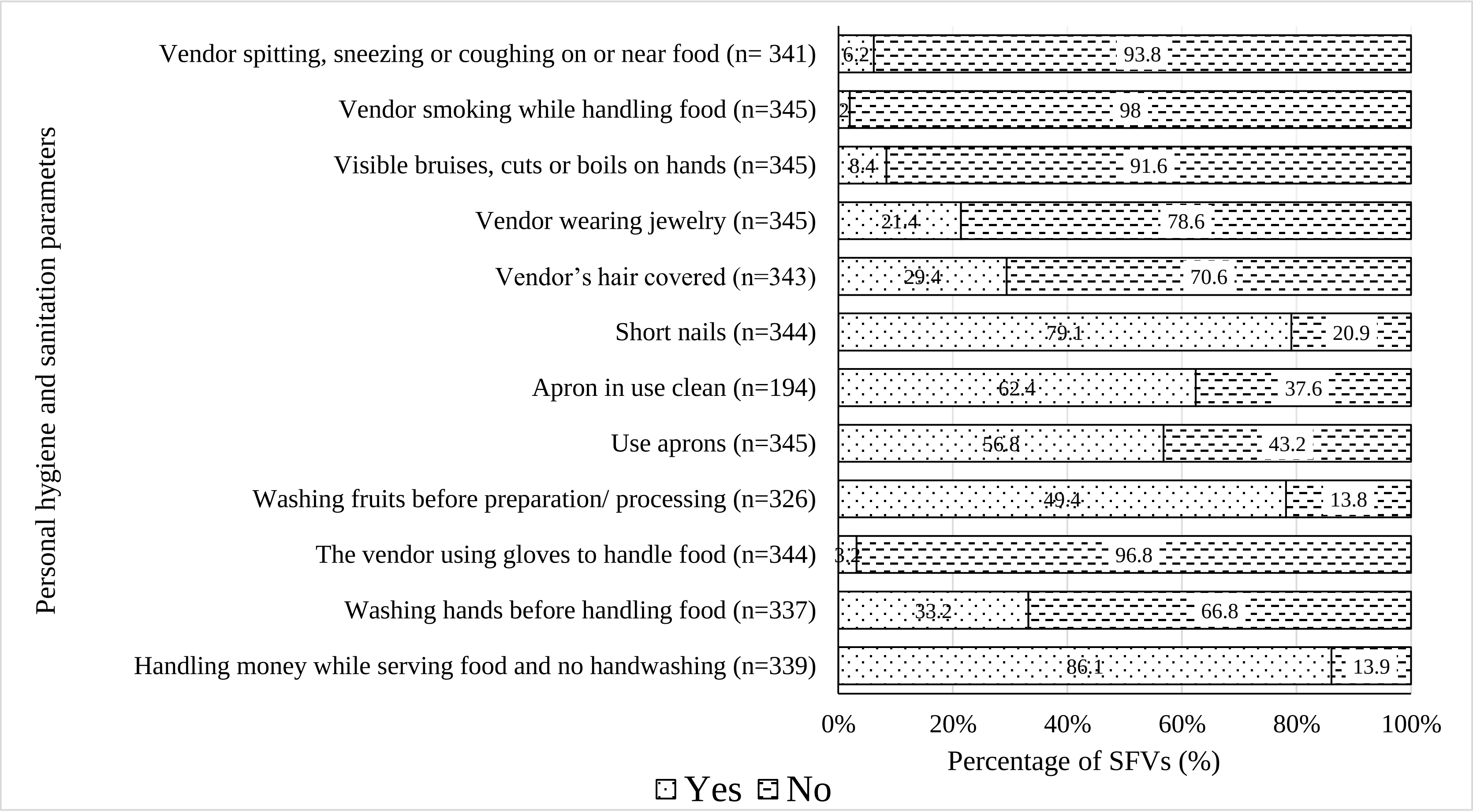


Figure 3.7: Observations on personal hygiene and practices of SFVs.

The continuous exchange of money between individuals has the potential for contamination with hazards, especially pathogenic microorganisms. Handling the money while serving RTE food can potentially result in the contamination of these foods. In a study carried out to determine the microbial contaminants in banknotes obtained from food outlets sampled from 10 different countries, Vriesekoop *et al.* (2010) reported the presence of *Escherichia coli*, which is indicative of fecal contamination of the money. Furthermore, *Salmonella* and *Staphylococcus aureus* were also isolated. Similar results were observed by Da Silva *et al.* (2014) who reported that 80.2% of the SFVs admitted to handling money and food simultaneously in Brazil.

Only 56.8% of the vendors wore aprons of which, only 58.1% had clean aprons. Almost all SFVs (96.8%) in this study handled food with bare hands while about 70.6% had not covered their hair. Most vendors in this study overlooked basic hygiene practices that have the potential to contaminate food. According to WHO (1996), street vendors should wear clean aprons, handle food using clean gloves, cover their hair, and wash their hands every time before handling food. Similar results were reported in Ethiopia by Eliku (2016) in their study investigating food hygiene and sanitary practices of SFVs in the city of Addis Ababa. In their study, the author reported that 88.6% of vendors did not wear aprons, 95% had uncovered hair and all street vendors handled money with bare hands while serving food.

Long nails, as well as nail polish, were found among 20.9% and 15.5% of the SFVs in this study, respectively. Since long nails may harbor pathogenic microorganisms (Ansong, 2015), these can end up contaminating food considering that almost all vendors (96.8%) in this study handled food with bare hands. Muyanja *et al.* (2011) reported similar findings in their study on the practices, knowledge, and risk factors of SFVs in Uganda where 68.6% of the vendors had uncut nails while 75.7% had unclean nails in one of their study locations.

A few vendors were found to be smoking (2.0%) or spitting, sneezing, or coughing near RTE food (6.2%). These practices heighten the chance for contamination of food with physical, chemical, or biological food safety hazards. They can also be avenues for the transfer of communicable diseases from ailing SFVs to the many consumers of street-vended foods. Smoking among SFVs was reported in 30% of street food vendors by Ma *et al.* (2019) in Handan, China.

3.3.7 Condition of the vending environment and the vending structures

Most vendors had temporary stalls constructed (44.2%) or used trolleys (24.7%) to display their foodstuff. Others utilized carts, tables, wheelbarrows, or car trunks to sell their foodstuffs. Most vendors sold foodstuff in dirty surroundings (54.7%) and only 45.3% were in clean areas. The choice of vending structures, as well as vending locations, can impact the quality and safety of street-vended foods (Bormann *et al.*, 2016). Selling RTE food using uncovered structures such as wheelbarrows, carts, tables and car trunks located in unhygienic environments may result in contamination of food with food safety hazards such as pathogens and chemical toxic contaminants in the air during preparation or service. Vending sites such as those close to waste disposal sites provide ideal breeding sites for rodents and insects which can easily contaminate the foods, especially with pathogenic microorganisms (Imathiu, 2017). Similarly, foods sold on roadsides that are often dusty and contaminated with exhaust fumes from vehicles may easily be contaminated by chemical hazards such as polycyclic aromatic hydrocarbons, lead, and arsenic(Omari & Omari, 2019)).

There was a highly significant relationship ($p = 0.0001$) between the hygiene and sanitary status of the vending structures, and the condition of the surrounding environment. Almost all the vendors (98.6%) selling around dirty environments had vending structures with poor hygiene and sanitary status. Therefore, dirty surroundings would result in unclean working surfaces and vending structures that were rated as having poor hygiene and sanitary status.

Garbage collecting bins were only found in 53.8% of the vendors of which only 36.4% were adequately covered and 20.9% were overfilled. Poor waste management results in contamination of the environment which in turn increases the chance of contaminating the

RTE food during handling (Reddy, Ricart, & Cadman, 2020; Tambekar *et al.*, 2008). As expected, vendors working without a dustbin were statistically more likely ($p = 0.0001$) to be in dirty surroundings than those who had dustbins. Poor waste management practices result in the dumping of waste around the vending premises. The waste attracts flies and other crawling insects that were noted in about 52.4% of the SFVs' premises in this study. These, in turn, may contaminate the working surfaces, utensils as well as exposed RTE food. In this study, more than half (54.5%) of the vendors left the packaging materials or serving utensils exposed (Figure 3.8).

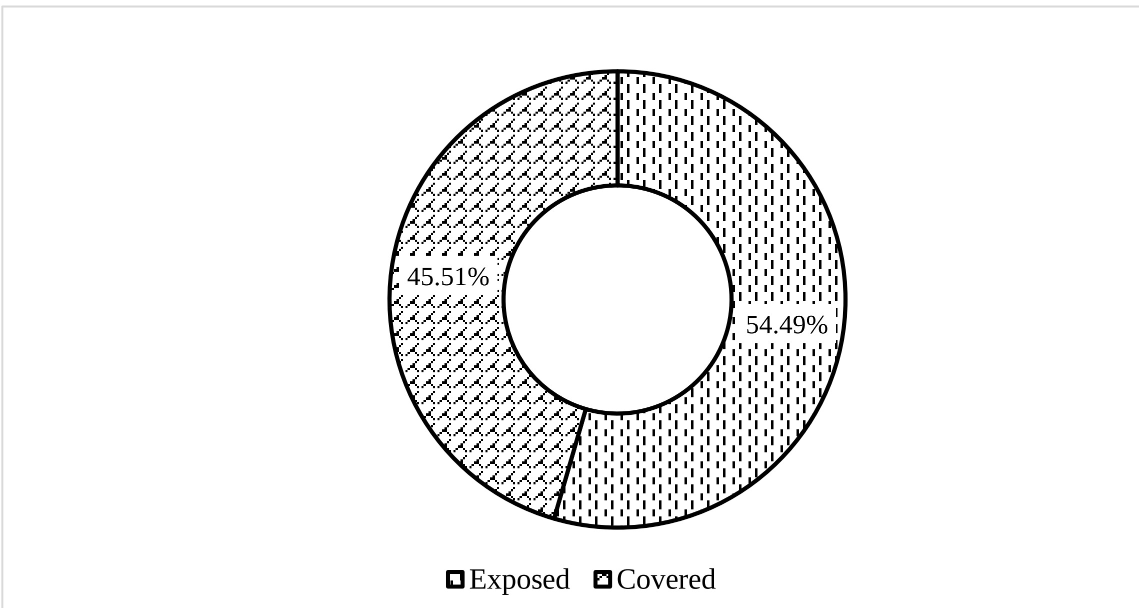


Figure 3.8: The proportion of SFVs whose serving utensils or packaging material were exposed to the environment

Similar results were reported in Benin City, Nigeria in a study on the sanitary conditions of vending sites where waste bins were found in 43.4% of the SFVs (Okojie & Isah, 2014). Okojie and Isah (2014) also reported the presence of flies in 41.3% and rodents and cockroaches in 2.4% of the SFVs' premises. This shows that insect control is an important aspect of the street food vending business. This is because the presence of insects as well as rodents have been reported to increase the chance of having contaminated food among SFVs (Amaami, Dominic, & Collins, 2017). While studying environmental factors and food handling practices associated with food contamination among SFVs in Nairobi county, Kenya, Amaami *et al.* (2017) reported that the presence of pests or rodents around street food vending sites was significantly ($p<0.001$) associated with food contamination. In this study, SFVs whose vending sites had presence of pests or rodents had a 5.9 fold risk of having contaminated foods.

3.3.8 Training in food hygiene and safety of street food vendors

About 93% of SFVs had no training in food hygiene and safety. This kind of training is expected to equip them with the right knowledge that will enhance the quality and safety of the foods sold. The lack of training for most of the vendors greatly contributed to the vendor's poor knowledge of food safety and unhygienic behavior. With this knowledge gap, vendors hardly pay attention to the cleanliness of the surrounding area or the safe handling practices for RTE food. The results were comparable to those reported by Okojie and Isah (2019) in their study on food hygiene knowledge and practices of SFVs where 73.9% of SFVs in Benin City, Nigeria had no formal food safety training. This highlights the need for training SFVs on food hygiene as well as food safety to preserve and protect the health of consumers. Training interventions on SFVs have been reported to be effective in changing their attitudes toward food safety knowledge as well as practices (Choudhury *et al.*, 2011).

When vendors were asked if street-vended food could be a source of pathogenic microorganisms, about 40.1% strongly agreed, 16.7% neither agreed nor disagreed while 39.8% and 3.5% disagreed or strongly disagreed, respectively. Although 40.1% of the street food vendors knew that pathogenic microorganisms could be found in street food, a substantial proportion (59.9%) of the SFVs were not aware of this possibility. This shows that most SFVs may be operating without the knowledge that foods could be sources of microorganisms some of which may be pathogenic to humans. With this knowledge gap, SFVs would hardly put effort into reducing or eliminating contamination of RTE foods with pathogenic and spoilage microorganisms. For instance, in the case of fruit juices that have the potential for contamination during preparation, most vendors (87.5%) in this study did not subject them to heat treatment (Figure 3.9). Heat treatment is a common method used to eliminate harmful pathogens that could potentially contaminate food and lead to health risks for consumers (Artes & Allende, 2005). The absence of heat treatment in the preparation of fruit juices carries implications for food safety.

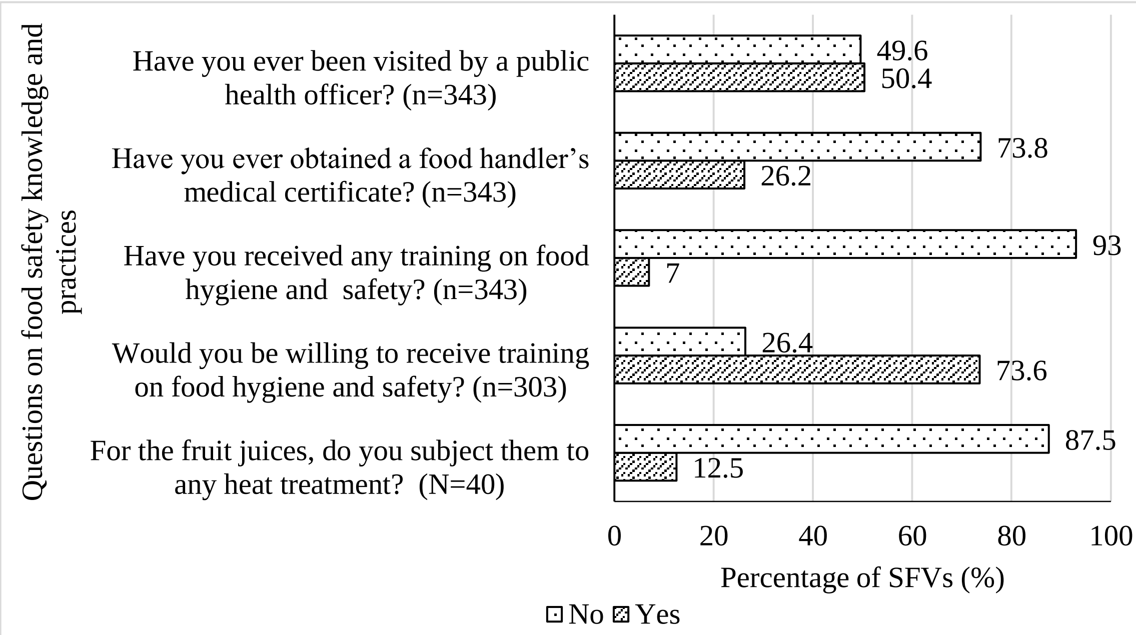


Figure 3.9: Questions on food safety knowledge and practices among street food vendors

3.3.9 Enforcement of food safety regulations among street food vendors

Seventy-three percent of the SFVs had not obtained a food handlers' medical certificate. Of the vendors who had a food handler's medical certificate, 42% of them never renewed it while about 1% of them renewed it within 3 months, 30% within 6 months, and 27% within 12 months. This is possibly due to factors such as ignorance, or weak enforcement of this requirement by the local government authority concerned (Okojie & Isah, 2019). Undertaking a medical fitness examination or screening for communicable diseases for any food handler is a requirement outlined in the public health Act, Chapter 242, 2012 of Kenya. Having a medical health certificate is important as it confirms that the handler has no communicable diseases and that the consumer is not at risk of contracting any diseases from the street food vendor. Although mandatory, most SFVs evade taking the examination possibly because it requires the commitment of not only money but also time (Apaassongo, Aidoo, & Ohene-Yankyera, 2016). This shows that SFVs may opt to sell foods even when they are not medically fit to handle food which poses food safety concerns due to the possibility of the spread of communicable diseases. Improved public health control can enhance compliance with food hygiene and safety guidelines in street food vending.

About 50% of the vendors indicated that they had never been visited by public health officials. Lack of oversight on street-vended foods presents an opportunity for vendors to sell food even when they are not medically fit to handle food. It may also increase the chance of adulteration of food with unlicensed harmful substances or the sale of uncertified food substances that may be harmful to the unsuspecting public. The vendors who received visits from the public health officers were more likely to have a food handler's medical certificate ($p<0.0001$). This underlines the importance of public health officers' oversight of food vending businesses. Continuous surveillance as suggested by Obaji *et al.* (2018) is therefore required as a strategy for improved street food safety.

3.4 Conclusion

The findings of this study demonstrate that street-vended foods sold in Kiambu County may constitute a significant potential hazard to public health. The majority of SFVs were educated to the secondary school level and had not received any formal training on food hygiene and safety. The lack of training for most of the vendors may have contributed to their unhygienic behavior and poor knowledge of food hygiene and safety. Of particular concern were the findings that almost all SFVs handled food with bare hands, and handled money and food at the same time without washing hands in between. Storage and preservation practices were poor as most vendors stored the RTE food including leftovers at ambient temperature. For most vendors, the condition of the vending environment, as well as the vending structures, was also poor. Considering the benefits of the street vending business, including the provision of income and employment for many young people, the inclusion of these businesses in street design may not only benefit the SFVs but also the consumers of street foods through the provision of high-quality and safe foods. Continuous provision of food hygiene and safety training to the SFVs, and enforcing the implementation of appropriate food hygiene and safety practices have the potential to improve street food quality and safety. Policies specific to the street food vending sector may streamline the sector and facilitate control and regulation by public health officials.

CHAPTER FOUR

DETERMINATION OF THE CATEGORIES OF FOOD HYGIENE AND SAFETY KNOWLEDGE AND PRACTICES AND THE FACTORS INFLUENCING FOOD SAFETY, HYGIENE AWARENESS, AND PRACTICES AMONG STREET FOOD VENDORS IN THIKA TOWN, KIAMBU COUNTY, KENYA.

4.1 Identification of the categories of food hygiene and safety knowledge and practices among street food vendors through nonlinear principal component analysis

4.1.1 Introduction

Street food vending is a fast-growing informal sector, especially in developing countries such as Kenya. Numerous studies have been reported investigating street food vendor (SFV) characteristics including their food hygiene and safety awareness, attitude, and practices (Bormann *et al.*, 2016; Dwumfour-Asare & Agyapong, 2014; Lawan *et al.*, 2015; Okojie & Isah, 2014, 2019; Rahman *et al.*, 2016). However, there are minimal reports that elucidate relationships between the SFV characteristics. Conclusions based on an analysis performed on individual SFV characteristics may not provide any indication of the relationships existing among these characteristics, nor allow the grouping of vendors with similar characteristics. Therefore, it is essential to have a few elements to synthesize the trends observed among SFVs and thus obtain more information from the large amount of heterogeneous data collected.

Principal component analysis (PCA) is one of the multivariate statistical methods that can yield such comparisons by analyzing data in which observations are characterized by many correlated quantitative dependent variables. Its purpose is to extract the key information from the data, represent it as a set of new orthogonal variables known as principal components, and display the pattern of similarity between the observations and variables as points on maps (Linting *et al.*, 2007). The new uncorrelated variables account for as much as possible of the variation observed in the data (Abdi & Williams, 2010;

Khikmah, Wijayanto, & Syafitri, 2017; Linting *et al.*, 2007). Whenever different measurement scales are used such that some variables are measured at nominal, ordinal, or numeric levels, as in the case of this study, PCA which is applied in numeric data may not be suitable for dimension reduction. Alternatively, nonlinear principal component analysis (NLPCA) also referred to as categorical principal component analysis (CATPCA) is ideal for data with different measurement scales including nominal and ordinal level data (Khikmah *et al.*, 2017).

The main objective of NLPCA is reducing a given set of variables to a smaller number of uncorrelated principal components or summary variables while taking into account non-numeric measurement levels (categorical variables at ordinal and nominal scales) and the probable nonlinear relationships in the data (Kemalbay & Korkmazoğlu, 2014; Linting *et al.*, 2007; Linting & van der Kooij, 2012). The extracted summary variables represent the information in the original data as closely as possible avoiding loss of information (Linting & van der Kooij, 2012; Šnirc *et al.*, 2017). Typically, the number of new uncorrelated key components is equivalent to the number of all the original variables in the large datasets and is extracted in diminishing order of importance. Thus, the first component accounts for the variation in the heterogeneous data as much as possible while the second component accounts for as much of the residual variation (Mwove *et al.*, 2018). The goal is to find a small number of variables that explain the variability of the data as much as possible, thereby revealing relationship structures among the observed variables and the most important directions of variability in a large set of heterogeneous data sets (Linting & van der Kooij, 2012; Meulman, Van der Kooij, & Heiser, 2004; Šnirc *et al.*, 2017).

Various researchers have employed NLPCA to study heterogeneous qualitative data (Manisera, van der Kooij, & Dusseldorp, 2010; Saukani & Ismail, 2019; Vilela, Monteiro, & Correia, 2017) although, at the time of this study, no research report was found employing NLPCA to study SFV characteristics. In this study, NLPCA was employed to identify the components of SFV's food hygiene and safety knowledge and practices taking into account the non-numeric measurement levels and the possible nonlinearity of relationships. The aim was to reduce and summarize the large heterogeneous nominal and ordinal data into fewer components (categories) of SFV food hygiene and safety knowledge and practices that may be used in further analysis such as in logistic regression analysis carried out in chapter 5.

4.1.2 Materials and methods

4.1.2.1 Description of the study

A cross-sectional descriptive study was conducted as described in subheadings 3.2.1 to 3.2.5. The pre-tested questionnaires contained 22 questions while the checklist comprised 41 questions.

4.1.2.2 Variable selection for NLPCA

This study included a total of 63 characteristics of SFVs from the six study locations. Education level, category of street food sold, age of the SFV, gender of the SFV, and length of time in the street food vending business were chosen as the five labeling variables for the object scores and were therefore not included in the PCA analysis. The selection of variables for NLPCA was based on the following rule of thumb as reported by Linting and van der Kooij (2012): for variance accounted for (VAF) in any variable per component, 10% is poor, 20% is fair, 30% is good, 40% is very good, and 50% is excellent. This study aimed at a good VAF for each variable across the principal components and thus the minimum VAF for inclusion was set as 30%. Nineteen variables with bad fits were dropped leaving a total of 39 variables for this analysis as shown in Table 4.1.

Table 4.1: Description of the variables selected for categorical principal component analysis.

Variable description	Abbreviation
Condition of working surfaces, cutting equipment, and chopping boards (1 = Dirty; 2 = Clean)	V1
Cleanliness of the place of vending (1 = Poor; 2 = Average; 3 = Good)	V2
Ready-to-eat (RTE) food adequately covered (1 = No; 2 = Yes)	V3
Condition of the surrounding environment (1 = Dirty; 2 = Clean)	V4
Working surfaces are in good condition without crevices or cracks (1 = No; 2 = Yes)	V5
Cleanliness of vendor's apron (1=Dirty; 2=Clean)	V6
Working surfaces are cleanable (1=No; 2=Yes)	V7
Serving utensils are in good condition with no scratches or rusting observed (1=No; 2=Yes)	V8
There is adequate separation between raw and RTE food (1=No; 2=Yes)	V9
Vendor does not touch their mouth, tongue, nose, or eyes while handling food (1=No; 2=Yes)	V10
Garbage collecting bin available (1=No; 2=Yes)	V11
Garbage collecting bin not overfilled (1=No; 2=Yes)	V12
Garbage collecting bin covered (1=No; 2=Yes)	V13
Houseflies and other insects are not present (1=No; 2=Yes)	V14
Water is available for washing (1=No; 2=Yes)	V15
Cleanliness of the garbage collecting bin (1=Poor; 2=Average; 3=Good)	V16
Vendor washes hands before handling food (1=No; 2=Yes)	V17
SFV knows that street-vended foods may be sources of pathogenic microorganisms (1=Strongly disagree; 2=Neither agree nor disagree; 3=Strongly Agree)	V18
SFV knows that training of SFVs is important to ensure the safety of consumers (1=Strongly disagree; 2=Neither agree nor disagree; 3=Strongly Agree)	V19
There is a drainage system for wastewater from the business (1=No; 2=Yes)	V20
Sufficient water for washing is available (1=No; 2=Yes)	V21
How the vendor washes their hands (1=No washing; 2=cold water only; 3=warm water only; 4=Coldwater with soap)	V22
How the vendor washes their equipment or utensils (1=No washing; 2=cold water only; 3=warm water only; 4=cold water with soap; 5=warm water with soap)	V23
The vendor is aware of food safety standards and regulations in Kenya (1=No; 2=Yes)	V24
The vendor can recall any food safety standard or regulation in Kenya (1=No; 2=Yes)	V25
SFV has received training on food hygiene and safety? (1=No; 2=Yes)	V26

Variable description	Abbreviation
The vendor employs refrigeration for food (1=No; 2=Yes)	V27
Handling of leftovers from the previous day (1=No leftovers; 2=Consume; 3=Store at ambient temperatures for selling next day; 4=Throw away; 5=Sell to other sellers selling overnight; 6=Preserve and sell next day; 7=Sell at a throwaway price; 8=Give out; 9=Give out on loan)	V28
Storage of serving utensils or packaging material (1=Uncovered; 2=Covered)	V29
How food is stored after preparation while awaiting consumers (1=Cold-Refrigerated; 2=Ambient temperatures; 3=Hot-Over the heat source; 4=Warm-Off the heat source but warmer than ambient temperatures)	V30
Nature of storage in practice for foodstuff that is yet to be prepared (1=No stock observed; 2=Refrigeration; 3=Hot – overheat; 4=Ambient temperatures)	V31
The vendor has obtained a food handler's medical certificate (1=No; 2=Yes)	V32
How often the vendor renews their food handler's medical certificate (1=Never renewed; 2=Every 6 months; 3=Every 12 months)	V33
Vendor's willingness to receive a food handler's medical certificate (Those without) (1=Unwilling; 2=Willing)	V34
The vendor would be willing to receive training on food hygiene and safety (1=No; 2=Yes)	V35
Vendor mobile (1=No; 2=Yes)	V36
Vending structures are washable (1=No; 2=Yes)	V37
SFV knows that street food vending is a major source of livelihood for many Kenyans (1=Strongly disagree; 2=Neither agree nor disagree; 3=Strongly agree)	V38
Place of vending (1=Hand-held containers; 2=Trolley, carts, or wheelbarrows; 3=Car trunks; 4=Stall/ Kiosk)	V39

4.1.2.3 Statistical analysis

To perform NLPCA, this study utilized SPSS software version 25, the categorical principal components analysis (CATPCA) module. In CATPCA, categories of nominal or ordinal variables are assigned numeric values through a process called optimal quantification or optimal scaling. Through this process categories of variables with ordinal or nominal analysis levels are transformed into numeric value variables referred to as category quantifications through the optimal quantification process. NLPCA is carried out such that, as much as possible the variance in the new quantified variables is accounted for (Linting *et al.*, 2007; Meulman *et al.*, 2004; Saukani & Ismail, 2019). A detailed procedure for conducting NLPCA using CATPCA has been described by Linting and van der Kooij (2012).

4.1.3 Results and discussion

4.1.3.1 Number of principal components

Table 4.2 shows the variance accounted for (VAF) by a seven-component model selected for this study. The goodness of fit in CATPCA is based on the total VAF in the transformed variables and Cronbach's alpha (Kemalbay & Korkmazoğlu, 2014).

Table 4.2: Proportion of the variance accounted for in a seven-dimensional CATPCA solution on 39 SFV food hygiene and safety characteristics

Dimension	Cronbach's alpha	Variance accounted for		
		Total (eigenvalue)	Percentage	Cumulative percentage
1	0.81	4.69	12.03	12.03
2	0.79	4.30	11.01	23.05
3	0.68	2.92	7.49	30.54
4	0.59	2.34	5.99	36.53
5	0.57	2.26	5.80	42.33
6	0.51	2.00	5.13	47.46
7	0.39	1.61	4.13	51.60
Total	0.98[a]	20.12	51.60	

[a] Total Cronbach's alpha is based on the total Eigenvalue

Two criteria have been suggested for choosing the number of dimensions or components to retain in any solution; one is based on eigenvalues while the other is based on the scree plot which is a graph that displays the VAF against the dimension number. Following the criterion based on eigenvalues ('eigenvalue values greater than one criterion), dimensions with eigenvalues (VAF) greater than one are usually retained while in the scree plot criterion, the number of dimensions to retain is the number of dimensions above the elbow in the plot (Manfredi, Manisera, & Dabrassi, 2009).

In the initial analysis requesting for all components, a total of 12 components were found to have eigenvalues higher than 1, meaning that 12 components should be extracted (Linting *et al.*, 2007). The scree plot was inconclusive on the number of components that should be retained as it did not show any distinct elbow. However, since these criteria are not always optimal (Kemalbay & Korkmazoğlu, 2014), the first seven principal components were extracted based on the interpretability of the components (Linting & van der Kooij, 2012). The seven principal components accounted for 51.60% of the variance observed in the thirty-nine SFV's characteristics. This means that over half of the variability observed at the individual objects (SFVs) level was explained by the seven-component model. The first two components accounted for approximately 23% of the variance observed in the transformed variables. The Cronbach's alpha, an internal consistency coefficient was calculated for each component and the total variance accounted for in this study. The alpha whose maximum value is 1 was found to be 0.975 for the total VAF in this study indicating a good global fit of the CATPCA solution (Meulman *et al.*, 2004).

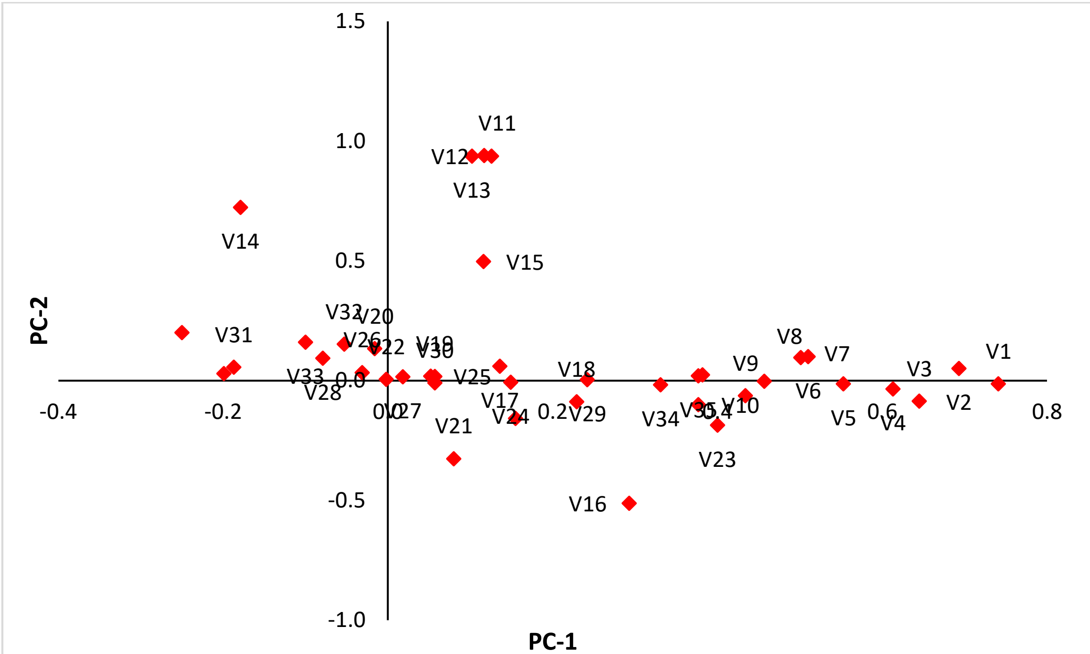
4.1.3.2 Component loadings

The rotated principal component loadings for the 39 SFV hygiene and safety characteristics are shown in Table 4.3. The variables in this table form roughly seven groups or components of SFV food hygiene and safety knowledge and practices. The table presents the classification of the 39 variables based on the components of SFV food hygiene and safety knowledge and practice. This loading indicates the Pearson correlations between the quantified variables and the components, and the values range from – 1 to 1. The sign on each loading, whether positive or negative indicates the relation of the variable to each principal component whether positively or negatively related (Linting & van der Kooij, 2012; Saukani & Ismail, 2019).

Table 4.3: Rotated component loadings from a seven-dimensional CATPCA on 39 SFV food hygiene and safety characteristics.

	PC-1	**PC-2**	**PC-3**	**PC-4**	**PC-5**	**PC-6**	**PC-7**
V1	0.741	-0.014	0.004	0.103	0.045	-0.046	0.108
V2	0.693	0.051	0.311	-0.004	0.024	0.099	-0.054
V3	0.645	-0.086	-0.078	0.041	0.010	0.046	0.049
V4	0.613	-0.035	0.329	0.071	0.086	-0.015	-0.130
V5	0.553	-0.014	0.200	-0.134	0.075	-0.030	0.048
V6	0.510	0.100	0.034	-0.057	0.072	0.094	0.025
V7	0.501	0.096	-0.190	0.177	-0.035	-0.050	0.049
V8	0.457	-0.003	0.056	-0.182	-0.050	0.025	0.257
V9	0.434	-0.063	0.009	0.142	0.024	0.210	0.071
V10	0.377	-0.100	0.372	0.024	0.085	-0.071	-0.323
V11	0.117	0.939	0.037	0.009	0.066	0.091	-0.106
V12	0.126	0.937	0.026	-0.011	0.065	0.078	-0.083
V13	0.102	0.937	0.033	0.008	0.054	0.110	-0.105
V14	-0.179	0.723	0.041	0.086	-0.024	-0.011	0.001
V15	0.116	0.497	-0.282	-0.010	0.079	-0.081	-0.383
V16	0.293	-0.512	0.194	0.005	0.171	-0.035	-0.193
V17	0.136	0.060	0.656	0.181	-0.105	-0.343	0.069
V18	0.229	-0.088	0.593	-0.178	-0.180	0.249	-0.041
V19	0.057	0.017	0.491	0.300	-0.274	0.110	0.174
V20	-0.016	0.133	0.462	0.222	0.029	-0.358	0.026
V21	0.080	-0.326	0.446	-0.019	0.052	0.192	-0.081
V22	-0.002	0.005	-0.678	0.369	-0.122	0.068	0.086
V23	0.400	-0.186	-0.391	0.064	-0.203	0.348	-0.187
V24	0.149	-0.007	0.021	0.783	-0.009	0.076	-0.092
V25	0.052	0.019	0.008	0.771	0.108	0.115	-0.045
V26	-0.031	0.034	-0.051	0.397	0.130	0.332	0.052
V27	0.018	0.016	0.032	0.288	0.607	0.099	-0.023
V28	-0.079	0.094	-0.187	0.113	0.505	0.029	0.135
V29	0.242	0.004	0.063	-0.186	0.489	-0.145	0.156
V30	0.057	-0.010	-0.077	0.056	-0.724	0.035	0.112
V31	-0.187	0.056	0.073	-0.043	-0.733	-0.148	0.119
V32	-0.053	0.152	0.043	0.168	0.116	0.755	0.091
V33	-0.100	0.160	-0.033	0.360	0.101	0.646	0.093
V34	0.331	-0.017	0.009	0.003	-0.006	0.536	-0.141
V35	0.377	0.020	-0.046	-0.004	-0.163	0.483	-0.143
V36	0.155	-0.158	-0.073	-0.114	0.051	-0.017	0.823
V37	0.382	0.024	-0.025	0.237	0.024	-0.144	0.544
V38	-0.199	0.030	0.037	0.173	-0.213	-0.052	0.361
V39	-0.250	0.200	-0.011	0.337	-0.086	-0.087	-0.668

Besides the component loadings table, two-dimensional component loading plots, referred to as biplots also provide further insight into the relationships between the variables. These biplots are shown in Figures 1a and b. To enhance the clarity of the graphs, the lines joining each variable to the origin (loading vectors) were removed. The length of the loading vector usually indicates the variable's VAF. Thus, the further away a variable is from the component, the more it is loaded on that component. In interpreting the rotated components' biplots, the cosines of the angles between the vectors indicate correlations between variables. Thus, the variables that have vectors that make up an angle of approximately 180^{o} with each other are closely related and negative. Furthermore, vectors that make up an angle of 90^{o} are not related but rather independent of each other. In addition, variables close together are positively correlated, while those lying opposite to each other tend to have a negative correlation (Baardseth, Helgesen, & Isaksson, 1996; Linting *et al.*, 2007; Šnirc *et al.*, 2017).


(a)

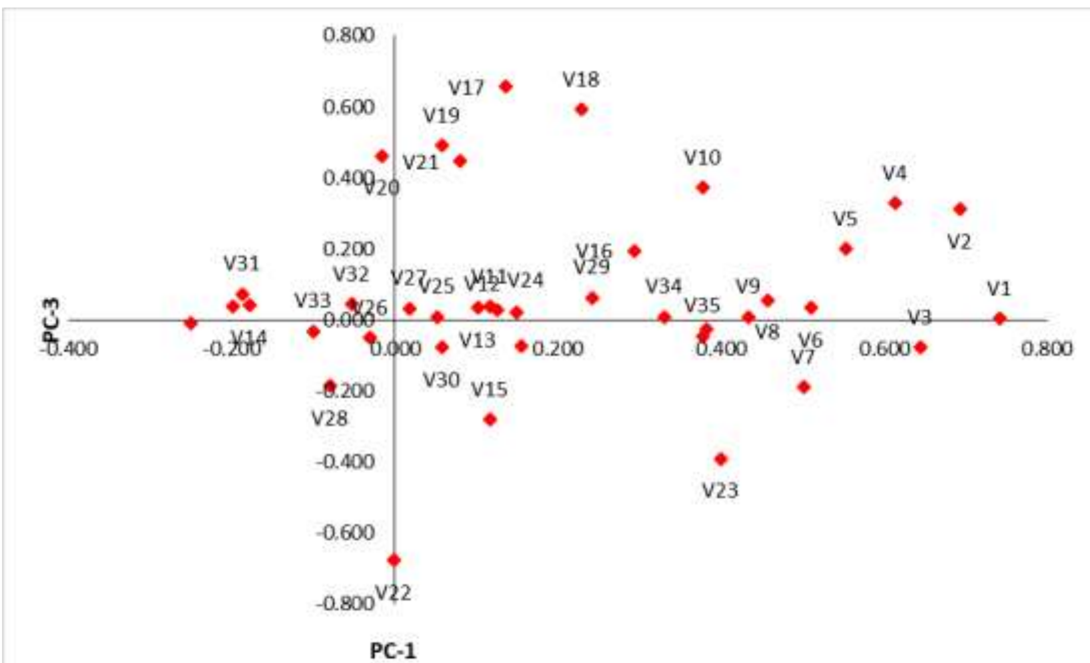

(b)

Figure 4.1a and b: Biplot for PC-1 against PC-2 (a) and PC-1 against PC-3 (b) for the seven-component CATPCA solution on the 39 SFV food hygiene and safety characteristics in (Table 4.1).

The first dimension was highly characterized by variables (V1-10) related to the condition of the vending place, personal hygiene, and food handling practices (Figure 4.1a and b). All 10 variables were positively correlated with this component. As shown in Figure 4.1a, the variables were located furthest from PC-1 which shows their usefulness in defining this PC. They are also placed close to one another showing that they are positively correlated with one another and thus, SFVs whose vending structures and the surrounding environment were clean were also more likely to exhibit better personal hygiene and food handling practices. It is also key to note that these variables are however placed very close to PC-2 meaning that they are less important in defining this component.

The second dimension was characterized by factors related to the initiatives put in place towards enhancing the hygiene of the vending environment, vending structures, and vending utensils (Figure 4.1a). All variables loaded positively on this PC except for V16 (cleanliness of the garbage collecting bin) which was negatively loading on this PC. V11, V12, and V13 are closely bundled together and are therefore highly positively correlated (Figure 4.1a) implying that vendors who had water available for washing were also more likely to have a covered garbage collecting bin that was not overfilled. However, having a clean garbage collecting bin was less likely. V14 and V16 are located on opposite quadrants with vectors that make approximately 180^{o} with each other. This shows that they were closely negatively related. Having a clean dustbin for waste has the potential to reduce the chance of the presence of houseflies and other insects. In this case, having good hygiene and the sanitary status of the bin reduced the chance of having houseflies and other insects present. Nonetheless, V14 and V16 have vectors that make approximately 90◦ with V15 suggesting that they are independent of V15. This implies that although some SFVs had water available, this did not influence the hygiene and sanitary status of the vending place.

The third component was characterized by factors related to washing practices and knowledge of food safety. V17-V21 are located furthest from PC-3 and are positively loading on this PC while V22 and V23 are located on the opposite side and are thus negatively loading on this PC (Figure 4.1b). This means that vendors who had water available and washed their hands before handling food were more likely to wash their hands or their utensils without using soap. V17 and V21 are closely located together in Figure 4.1b indicating that they are positively correlated. Thus, having sufficient water available for washing was associated with the practice of washing hands before handling food.

The fourth component was characterized by factors related to SFV's knowledge of food safety standards and regulations in Kenya and training on food hygiene and safety. Training on food safety would increase SFV's awareness of food safety standards and regulations in Kenya. The fifth component was characterized by factors related to storage practices for raw and RTE food while the sixth component was characterized by factors related to adherence and attitude towards food safety stipulations, specifically the requirement to obtain a medical health certificate and renew it periodically. SFVs who had obtained a food handler's medical certificate were more likely to renew it and be willing to receive training on food hygiene and safety.

The seventh component was characterized by whether the SFV was mobile and their place of vending. Thus, mobile vendors would be more likely to be using hand-held containers or trolleys in vending. According to these findings, the NLPCA solution seems to give sensible insight into the components of hygiene and safety knowledge and practices of SFVs in the study area. Since all seven components are based on SFV's hygiene and safety knowledge and practice, different food safety issues and concerns may occur in line with each. Thus, the components identified by CATPCA may also be termed as the categories of concern in enhancing the quality and safety of street food.

4.1.3.3 Object scores

Object scores are also referred to as component scores and are the aggregated summation of the 39 variables used for CATPCA in this study. An object point (in this case, a street food vendor (SFV)), in any biplot, is situated as close as possible to the variables or clusters in which the object (SFV) scored most, taking into account the constraints imposed by the level of analysis of the different variables, the fact that the component scores are uniform and that the components are uncorrelated (Linting *et al.*, 2007; Saukani

& Ismail, 2019). Figure 4.2, Figure 4.3, Figure 4.4, and Figure 4.5 shows the object scores plotted on the same axis as the variable scores. To plot the variable scores on the same axis as the object scores, the variable scores were elongated by a factor of 3.

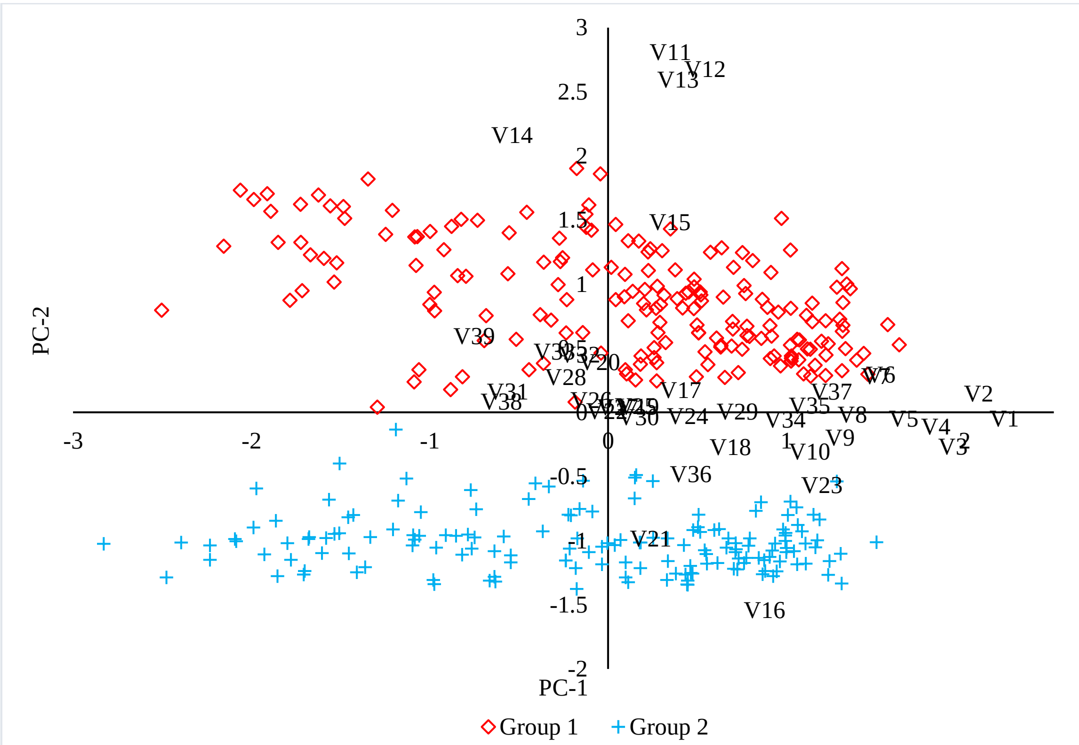


Figure 4.2: Triplot showing object scores plotted on the same axis as the variable scores for PC-1 against PC-2 for the seven-component CATPCA solution on the 39 SFV food hygiene and safety characteristics (Table 4.1).

Two sets of SFVs were clearly distinguished by PC-2 as shown in Figure 4.2. Vendors who scored better in V11 - V15, were labeled as group 1 objects, and those who scored well in V16 were labeled as group 2 objects. Although SFVs in group 1 were more likely to be having water available for washing (V15) and having a covered garbage collecting bin and not overfilled (V11, V12, and V13), they were less likely to have clean garbage collecting bin (V16). On the contrary, SFVs in group 2 were more likely to have a garbage collecting bin that was clean (V16). This is true since they had sufficient water for washing available considering that they also scored better in V21.

The majority of vendors who had secondary school or tertiary education were clustered on the left side of the biplot and scored better in V1-V8 (Figure 4.3). Similar observations can be drawn for the SFVs who were below 2 years in the street food vending business as shown in Figure 4.4. This means that the vendors who had secondary school or tertiary education and those who were below 2 years in vending business were more likely to have better personal hygiene and food handling practices, clean vending structures, and vended from a clean environment.

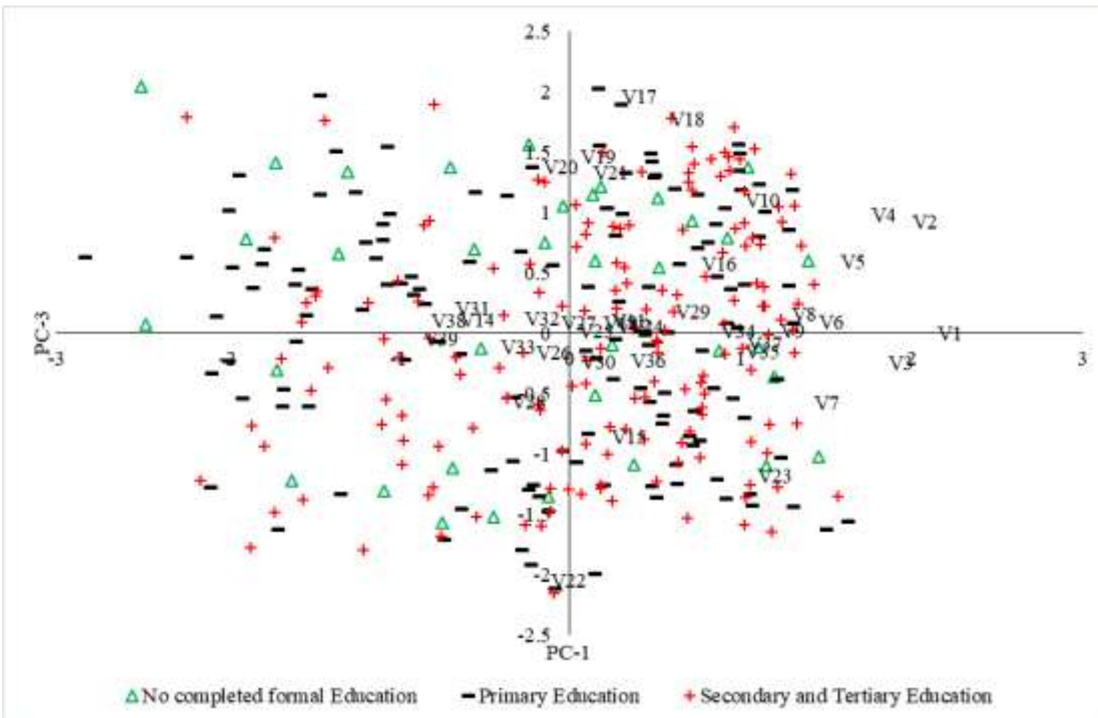


Figure 4.3: Triplot showing object scores split by education levels and plotted on the same axis as the variable scores for PC-1 against PC-3 for the seven-component CATPCA solution on the 39 SFV food hygiene and safety characteristics (Table 4.1).

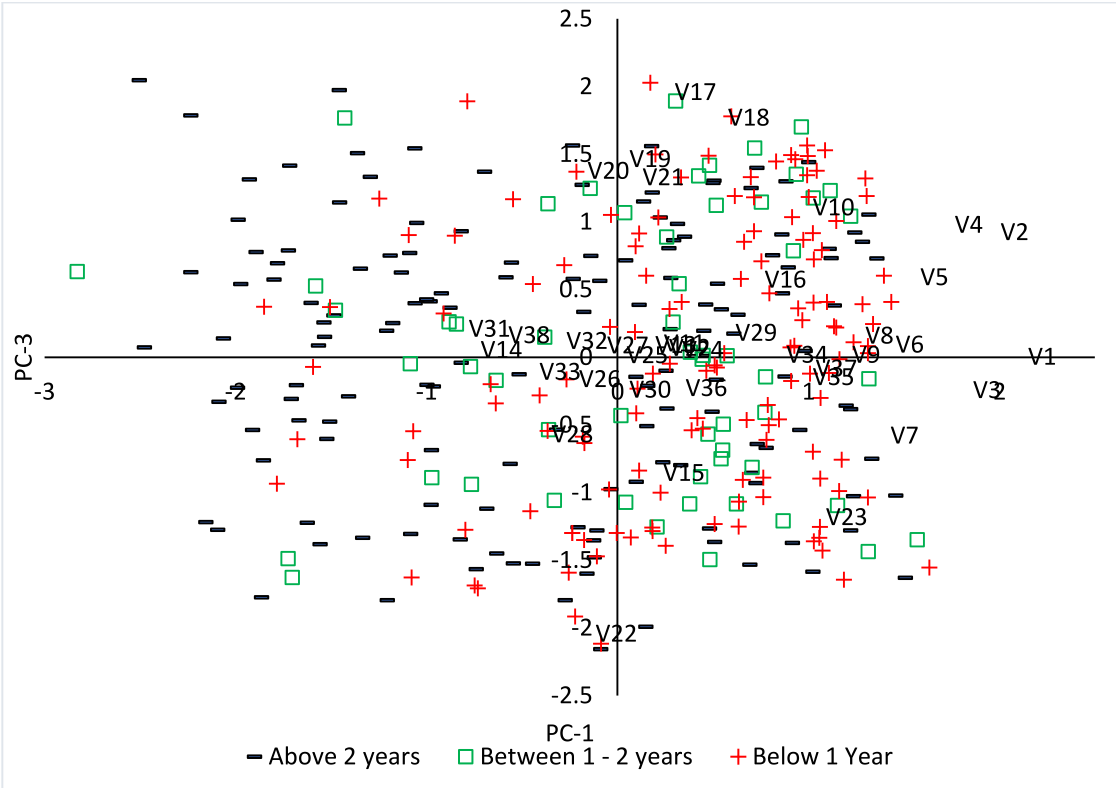


Figure 4.4: Triplot showing object scores split by the length of time in street food vending and plotted on the same axis as the variable scores for PC-1 against PC-3 for the seven-component CATPCA solution on the 39 SFV food hygiene and safety characteristics (Table 4.1).

There was a clear separation of vendors based on whether they sold animal-based foods only or a combination of plant and animal-based foods (Figure 4.5). Vendors of animal-based foods scored better on V18 – V21. On the contrary, those who sold both animal and plant-based foods scored best on V15, V22, and V23. This means that although vendors of animal-based foods were more likely to wash their hands before handling foods, vendors of both plant and animal-based foods were more likely to use soap in washing both hands and equipment. This may be because vendors of animal-based foods were mostly mobile and would probably carry water without soap unlike those selling both animal and plant-based foods who were operating from fixed locations.

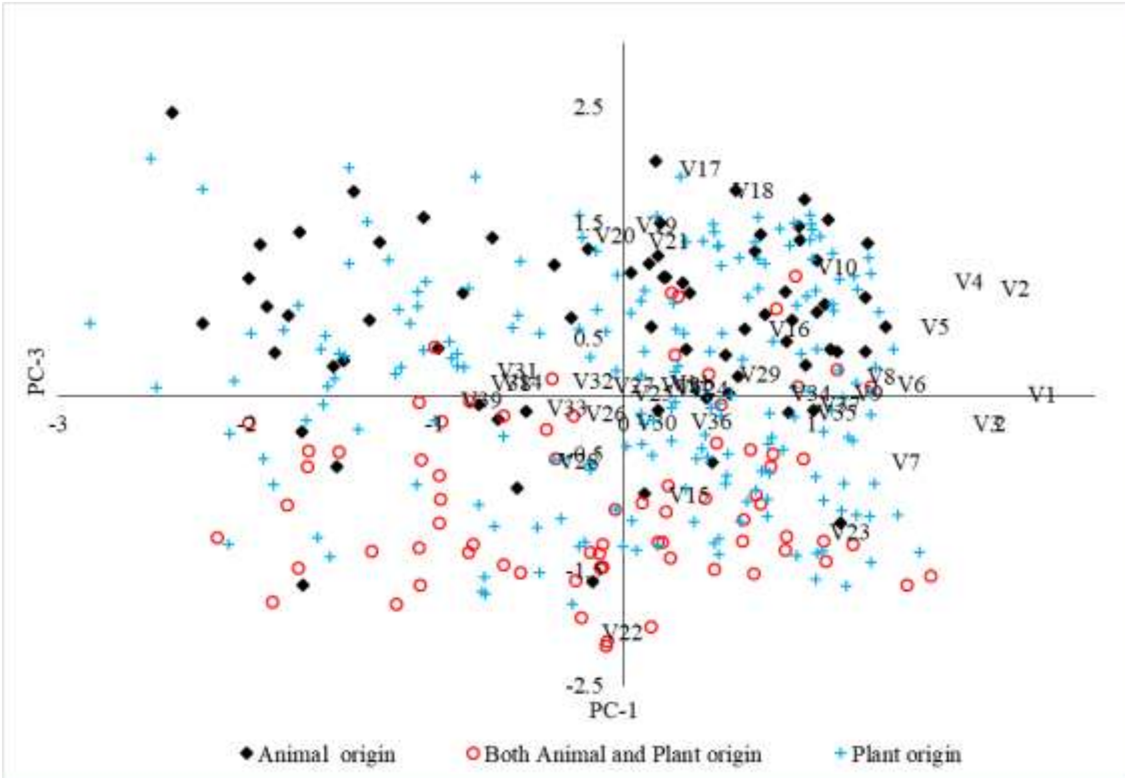


Figure 4.5: Triplot showing object scores split by the nature of food sold by SFVs and plotted on the same axis as the variable scores for PC-1 against PC-2 for the seven-component CATPCA solution on the 39 SFV food hygiene and safety characteristics (Table 4.1).

4.1.4 Conclusion

The results of this study showed that CATPCA is an effective procedure for summarizing and making a judgment on data that has mixed measurement levels such as numeric, nominal, or ordinal that may have non-linear relationships with each other. The study identified seven components of food hygiene and safety knowledge and practices among SFVs which represent the categories of concern in enhancing the quality and safety of street food. These included the condition of the vending place, personal hygiene, and food handling practices, initiatives put in place to ensure food hygiene and safety, washing practices and food safety knowledge, food safety standards and regulations, storage practices for raw and ready-to-eat food, adherence and attitude towards food safety stipulations and SFVs' mobility. Furthermore, CATPCA was also able to group SFVs depending on whether they had good or poor food hygiene and safety awareness and practices. These components may be used as the basis for evaluating street food quality and safety. Further research may be carried out to study the factors influencing street food vendor knowledge and practice putting into consideration the seven components of food hygiene and safety knowledge and practices among SFVs.

4.2 Multinomial logistic regression analysis of factors influencing food safety, hygiene awareness, and practices among street food vendors in Thika town, Kiambu County, Kenya.

4.2.1 Introduction

Although many researchers have studied the operation of SFVs (Dwumfour-Asare & Agyapong, 2014; Lawan *et al.*, 2015; Okojie & Isah, 2014, 2019; Rahman *et al.*, 2016), few have reported the specific factors that may influence the SFVs choices regarding food safety and hygiene and the resulting outcomes. Due to the different social-economic characteristics of SFVs in different locations, different factors have been reported to influence food hygiene and safety awareness and practices among SFVs. These factors include gender, ethnicity, age, training, duration of time in business, food handler's license status, marital status, and religion (Adane *et al.*, 2018; Addo-Tham *et al.*, 2020; Birgen *et al.*, 2020; Hamed & Mohammed, 2019; Mesele, 2014; Rahman *et al.*, 2016). Whereas these factors influence the vendors' food safety and hygiene knowledge and practices directly, they may also indirectly influence hygiene and safety outcomes including the quality and safety of RTE foods. SFVs choices, as well as outcomes related to food safety and hygiene in street food vending, involve trade-offs between these factors. This means that a single factor may not independently influence SFV's food safety and hygiene choices and outcomes in the street food vending business. Thus, there is a need to study the contribution that all these factors have on food safety, hygiene awareness, and practices (FSHAP) among SFVs.

Logistic regression is one of the statistical analysis tools that can be used in modeling data to describe and test hypotheses concerning relationships between predictor variables and a categorical outcome variable (Peng, Lee, & Ingersoll, 2002). However, the literature on statistical modeling to predict SFV's food hygiene and safety knowledge and practices is scarce. A few researchers have employed logistic regression to predict FSHAP among SFVs. Rahman *et al.* (2016) studied the influence of age, training, knowledge score, duration of time in vending, ethnicity, and marital status on food safety awareness, practice, and attitude among SFVs in Sarawak, Malaysia. Their results revealed that age and ethnicity were crucial for food safety awareness while training was important in influencing attitude among SFVs. Akabanda, Hlortsi, and Owusu-Kwarteng (2017) developed four models on SFVs' knowledge and attitudes regarding food safety, personal hygiene, and food hygienic practices in Ghana. Their research included age, length of employment, and education level as predictors for general knowledge of food safety revealing education level as a crucial factor influencing the understanding of food safety issues among SFVs. Such predictive models may be useful in identifying factors of importance in determining intervention strategies to enhance hygiene and safety among SFVs for a given location. This study, therefore, employed multinomial logistic regression analysis to explore the factors influencing FSHAP among SFVs in Thika town, Kenya.

4.2.2 Materials and methods

4.2.2.1 Study area and design

This study was conducted as elaborated in subheading 3.2.1. The study hypothesized that gender, age, education level, food hygiene, and safety training, public health inspection, duration of time in street food vending, category of SFVs, and vendor mobility had a positive influence on the SFV's food safety and hygiene knowledge and practices.

4.2.2.2 Inclusion criteria and sampling procedure for street food vendors

The sampling procedure and inclusion criterion for street food vendors were discussed in subheading 3.2.2.

4.2.2.3 Data collection

Data collection was done using a pre-tested questionnaire and a checklist for observation of street food vendors’ (SFVs) food safety and hygiene practices as discussed in subheadings 3.2.3 and 3.2.4. Permission to undertake this study was obtained from the National Commission for Science and Technology (NACOSTI) as well as the County Commissioner for Kiambu County (NACOSTI/P/19/87469/31129) as discussed in subheading 3.2.5.

4.2.2.4 Variable selection for analysis

Eight social and demographic characteristics including gender, age, education level, training on food safety and hygiene, public health inspection, duration of time in street food vending, category of street food vendors (SFVs), and vendor mobility were extracted from the data collection tools and used as predictors (Table 4.4) in the logistic regression models.

Table 4.4: Description of the predictors used in logistic regression analysis.

Variable	Description of codes	Abbreviation
Gender	1 = Male	G1
	2 = Female †	G2
Age	1 = Vendors aged 25 years and below	A1
	2 = 26 – 35 Years	A2
	3 = 36 – 45 Years	A3
	4 = Above 45 Years †	A4
Education level	1 = No completed formal Education	E1
	2 = Primary Education	E2
	3 = Secondary Education	E3
	4 = Tertiary Education level †	E4
Training on food hygiene and safety	1 = No training	T1
	2 = Trained †	T2
Public health inspection	1 = No public health inspection	P1
	2 = Inspected †	P2
Category of SFVs based on the type of RTE food sold	1 = Animal-based foods	C1
	2 = Plant-based foods	C2
	3 = Sellers of both plant and animal-based foods †	C3
Mobility of SFVs	1 = SFV not mobile	M1
	2 = SFV mobile †	M2
Length of time in the street vending business	1 = Above 2 years	L1
	2 = Between 1 - 2 years	L2
	3 = Between 6 months to 1 Year	L3
	4 = Between 1 - 6 Months	L4
	5 = One month or below †	L5

† Category was chosen as the reference group in each variable in the logistic regression analysis*;* SFV – Street Food Vendor

Thirty-eight characteristics relating to SFVs' food safety, hygiene knowledge, and practices were extracted from the research tools and used as dependent variables in the logistic regression models (Table 4.5). These characteristics were grouped into four food safety, hygiene awareness, and practices (FSHAP) categories; food safety and hygiene awareness (AS), working conditions (WC), food handling practice (FH), and personal hygiene practice (PH). Each vendor was awarded a score for each characteristic depending on their response or what was observed. For instance, if the SFV had a food handler's medical certificate (Yes), their score for this characteristic was one (1) while if the SFV had no food handler's medical certificate (No), their score was zero (0).

Hygiene and sanitary status were determined using a 3-point rating scale as follows; poor (1), average (2), or good (3). Hand and equipment washing practices were scored as follows; using cold water only (1), using warm water only (2), using cold water with soap (3), and using warm water with soap (4) (Table 4.5). Afterward, the total scores were tallied for each vendor within each FSHAP category and converted into percent scores. Percent scores below 50% were classified as poor FSHAP scores while scores greater or equal to 50 were classified as good FSHAP scores.

Table 4.5: Food safety, hygiene awareness, and practices characteristics with their respective categories and scores

Categories[+]	**SFV food safety, hygiene awareness, and practice characteristics (FSHAP)†**
Food safety and hygiene awareness (AS) Highest score = 3	SFV has a food handler's medical certificate (Yes=1, No=0) SFV is aware of food safety standards and regulations in Kenya (Yes=1, No=0) SFV is aware that street food may be a source of pathogenic microorganisms (Yes=1, No=0)
Working conditions (WC) Highest score = 13	The vending structures are washable (Yes=1, No=0) The environment around the vending place is clean (Yes=1, No=0) A garbage collecting bin is available (Yes=1, No=0) The garbage collecting bin is covered (Yes=1, No=0) The garbage collecting bin is not overfilled (Yes=1, No=0) Houseflies and other insects are not present around the vending place (Yes=1, No=0) There is the presence of a drainage system for wastewater from the business (Yes=1, No=0) Vending place hygiene and sanitary status (Poor=1, Average=2, Good=3) Garbage collecting bin hygiene and sanitary status (Poor=1, Average=2, Good=3)
Personal hygiene practices (PH) Highest score = 18	Water is available for washing (Yes=1, No=0) There is a sufficient amount of water for washing (Yes=1, No=0) SFV does not handle money while serving food and if so, washes hands after (Yes=1, No=0) SFV washes hands before handling food (Yes=1, No=0) SFV wears aprons (Yes=1, No=0) SFV uses gloves to handle foods (Yes=1, No=0) SFV has short clean nails (Yes=1, No=0) SFV's hair is covered (Yes=1, No=0) SFV is not wearing jewelry (Yes=1, No=0) SFV has no visible bruises, cuts, or boils on any visible part of the body (Yes=1, No=0) SFV does not chew gum or any other foodstuff while handling food (Yes=1, No=0) SFV does not smoke while handling food (Yes=1, No=0) SFV does not sneeze, spit or cough on or near food (Yes=1, No=0) SFV does not touch the mouth, tongue, nose, or eyes while handling food (Yes=1, No=0)

Categories[+]	SFV food safety, hygiene awareness, and practice characteristics (FSHAP)†
	How the SFV washes their hands (cold water only=1, warm water only=2, Coldwater with soap=3, warm water with soap=4)
Food handling practices (FH) Highest score = 14	The food handling surfaces are cleanable (Yes=1, No=0)
	The food handling surfaces, cutting equipment, and chopping boards are clean (Yes=1, No=0)
	There is adequate separation between raw and RTE foodstuffs (Yes=1, No=0)
	There are no scratches or rusting observed on serving utensils (Yes=1, No=0)
	Serving utensils or packaging material are adequately covered (Yes=1, No=0)
	There are separate basins for utensils and food preparation (Yes=1, No=0)
	The food handling surfaces are in good condition without crevices or cracks (Yes=1, No=0)
	There is a drying rack for clean utensils (Yes=1, No=0)
	There are dry clean wiping towels available (Yes=1, No=0)
	RTE food is adequately covered (Yes=1, No=0)
	How the SFV washes their utensils and equipment (cold water only=1, warm water only=2, Coldwater with soap=3, warm water with soap=4)

SFV – Street Food Vendor, RTE – Ready to Eat, † Scores for the specific characteristics are shown in brackets

4.2.2.5 Statistical analysis

Multinomial logistic regression was used to construct statistical models (one for each of the four categories described in Table 4.5) to describe the relationship between the explanatory variables in Table 4.4 and the street food vendors' food safety, hygiene awareness, and practice (FSHAP) scores categories (good or poor score) from Table 4.5. Logistic regression uses a set of predictors (explanatory variables) to predict the logit (the natural log of the odds (probability/(l-probability)) of an event outcome. Starting with the saturated models (models containing all predictors), the least significant predictors were dropped one by one until the predictors that remained in the models were significantly ($p<0.05$) contributing to the model.

Overall evaluation of the final model containing significant ($p<0.05$) factors was done using the likelihood ratio, Wald, and score tests. The likelihood ratio test compares the fit of two models by evaluating the difference in log-likelihoods, using a chi-squared distribution to determine statistical significance; it helps decide whether a more complex model with additional variables is a significantly better fit than a simpler one. The Wald test estimates the significance of parameters by testing if their values are significantly different from zero, evaluating the parameter estimates in terms of their standard errors. The score test, measures the potential improvement in model fit by assessing the change in the likelihood function if specific parameters are added to the model; it is used to identify whether omitted variables or constraints should be reconsidered for model improvement (Bruin, 2011). The three tests test the null hypothesis that the coefficient (β)=0. A significant ($p<0.05$) test result indicated that the model with added variables fitted the data significantly better.

The Wald Chi-square test was utilized to test the significance of individual predictors' regression coefficients in each model. The Hosmer and Lemeshow goodness-of-fit test was used to evaluate the fitness of the logistic regression models against actual outcomes. Validation of predicted probabilities was done using Goodman-Kruskal's Gemma and the c statistic (concordance index). The Goodman-Kruskal's Gemma statistic is Kendall's rank order correlation coefficient with adjustments for ties while the c statistic quantifies the fraction of pairs of vendors with distinct observed results, where the model accurately forecasts a greater likelihood for instances with the event outcome compared to instances without the event outcome. Odds ratios (OR) were calculated by exponentiation of the regression coefficients of the respective logistic regression coefficient for any given predictor in the final models. G2, A4, E4, T2, P2, C3, M2, and L5 were chosen as the reference group for gender, age, education level, training on food safety and hygiene, public health inspection, category of SFVs, mobility of SFVs, and duration of time in the street vending business in the logistic regression analysis, respectively. All statistical analyses in this study were carried out using SAS software version 9.4M6 (SAS Institute).

4.2.3 Results and discussion

4.2.3.1 Evaluation of the logistic regression models

Overall evaluation of the four models (AS, WC, PH, and FH) using the likelihood ratio test, Wald test, and Score tests (Table 4.6) showed a significant ($p<0.001$) improvement in the logistic models compared to the intercept-only model (null model with no predictors). This means that the models with the predictors were more effective in fitting the data on street food vendors' (SFVs) food safety, hygiene awareness, and practices than the intercept-only model. The null model was chosen as a baseline for comparison to the model containing the predictors since it had no predictors. The Hosmer and Lemeshow Tests showed no significant results ($p>0.05$) for all the models meaning that the models were a good fit for the data.

Since logistic regression uses a given set of explanatory variables to predict the logit of an event outcome, it may be transformed back to the probability scale. It is expected that high probabilities are associated with the outcome of the event (good score) while lower probabilities are associated with nonevents (Peng *et al.*, 2002). These predicted probabilities can be re-evaluated as part of the process of ascertaining the usefulness of the model in predicting the outcomes using measures of association such as Goodman-Kruskal's Gemma and the c statistic (Peng *et al.*, 2002). The Goodman-Kruskal's Gemma statistic for the models predicting food safety and hygiene awareness (AS), working conditions (WC), food handling practices (FH), and personal hygiene practices (PH) scores were 0.514, 0.330, 0.410, and 0.425, respectively. This means that 51.4, 33.0, 41.0, and 42.5% fewer errors were made in predicting which SFVs had a good or poor score by using the probabilities estimated by the models than by chance alone for the AS, WC, FH, and PH scores respectively.

The c statistic is a standard measure that shows the predictive accuracy or the discriminative ability of any logistic regression model (Austin & Steyerberg, 2012). In this study, it denotes the probability that any randomly selected street food vendors who had a good score also had a higher predicted probability of having good food safety, hygiene awareness, and practice (FSHAP) score compared to randomly selected street food vendors who did not have a good score. The c statistic normally ranges from 0.5 to 1. A value of 0.5 means that the model is poor and is, therefore, no better than randomly assigning the observations within outcome categories. Higher values mean that the models are assigning higher probabilities to all the event observations, as compared to those observations with non-vent outcomes (Peng *et al.*, 2002). The c statistic in this study was between 0.652 and 0.741 for the models. This means that between 65.2 - 74.1% of all possible street food vendor pairs (one with good and the other with poor FSHAP score), the models correctly assigned higher probabilities to the SFVs who had good FSHAP scores. Both the Gemma and c statistic shows that the four models were moderately good in predicting outcomes in this study. With the cutoff (probability for assigning outcomes as either events or nonevents) set at 0.5, the overall correct prediction for the models ranged between 60.2 - 79.60%, which is an improvement over the chance level set at 50% (Figure 4.6).

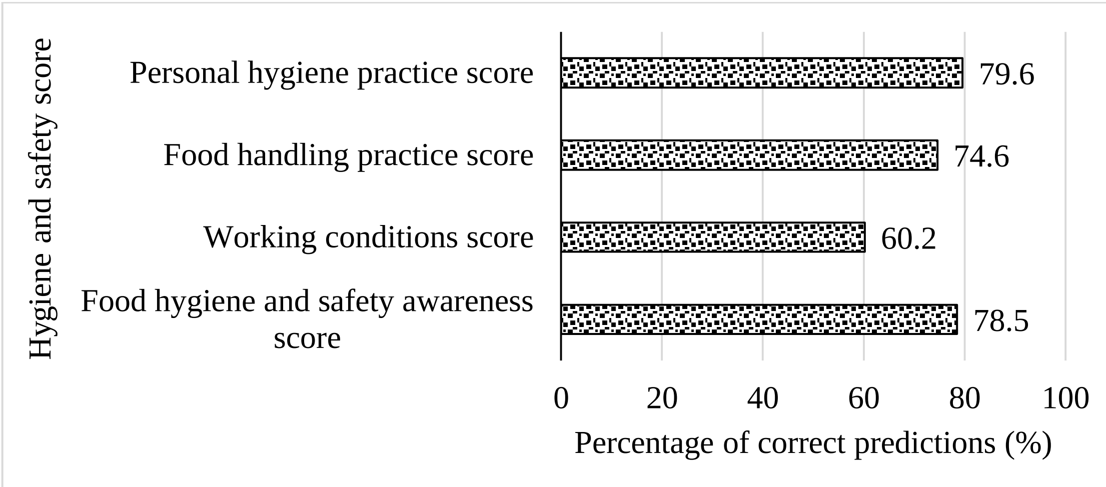
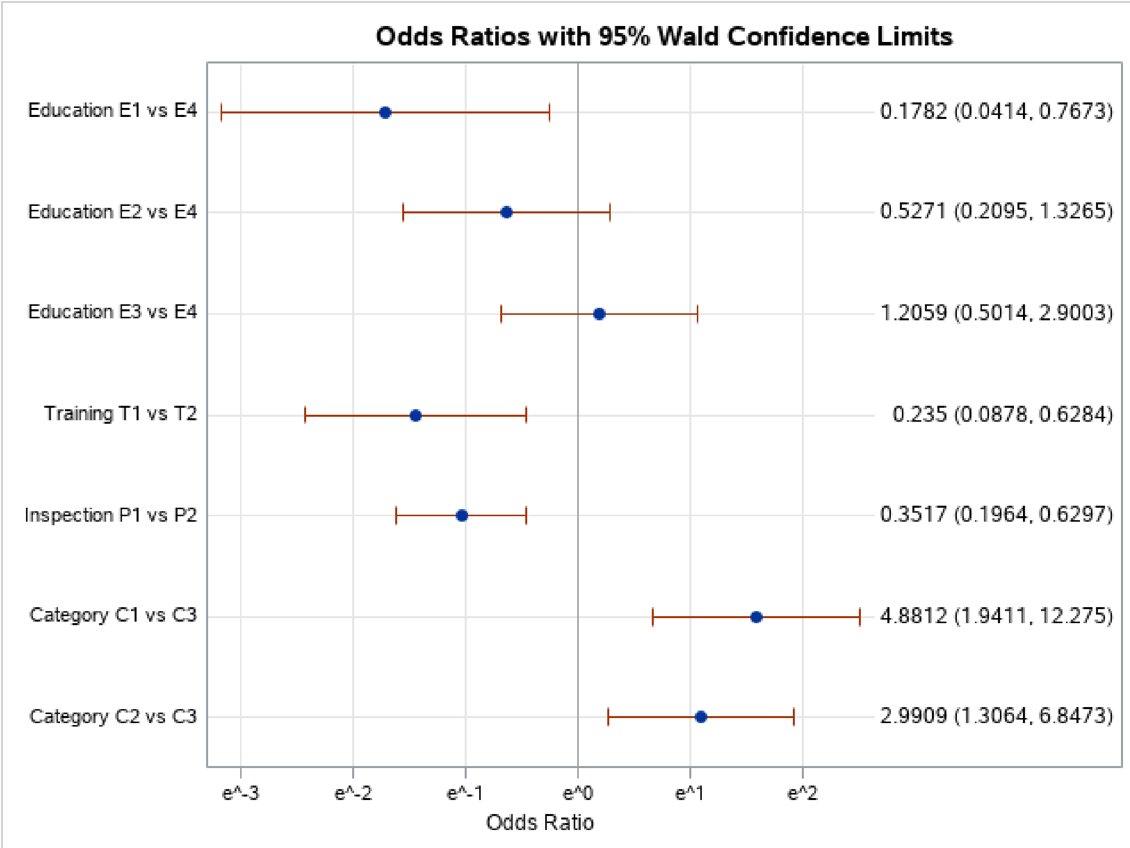


Figure 4.6: The proportion of correct predictions for the four logistic regression models at a cut-point set at 0.5.

4.2.3.2 The education level of street food vendors

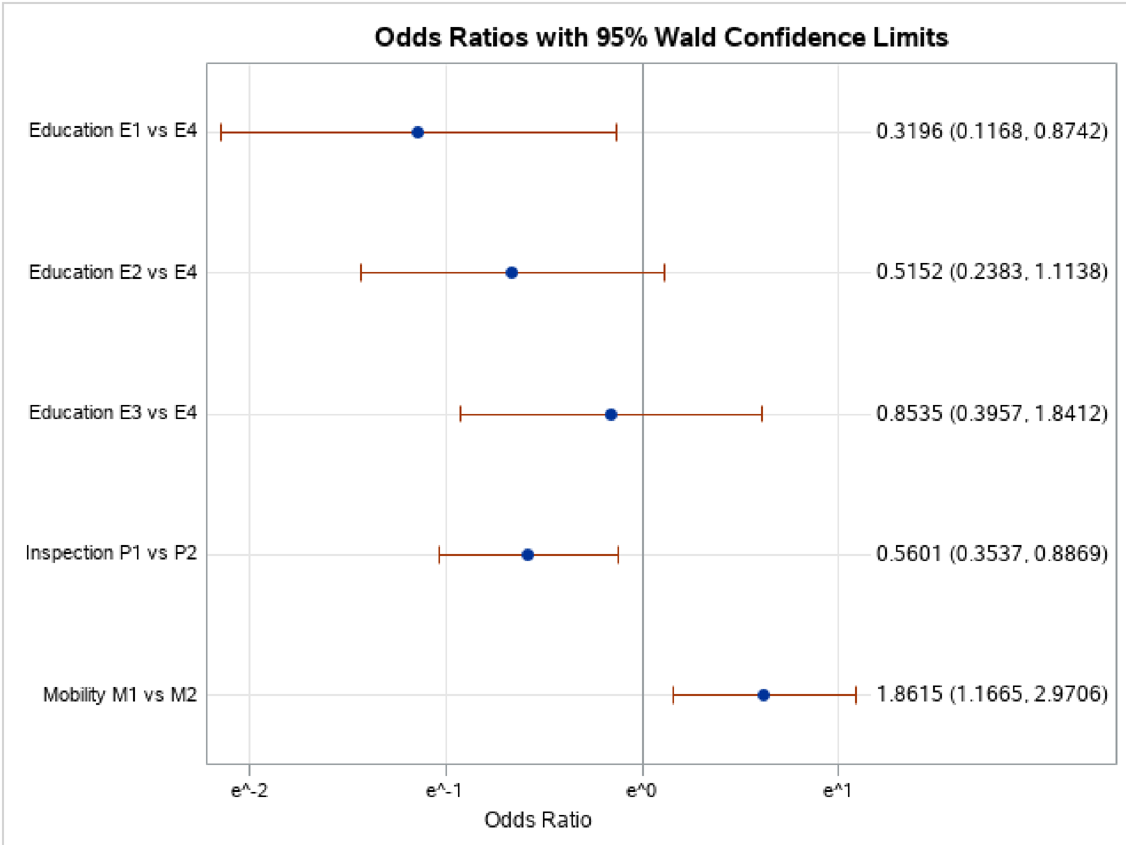
Results showed that the education level was significant in predicting food safety and hygiene awareness (AS) score and working conditions (WC) score as shown in Table 4.6. The odds of having a good AS or WC score for street food vendors (SFVs) who had no formal education were 0.18 and 0.32 as shown in Figure 4.7 and Figure 4.8 respectively. Meaning a lack of formal education has the potential to negatively influence food safety, hygiene awareness, and practice (FSHAP) among SFVs. Similar findings of food handlers with higher education levels who demonstrated a significantly better understanding of food safety issues were reported by Akabanda *et al.* (2017) in Ghana.

Hamed and Mohammed (2019) studying food safety practices and knowledge amongst food handlers in Egypt also reported that higher education was a strong indicator of good food safety awareness. Since the street food vending business is popular among persons who may not have attained higher education, strategies to enhance the hygiene of SFVs have to be put in place to ensure food safety and therefore public health. This can be achieved by training all food handlers on food hygiene and safety.



Key: E1 - not completed primary education, E2 - primary education, E3 - secondary education, and E4 - tertiary education; T1 - not trained and T2 - trained; P1 - not inspected and P2 - inspected; C1 - sellers of animal-based foods, C2 - sellers of plant-based foods, and C3 - sellers of both plant and animal-based foods.

Figure 4.7: Odds ratios with 95% Wald confidence limits for food safety and hygiene awareness (AS) score.



Key: E1 - not completed formal education, E2 - primary education, E3 - secondary education, and E4 - tertiary education level; P1 - not inspected and P2 - inspected; M1 - SFVs not mobile and M2 - mobile.

Figure 4.8: Odds ratios with 95% Wald confidence limits for working conditions (WC) score.

Table 4.6: Logistic regression analysis results for the four models

	AS		WC		FS		PH	
	β(SE)	**X^2**	**β(SE)**	**X^2**	**β(SE)**	**X^2**	**β(SE)**	**X^2**
Intercept	-0.20(0.54)	0.13	-0.03(0.39)	0.01	1.52(0.63)	5.82*	1.45(0.27)	28.28***
E1	-1.72(0.74)	5.36*	-1.14(0.51)	4.94*	-	-	-	-
E2	-0.64(0.47)	1.85	-0.66(0.39)	2.84	-	-	-	-
E3	0.19(0.45)	0.17	-0.16(0.39)	0.16	-	-	-	-
T1	-1.45(0.50)	8.33**	-	-	-	-	-	-
P1	-1.04(0.30)	12.36***	-0.58(0.23)	6.11*	-0.62(0.27)	5.15*	-0.85(0.29)	8.53**
C1	1.59(0.47)	11.35***	-	-	-	-	-	-
C2	1.10(0.42)	6.72**	-	-	-	-	-	-
M1	-	-	0.62(0.24)	6.79**	-	-	0.79(0.28)	7.74**
L1	-	-	-	-	-0.66(0.62)	1.11	-	-
L2	-	-	-	-	-0.22(0.67)	0.11	-	-
L3	-	-	-	-	0.71(0.67)	1.13	-	-
L4	-	-	-	-	1.13(0.79)	2.06*	-	-
Testing the global null hypothesis: all coefficients except for the intercept are equal to 0 (β = 0) (degrees of freedom are shown in brackets)								
Likelihood Ratio	-	46.46(7)***	-	24.72(5)***	-	24.11(5)***	-	20.04(2)***
Score	-	45.00(7)***	-	23.95(5)***	-	22.48(5)***	-	19.70(2)***
Wald	-	37.61(7)***	-	22.61(5)***	-	20.68(5)***	-	18.50(2)***
Goodness-of-fit test								
Hosmer and Lemeshow Test	-	9.26^{ns}	-	6.74^{ns}	-	1.74^{ns}	-	0.01^{ns}

The models are predicting whether the vendor had a "good" food safety, hygiene awareness, and practice (FSHAP) score. β is the estimated coefficients for the independent variables, SE is the standard error for the estimated coefficients, X^2 is Chi-square; E1, E2, E3, T1, P1, C1, C2, M1, L1, L2, L3, and L4 descriptions are in Table 4.4; AS, WC, FS, and PH description in Table 4.5; * Significant at 0.05; ** Significant at 0.01; *** Significant at 0.001; ns – Not significant

4.2.3.3 Street food vendors' food safety and hygiene training

Training on food safety and hygiene was significant in predicting AS score only (Table 4.6). The odds of having a good AS score for street food vendors (SFVs) who had not received any training was 0.24 (Figure 4.7). This means that training on food hygiene and safety positively influenced good food hygiene and safety awareness among SFVs. Vendors who had been trained were thus highly likely to make better food safety choices such as obtaining a food handler's medical certificate. Training may enhance awareness of safety standards and regulations applicable in the region which ensures adherence to these requirements and upholding of good food safety and hygiene practices. Adane *et al.* (2018) reported that the odds of having good safety and hygiene practices among food handlers in Ethiopia who had received training on food handling and preparation were 6.7 times higher as compared to those who had no training. This underlines the importance of regular training of SFVs on food safety and hygiene practices to enhance the safety of RTE food and hence assure public health.

4.2.3.4 Public health officers' inspection

Public health inspection was the only predictor that was important in predicting all the four-food safety and hygiene scores (Table 4.6). The odds of having good FSHAP scores for vendors who had not received any public health inspection visit were lower than one as shown in Figure 4.7 to Figure 4.9. This means that these street food vendors (SFVs) were likely to have poor food safety and hygiene practice (FSHAP) scores. Public health inspection is inscribed in the public health act of Kenya (CAP 242, 2012), (GoK, 2012) which stipulates that no person is allowed to present any foodstuffs for sale without putting in place adequate measures to safeguard against infections or contamination. Public health officers are empowered through this act to oversee the safety and hygiene of food sold in Kenya. They are required to occasionally inspect and examine the suitability for human consumption of any food found on any food premises with the interest of ensuring public health. Thus, their role is to ensure compliance with all stipulated standards and regulations relating to food hygiene and safety. Their regular inspection therefore would enhance compliance with these stipulations which has the potential to increase awareness of food safety and better hygiene and safety practices among SFVs. Similar findings on SFVs who were inspected by environmental health inspectors being 2.41 times more likely to practice safe food handling as compared to those who had no inspection by the regulatory bodies were reported by Mesele (2014) in Ethiopia. They reported that SFVs who were inspected by environmental health inspectors were 2.4 times more likely to practice safe food handling when compared to those who were not inspected by regulatory bodies.

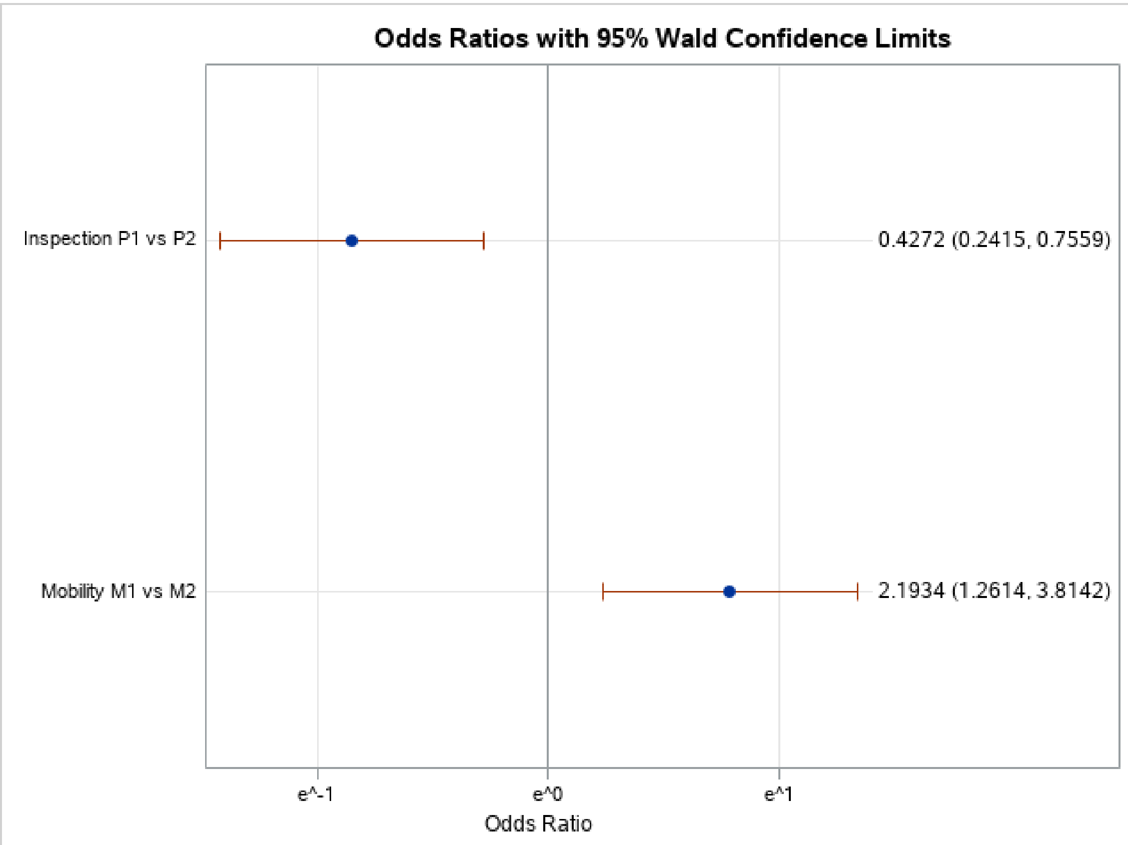
Although the fear of regulators may be the motivation to adhere to food hygiene and safety regulations, the regular inspection may grow the desire to improve the quality and safety of food among the SFVs. This shows the importance of such inspection in enhancing food safety and hygiene practices among SFVs. Thus, there is a need to sensitize SFVs on the need for good food safety and hygiene practices as poor choices facilitate poor hygiene outcomes which have the potential of causing public health issues. Furthermore, the legal implications of selling unwholesome food that has the potential to negatively affect public health should be communicated to the SFVs (Okojie & Isah, 2014).

4.2.3.5 Category of street food vendors

Results showed that the category of the street food vendors (SFVs) based on the type of RTE food sold significantly predicted the vendor’s food safety and hygiene awareness (AS) score as shown in Table 4.6. The odds of having a good AS score were 4.88 times higher for SFVs selling animal-based foods only and 2.99 times higher for those selling plant-based foods only (Figure 4.7). Meaning SFVs selling both plant and animal-based foods were less likely to obtain a food handler’s medical certificate, to be aware of food hygiene and safety standards, or even to be aware of the fact that street foods could be contaminated. Although there are differences in hygiene and safety practices depending on the type of food sold, all SFVs must have the basic knowledge of food safety and hygiene to ensure the safety of the food as stipulated in Kenya’s public health act (CAP 242, 2012) (GoK, 2012). Therefore, strategies targeting to improve hygiene and safety practices among SFVs selling different foodstuffs should also seek to improve their food safety and hygiene knowledge which has the potential to improve public health.

4.2.3.6 Street food vendors' mobility

The street food vendors' (SFVs) mobility was important in predicting the working conditions (WC) and personal hygiene practices (PH) scores (Table 4.6). The odds of having a good score for vendors who were not mobile were 1.86 and 2.19 for WC (Figure 4.8) and PH scores respectively (Figure 4.9).



Key: P1 - not inspected, P2 - inspected; M1 - SFVs not mobile, and M2 - SFVs mobile.

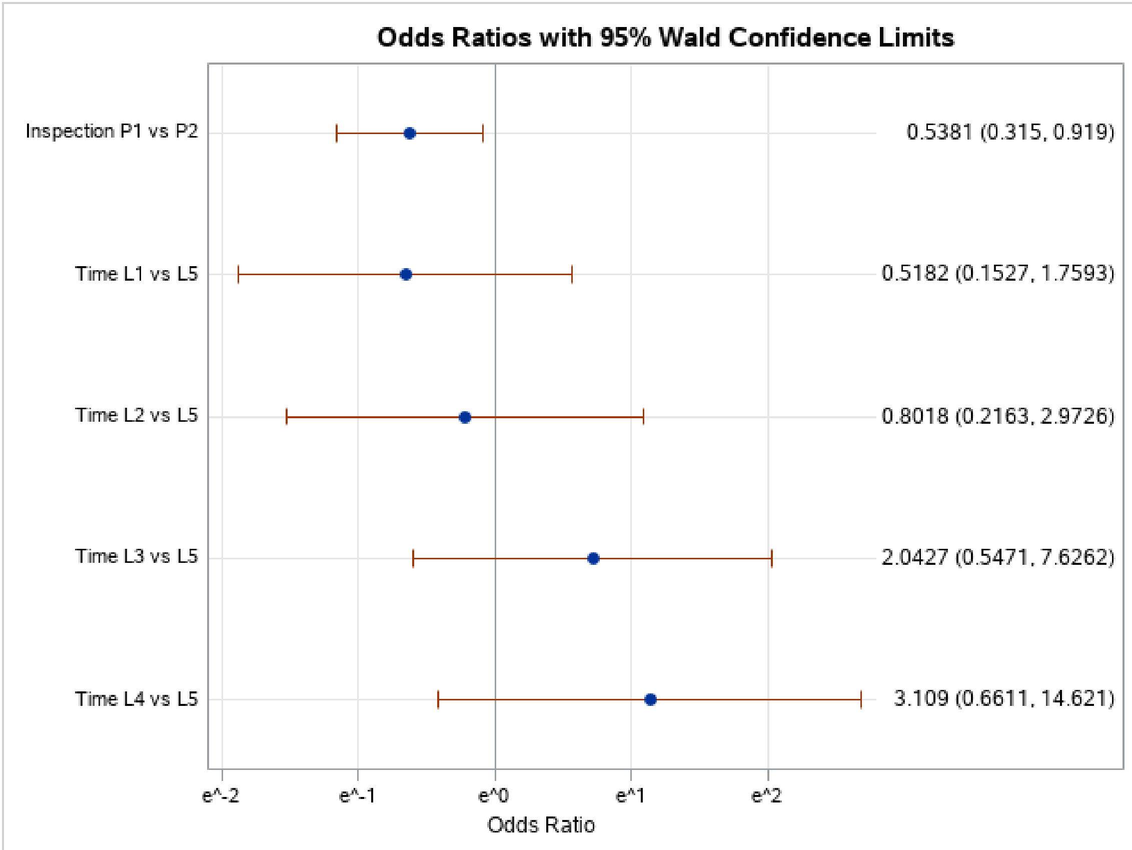
Figure 4.9: Odds ratios with 95% Wald confidence limits for personal hygiene practices (PH) score.

Mobile vendors were often found selling in unhygienic surroundings and had poor personal hygiene practices compared to the vendors operating in stationary locations. Vending from a designated location allows control of many aspects of street food vending including the sanitary condition of the surrounding environment, SFVs' hygiene as well as food handling practices. On the contrary, mobile vendors may not be able to clean their vending place or carry sufficient water facilities for ensuring adequate personal hygiene which explains the poor score observed for mobile vendors. A similar finding on mobile vendors exhibiting poor food hygiene and safety practices was reported by Dwumfour-Asare and Agyapong (2014) in a Ghanaian study.

Since street vending business is not legal in Kenya (Muiruri, 2010), consideration of street food vending business locations in the design of towns does not happen. Thus, even the stationary SFVs may be found setting up their locations in unsanitary sites. This calls for the inclusion of street vending locations in the design of cities and towns which will limit mobile vending practices and the haphazard placement of SFVs in unsanitary locations.

4.2.3.7 Duration of time in street food vending business

The duration of time spent in street food vending is an indication of the experience gained by street food vendors (SFVs) over time. It is assumed that with time SFVs should have better food hygiene and safety practices. The duration of time in street food vending was significant in predicting the food handling practices (FH) score (Table 4.6). Vendors who had been in business between 1 to 6 months and between 6 to 12 months were 3.11 and 2.04 times more likely to show good FH scores compared to the vendors who were in vending for one month and below as shown in Figure 4.10.



Key: P1 - not inspected, P2 - inspected; T1 - above 2 years, T2 - between 1 to 2 years, T3 - between 6 months to 1 year, T4 - between 1 to 6 months, and T5 - one month or below.

Figure 4.10: Odds ratios with 95% Wald confidence limits for food handling practices (FH) score.

This is an indication that vendors who had been in vending for a shorter time had better food safety and hygiene practices although this was not the case for vendors who were over 1 year in business. This may mean that although some vendors may have been in the street food vending business for longer, their food safety and hygiene practices were poor or deteriorated with time which explains the gradual decrease in the chance of having a good score with an increase in the length of time in the vending business as shown in Figure 4.10. These findings suggest that better behavioral practices among SFVs may not necessarily be acquired simply by work experience but by conscious effort on the part of the SFVs in doing the right thing as reported by Dwumfour-Asare and Agyapong (2014).

4.2.4 Conclusions

These findings revealed that public health inspection and street food vendors' (SFVs) mobility were the most important factors influencing food safety, hygiene awareness, and practices (FSHAP) among SFVs in the study area. Public health inspection improved the chance of having a good FSHAP score while being mobile increased the likelihood of poor scores. Efforts to reduce the movement of SFVs should be put in place as mobility impairs the achievement of certain hygienic practices such as regular washing of hands and maintenance of environmental hygiene.

All the other predictors including education level, training, category of SFV, and the length of time in vending were significant in predicting at least one FSHAP score except for the age and gender of the SFVs. Therefore, to improve the hygiene and safety of street food, emphasis should be placed on all the factors that have the potential to influence SFVs' food safety and hygiene practices in an integrated approach. These findings can be used to establish priorities for programs geared toward enhancing street hygiene and food safety. The study further recommends regular inspection of SFVs by public health officials to improve compliance with food safety and hygiene standards and regulations governing the food sector as well as scheduled training on food safety and hygiene targeting all categories of SFVs. Further, the inclusion of street food vending locations in the designing as well as planning of cities, towns, and market centers may limit the mobile vending practices and the haphazard placement of street vendors in unsanitary locations which have been proven to impair the safety of street food.

CHAPTER FIVE

DETERMINATION OF MICROBIAL QUALITY AND SAFETY OF READY-TO-EAT STREET-VENDED FOODS

5.1 Introduction

Contrary to the potential benefits of street food vending such as affordability, accessibility, convenience, source of nutrients, and employment (Choudhury *et al.*, 2011; IFRA, 2016; Micah *et al.*, 2012; Namugumya & Muyanja, 2011; Oyunga-Ogubi *et al.*, 2009; Steyn *et al.*, 2014; Tesfaye, 2019), the conditions in which they are prepared, processed, stored and distributed do not always assure their quality and safety (Boko *et al.*, 2017). SFVs who are mostly untrained in food hygiene and sanitation (IFRA, 2016; Imathiu, 2017) operate informally with minimal control since they are often unlicensed to handle food. Vendors often use inefficient vending structures lacking running water, waste management systems, and accessible toilets. In many cases, handwashing before handling food or after handling money does not occur and safe storage temperatures for food are hardly maintained as reported earlier in section 3.0. These conditions and practices are likely to lead to contamination of RTE foods (Bereda *et al.*, 2016), thus not only contributing to food waste due to spoilage but also leading to probable foodborne disease outbreaks. Different countries have different cultures and therefore, there is great variation in terms of ingredients used, processing, marketing methods, and consumption of SVFs. This diversity represents the increasing difficulty in ensuring the safety of SVFs (Tesfaye, 2019).

The microbial quality and safety of SVFs are always uncertain (Kassa & Azene, 2017). Microbiological analyses of SVFs across different countries suggest a high number of bacteria and a heightened risk of foodborne bacterial pathogens (Nemo *et al.*, 2017; Rane, 2011). For instance, in Bharatpur, Nepal, a study on SVFs revealed contamination with 13 different bacterial species including *Salmonella typhi*, *Salmonella paratyphi*, *Bacillus cereus*, and *S. aureus* (Khadka *et al.*, 2018). In Benin city, Nigeria, Isara *et al.* (2017) reported that poor handling practices amongst SFVs resulted in contamination with coliforms as well as *S. aureus* while in Ethiopia, Bereda *et al.* (2016) reported the presence of *E. coli, S. aureus,* and *Salmonella* spp in SVFs. In Kenya, Kariuki *et al.* (2017) reported *E. coli* and *Klebsiella pneumoniae* in a sample of boiled egg with a raw vegetable salad sold on the streets in Githurai and Gikomba markets while Awino (2015) found SVFs to contain *S. aureus*, *E. coli,* and *Salmonella* in Kisumu in Western Kenya.

A major contributor to the spread of food-borne diseases in most developing countries is microbiologically contaminated street foods which often result in high morbidities and mortalities (Amare *et al.*, 2019). There have been several cases of documented food poisoning outbreaks linked to street foods (Tesfaye, 2019). As a result, billions of consumers are at high risk and millions contract food-borne diseases of microbiological nature every year, many of whom die from consuming these unsafe foods (WHO, 2015). According to the WHO (2022), approximately 600 million individuals worldwide, become sick due to consumption of contaminated food. Tragically, this leads to approximately 420,000 deaths annually, resulting in a total loss of 33 million years of healthy life with children under 5 years of age carrying about 40% of the food-borne disease burden, with about 125,000 deaths occurring every year. Therefore, there is a need to develop interventions on food hygiene that can be implemented to curb the spread of pathogenic microorganisms, especially in SVFs. However, in developing countries such as Kenya where street-food vending is common, there is generally a lack of information on the incidence and prevalence of food-borne diseases linked to SVFs. Furthermore, information on the microbiological safety and quality of SVFs is scarce.

Considering the prevailing burden of infectious diseases, particularly in developing countries, the microbiological profile of these SVFs should be continuously assessed to increase awareness and prevent the occurrence of diseases associated with the ingestion of contaminated foods. Therefore, this study aimed at determining the microbial quality and safety of RTE street-vended foods sold in selected locations within Thika town, Kiambu County, Kenya.

5.2 Materials and methods

5.2.1 Experimental design and study area

A cross-sectional study was conducted between September 2020 and February 2021 in six locations where street vending activities are high in Thika town, Kiambu County, Kenya. These areas included the area around Thika Level 5 Hospital, Juakali area, Kiandutu slums, Makongeni area, Ngoigwa area, and Thika Town center.

5.2.2 Sampling of street-vended foods

Sampling was done for all food samples offered for sale by randomly selecting SFVs without considering the food history. Table 5.1 shows the constituents and description of the twelve food samples that were selected for microbiological analysis from the six study locations. Three samples of the same food type were obtained from each location for analysis. Between 200 - 300 g sample of each food was collected and bagged in a sterile 500 g plastic ziplock sample bag. Samples were immediately transferred into a cool box ($4^{o}C$) for transportation to the laboratory for analysis. All analyses were carried out in the microbiology laboratory in the Department of Animal Science at Chuka University.

Table 5.1: Description of food samples selected from six locations in Thika town for microbiological analysis

Food sample type	Number of samples	Description of samples
Sausages	18	Comminuted meat products containing curing salts and spices. Three sausages were randomly selected from the SFV's cart, prepared by SFV in the manner that they do before presenting them to customers, and bagged in a sterile sample bag as a single sample. Accompanying additives such as salt and salads were not included.
Smokies	18	Smoked comminuted meat products containing curing salts and spices. Three smokies were randomly selected from the SFV's cart, prepared by SFV in the manner that they do before presenting them to customers, and bagged in a sterile sample bag as a single sample. Accompanying additives such as salt and salads were not included.
Boiled deshelled eggs	18	Boiled eggs without shells. Three boiled eggs were randomly selected from the SFV's cart, their shells removed by SFV in the manner that they do before presenting them to customers, and bagged in a sterile sample bag as a single sample. Accompanying additives such as salt and salads were not included.
Cereals	18	Maize mixed with legumes such as beans and peas (locally referred to as '*Githeri*"). Products were fried with onions, tomatoes, and cabbage.
French fries	18	Deep-fried Irish potato chips
Groundnuts	18	Roasted unpeeled groundnuts
Juices	20	Blended fruit juice mixes. Commonly used fruits included bananas, watermelons, avocados, pineapples, mangoes, and oranges. Other uncommon additions included sugarcane juice, aloe vera juice, milk, and groundnuts.
Water melons	18	Sliced watermelon fruit
Pineapples	19	Peeled and sliced pineapple fruit
Salads	19	An assortment of sliced tomatoes, and onions with or without pepper.
Arrowroots	4	Boiled unpeeled arrowroots
Sweet potatoes	11	Boiled unpeeled sweet potatoes

5.2.3 Microbial analysis

5.2.3.1 Sample preparation for microbial analysis

A 25 g sample from each food was blended in 225 ml of peptone water and homogenized in a sterilized laboratory blender. Ten-fold serial dilutions were then prepared for subsequent microbial analysis. Microbiological media were prepared according to the manufacturer's instructions.

5.2.3.2 Determination of total viable counts

Determination of total viable counts (TVC) was done following the method outlined by Maturin and Peeler (2001). From the diluted samples, 1 ml was pour-plated on Plate Count Agar (PCA) in duplicate. Incubation was done at 35°C for 48 hours after which all visible colonies were counted and recorded as the number of colony-forming units per gram (CFU/g).

5.2.3.3 Determination of yeasts and mold counts

Determination of yeast and mold counts was done following the method outlined by Tournas *et al.* (2001). From the diluted samples, 1 ml was pour-plated onto chloramphenicol yeast extract agar in duplicate. Incubation of inoculated plates was done at 25 °C for 3-5 days. Molds and yeasts were then counted and recorded as CFU/g.

5.2.3.4 Determination of total coliform count and *Escherichia coli*

Total coliforms were determined following the method outlined by Feng *et al.* (2017). One milliliter of each diluted sample was pour-plated onto violet-red bile agar (VRBA) in duplicate and incubated at 35°C for 24 h. Purple-red colonies that were 0.5 mm or larger in diameter and surrounded by a zone of precipitated bile acids were counted. To confirm coliforms, ten representative colonies were transferred to a sterile brilliant green lactose broth tube and incubated at 35°C for 24 h. Gas-positive tubes showing a pellicle were subjected to Gram staining to eliminate Gram-positive, lactose-fermenting bacilli. The coliform count was reported as the number of colony-forming units per gram. Determination of *E. coli* was carried out using tryptone-bile-glucuronide (TBX) agar as described by Vergine *et al.* (2017). Confirmation was done through the determination of the presence of cytochrome oxidase, the ability to ferment lactose, and the production of indole. In addition, Voges-Proskauer test, methyl red test, and citrate test were done.

5.2.3.5 Detection and enumeration of *Staphylococcus aureus*

Isolation and identification of *S. aureus* in food samples were carried out following the procedures outlined by Bennett and Lancette (2016). From each diluted sample, 1 ml was pour-plated onto Baird-Parker agar containing egg-yolk tellurite emulsion in duplicate. Plates were incubated at 37°C for 48 hours. Grey-black shiny convex colonies surrounded by a thin white border, and a light area in the media around the colonies, typical of *S. aureus* were subjected to the coagulase test for confirmation. Results were reported as the number of CFU of *S. aureus/*g of food.

5.2.3.6 Detection and identification of *Salmonella* spp.

Enrichment, isolation, and identification of *Salmonella* spp. in food samples were carried out following the procedures outlined by Andrews *et al.* (2018). Pre-enrichment was done using a 25 g sample in 225 ml buffered peptone water followed by incubation at 37°C for 18 hours. Afterward, enrichment was done by transferring 1 ml of pre-enrichment media into Rappaport-Vassiliadis media and incubating at 42°C for 24 hours. After enrichment, culturing was done by streaking onto xylose lysine deoxycholate (XLD) agar and incubating at 37°C for 24 hours. Suspect colonies (red colonies with black centers) were tested for fermentation of glucose, decarboxylation of lysine, and H_2S production using Triple sugar iron agar and lysine iron agar. Hydrolysis of urea was tested using urea agar containing urea 40% FD048 supplement while citrate hydrolysis was determined using Simon's citrate agar. In addition, the Voges Proskauer test, 0.5% dulcitol fermentation test, indole test as well as methyl red test were also carried out.

5.2.3.7 Detection and identification of *Listeria monocytogenes*

Enrichment, isolation, and identification of *L. monocytogenes* in food samples were carried out following the procedures outlined by Hitchins, Jinneman, and Chen (2017). A 25g representative food sample was obtained and mixed in a laboratory blender with 225 ml buffered *Listeria* enrichment broth, modified (mBLEB). All samples were incubated at 30°C for 48 hours. After enrichment, streaking was done onto modified *Listeria* oxford agar containing *Listeria* selective supplement II, modified (FD163), and incubated at 30°C for 48 hours. Identification of *L. monocytogenes* was done after streaking purified colonies onto trypticase soy agar with 0.6% yeast extract (TSAYE). Colonies from TSAYE were inoculated onto 5% sheep blood agar by stabbing thickly poured plates that were dried well to perform the hemolysis test. Incubation was then done for 24 hours at 35°C. In addition, Gram staining, motility test, catalase test, and carbohydrate fermentation tests using dextrose, maltose, mannitol, rhamnose, and xylose were carried out.

5.2.4 Data analysis

Data were analyzed using statistical analysis system version 9.4 to perform an analysis of variance and means separated using Tukey's HSD (honestly significant difference) test. Significance was established at $p < 0.05$ level. Prevalence was reported as a percentage of positive samples. Results were reported as mean ± standard deviation $\log_{10}$ CFU/g for all SVF samples.

5.3 Results and discussion

5.3.1 Determination of total viable counts

There were highly significant differences ($p<0.0001$) in total viable counts (TVC) between the food samples as shown in Table 5.2. The highest contamination level was observed in cereals (6.60±1.02 $\log_{10}$ CFU/g) while the lowest was in groundnuts (3.38±1.76 $\log_{10}$ CFU/g). The second-highest level of contamination (6.56±1.00 $\log_{10}$ CFU/g) was found in sliced watermelon samples. These contamination levels are comparable to findings reported by Mafune *et al.* (2016) who observed the highest contamination in cereal-based foods (5.08 Log_{10} CFU/g) in a study investigating microbial safety of SVFs in Thohoyandou, South Africa. Similarly and consistent with findings from this study, Oluboyo *et al.* (2020) reported that watermelons were among the most contaminated foods (6.02 $\log_{10}$ CFU/g) among other RTE sliced fruits in Ado-Ekiti, Nigeria. The presence of such high microbial counts can be attributed to improper handling during preparation and inappropriate storage conditions for these products before the sale (Birgen *et al.*, 2020). Cereal-based foods are high in moisture and thus they are more prone to the proliferation of microorganisms as compared to dry groundnuts. Similarly, watermelons are categorized as potentially hazardous foods since they are high in moisture and do not undergo any processing after slicing which can potentially reduce contamination (Bhattacharjee, Saxena, & Dutta, 2019).

Table 5.2: Microbial quality of street-vended food samples sold in selected locations in Thika town, Kenya.

Food type	Total viable counts (log_{10} CFU/g)	Total coliforms (log_{10} CFU/g)	Yeasts and mold count (log_{10} CFU/g)	*Escherichia coli* (log_{10} CFU/g)	*Staphylococcus aureus* (log_{10} CFU/g)
Arrowroots	5.589±0.611[abc]	4.907±1.370[a]	4.602±0.442[ab]	2.033±1.229[a]	4.807±1.156[ab]
Boiled deshelled eggs	4.559±1.428[bcd]	1.647±2.307[d]	1.840±2.055[cd]	0.000±0.000[c]	2.459±2.613[cd]
French fries	5.140±1.805[abcd]	3.866±2.279[abcd]	3.243±1.977[abcd]	0.279±1.185[bc]	5.035±1.960[ab]
Groundnuts	3.377±1.764[d]	1.594±2.299[d]	1.595±2.146[d]	0.000±0.000[c]	1.905±1.638[d]
Juices	5.968±1.016[ab]	4.807±2.329[ab]	5.052±1.201[a]	0.801±1.433[abc]	3.664±2.530[bcd]
Cereals	6.590±1.020[a]	5.567±2.233[a]	4.581±2.515[ab]	1.445±2.163[abc]	5.972±1.170[a]
Salads	5.830±1.210[ab]	5.295±1.070[a]	3.287±2.118[abcd]	0.105±0.315[bc]	4.688±1.250[abc]
Sausages	4.508±2.470[bcd]	2.285±2.828[bcd]	2.300±2.504[bcd]	0.243±1.030[bc]	3.011±2.959[bcd]
Sliced pineapples	5.311±1.279[abc]	3.588±2.381[abcd]	4.048±2.180[abc]	0.483±1.459[bc]	1.888±1.660[d]
Sliced watermelons	6.564±1.001[a]	5.431±1.785[a]	4.853±1.737[a]	0.805±1.443[abc]	5.055±1.809[ab]
Smokies	3.900±2.109[cd]	1.985±2.737[cd]	1.857±2.185[cd]	0.000±0.000[c]	2.076±2.343[d]
Sweet potatoes	5.956±1.456[ab]	4.473±2.938[abc]	4.339±1.567[ab]	1.556±2.823[ab]	4.819±2.059[ab]

Values are means ± standard deviation log_{10} CFU/g. Means with different superscript letters in each column are significantly different ($p<0.05$).

Table 5.3: Ready-to-eat foods specification by Kenya Bureau of Standards

Food type	Total viable counts (CFU/g)	Total coliforms (CFU/g)	Yeasts and mold count (CFU/g)	*Escherichia coli*	*Staphylococcus aureus* (CFU/g)
Arrowroots*	10^5	-	-	10^2 CFU/25g	10^2
Boiled deshelled eggs*	10^5	-	-	10^2 CFU/25g	10^2
French fries**	10^3	-	-	-	10^2
Groundnuts*	10^5	-	-	10^2 CFU/25g	10^2
Juices$^+$	50	absent	20	-	absent
Cereals**	10^3	-	-	-	10^2
Salads^{++}	10^2	-	-	10 CFU/g	-
Sausages**	10^3	-	-	-	10^2
Sliced pineapples$^+$	50	absent	20	-	absent
Sliced watermelons$^+$	50	absent	20	-	absent
Smokies**	10^3	-	-	-	10^2
Sweet potatoes*	10^5	-	-	10^2 CFU/25g	10^2

Source: KEBs (2022). ** Foods/meals cooked immediately prior to sale or consumption such as pizza, sausages, lasagna, filled pasta, street foods, burgers kebabs, meat and vegetable nuggets, and frozen doughs with fillings or toppings, etc; $^+$ Fresh fruit and vegetable juices/drinks, beverages or other related products; $^{++}$ Salad from raw vegetables and/ or fruits including mixed salads; ***** Other ready to eat foods not specified above. – No limits were found.

Plant-based foods had significantly higher ($p<0.0001$) TVC compared to animal-based foods as shown in Figure 5.1. This high level of contamination could be attributed to contamination and cross-contamination between RTE foods and contaminated surfaces occurring due to poor hygiene practices during the handling, preparation, and storage of plant-based foods as reported earlier in section 3.0. For instance, the microbial quality of the water used in washing and preparation, as well as the length of time the foods stay before purchase could have a significant effect on the growth and proliferation of microorganisms in these foods (Izah, Aseibai, & Orutugu, 2015). In addition, some of the plant-based foods were prepared and consumed raw.

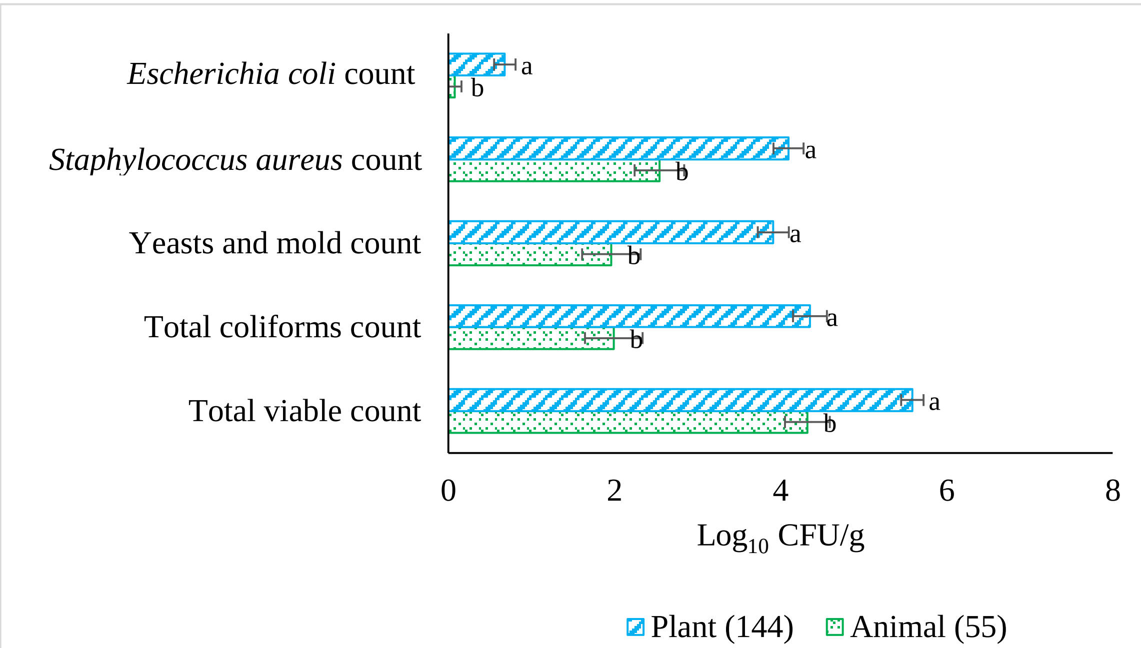


Figure 5.1: Comparison of microbiological quality between plant-based and animal-based street-vended foods.

There were no significant differences ($p>0.05$) in TVC between foods whose preparation involved heating and those that did not involve heating (Figure 5.2). Heating has the potential to reduce the microbial load in foods (Cardinale *et al.*, 2015). Foods that were prepared through heating may have been contaminated after preparation probably due to poor handling practices during service or storage before selling. As reported earlier in section 3.0, vendors stored foods at ambient temperatures awaiting sale. Furthermore, leftovers would also be stored under such conditions and sold the following day. These practices have the potential to negatively affect the quality and safety of SVFs.

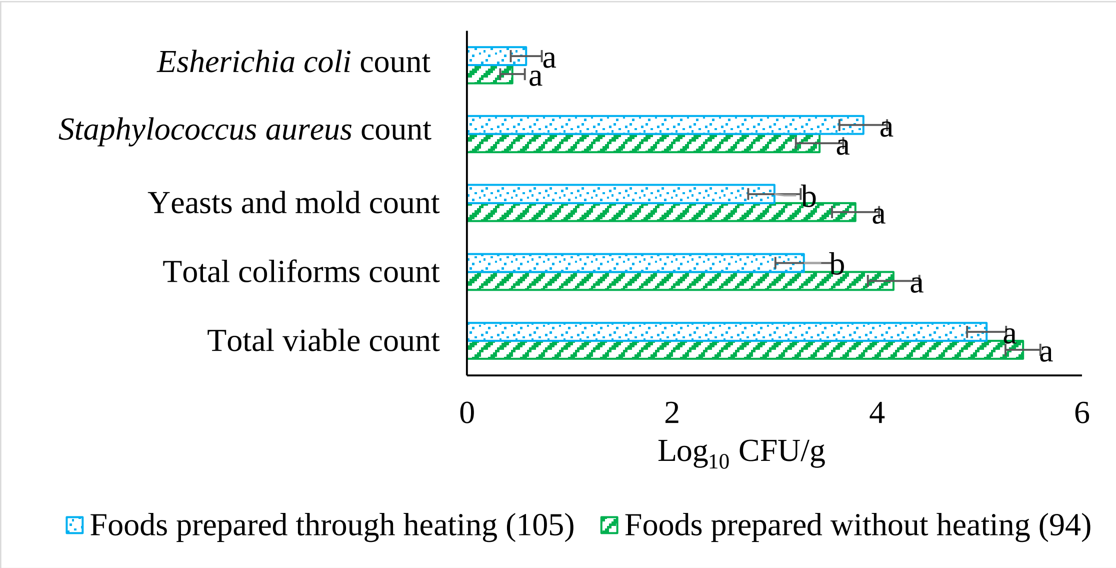


Figure 5.2: Comparison of microbiological quality between street-vended foods prepared through heating and those prepared without heating.

According to the Centre for Food Safety (2014), foods that are satisfactory for human consumption should have aerobic colony counts lower than 3.0 Log_{10} CFU/g. Foods with counts of 5.0 Log_{10} CFU/g or more are categorized as unsatisfactory while borderline cases are those with counts from 3.0 to 5.0 Log_{10} CFU/g. Following these guidelines, on average, none of the foods assessed in this study could be categorized as satisfactory. This is worrying from a food safety standpoint considering that many consumers depend on these foods for their meals daily (Moussavi *et al.*, 2016; Tesfaye, 2019).

On average, all food samples were above the established Kenya Bureau of Standards limits (Table 5.3) for total viable counts in ready-to-eat foods except boiled deshelled eggs. This suggests that the microbial load in most of the samples exceeded the permissible levels for consumption, raising concerns about the overall quality and safety of these ready-to-eat foods.

5.3.2 Determination of total coliform counts

There were highly significant differences ($p<0.0001$) in total coliform counts (TCC) between the food samples as shown in Table 5.2. TCC was highest in cereals (5.57±2.23 Log_{10} CFU/g) although this level of contamination was not significantly different from that observed in arrowroots, french fries, juices, salads, sliced pineapples, sliced watermelons, and sweet potatoes. The lowest TCC was observed in the groundnuts (1.59±2.30 Log_{10} CFU/g) (Table 5.2). These levels are comparable to those reported in salads (4.12 Log_{10} CFU/g) by Were, Were, and Aduol (2020) in a study investigating hygiene practices and microbial contamination of SVFs around Kenyatta university in Kenya. This variation could be attributed to the differences in SFV practices. Whereas only vendors with pushcarts were involved in Were *et al.* (2020) study, the diversity of SFVs in our study was large including SFVs who were mobile or established in specific vending locations, who were found vending ready-to-eat foods. Bohara (2018) reported comparable coliform contamination levels ranging between 2.1 to 5.2 log_{10} CFU/g in all SVFs sold in Mahendranagar, Farwestern Nepal that were studied. The presence of high counts of TCC suggests that SVFs were not prepared under hygienic conditions. Cereal-based foods as well as arrowroots, french fries, juices, salads, sliced pineapples, sliced watermelons, and sweet potatoes may have recorded high levels of contamination with coliforms due to their high moisture levels that would have encouraged multiplication of the bacteria, unlike the groundnuts that were dry. Thus, despite contamination for all samples, food high in moisture had bacteria proliferating at a higher rate.

There were highly significant ($p<0.0001$) differences in total coliform counts between the six study locations as shown in Table 5.4. The Hospital area reported the highest TCC (4.64±2.66 log_{10} CFU/g) although the level was not significantly different from Juakali (4.04±2.51 log_{10} CFU/g), Thika town center (3.83±2.99 log_{10} CFU/g), and Kiandutu (3.41±2.81 log_{10} CFU/g). The lowest contamination levels were reported in Makongeni and Ngoigwa areas. Makongeni and Ngoigwa areas are mainly residential areas that may have better water supply services, unlike the other areas where vendors may not have access to clean water near their vending areas.

Table 5.4: Comparison of microbial quality of street-vended foods from the six study locations in Thika town.

Location	Total viable counts	Total coliform counts	Yeasts and mold count	*Staphylococcus aureus*	*Escherichia coli*
Hospital area	5.795±2.234 [a]	4.642±2.663 [a]	2.843±2.721 [a]	3.798±2.753 [a]	0.444±1.273 [a]
Juakali area	5.236±1.731 [a]	4.043±2.514 [ab]	3.833±2.106 [a]	4.230±2.129 [a]	0.529±1.307 [a]
Kiandutu slums	4.900±1.660 [a]	3.413±2.805 [ab]	3.186±2.210 [a]	3.292±2.655 [a]	0.268±0.767 [a]
Makongeni	5.071±1.397 [a]	3.210±2.241 [b]	3.245±2.205 [a]	3.454±2.048 [a]	0.493±1.151 [a]
Ngoigwa	4.943±1.619 [a]	3.169±2.781 [b]	3.472±2.348 [a]	3.589±2.387 [a]	0.523±1.445 [a]
Thika town center	5.510±2.135 [a]	3.833±2.993 [ab]	3.621±2.498 [a]	3.659±2.767 [a]	0.794±2.029 [a]

Values are means ± standard deviation log_{10} CFU/g. Means with different superscript letters in the same column are significantly different ($p<0.05$).

Plant-based foods had significantly ($p<0.0001$) higher TCC compared to animal-based foods (Figure 5.1). This is possibly due to poor hygiene practices and the fact that some plant-based foods such as sliced fruits do not undergo any form of heat treatment before consumption. This is further qualified by the fact that foods prepared without heating had significantly higher levels ($p = 0.021$) of contamination with coliforms as shown in Figure 5.2.

Even though the established standards specify that coliforms should not be present in these products (Table 5.3), these microorganisms were found in both juices and the slices of watermelons and pineapples. Coliforms are a group of bacteria that are commonly used as indicators of overall hygiene and potential fecal contamination in food and water. Their presence in food products can suggest unsanitary conditions during processing, handling, or storage, and could also indicate the possible presence of other harmful pathogens. This emphasizes the importance of proper sanitation, quality control measures, and adherence to food safety standards throughout the entire production and distribution process to ensure that the final products are free from contaminants that could lead to foodborne illnesses.

5.3.3 Determination of yeasts and mold counts

There were highly significant differences ($p<0.0001$) in yeasts and mold counts (YMC) between the food samples as shown in Table 5.2. YMC was highest in the juices at a level of 5.05±1.201 $\log_{10}$ CFU/g as well as sliced watermelons at 4.85±1.74 $\log_{10}$ CFU/g. Notably, these contamination levels were above the limits set by the Kenya Bureau of Standards of 20 CFU/g in juices and fruits (Table 5.3). Plant-based foods had significantly higher ($p<0.0001$) YMC as shown in Figure 5.1. This was expected since most fruits have a lower pH which favors the growth of yeasts and molds. Molds and yeasts are generally acid-tolerant, and as a result, they are linked to the deterioration of acidic foods. Molds may grow in a pH range of 2 to 8.5 although they prefer an acid pH, while yeasts can thrive in a pH range of 4 to 4.5 (Perricone *et al.*, 2017). Molds and yeasts are also ubiquitous in the environment (Yadav *et al.*, 2021). Poor food hygiene practices may have contributed to the high contamination reported in most plant-based foods. Food that did not undergo any heat treatment before service had significantly ($p = 0.017$) higher yeasts and mold counts as shown in Figure 5.2. Room temperature favors the growth of molds and yeasts as yeasts can thrive at temperatures ranging from 0^oC to 50^oC (Perricone *et al.*, 2017). Molds have been reported to have a wide range of growth temperatures. For instance, *Aspergillus niger* can grow at temperatures ranging from 8 to 45^oC (Perricone *et al.*, 2017). The presence of molds in SVFs poses a food safety concern since some mold species have been reported to produce mycotoxins which are of food safety concern to human health (Peles *et al.*, 2019; Sombie *et al.*, 2018).

5.3.4 Determination of *Escherichia coli*

There were highly significant differences ($p<0.0001$) in *Escherichia coli* counts between the food samples as shown in Table 5.2. *Escherichia coli* counts were highest in arrowroots (2.03 ± 1.23 log_{10} CFU/g) but absent in boiled deshelled eggs, groundnuts, and smokies. All arrowroot samples were contaminated with *E. coli* while 44.4% of cereals were contaminated as shown in Table 5.5. Only arrowroots exceded the limits set by the Kenya Bureau of Standards (Table 5.3) for *Escherichia coli* in ready-to-eat foods. Higher contamination levels with *E. coli* have been reported in SVFs. For instance, Birgen *et al.* (2020) reported contamination levels of 2.67 log_{10} CFU/g in RTE chicken in a study investigating the microbial quality of street-vended chicken products sold in Nairobi County, Kenya. Sabuj *et al.* (2018) also reported *E. coli* counts ranging from 4.43 to 4.60 log_{10} CFU/g in a study investigating the microbial quality of SVFs in Bangladesh. This was expected since contamination levels with *E. coli* depend majorly on food hygiene practices which may differ from one region to another. The high contamination reported in arrowroots may be attributed to poor hygiene practices such as vending from contaminated environments, using contaminated packaging materials, handling foods with bare hands, and handling money while serving food without washing hands during the preparation, storage, and service of SVFs as earlier reported in section 3.0. In addition, arrowroots were among the foods that were probably prepared elsewhere and transported to the vending site. Long storage coupled with contamination due to poor handling may explain the high level of contamination with *E. coli*.

Table 5.5: Prevalence of *E. coli, S. aureus, Salmonella* spp., and *L. monocytogenes* in street-vended food samples

Food type	N	*Salmonella* spp. (%)	*Escherichia coli* (%)	*Staphylococcus aureus* (%)	*Listeria monocytogenes*
Arrowroots	4	25.0	100.0	100.0	Negative
Boiled deshelled eggs	18	5.6	0.0	50.0	Negative
French fries	18	5.6	5.6	94.4	Negative
Groundnuts	18	Negative	0.0	61.1	Negative
Juices	20	5.0	30.0	80.0	Negative
Cereals	18	11.1	44.4	100.0	Negative
Salads	19	Negative	10.5	100.0	Negative
Sausages	18	Negative	5.6	55.6	Negative
Sliced pineapples	19	Negative	10.5	68.4	Negative
Sliced Watermelons	18	Negative	33.3	94.4	Negative
Smokies	18	Negative	0.0	50.0	Negative
Sweet potatoes	11	Negative	27.3	90.9	Negative

N – Number of samples

Plant-based foods had significantly ($p = 0.006$) higher *E. coli* counts compared to animal-based foods as shown in Figure 5.1. Fisher's Exact test revealed that there was a significant relationship ($p = 0.0002$) between the type of food and the presence of *E. coli*. The odds for a positive sample were 15.4 times higher for plant-based foods compared to animal-based foods. The relative risk was 12.2 indicating that the chance for a positive sample was higher for plant-based foods. Whereas most of the plant-based foods were reported to be contaminated with *E. coli*, among all the animal-based foods tested, only 5.56% of sausages were found to be contaminated with *E. coli.* This could be attributed to poor hygiene practices such as vending from contaminated environs, using contaminated packaging materials, handling foods with bare hands, and handling money while serving food without washing hands during the preparation, storage, and service of SVFs as earlier reported in section 3.0. There was no significant difference ($p = 0.4967$) in *E. coli* counts between foods prepared through heating and those that were not prepared through heating (Figure 5.2). This may suggest that post-heat contamination occurred after preparation, probably during storage or while handling before service. This also demonstrates poor hygiene practices among SFVs since the presence of *E. coli* in food is indicative of fecal contamination (Holcomb *et al.*, 2020).

5.3.5 Determination of *Staphylococcus aureus*

There were highly significant differences ($p<0.0001$) in *Staphylococcus aureus* counts between the food samples as shown in Table 5.2. *Staphylococcus aureus* counts were highest in cereals (5.97±1.17 $\log_{10}$ CFU/g) although this was not significantly different from arrowroots, french fries, salads, sliced watermelons, and sweet potatoes. This may be attributed to poor hygiene practices that resulted in the contamination of RTE food with *S. aureus*. *Staphylococcus aureus* is ubiquitous in the environment and is often found contaminating food surfaces, hands, and equipment (Ahmad *et al.*, 2020). All these foods are bulked in a single container from where service is occasionally done for individual customers. Continuous uncovering and handling during service may potentially result in contamination with *S. aureus*. At least one sample in each type of food was found to be contaminated with *S. aureus* as shown in Table 5.5. All arrowroots, cereals, and salads were contaminated with *S. aureus*. Nemo *et al.* (2017) reported lower *S. aureus* prevalence (29.38%) in a microbiological quality and safety of SVFs study in Jimma Town, Southwestern Ethiopia. Similarly, the lower prevalence was also reported by Asiegbu *et al.* (2020) in a study on the microbial quality of RTE street-vended foods sold in the Johannesburg Metropolis, South Africa. Compared to these findings, the contamination rate in this study was higher which poses significant health concerns to the consumers. This may be attributed to poor hygiene and safety practices during the preparation and sale of SVFs in the areas included in this study. This is because *S. aureus* is ubiquitous (Ahmad *et al.*, 2020) and would often contaminate foods due to poor handling and storage practices.

Plant-based foods had significantly higher ($p<0.0001$) *S. aureus* counts as shown in Figure 5.1 compared to animal-based foods. Fisher's exact test revealed that there was a highly significant relationship ($p<0.0001$) between the type of food and the presence or absence of *S. aureus*. The odds for a positive sample were 5.56 times higher for plant-based foods as compared to animal-based foods. The relative risk was 1.63 indicating that the chance for a positive sample was higher for plant-based foods compared to animal-based foods. *Staphylococcus aureus* can be isolated from persons and their environs since they are frequent environmental pathogens that could have contaminated the SVFs after it was cooked, for example, through utensils, and vendors' hands when handling foods, wiping cloths, or the water used for washing raw food, dishwashing or handwashing. Plant-based foods could have been exposed to contamination before preparation or during preparation unlike some of the animal-based foods such as smokies and sausages that were already preprocessed and vacuum packaged by the manufacturer.

There was no significant difference ($p = 0.22$) in *S. aureus* counts between food that was prepared through heating and those that did not undergo any heating during preparation (Figure 5.2). Although heat treatment has been shown to reduce microbial contamination levels (Mepba *et al.*, 2007), foods prepared through heating were not necessarily served hot. Thus, poor handling and storage may have occurred resulting in contamination of the heat-treated food products before sale.

According to the Centre for Food Safety (2014), foods can be categorized as satisfactory if they have less than 1.3 Log_{10} CFU/g, borderline if they have contamination levels from 1.3 to less than 4.0 Log_{10} CFU/g, and unsatisfactory if they have counts equal or above 4.0 Log_{10} CFU/g of *S. aureus*. Following this criterion, on average, none of the food samples could be categorized as satisfactory. Boiled deshelled eggs, groundnuts, juices, sausages, sliced pineapples, and smokies were categorized as borderline while all the other foods were unsatisfactory. Unacceptable handling practices, such as displaying RTE food in the open air, handling by vendors with dirty hands, and unhygienic food contact surfaces may be to blame for the unsatisfactory *S. aureus* contamination levels (Shiningeni *et al.*, 2019). The presence of high levels of *S. aureus* is worrying since *S. aureus* can produce heat-resistant toxins that are responsible for various diseases such as toxic shock syndrome, necrotizing pneumonia, and staphylococcal scalded skin syndrome or deep-seated skin infections (Oliveira, Borges, & Simões, 2018).

Despite the specified KEBs standards indicating the absence of *Staphylococcus aureus* in such products, this pathogen was detected in juices as well as in sliced watermelons and pineapples. Only groundnuts were reported to have mean contamination levels below the Kenya Bureau of Standards limits (Table 5.3) for *Staphylococcus aureus* in ready-to-eat foods. This dissonance between the expected absence and the actual presence of these microorganisms suggests a breakdown in the production, handling, or storage processes of these foods. It raises concerns about the hygiene and quality control measures implemented during the production and distribution of these products. The implication is that the detected microorganisms could potentially lead to foodborne illnesses if contaminated street foods are consumed. This underscores the importance of rigorous quality control, adherence to safety regulations, and proper handling practices throughout the food supply chain to ensure that food products meet the specified safety standards and are safe for consumption.

5.3.6 Detection of *Salmonella* spp.

Salmonella spp. were only detected in boiled arrowroots, boiled deshelled eggs, french fries, juices, and cereal-based foods. The highest prevalence was observed in arrowroots

(25%) followed by cereals (11.1%). Juakali, Kiandutu, Makongeni, and Thika town center recorded at least one sample that was contaminated with *Salmonella* spp. The highest prevalence was recorded in Kiandutu (6.5%) followed by the Juakali area (6.3%) as shown in Table 5.6. However, Fisher's exact test revealed that there was no significant relationship ($p>0.05$) between the type of food as well as the method of preparing food and the presence or absence of *Salmonella*. Heating has the potential to reduce the risk of *Salmonella* in foods. Cardinale et al. (2005) reported a decreased risk of contamination with Salmonella when food was adequately cooked.

The overall prevalence of *Salmonella* in this study was 3.02% which was low compared to the findings of Nemo *et al.* (2017) who reported a prevalence of 13.13% in SVFs sold in Jimma Town, Southwestern Ethiopia. Estrada-Garcia *et al.* (2004) reported a prevalence of 5% in taco dressings sold on the street in Mexico City while Shiningeni *et al.* (2019) reported *Salmonella* spp. in 11% and 40% of samples from two study locations in Windhoek, Namibia.

Table 5.6: Prevalence of *E. coli, S. aureus, Salmonella* spp., and *L. monocytogenes* in the six study locations.

Sampling locations	**N**	***Salmonella* spp. (%)**	***Escherichia coli* (%)**	***Staphylococcus aureus* (%)**	***Listeria monocytogenes***
Hospital	31	Negative	12.9	74.2	Negative
Juakali	32	6.3	15.6	90.6	Negative
Kiandutu	31	6.5	16.1	67.7	Negative
Makongeni	35	2.9	17.1	80.0	Negative
Ngoigwa	35	Negative	22.9	77.1	Negative
Thika	35	2.9	14.3	71.4	Negative

N – Number of samples

Salmonella spp. detected in a 25 g meat sample is regarded as potentially hazardous rendering the food unfit for human consumption (Centre for Food Safety, 2014). Inadequate cooking, contamination from an unsanitary environment as well as food handlers, and poor food handling methods have all been linked to the occurrence of this pathogen (Shiningeni *et al.*, 2019). Although the sources of the raw materials for foods contaminated with *Salmonella* spp. were not examined in this study, the presence of these pathogens could be due to contamination during the handling of food especially if the raw materials were already contaminated with the bacteria. In addition, food handlers have been identified as mechanical vehicles of *Salmonella* contamination from raw foods such as vegetables, and meat, or the environment through utensils and other cooking vessels (Cardinale *et al.*, 2015).

Plant-based foods, as well as foods prepared through heating, revealed high prevalence levels for *Salmonella* spp. (Figure 5.3 and Figure 5.4). However, Fisher's exact test revealed that there was no significant relationship (p>0.05) between the type of food as well as the method of preparing food and the presence or absence of *Salmonella*. Heating has the potential to reduce the risk of *Salmonella* in foods. Cardinale *et al.* (2005) reported a decreased risk of contamination with *Salmonella* when food was adequately cooked.

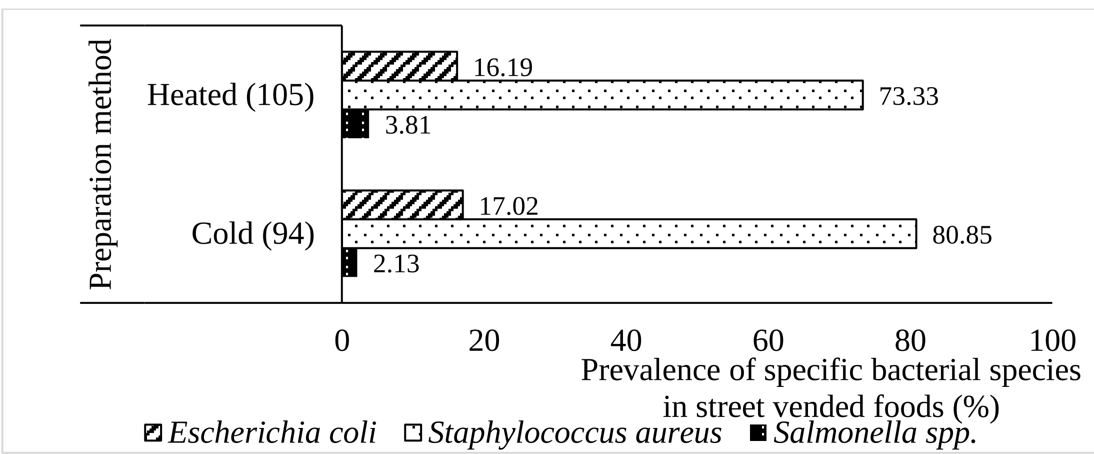


Figure 5.3: Comparison of prevalence of *E. coli, S. aureus,* and *Salmonella* spp. in street-vended foods prepared through heating and those prepared without heating.

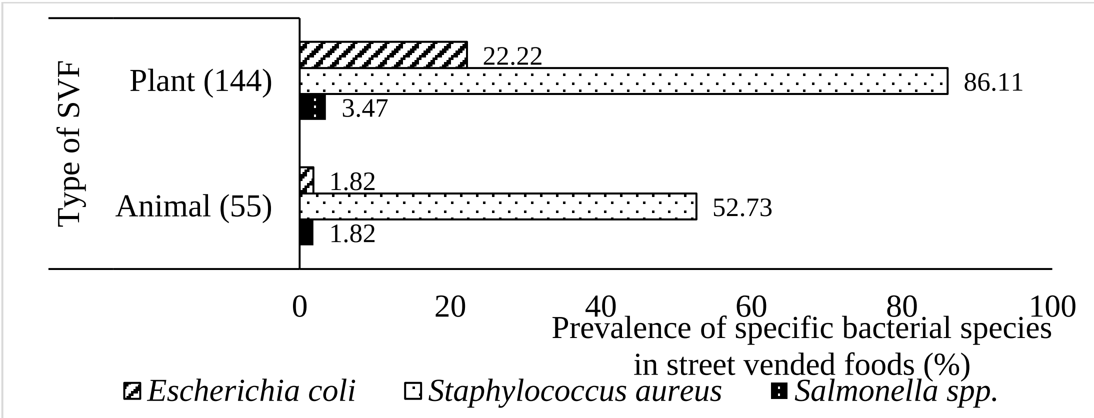


Figure 5.4: Comparison of prevalence of *E. coli*, *S. aureus*, and *Salmonella* spp. in animal and plant-based street-vended foods.

For food prepared without heating, the risk is higher, and thus, these are categorized as potentially hazardous foods. In this study, there was no significant relationship ($p = 0.22$) between the method of preparing food (cooked through heating and those that did not undergo heating) and the presence or absence of *Salmonella*. This may imply that foods prepared through heating did not significantly have a reduced risk of contamination with *Salmonella*. This is possibly due to post-preparation contamination resulting from poor handling and storage practices before foods were sold.

5.4 Conclusion

The findings of this study demonstrate that SVFs sold in the streets of Thika Town constitute a potential health hazard to consumers. TVC, coliform, *E. coli,* yeast, and mold counts in all street-vended foods were generally high, making most of these foods unsatisfactory and unsafe for human consumption. The presence of *E. coli* in RTE foods was indicative of poor hygiene and safety practices among SFVs. Pathogenic bacteria such as *Salmonella* spp. and *S. aureus* were also isolated from the SVFs. The presence of these pathogenic bacteria in RTE foods indicates a major risk to the SFVs as well as the consumers since they can cause microbiological foodborne diseases. Consequently, there is a need to regulate the informal food processing and marketing channels, to enhance the quality and safety standards of SVFs. The public health sector should enhance awareness among SFVs and consumers on food hygiene and safety through education and/or training. In addition, the provision of basic infrastructure for enhancing hygiene among SFVs has the potential to improve their food preparation and selling conditions/environments thus contributing to the production and sale of quality and safe foods.

CHAPTER SIX

DETERMINATION OF LEAD AND CADMIUM IN STREET-VENDED FOODS

6.1 Introduction

Food safety concerns have been raised regarding the contamination of street-vended foods with chemical toxic elements (Ankar-Brewoo *et al.*, 2020; Proietti *et al.*, 2014b). Heavy metals are among the chemical contaminants that may potentially contaminate street-vended foods (SVFs) before, during, and after preparation for sale (Proietti *et al.*, 2014b). It has been reported that the use of unsuitable cookware, utensils, and food packaging material could release harmful chemicals such as heavy metals into the food (Pereira *et al.*, 2021). In addition, the source of raw food products, and exposure to environmental contaminants such as vehicle exhaust emissions, and airborne dust particles may cause contamination of food with heavy metals (Ali & Al-Qahtani, 2012). For instance, the vegetables used by street food vendors may be contaminated with significant levels of heavy metals due to farming on contaminated soils, irrigation with polluted wastewater, as well as industrial and transportation emissions that are released into the environment (Ankar-Brewoo *et al.*, 2020; Fasinu & Orisakwe, 2013; Iriabije & Uwadiae, 2020; Osaili *et al.*, 2016). The growing of vegetables in cities and most industrial places has been reported to yield foodstuff contaminated with heavy metals (Ali & Al-Qahtani, 2012). Njagi *et al.* (2017) reported that vegetables grown around dumpsites in Nairobi City County in Kenya were heavily contaminated with mercury and lead. Foods of animal origin are also at risk of contamination with heavy metals due to exposure from feeds given to the animals, or from contaminated air during transportation, and handling practices at the retailing stages (Ankar-Brewoo *et al.*, 2020).

Heavy metals are extremely toxic to human health and are capable of bioaccumulation (Ismail *et al.*, 2017; Khan *et al.*, 2015). Continuous ingestion of heavy metals has a damaging effect on human health (Israel *et al.*, 2020; Jaishankar *et al.*, 2014). The adverse effects of heavy metals on human health include structural damage, renal failure, damage to cells and tissues, osteoporosis, lung or even blood cancer, hormone imbalances, gastrointestinal problems, and anemia (Ismail *et al.*, 2017). Previous research has also linked heavy metals to the increasing cases of cancer in sub-Saharan Africa (Fasinu & Orisakwe, 2013). Health problems caused by these toxic contaminants may not be immediate but accumulation in the body may reach toxic levels causing health issues later in life (Ogu & Akinnibosun, 2020). Lead and cadmium are among the heavy metals of interest in street-vended foods owing to their frequency of occurrence, toxicity, and potential for exposure to humans (Proietti, Frazzoli, & Mantovani, 2014a). The International Agency for Cancer Research (IACR) has classified cadmium and its compounds as group 1 carcinogens, with substantial evidence linking cadmium exposure to an increased risk of lung cancer, and albeit limited, evidence suggesting a potential association between cadmium exposure and kidney, liver, and prostate cancer, while lead and its compounds have been categorized as 'probably' human carcinogens (group 2A), (Joint FAO/ WHO Expert Committee on Food Additives, 2011). Accumulation of lead in different organs can result in detrimental effects that may contribute to anemia, disorders of the nervous system, impairment of kidney and liver function, hearing problems, gastrointestinal damage, diminished IQ, and behavioral and learning disorders in children. Furthermore, it has been associated with Alzheimer's disease, cancer, and the progression of breast cancer and other types of cancers. Likewise, cadmium has the potential to harm various organs including the lungs, liver, and kidneys, and it can lead to the development of liver, prostate, breast, lung, kidney, skin, and pancreatic cancer (Ebrahimi *et al.*, 2020). For SVFs that have minimal regulation, research on heavy metal contamination can inform the making of policies to govern street food quality.

Several researchers have reported the presence of heavy metals including lead and mercury in SVFs (Chavez *et al.*, 2014; Ekhator *et al.*, 2017; Ihsan & Edwin, 2018; Mohammed, 2010; Solidum, 2010). In a study carried out in Jordan, Osaili *et al.* (2016) reported that the mean level of lead (0.15-1.15 mg/kg) in onions, exceeded the European Union set limits (0.1 mg/kg fresh weight). Ali and Al-Qahtani (2012) reported lead in both onions (3.52 – 4.28 mg/kg) and tomatoes (2.78 – 3.32 mg/kg) sold in Saudi Arabian markets. In Nigeria, Ogunkunle *et al.* (2014) reported the presence of lead (0.07 – 1.93

mg/kg) and cadmium (0.00-0.09 mg/kg), in street-vended mangoes, pawpaw, and watermelons while Ekhator *et al.* (2017) reported the presence of lead (0.12 - 1.37 mg/kg) and cadmium (<0.001 – 0.0014 mg/kg)) in commonly consumed street-vended foods sold in Benin City and Umunede, Nigeria. In Kenya, research on heavy metals especially ready-to-eat food products is minimal. Kinyanjui (2009) reported lead levels ranging from 0.00 - 0.38 mg/100 g in fruits and vegetables sold in Kisumu County, Kenya. Tomno *et al.* (2020) reported contamination of kale and spinach cultivated and sold in Machakos Municipality, Kenya with cadmium levels ranging between 0.013 – 3.19 mg/kg and lead levels ranging between 0.02 – 0.368 mg/kg. Knowledge regarding concentrations of heavy metals in foods and their dietary intake is very useful in the determination of their risk to human health (Ankar-Brewoo *et al.*, 2020; Khan *et al.*, 2015). Therefore, this study aimed to determine the level of selected heavy metals in SVFs sold in Thika town, Kenya.

6.2 Materials and methods

6.2.1 Study site

This study was carried out in 6 locations namely Thika town center, Goingwa, Juakali area, Makongeni, Kiandutu, and Thika Level 5 hospital area in Thika town, Kenya. Heavy metal analysis was carried out at Chuka University, Department of Physical Sciences, Chemistry laboratory.

6.2.2 Sampling of street-vended foods

The sampling of food samples was done from randomly selected street food vendors in each study location. There were twelve food sample types selected for analysis including sausages, smokies, eggs, cereal-based foods (maize mixed with various legumes), french fries, groundnuts, fresh fruit juices, sliced watermelons, sliced pineapples, salads, arrowroots, and sweet potatoes. In total, 198 food samples were collected. Approximately 200 - 300 g of each food sample was collected from the randomly selected street food vendors and bagged in a sterile 500 g sample bag. Samples were immediately transferred into a cooler box (4^oC) for transportation to the laboratory for analysis.

6.2.3 Preparation of reagents and standard curves

All reagents used were of analytical grade. Standards for Lead and Cadmium were procured from Sigma Aldrich Company. The standard analytes for the calibration curve were made by diluting a 1000 mg/L stock solution of the examined element. For each of the elements to be examined, different concentrations were prepared from the stock solution and a calibration curve was plotted using concentration and absorbance data from each set of standards.

6.2.4 Sample preparation, digestion, and analysis

The levels of Lead and Cadmium in food samples were determined using atomic absorption spectrophotometer (PG 990 model) as described by Puwastien *et al.* (2011). Solid samples were dried at 105^{o}C for 24 hours and homogenized in a laboratory grinder. Fresh fruit juices, sliced watermelons, sliced pineapples, and salads were blended into a homogenous mixture and used in their liquid form for analysis. Dry ashing was done in a muffle furnace at 525^{o}C for 8 hours using 3 g of the dried samples and 10 g of the fresh fruit juices, sliced watermelons, and sliced pineapples and salads. The fresh fruit juices, sliced watermelons, sliced pineapples, and salad samples were first dried in an oven at 105^{o}C until all moisture was removed before charring and ashing. The ash obtained was dissolved in 1 N nitric acid solution, filtered using the Whatman filter paper No. 1, and the volume adjusted to 50.0 mL with distilled water. A blank sample was digested in the same way. The instrument wavelength was set at 283.3 and 228.8 nm, for lead and cadmium, respectively. In both cases, the lamp current was 2.0 A while the slit was 0.4 nm. Measurements were carried out in an air/acetylene flame.

6.2.5 Data analysis

All analyzed sample results were subjected to statistical analysis using SAS (Version 9.4) software for analysis of variance (ANOVA) and mean separation using Tukey's studentized range (HSD) test at a 95% confidence interval.

6.3 Results and discussion

6.3.1 Level of cadmium in the street-vended foods

Cadmium (Cd) contamination was only quantified in cereal-based foods, eggs, french fries, fresh fruit juices, sliced watermelons, sausages, and sweet potato samples (Table 6.1). Detectable contamination levels ranged between 0.001±0.001 and 0.010±0.003 mg/Kg. Significantly higher levels ($p<0.0001$) of Cadmium were observed in cereals-based foods (0.010 mg/Kg) and fresh fruit juices (0.008 mg/Kg) compared to all other samples although, none of the samples were above the MRLs established by Codex Alimentarius Commission (2019). The lowest detectable levels of Cadmium were observed in french fries although this was not significantly different from the sliced watermelons.

Table 6.1: Level of cadmium in specific street-vended foods sold in selected locations in Thika town, Kenya.

Sample	Number of samples	Cadmium Level		
		Mean (mg/Kg)	Range (mg/Kg)	MRL (mg/Kg)
Arrowroots	6	nd	0.000 - 0.000	0.1
Cereal-based	18	0.010±0.003$^{a\gamma}$	0.000 - 0.034	0.1**
Boiled deshelled eggs	18	0.004±0.002^{b}	0.000 - 0.031	
French fries	18	0.001±0.001$^{cd\gamma}$	0.000 - 0.013	0.1
Groundnuts	18	nd	0.000 - 0.000	
Juice	18	0.008±0.003^{a}	0.000 - 0.038	
Watermelon	18	0.003±0.001^{bc}	0.000 - 0.016	
Pineapple	18	nd	0.000 - 0.004	
Salad	18	nd	0.000 - 0.000	0.05*
Sausages	18	0.005±0.003^{b}	0.000 - 0.036	
Smokies	18	nd	0.000 - 0.000	
Sweet potatoes	12	0.001±0.000$^{d\gamma}$	0.000 - 0.004	0.1

Values are mean ± standard deviation. Values in the same column with different superscript letters are significantly different ($p<0.05$). nd - not detected. MRL - Maximum Recommended Limit. * Cadmium level in fruiting vegetables (0.05) and bulb vegetables (0.05), ** Cadmium Level for pulses (0.1) and cereal grains (0.1) (Codex Alimentarius Commission, 2019). $^{\gamma}$ The means are below the MRLs specified.

Table 6.2: Level of lead in specific street-vended foods sold in selected locations in Thika town, Kenya.

Sample	Number of samples	Lead Level		
		Mean (mg/Kg)	Range (mg/Kg)	MRL (mg/Kg)
Arrowroots	6	0.558±0.093[b]	0.331 - 0.842	0.1
Cereal-based	18	0.580±0.057[b]	0.194 - 0.994	0.1-0.2[+++]
Boiled deshelled eggs	18	0.442±0.204[c]	0.000 - 2.391	0.1[++++]
French fries	18	0.511±0.149[bc]	0.000 - 1.472	0.1
Groundnuts	18	1.891±0.130[a]	0.937 - 2.986	-
Juice	18	0.271±0.071[e]	0.000 - 0.815	0.03
Watermelon	18	0.466±0.081[c]	0.092 - 1.180	0.1
Pineapple	18	0.335±0.059[de]	0.000 - 0.588	0.1
Salad	18	0.547±0.200[b]	0.000 - 2.448	0.05 – 0.1[+]
Sausages	18	0.560±0.073[b]	0.052 - 0.955	0.1[++]
Smokies	18	0.577±0.086[b]	0.000 - 1.003	0.1[++]
Sweet potatoes	12	0.356±0.100[d]	0.000 - 0.758	0.1

Values are mean ± standard deviation. Values in the same column with different superscript letters are significantly different ($p<0.05$). nd - not detected. MRL - Maximum Recommended Limit. [+] Lead range given for fruiting vegetables (0.05) and bulb vegetables (0.1), [++] Lead level set for meat from poultry, cattle, pigs, and sheep, [+++] Lead range taken for pulses (0.1) and cereal grains (0.2) (Codex Alimentarius Commission, 2019). [++++] Level of Lead suggested by Joint FAO/WHO food standards programme (2021). [γ] The means are below the MRLs specified.

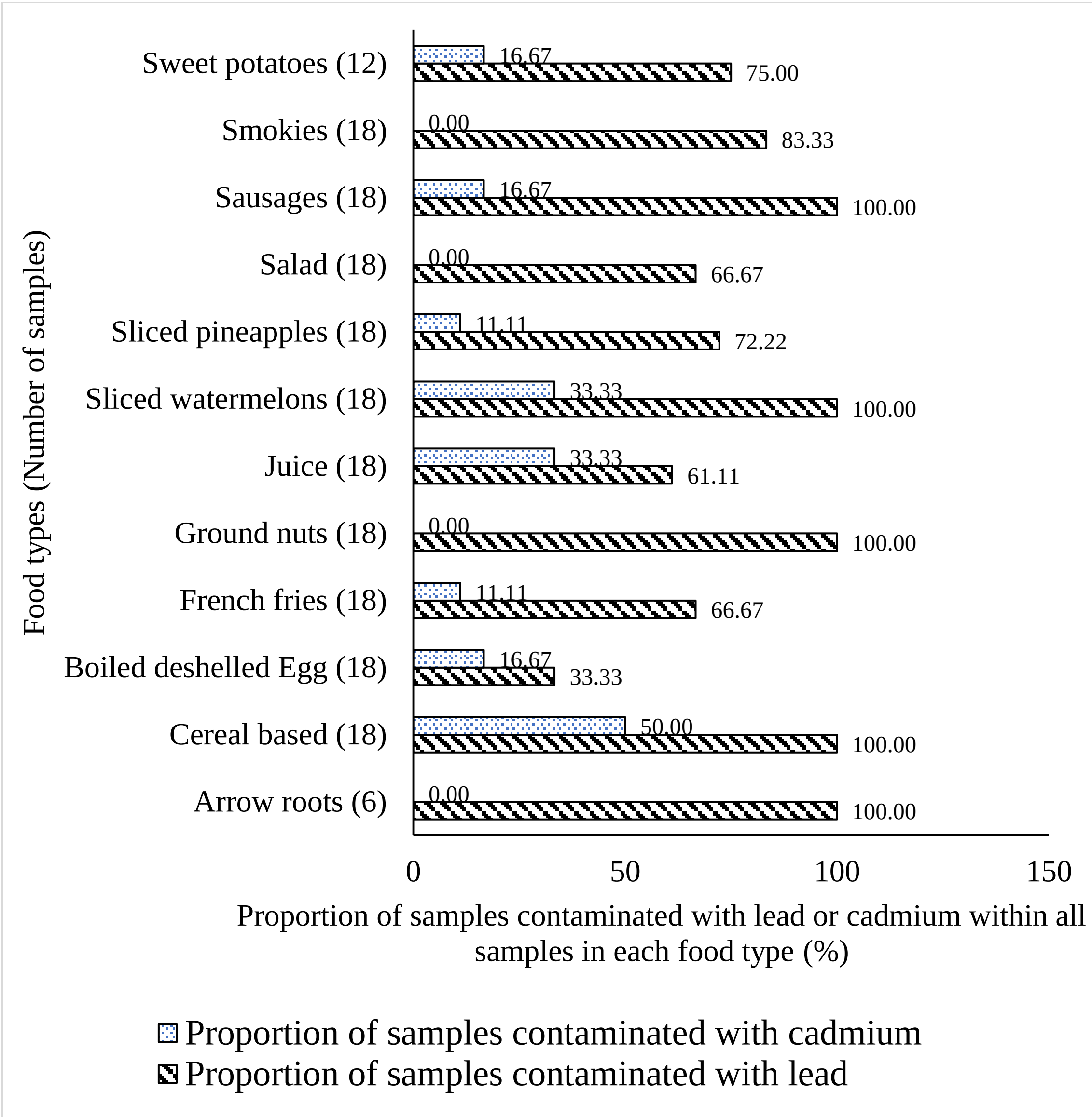


Figure 6.1: Proportion of samples contaminated with lead or cadmium within all samples in each food type

Cereal-based foods had the highest number of samples contaminated with cadmium (Figure 6.1) which were only found in three study locations as shown in Table 6.3. Contrary to expectations, the Juakali area which is an industrial area within Thika town reported no contamination with cadmium. In contrast to the findings of this study, Ezeilo *et al.* (2020) reported higher contamination levels ranging between 0.03 mg/kg and 0.70 mg/kg in fruits and vegetables.

The presence of cadmium in cereals and fresh fruit juices might be a result of using raw materials that were contaminated during the preparation of the SVFs. Cadmium contamination reaching the food chain may originate from geogenic and anthropogenic activities (Bolan *et al.*, 2013). In other studies, the presence of Cadmium in plant-based foods such as cereals and fruits has been attributed to Cadmium impurities in fertilizers and amendments applied to soils (McLaughlin & Singh, 1999). Furthermore, wastewater carrying industrial wastes that may be used to irrigate agricultural lands, the burning of fossil fuels such as coal or oil, and the incineration of municipal waste may be major sources of Cadmium in the food chain (Adedapo & Adeoye, 2014; Mahmood *et al.*, 2019). The migration of heavy metals from plastic utensils used for handling food has also been reported to contaminate food with Cadmium (Pereira *et al.*, 2021). Different foods undergo different handling and preparation practices. These practices influence the presence of heavy metals in foods in different ways. This may explain the differences observed in the concentration of cadmium in different food samples.

Table 6.3: Cadmium contamination levels (mg/Kg) in different street-vended food samples within different study locations in Thika town, Kenya.

	Study area							
Food Type	**Range (mg/Kg)**	**Hospital Area**	**Juakali Area**	**Kiandutu**	**Makongeni**	**Ngoigwa**	**Thika town center**	**Limit**
Arrow roots	0.000 - 0.000	-	-	-	nd	nd	-	0.1
Cereal based	0.000 - 0.034	nd	nd	0.025±0.003[a]	nd	0.006±0.001[b]	0.03±0.002[a]	0.1**
Boiled deshelled eggs	0.000 - 0.031	nd	nd	nd	nd	0.022±0.005[a]	nd	-
French fries	0.000 - 0.013	nd	nd	nd	0.006±0.004[a]	nd	nd	0.1
Groundnuts	0.000 - 0.000	nd	nd	nd	nd	nd	nd	-
Juice	0.000 - 0.038	0.036±0.001[a]	nd	nd	nd	0.01±0.002[b]	nd	-
Mellon	0.000 - 0.016	0.013±0.002[a]	nd	nd	0.006±0.001[b]	nd	nd	-
Pineapple	0.000 - 0.004	nd	nd	nd	nd	nd	0.002±0.001[a]	-
Salad	0.000 - 0.000	nd	nd	nd	nd	nd	nd	0.05*
Sausages	0.000 - 0.036	nd	nd	nd	nd	nd	0.029±0.003[a]	-
Smokies	0.000 - 0.000	nd	nd	nd	nd	nd	nd	-
Sweet potatoes	0.000 - 0.004	-	nd	-	nd	nd	0.002±0.001[a]	0.1

Values are means ± standard deviation. Values in each row with different superscript letters are significantly different ($p<0.05$). nd means not detected. * level of Cadmium in fruiting vegetables (0.05) and bulb vegetables (0.05), ** Level of Cadmium for pulses (0.1) and cereal grains (0.1), (Codex Alimentarius Commission, 2019). MRL is Maximum Recommended Limit. The means in bold are below the MRLs specified.

The level of Cadmium was highest in SVFs sold around the hospital area (0.005 mg/Kg) and Thika town center (0.006 mg/Kg) as shown in Table 6.4. As earlier observed, Thika town center also recorded the highest number of samples contaminated with Cd. In addition, at least one foodstuff was contaminated with cadmium in all study locations except the Juakali area (Table 6.3). This was contrary to our expectations since the Juakali area is an industrial area within Thika Town. This is because, industrial activities and wastes have been identified as anthropogenic sources of cadmium in the environment which could be a major source of contamination in food (Kubier, Wilkin, & Pichler, 2019; Saini & Dhania, 2020). The high levels of contamination of foods with Cadmium in areas around the hospital area and Thika town center could be attributed to the heavy traffic around these places as compared to the Juakali area. Exhaust and non-exhaust vehicle emissions such as brake wear, tire wear, and road wear in urban and motorway road dust have been found to contain Cd, which may contaminate food and the environment (Adamiec, Jarosz-Krzemińska, & Wieszała, 2016; Ferretti *et al.*, 1995). Thus, foods that are not covered adequately during preparation or sold along roads that have heavy traffic may be contaminated with cadmium to a larger extent as compared to those sold further away.

Table 6.4: The level of lead and cadmium in street-vended foods within selected locations in Thika town, Kenya.

Location	Number of samples	Cadmium (mg/Kg)	Lead (mg/Kg)
Hospital Area	30	0.005 ± 0.002^{a}	0.687 ± 0.136^{a}
Juakali Area	33	nd	0.436 ± 0.060^{c}
Kiandutu	30	0.002 ± 0.001^{b}	0.554 ± 0.092^{b}
Makongeni	36	0.001 ± 0.000^{c}	0.410 ± 0.094^{c}
Ngoigwa	36	0.003 ± 0.001^{b}	0.935 ± 0.137^{a}
Thika town center	33	0.006 ± 0.002^{a}	0.570 ± 0.116^{b}

Values are means ± standard deviation. Values in each column with different superscript letters are significantly different ($p<0.05$). nd means not detected.

Although the levels reported in this study were below the MRLs established by Codex Alimentarius Commission (2019) shown in Table 6.3, the presence of Cadmium in foods is a major health concern since there is no treatment for Cadmium poisoning (Ellen & Costa, 2010). Cadmium has been classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans (Group 1), with sufficient evidence for lung cancer (Joint FAO/ WHO Expert Committee on Food Additives, 2011). Excessive intake and long-term exposure to Cadmium have also been reported to cause serious illnesses such as *itai-itai* disease, chemical pneumonitis, and chronic obstructive lung disease (Bolan *et al.*, 2013; Ellen & Costa, 2010; Rahimzadeh *et al.*, 2017). Therefore, its presence in SVFs poses a public health concern considering the huge population of people who frequently consume these foods daily.

6.3.2 Level of lead in the street-vended foods

At least one sample in each food sample type collected was contaminated with Lead (Table 6.2). The level of Lead contamination quantified in street-vended food samples ranged between 0.271±0.07 and 1.891±0.130 mg/Kg. The highest contamination levels were found in groundnuts (1.891 mg/Kg) while the lowest contamination was in fresh fruit juices at 0.271 mg/Kg. All arrowroots, cereal-based foods, groundnuts, sliced watermelons, and sausage samples collected from the different regions were contaminated with Lead (Figure *6.1*). Boiled deshelled eggs were the least contaminated with only 33.3% of all the egg samples analyzed contaminated with Lead.

In contrast to this study, Ezeilo *et al.* (2020) reported higher Lead contamination levels ranging between 1.23 ± 0.01 mg/kg to 10.66 ± 0.01 mg/kg in various fruits and vegetables grown in Anambra State, Nigeria. Similarly, Ankar-Brewoo *et al.* (2020) reported higher Lead levels ranging from 0.9 mg/kg to 18 mg/kg in fried rice and chicken samples in Kumasi, Ghana. Contamination levels quantified in sliced watermelons and sliced pineapples were higher than those reported by Rotimi, Ogunyebi, and Fingesi (2018) who found pineapples and watermelons to contain 0.10 and 0.13 mg/Kg, respectively in a study investigating heavy metal contamination in fruits commonly sold from selected markets in Lagos, Nigeria.

Lead contamination was highest around the hospital area (0.687 mg/Kg) and Ngoigwa (0.935 mg/Kg) as shown in Table 6.4. Juakali area (0.436 mg/Kg) and Makongeni area (0.410 mg/Kg) recorded the lowest contamination levels which were significantly ($p<0.0001$) lower than all other study areas. At least one street-vended food sample in each food type was reported to contain Lead in all study locations (Table 6.5). Eggs were the least contaminated food type with contamination only reported around the hospital area and Kiandutu area. SVFs were most contaminated with Lead in the Ngoigwa area, with arrowroots, french fries, groundnuts, sliced pineapples, salad, smokies, and sweet potatoes having the highest contamination levels.

Table 6.5: Lead contamination levels (mg/Kg) in different street-vended food samples within different study locations in Thika town, Kenya.

Food type	Range (mg/Kg)	Study area						
		Hospital area	Juakali area	Kiandutu	Makongeni	Ngoigwa	Thika town center	Limits
Arrow roots	0.331 - 0.842	-	-	-	0.354±0.011[b]	0.762±0.04[a]	-	0.1
Cereal based	0.194 - 0.994	0.423±0.039[c]	0.644±0.012[b]	0.962±0.017[a]	0.202±0.007[d]	0.635±0.026[b]	0.616±0.046[b]	0.1-0.2[+++]
Boiled deshelled eggs	0.000 - 2.391	2.302±0.058[a]	nd	0.348±0.009[b]	nd	nd	nd	0.1*
French fries	0.000 - 1.472	0.182±0.058[b]	0.14±0.037[b]	nd	nd	1.402±0.041[a]	1.342±0.049[a]	0.1
Ground nuts	0.937 - 2.986	1.766±0.087[c]	1.026±0.048[d]	1.674±0.081[c]	1.928±0.08b[c]	2.75±0.118[a]	2.205±0.074[b]	-
Juice	0.000 - 0.815	0.77±0.023[a]	0.462±0.059[b]	0.373±0.006[b]	0.019±0.014[c]	nd	nd	0.03
Sliced watermelons	0.092 - 1.180	0.321±0.024[c]	0.128±0.02[d]	0.598±0.004[b]	1.118±0.039[a]	0.446±0.042[c]	0.186±0.02[d]	0.1
Sliced pineapple	0.000 - 0.588	nd	0.38±0.039[b]	0.008±0.008[c]	0.511±0.004[a]	0.567±0.01[a]	0.545±0.002[a]	0.1
Salad	0.000 - 2.448	0.22±0.043[c]	nd	0.221±0.01[c]	nd	2.347±0.079[a]	0.497±0.005[b]	0.05–.1[+]
Sausages	0.052 - 0.955	0.061±0.007[c]	0.92±0.03[a]	0.354±0.027[c]	0.467±0.026[c]	0.727±0.034[b]	0.831±0.048[ab]	0.1[++]
Smokies	0.000 - 1.003	0.825±0.046[a]	0.455±0.05[b]	1±0.003[a]	0.323±0.015[b]	0.857±0.073[a]	nd	0.1[++]
Sweet potatoes	0.000 - 0.758	-	0.638±0.018[b]	-	nd	0.734±0.014[a]	0.053±0.011[c]	0.1

Values are means ± standard deviation. Values in each row with different superscript letters are significantly different ($p<0.05$). nd means not detected. * Level suggested by the Joint FAO/WHO food standards programme (2021). [+] Range given for fruiting vegetables (0.05) and bulb vegetables (0.1), [++] Level set for meat from poultry, cattle, pigs, and sheep, [+++] Range taken for pulses (0.1) and cereal grains (0.2), (Codex Alimentarius Commission, 2019).

Atter *et al.* (2015) reported Lead contamination levels averaging between 0.34 to 1.25 mg/Kg in a street-vended traditional maize beverage sold in Ghana. Ekhator *et al.* (2017) reported Lead contamination levels ranging between 0.014 - 1.37mg/kg in SVFs consumed in Mid-West Nigeria. These levels are high and comparable to the contamination levels reported in our study. The high levels of contamination of foods with Lead in areas around the hospital and Ngoigwa could be attributed to the heavy traffic around these places. Exhaust and non-exhaust vehicle emissions in urban and motorway road dust have been found to contain Lead, which may contaminate food and the environment (Adamiec *et al.*, 2016; Ferretti *et al.*, 1995). The low contamination reported in eggs could be because eggs were deshelled before sampling was carried out. Eggshells have been reported to be an avenue for the excretion of lead in birds (Burger, 1994; Trampel *et al.*, 2003). Thus, contamination with Lead that was possibly in the shell may have been removed when the eggs were deshelled.

Plant-based foods had significantly higher Lead contamination levels compared to animal-based foods as shown in Figure 6.2. The sources of Lead in the environment are both natural and anthropogenic (Davis *et al.*, 2009). The contamination in foods may originate from vehicle exhaust emissions and contaminated soils which in turn contaminate plant-based foods and feeds, with the latter contaminating animal-based food products when animals consume the contaminated feeds (FDA, 2020). Researchers have reported widespread contamination of soil, water, and food in Kenya. According to research conducted in Kisumu, Kenya, Makokha *et al.* (2008) discovered that lead contamination was prevalent in soil, drinking water, vegetables, and fish. In addition, industrial pollution with heavy metals has also been reported. For instance, Kinuthia *et al.* (2020) in a study investigating levels of heavy metals in wastewater soil samples collected from open drainage channels in Nairobi, Kenya reported Lead levels in wastewater above Kenya's allowable limits of 0.01 mg/kg. Furthermore, Kinuthia *et al.* (2020) also reported that the soil was also contaminated with Lead above the WHO limits (0.1 mg/kg) for agricultural soils. This may explain the high level of lead in plant-based foods such as groundnuts that may absorb the metal whenever the soil is contaminated. These contaminated discharges are released into the waterways further resulting in the contamination of water and irrigated lands (Kinuthia *et al.*, 2020). As a consequence, foods prepared using contaminated water or plants irrigated with contaminated water will have heavy metal residues. Thus, street-vended foods could have been prepared from contaminated raw materials or water, or exposed to contaminated dust when left uncovered during the sale in areas that have heavy traffic.

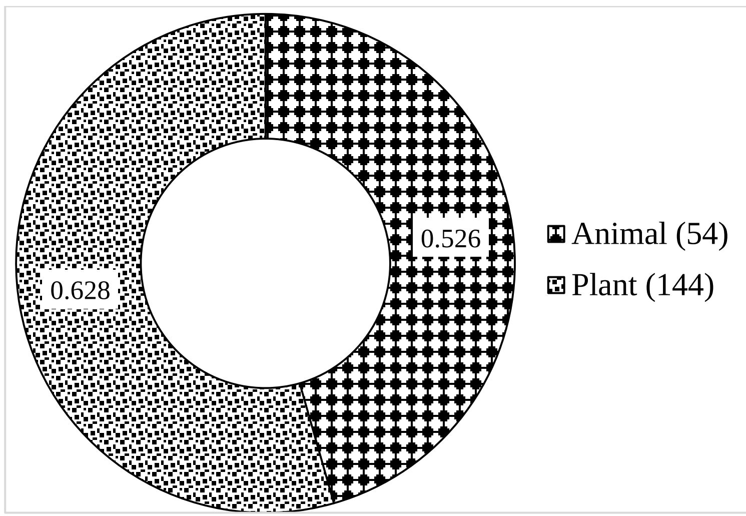


Figure 6.2: Mean lead contamination levels in animal and plant-based street-vended food products. The number of samples is indicated in brackets.

On average, all of the street-vended food samples analyzed were above the MRL (0.03 mg/Kg) suggested by the Joint FAO/WHO food standards programme (2021) for RTE foods intended for infants and young children regarding Lead contamination. As shown in Figure 6.3, 78.79% of all food samples had Lead within detectable levels of which 77.78% had Lead levels above the MRL suggested by the Joint FAO/WHO food standards programme (2021) for RTE foods intended for infants and young children. This poses serious public health concerns considering that children are among the many consumers of street-vended foods.

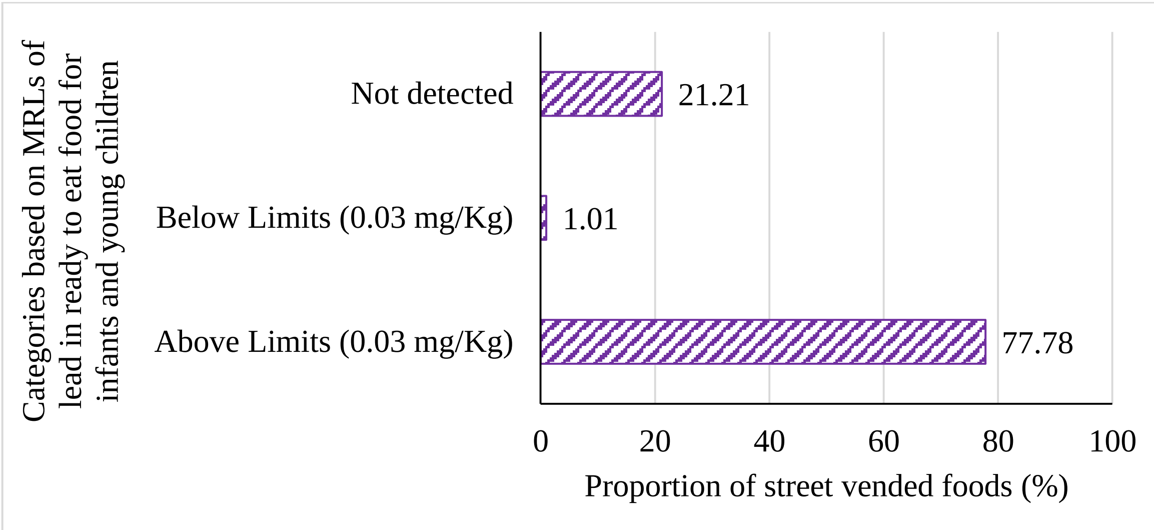


Figure 6.3: Lead contamination levels in street-vended foods compared to the limits suggested by the Joint FAO/WHO food standards programme (2021) for RTE foods for infants and young children.

Like many other heavy metals, Lead is not biodegradable and thus it does not disappear from the environment over time (FDA, 2020). Furthermore, Lead builds up in the body over time, and thus, even low-level exposure over time can be dangerous (FDA, 2020; Naranjo, Hendricks, & Jones, 2020). Infants, young children, pregnant women, and their fetuses, and individuals with chronic health issues are particularly vulnerable to Lead poisoning (FDA, 2020). According to Dobaradaran *et al.* (2010), Lead is toxic even at a trace level. Lead may cause renal failure, liver damage, impaired hearing, mental retardation, and shortened gestation in humans (Ankar-Brewoo *et al.*, 2020; Islam *et al.*, 2014). In children, it can cause adverse and permanent neurodevelopmental problems resulting in learning deficits, behavioral problems, and a lower IQ in early childhood (FDA, 2020; Naranjo *et al.*, 2020). Lead

6.4 Conclusion

The vast majority of samples analyzed in this study had Lead contamination levels exceeding the MRLs suggested by the Joint FAO/WHO food standards programme. At least one of the food sample types was contaminated with Lead, with the highest contamination levels being observed in groundnuts. In addition, at least one foodstuff was contaminated with Cadmium in all study locations except the Juakali area. The presence of Lead and Cadmium in SVFs poses a public health concern considering the huge population of people who consume these foods daily. Furthermore, these heavy metals can bioaccumulate in the body posing health risks later in life. Thus, there is a need for continuous monitoring of SVFs to increase awareness of heavy metal contamination in the food chain. Furthermore, the establishment and enforcement of policies to govern the SVFs businesses aimed at reducing heavy metal contamination are recommended.

CHAPTER SEVEN

DETERMINATION OF ACRYLAMIDE IN STREET-VENDED FRENCH FRIES

7.1 Introduction

Acrylamide can be formed in starchy foods through the Maillard reaction, a process that requires two precursors; free amino acid (asparagine) and reducing sugars (glucose) (Mencin *et al.*, 2020; Quan *et al.*, 2020; Žilić *et al.*, 2020). When food is heated, carbonyl-containing compounds may interact with amino groups, especially from amino acid asparagine to produce acrylamide. Acrylamide forms in food when they are subjected to high processing temperatures of greater than 120°C. Therefore, higher levels of this compound may be found in fried, deep-fat fried, and baked food products (Mencin *et al.*, 2020). Besides potatoes and coffee, cereal products that have been processed through frying, roasting or baking may have high levels of acrylamide (Žilić *et al.*, 2020). In street-vended products, few researchers have reported the levels of acrylamide. Ogolla *et al.* (2015) reported high levels of acrylamide (8556.8-9728.1 µg/kg) in especially street-vended potato crisps in Nairobi, Kenya. A study estimating acrylamide intake amongst young people found the highest contamination in pizza and French fries (Altissimi *et al.*, 2017), foods that rank highest in this category of people.

Street food vendors have been reported to heat foods for an extended period (Abong & Kabira, 2015) which has a potential for the development of toxic compounds in street-vended foods. Frying which is employed by most street food vendors has been reported as a cooking process that can generate a wide variety of toxic contaminants in food (Kamboj *et al.*, 2020). One of the commonest process contaminants of interest in street-vended foods is acrylamide (Imathiu, 2017; Kamboj *et al.*, 2020; Sen, 2018). These process contaminants have been linked to causes of non-communicable diseases such as cancer whose prevalence in Kenya is on the rise (Abong & Kabira, 2015). Acrylamide is a powerful neurotoxin and possesses mutagenic and carcinogenic properties (Navarro *et al.*, 2017; Quan *et al.*, 2020). It is classified by the International Agency for Research on

Cancer as a Group 2A agent, indicating an agent that is probably carcinogenic to humans, (Kuek *et al.*, 2020; Mencin *et al.*, 2020). However, the number and amount of these chemicals and toxins that make it into the food supply and eventually into ready-to-eat foods is unknown (WHO, 2015). Thus, this study aimed to determine the presence of acrylamide in street-vended french fries sold in selected locations within Thika town, Kiambu County, Kenya.

7.2 Materials and methods

7.2.1 Study site

A cross-sectional study was conducted on SFVs in six street food vending locations in Kiambu County, Kenya as described in subheading 3.2.1.

7.2.2 Sampling

A total of 18 street-vended french fries samples were randomly collected from the six study locations. Approximately 200 grams were collected and immediately transferred into a cooler box (4^oC) and transported to the laboratory for analysis.

7.2.3 Preparation of chemicals and standard curves

Analytical grade acetonitrile, acetone, methanol, and acetic acid were used during this analysis. Acrylamide standard was procured from Sigma Aldrich (Germany) while potassium hexacyanoferrate (Carrez I (15 g in 100mL distilled water)) and zinc sulfate (Carrez II (30 g in 100mL distilled water)) were obtained from Merck (Germany). Acrylamide stock solution (1 mg/mL) was prepared using distilled water. Dilution of the stock solution was done to obtain the working standards (0.5, 1.0, 3.0, 5.0, and 8.0 µg/mL) for the calibration curve.

7.2.4 Sample preparation, extraction, and analysis procedure

All french fries samples were first dried in a hot air oven at 60^oC for 24 hours and then ground into a powder using an MRC laboratory grinder (Model SM-450). The powder obtained was used for all analyses. Sample extraction and analysis were done following the procedure outlined by Ghalebi, Hamidi, and Nemati (2019). One gram of finely ground dried french fries was weighted and mixed well with 10 mL of acetone in a 15 mL centrifuge tube. The resulting solution was centrifuged at 10,000 rpm for 10 min at 10 °C using a centrifuge (Eppendorf 5430R). The supernatant was carefully transferred into another test tube and treated with Carrez I (15 g potassium hexacyanoferrate in 100ml distilled water) and Carrez II (30g zinc sulfate in 100ml distilled water) solutions to isolate the co-extractives. Carrez solutions are useful in purifying the extract from colloids as well as helping to prevent acrylamide evaporation during the evaporation process. The sample was then centrifuged again at 10,000 rpm at 10°C for 10 min. The resulting supernatant was carefully transferred into a conical flask and placed in a rotary vacuum evaporator until dry. The remaining residue was then dissolved in 4 mL of acidified water (pH 3) and vortexed for 2 min. The solution obtained was afterward filtered through a 0.45 µm syringe filter. For quantification, 20 µL of the final solution was injected into the HPLC system fitted with a C18 column (15 × 4.6 mm × 5µm) and a diode array detector (DAD), (Agilent 1100, Waldbronn, Germany) set at 222nm. The flow rate of the mobile phase (0.1% acetic acid in HPLC grade water) was adjusted to 1.0 mL/min with a run time of 20 min.

7.2.5 Daily consumption level for french fries

This study did not determine the consumption level of french fries in Thika town, Kenya. Therefore, for purposes of calculating estimated exposure levels and the margin of exposure to acrylamide, the daily french-fries consumption data presented by George *et al.* (2021) who were studying the levels of acrylamide intake in Nairobi, Kenya was adopted. In their study, a plate of french fries was found to be equivalent to 311 g. Respondents in their study were reported to often purchase a single full plate of french fries. For purposes of comparing exposure to young children and adults, adults (weighing 60 Kg) were assumed to be consuming a full plate equivalent to 311 g while children (20 kg) would consume half the plate equivalent to 155 g. Estimated weight for children at 5 years of age was determined using the formula provided by Tinning and Acworth (2007): Weight (kg) = 2 x (age in years + 5).

7.2.6 Data analysis

Data were analyzed using statistical analysis system (SAS) version 9.4 to perform an analysis of variance and means separated using the least significant difference (LSD) test. Significance was established at a $p < 0.05$ level of significance. Results were reported as mean ± standard deviation. The margin of exposure was calculated using Equation 8.1 where D_e is the acrylamide dietary exposure (μg/kg BW/day), and $BMDL_{10}$ is the benchmark dose lower limit of 10% (μg/kg BW/day) provided by Nematollahi *et al.* (2020).

$$Margin\ of\ exposure\ (MOE) = \frac{BMDL_{10}}{D_e}$$ …………………………. Equation 7.1

The estimation of margin of exposure (MOE) was based on the lower limit on the benchmark dose for a 10% response ($BMDL_{10}$) of 0.31 mg/kg BW/day for mammary tumors in rats and 0.18 mg/kg BW/day for Harderian gland tumors in mice (Joint FAO/WHO Expert Committee on Food Additives, 2011). Higher MOEs mean that there is a lower risk of a given contaminant while a lower MOE value means there is a higher risk posed to the consumers (George *et al.*, 2021).

7.3 Results and discussion

7.3.1 Level of acrylamide in street-vended french fries

The mean acrylamide level for the street-vended french fries that were obtained randomly from selected locations in Thika town was 0.558±0.128 μg/g. The highest acrylamide level was found in the Kiandutu slums area, while the lowest acrylamide level was in french fries collected around Thika Level 5 hospital area. High variability in the amounts of acrylamide was seen for these streets vended french fries, which ranged from 0.333 μg/g to 0.764 μg/g (Figure 7.1). These average levels of acrylamide were higher compared to the average level (0.354 μg/g) reported in french-fries sold in the streets of Nairobi, Kenya by George *et al.* (2021) and in Spain (0.329 μg/kg) by Mesias *et al.* (2020) who studied the level of acrylamide in french fries prepared in 31 primary school canteens.

Acrylamide in fried products varies considerably depending on the variety of potatoes used, storage and handling methods as well as processing methods, and process parameters (George *et al.*, 2021). The level of reducing sugars and asparagine in potatoes has been linked to acrylamide formation in fried potatoes, with lower levels resulting in lower acrylamide formation (Becalski *et al.*, 2004; Pedreschi, Kaack, & Granby, 2008; Wang *et al.*, 2021). Storage of potatoes for a long period generates reducing sugars which may also contribute to high levels of acrylamide in french fries if the potatoes are used (Foot *et al.*, 2007). Burnt or dark golden-colored food products have been found to possess higher levels of acrylamide as compared to lightly colored products (Mesias *et al.*, 2020). Other factors such as the level of free fatty acids, oil types and the number of frying cycles (Kuek *et al.*, 2020), cooking time, and frying temperature (Pedreschi *et al.*, 2007; Romani *et al.*, 2009), as well as pretreatments such as immersion in a citric acid solution, have been reported to potentially influence the levels of acrylamide in fried french fries. These factors may explain the variation in the levels of acrylamide reported in different locations owing to the huge diversity in preparation and handling practices among street food vendors reported earlier in this study(Section 3.0).

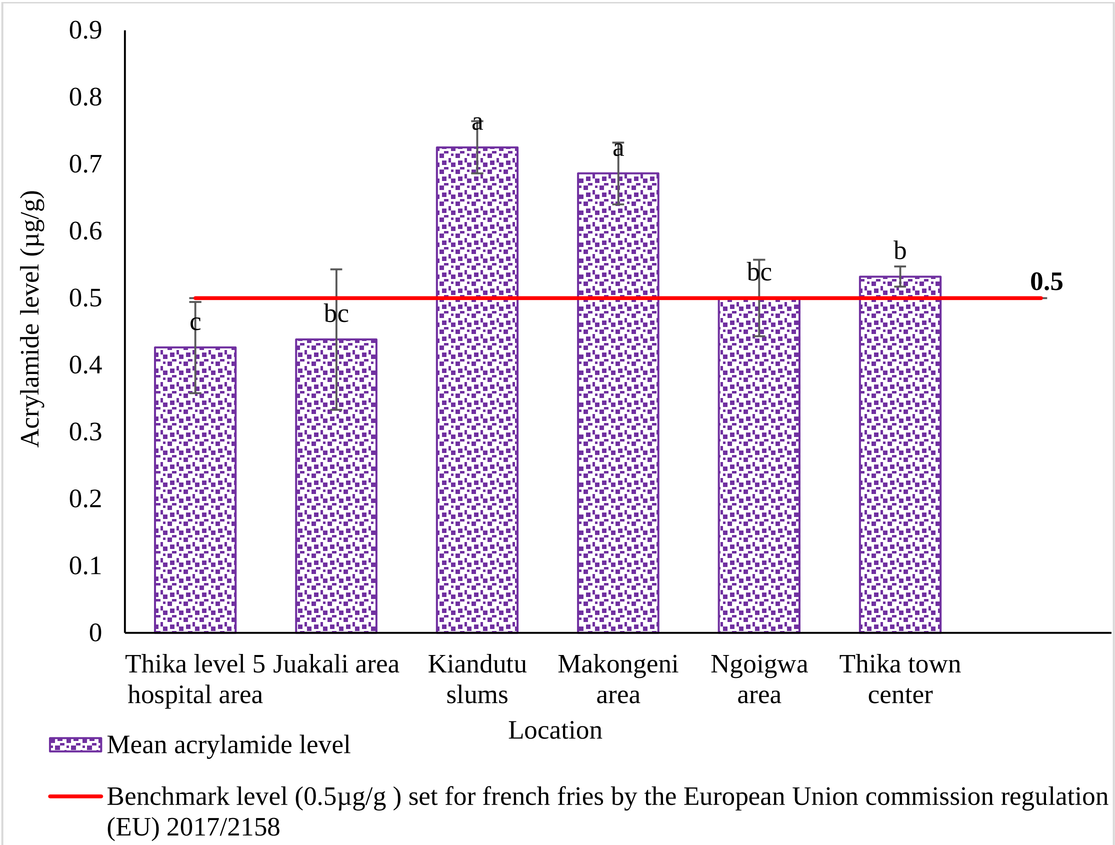


Figure 7.1: Level of acrylamide in street-vended french fries sold in Thika Town, Kenya.

The benchmark level for acrylamide in ready-to-eat french fries as set by the European Union Commission (Article 6 Regulation 2017/2158) is 0.5 µg/g. At least one food sample in all locations had acrylamide levels above this benchmark level, except in Thika Level 5 hospital area. In addition, 33% of all street-vended french fries had acrylamide levels above the allowable limits by the EU regulation. Higher levels of contaminated french fries were reported in a study in Ethiopia, where 40% of french fries surpassed the levels recommended by the EU (Deribew & Woldegiorgis, 2021). This shows that the french fries sold in Thika town pose a health risk due to the higher levels of acrylamide contamination. Intervention strategies designed to help reduce contamination levels during food preparation should be implemented to reduce production and exposure to consumers.

7.3.2 Estimation of the dietary exposure to acrylamide in Thika Town

The dietary exposure to acrylamide was found to be highest in the Kiandutu slums and lowest in the Thika Level 5 hospital area (Figure 7.2). Intake levels (from half a plate of french fries (155g)) were found to be higher than the stated tolerable daily intake level (2.6 µg/kg BW/day) for children (5 years, 20 kg BW) to avoid acrylamide carcinogenic effects (Mencin *et al.*, 2020). Kiandutu slums and Makongeni areas had as much as two-fold the stated tolerable daily intake level. The high levels of acrylamide intake may be due to the nature of the potato variety used, the storage practices, or processing practices that increase the level of acrylamide in french fries. This reveals the high risk posed to children who consume street-vended french-fries daily. This is a health concern considering acrylamide is both carcinogenic and genotoxic.

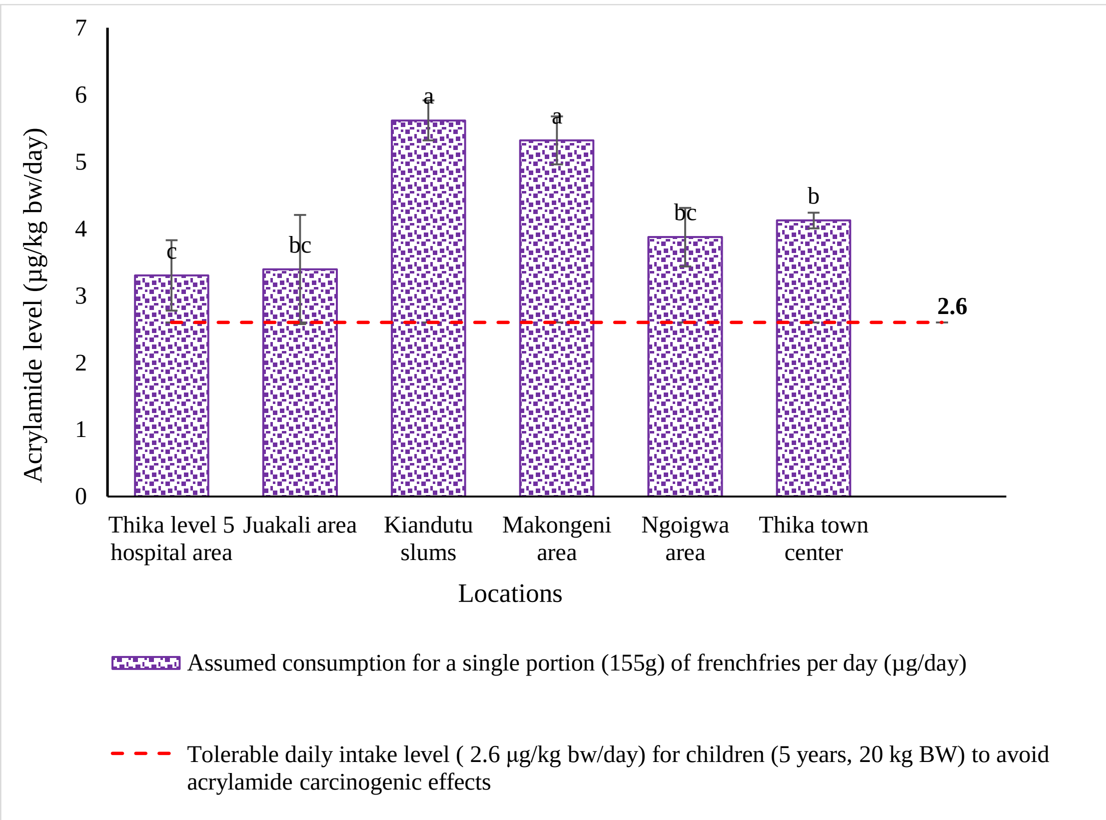


Figure 7.2: Dietary exposure to acrylamide among children (5 Years) in Thika Town Kenya.

Intake levels for acrylamide for adults (assuming consumption of a full plate of french fries (311g)) were highest in both Kiandutu slums and Makongeni areas (Figure 7.3). All locations had at least one food sample whose acrylamide levels exceeded the tolerable daily intake level for the assumed consumption level for adults except Thika Level 5 hospital area. Although the risk is still high for adults since over 66% of samples exceeded the TDI level for the assumed consumption level, children are exposed to much greater risk when consuming these street vended french fries. The TDI of acrylamide to avoid its neurotoxicity estimated at 40 µg/kg bw/day, was not reached for both children (Figure 7.2) and adults (Figure 7.3).

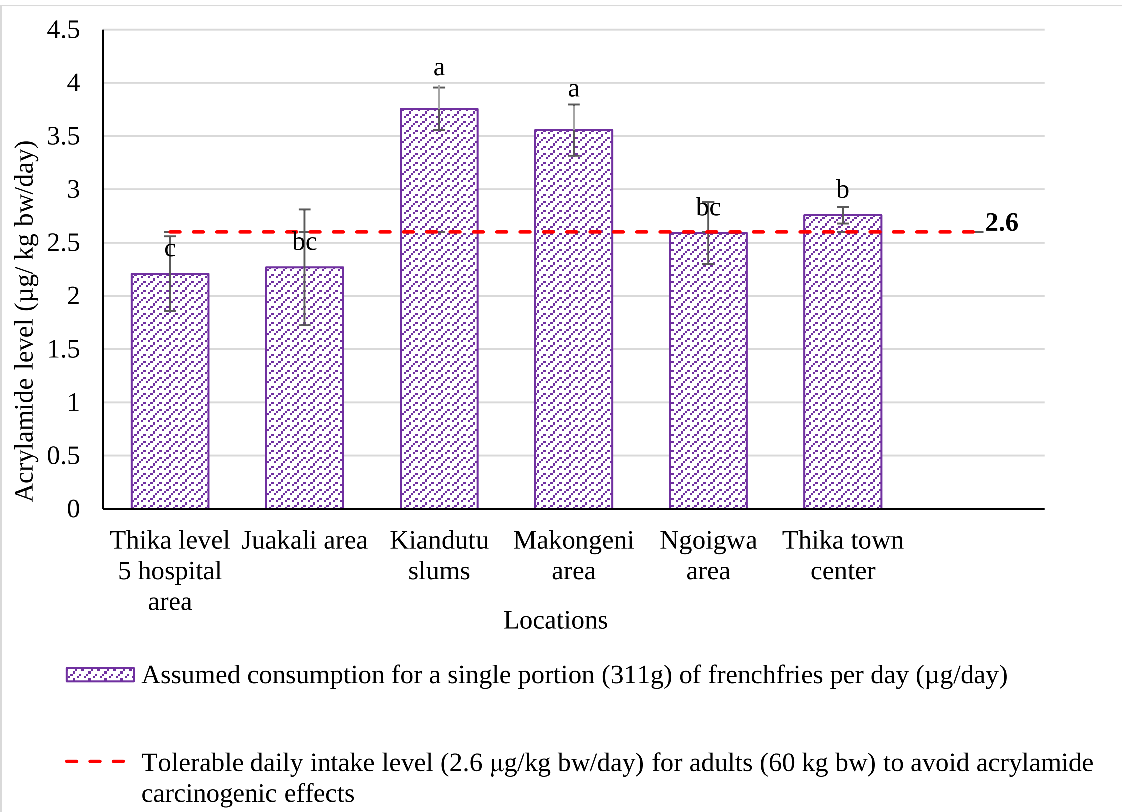


Figure 7.3: Estimated dietary exposure to acrylamide among adults (weighing 60kg) in Thika Town, Kenya.

Table 7.1: Margin of exposure to acrylamide in street-vended french fries sold in Thika Town, Kenya.

		Thika Level 5 Hospital area	Juakali Area	Kiandutu slums	Makongeni area	Ngoigwa area	Thika Town Center
Children (5 years, BW=20Kg, consuming 155g of french fries per day)	Acrylamide exposure (µg/kg bw/day)	3.300	3.391	5.616	5.318	3.874	4.122
	MOE ($BMDL_{10}$ = 180 µg/kg BW per day)	54.540	53.076	32.054	33.845	46.470	43.670
	MOE ($BMDL_{10}$ = 310 µg/kg BW per day)	93.929	91.409	55.203	58.289	80.031	75.209
Adults (60 Kg, consuming 311g of french fries per day)	Acrylamide exposure (µg/kg bw/day)	2.207	2.268	3.756	3.557	2.591	2.757
	MOE ([a]$BMDL_{10}$ = 180 µg/kg BW per day)	81.547	79.358	47.926	50.604	69.480	65.294
	MOE ([b]$BMDL_{10}$ = 310 µg/kg BW per day)	140.442	136.672	82.539	87.152	119.660	112.451

MOE – Margin of exposure, [a]$BMDL_{10,}$ and [b]$BMDL_{10}$ - Benchmark dose for a 10% response of 0.18 mg/kg body weight (BW) per day for Harderian gland tumors in mice and 0.31 mg/kg BW per day for mammary tumors in rats, respectively (Joint FAO/WHO Expert Committee on Food Additives, 2011).

7.3.3 The margin of exposure to acrylamide in street-vended french fries

Dose-response modeling using exposure studies has been employed by the Joint FAO/WHO Expert Committee on Food Additives, to evaluate exposure-related effects and to derive points of departure (POD) for the estimation of margin of exposure (MOE) to acrylamide (Joint FAO/ WHO Expert Committee on Food Additives, 2011). The estimation of the margin of exposure was based on the lower limit on the benchmark dose for a 10% response ($BMDL_{10}$) of 0.31 mg/kg BW per day for the development of mammary tumors in rats and 0.18 mg/kg BW per day for Harderian gland tumors in mice (Joint FAO/WHO Expert Committee on Food Additives, 2011). Considering the possibility of the development of mammary tumors in rats, the Joint FAO/WHO Expert Committee on Food Additives (2011) reported that margins of exposure; 310 and 78 for average and high dietary exposures, respectively indicate a health concern since acrylamide is both genotoxic and carcinogenic (Kuek *et al.*, 2020; Mencin *et al.*, 2020). Similarly, in the case of the development of harderian gland tumors in mice, MOEs; 180 and 45 for average and high exposures, respectively indicate a health concern to human beings.

The margin of exposure to acrylamide from street-vended french fries was found to be extremely low between 32-54 and 55-94 in children for Harderian gland and mammary tumor induction endpoints, respectively (Table 7.1). Amongst the adults, the margin of exposure was between 47-81 and 82-140 for an adult averaging 60kg in weight for Harderian gland and mammary tumor induction endpoints respectively. All study locations revealed MOEs below 141 in both adults and children. In a study on acrylamide intake in Nairobi, Kenya, George *et al.* (2021) reported the margins of exposure for street-vended french fries to be 260. Although these authors' margins were lower than 310, indicating a health risk to consumers, this study revealed even lower MOEs. This shows that there is even a greater risk posed to consumers of french fries in the area of study. An even greater risk is posed to children who may consume these street-vended french fries daily.

7.4 Conclusion

This study estimated the level of acrylamide in street-vended french fries where the mean level was found to be higher than the EU benchmark value. Intake levels of acrylamide were found to be higher than the stated tolerable daily intake level for children in all locations. For the adults, over 66% of samples exceeded the TDI level for the assumed consumption level. The margin of exposure to acrylamide from street-vended french fries was found to be extremely low in both adults and children in all locations. This shows that the consumption of street-vended french fries in some locations within Thika town poses a great risk to the health of street-vended french fries consumers. An even greater risk is posed to children who consume these street-vended french fries daily. The high exposures reported in this study, especially in children are a major health concern and calls for the training of street food vendors on strategies such as decreasing the frying temperatures, cooking to a lighter color, or selecting potato varieties that are low in precursors of acrylamide to minimize the risk of exposure to acrylamide through street-vended french fries in Kenya. However, research is required to provide information on the varieties of potatoes that are low in precursors of acrylamide.

CHAPTER EIGHT

DETERMINATION OF AFLATOXIN IN GROUNDNUTS AND CEREAL-BASED STREET-VENDED FOODS

8.1 Introduction

Mycotoxins are secondary metabolites of a variety of mold species that produce toxins with adverse health effects on humans, resulting mostly in acute and chronic illnesses called mycotoxicoses (Peles *et al.*, 2019; Sombie *et al.*, 2018). Among the mycotoxins of the greatest health and economic importance are aflatoxins (Hussein & Brasel, 2001; Sombie *et al.*, 2018). Aflatoxins are produced by some strains of *Aspergillus flavus*, *Aspergillus parasiticus,* and *Aspergillus nomius*. There are four main aflatoxin types (B_1, B_2, G_1, G_2) and two more (M_1, M_2) that are produced by animals through milk after metabolizing the main four types (Bullerman, 2003).

A wide range of food commodities including cereals especially maize and maize products, rice, sorghum, millet, cassava, yams, beer, and animal products; dairy products, dried fish, meat, and eggs have been implicated in mycotoxin contamination (Omara *et al.*, 2021; Peles *et al.*, 2019; Rubert *et al.*, 2013). In street-vended foods, aflatoxins were reported in corn, groundnut, coconut, tiger nut, walnut, and wheat snacks among other street-vended products in Nigeria and Congo (Ezekiel *et al.*, 2012; Kamika & Takoy, 2011). In Kenya, there is limited research on mycotoxin contamination in street-vended RTE foodstuffs. Nevertheless, aflatoxins and aflatoxicosis incidences have been reported involving foodstuffs (Daniel *et al.*, 2011; Mutiga *et al.*, 2015; Probst *et al.*, 2007). In Kenya, at least 500 acute human illnesses as well as 200 deaths due to aflatoxins have been reported (Omara *et al.*, 2021). Recently, aflatoxin was reported in ready-to-eat peanut butter in Kenya (Merab, 2019).

Cereals as well as groundnuts form a substantial part of street-vended foods (Haleegoah *et al.*, 2015). Many researchers have reported the presence of mycotoxigenic fungi and the presence of mycotoxins in especially cereals and nuts (Elzupir, 2019; Oranusi & Olorunfemi, 2011; Rubert *et al.*, 2013). Food contamination with mycotoxins such as aflatoxin may occur at various points along the food chain if conditions such as temperature and moisture are suitable for mycotoxin production (Asemoloye *et al.*, 2017). This can be during the pre-harvest, harvest, drying, or storage period for the raw materials used in making ready-to-eat food (Adetunji *et al.*, 2018; Asemoloye *et al.*, 2017; Temba, Njobeh, & Kayitesi, 2017). Contamination may also result from the use of additives in food processing. For instance, spices may be contaminated with aflatoxins (Jonathan, Adeniyi, & Asemoloye, 2016) which may end up in processed foods.

Consumption of food that contains mycotoxins may cause serious health complications in humans. Mycotoxins such as aflatoxins are known to be hepatotoxic, carcinogenic, genotoxic, nephrotoxic, teratogenic, and immunosuppressive. They are also capable of causing bile-duct hyperplasia as well as hemorrhage in the intestinal tract and the kidneys (Bullerman, 2003; Omara *et al.*, 2021; Temba *et al.*, 2017). Aflatoxin exposure among school children in Kenya, who form a substantial part of street food consumers has been reported as a potential cause of chronic hepatomegaly (Gong *et al.*, 2012).

The risks associated with mycotoxins have a huge economic impact which strongly supports the need for further research in this area (Asemoloye *et al.*, 2017; Peles *et al.*, 2019). Thus, there is a need for the analysis of street-vended foods to identify the levels of aflatoxin contamination. This study aimed to determine the presence of aflatoxin in street-vended foods sold in selected locations in Thika town.

8.2 Materials and methods

8.2.1 Study location

This study was carried out in six street food selling locations including Thika Level 5 Hospital area, Juakali area, Kiandutu area, Makongeni area, Ngoigwa area, and Thika Town Center in Thika town. Sample analysis for aflatoxin was carried out at the Kenya Bureau of Standards (KEBs) laboratory.

8.2.2 Sampling

A total of 36 street-vended food samples consisting of cereal-based (maize mixed with a variety of legumes) foods (18) and groundnuts (18) were randomly collected from the six study locations. Approximately 200 grams were collected from each street food vendor and bagged in a sterile sample bag. Samples were immediately transferred into a cooler box (4^{o}C) and transported to the laboratory for analysis.

8.2.3 Determination of moisture content of street-vended food samples

Determination of moisture content was done using the standard oven drying method. Approximately 5 g of each sample was weighed after grinding and placed in a drying oven at 105°C for 3 hours. The sample was then cooled in a desiccator and weighed again taking care not to expose the sample to the atmosphere. Moisture content was calculated and reported as the percentage of the wet sample.

8.2.4 Screening for aflatoxins in cereals and groundnuts using NEOGEN®'s Reveal® Q+ for Aflatoxin test kit

The screening was carried out using NEOGEN®'s Reveal® Q+ for the Aflatoxin test kit following the manufacturer’s instructions. Dried samples were ground using an MRC laboratory grinder (Model SM-450). Ten grams of the ground material were weighed into an extraction cup and 125 ml of 65% ethanol solution was added. The mixture was vigorously shaken by hand for 3 min and allowed to settle. Filtration followed using Whatman No. 4 filter paper to collect 3 mL filtrate into a sample collection tube. A new Reveal Q+ for the Aflatoxin test strip was inserted into the sample cup and allowed to stand for 6 min. The test strip was withdrawn from the sample cup and immediately read using the AccuScan reader.

8.2.5 Determination of aflatoxin B1 and total aflatoxin in cereals, nuts, and derived products by competitive direct enzyme-linked immunosorbent assay

8.2.5.1 Sample extraction and analysis

Determinations were carried out using enzyme-linked immunosorbent assay (ELISA) testing kits (Helica Biosystems, USA) for total aflatoxin and aflatoxin B1 levels, following the manufacturer's instructions. Preparation and analysis of the groundnut samples were carried out at room temperature. A 20 g ground (capable of passing through a 20 mesh screen) portion of the ground nuts sample was accurately weighed into a test tube into which 100 ml of 70% methanol in distilled water was added for the extraction process. This mixture was shaken for 2 min and then filtered through a Whatman No.1 filter paper to obtain 5 – 10 ml of the filtrate. The extract obtained was used in the testing process.

The appropriate number of mixing wells for all the samples and standards were placed into a microtitre wells holder. In addition, two antibody-coated wells were set in place for each sample or standard. Test wells were correctly labeled for standards and samples to be tested. Then**,** 200 µL of the enzyme conjugate was pipetted into each mixing well and 100 µL of standards and samples were added to the respective mixing wells. For each addition, mixing was achieved by priming the pipettor at least 3 times. Using a new pipette tip for each sample or standard, 100 µL of contents from each mixing well was transferred to a corresponding labeled antibody-coated well after which incubation was done for 15 min. Afterward, the contents of the antibody-coated wells were appropriately discarded. Then, the antibody-coated wells were filled with the manufacturer's wash buffer solution, and the contents were also discarded. The washing process using the wash buffer was then repeated four more times. After the final wash, the antibody-coated wells were carefully inverted and tapped onto absorbent paper to remove the remaining wash buffer solution. Afterward, 100 µL of the substrate was transferred into each antibody-coated well, covered to avoid direct light, and incubation was carried out at room temperature for 5 min. Finally, 100 µL of stop solution was transferred into each test well in the same sequence and pace as the substrate. Then optical densities of each antibody-coated well were read at 450 nm using a microtitre plate reader.

8.2.6 Data analysis

Data were analyzed using statistical analysis system (SAS) version 9.4 to perform an analysis of variance and means separated using Tukey's HSD (honestly significant difference) test. Significance was established at a $P < 0.05$. Results were reported as mean ± standard deviation for all samples.

8.3 Results and discussion

8.3.1 Moisture level in street-vended groundnuts

Moisture levels in stored groundnuts have also been reported as a risk factor for the production of aflatoxins (Hell & Mutegi, 2011; Mutegi *et al.*, 2013). However, in this study, no link could be established between the moisture level in groundnuts and the level of aflatoxin present in the samples. Groundnuts in this study had moisture levels between 0.8 to 3.7% for the six study locations (Table 8.1).

There was no significant linear correlation between the moisture level in groundnuts and the total aflatoxin ($r = 0.026$, $p = 0.92$) or aflatoxin B1 ($r = -0.035$, $p = 0.89$) levels reported. Similar findings were reported by Hlashwayo (2018) who found no relationship between high levels of aflatoxin B1 ($\chi^2 = 0.04$, $p = 0.85$) in groundnuts and the moisture level of the groundnuts. Although many fungal strains have the capability of producing mycotoxins, they may not do so until many conditions are met. Despite the availability of moisture, other physical, chemical, and biological factors may also affect toxin production (Asemoloye *et al.*, 2017). Thus, higher moisture levels may not always be indicative of high aflatoxin levels in food samples.

Table 8.1: The moisture level in street-vended cereal-based foods and groundnuts.

Location	Cereal-based foods (%)	Ground nuts (%)
Thika level 5 hospital area	66.293±2.823[a]	0.877±0.160[a]
Juakali area	64.910±0.130[a]	1.497±0.463[a]
Kiandutu slums	64.670±4.964[a]	3.758±2.854[a]
Makongeni area	68.630±1.011[a]	1.270±0.632[a]
Ngoigwa area	71.397±1.689[a]	1.162±0.461[a]
Thika town center	65.763±5.406[a]	1.702±0.456[a]

Values are means ± standard deviation. Values in each column with different superscript letters are significantly different ($p<0.05$).

8.3.2 Screening for aflatoxins in cereal-based foods and groundnuts

The results for screening cereal-based foods and groundnuts for aflatoxins are shown in

Table 8.2. All cereal-based food samples had aflatoxin levels below the detectable level (limit of detection = 0.002 µg/g) while 83.3% of all groundnuts had aflatoxin levels above the detection level according to the NEOGEN®'s Reveal® Q+ for Aflatoxin test kit. All samples showing the presence of aflatoxins were subjected to the competitive direct enzyme-linked immunosorbent assay (ELISA) test for quantification.

Table 8.2: Proportion of samples contaminated with aflatoxin in street-vended cereal-based foods and groundnuts.

Location	Cereal-based foods*	Groundnuts (%)
Makongeni	Not detected	100.0
Thika town center	Not detected	100.0
Kiandutu	Not detected	66.6
Thika Level 5 Hospital area	Not detected	100.0
Ngoigwa	Not detected	100.0
Juakali	Not detected	100.0

*Cereal-based foods included maize mixed with legumes such as beans and pigeon peas.

Not detected = <2 µg/kg.

8.3.3 Total aflatoxin and aflatoxin B1 in groundnuts

Figure 8.1 shows the total aflatoxin levels reported in groundnuts from selected locations in Thika Town. Total aflatoxin in street-vended groundnuts averaged between 4.4 - 14.2 µg/kg.

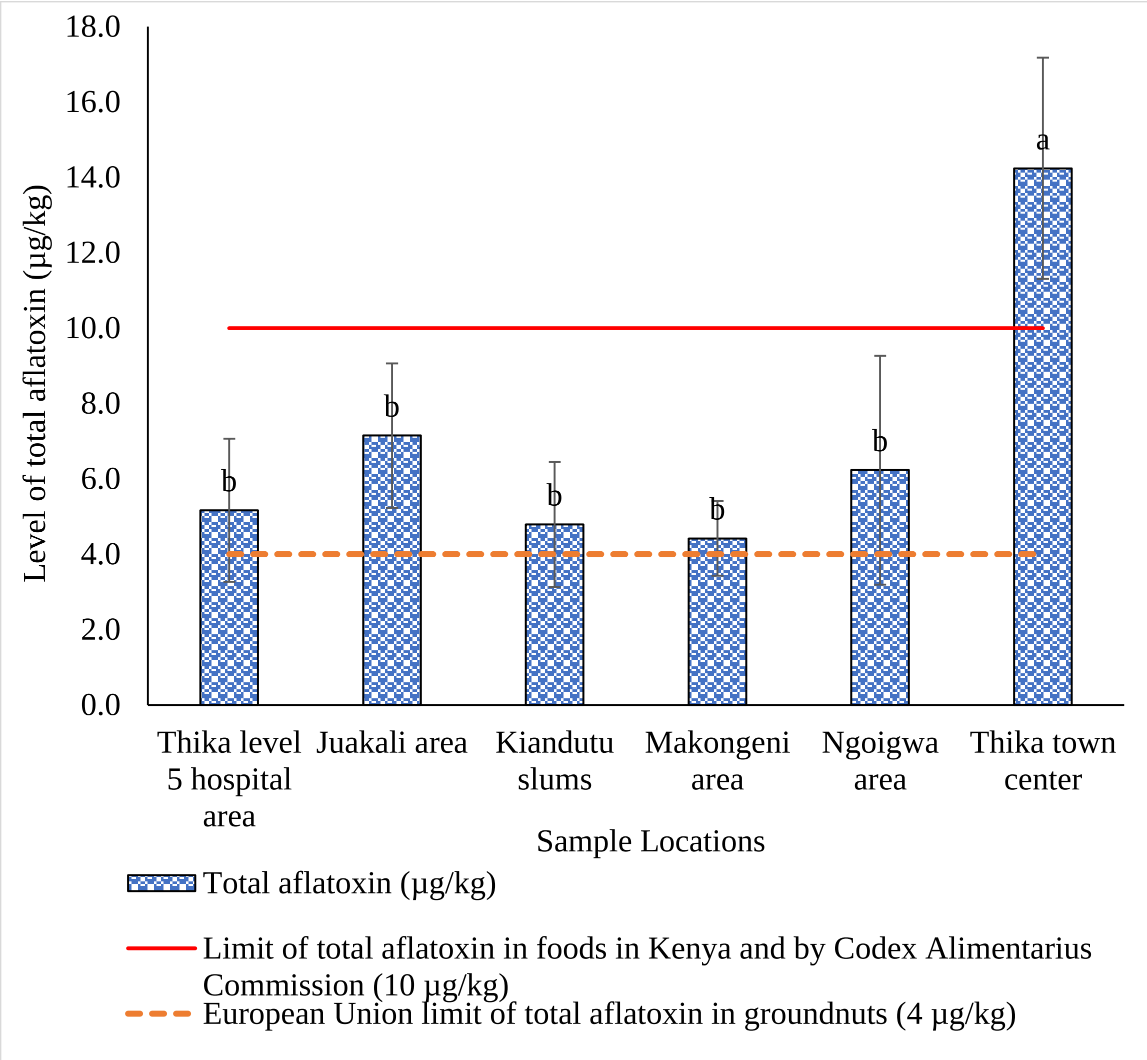


Figure 8.1: The mean total aflatoxin level in groundnuts from selected locations in Thika Town.

There was no significant difference in the total aflatoxin level in groundnuts for all locations except Thika town center which had significantly ($p=0.0012$) higher total aflatoxin level. The range of total aflatoxin in this study in groundnuts was comparable but lower than those reported in a study on the safety of chilled cereal beverages sold as street food in some open markets in Ghana (Atter *et al.*, 2015), where the total aflatoxins content in samples ranged from 7.0 to 22.2 µg/kg. Higher contamination levels were also reported by Sombie *et al.* (2018) in Sierra Leone where they found roasted street-vended nuts to contain aflatoxins averaging 487.8 µg/kg.

The Kenyan regulatory limit for total aflatoxin in food products is 10 µg/kg as set by the Kenya Bureau of Standards (KEBs) (Mutegi *et al.*, 2013; Sirma *et al.*, 2018). On average 83.3% of groundnut samples had aflatoxin levels below this regulatory limit while only 16.7% of samples had aflatoxin levels above the limits. Compared to the 4 µg/kg limit set by the European Union (European Commission, 2006; Rubert *et al.*, 2013) for total aflatoxin, 72.2% of the samples were above the limit. However, on average, none of the study locations had mean total aflatoxin levels below the European Union established limit. Higher contamination levels were reported by Mutegi *et al.* (2013) in a study on the incidence of aflatoxin in groundnuts from various markets in Kenya where they observed that aflatoxin levels in 37% of the samples exceeded the regulatory limit for aflatoxin levels (10 µg/kg) set by the KEBs.

Aflatoxin B1 level in street-vended groundnuts averaged between 3.4-11.3 µg/kg as shown in Figure 8.2. There was no significant difference in aflatoxin B1 level in groundnuts for all locations except Thika town center which had significantly higher aflatoxin level ($p = 0.001$). Sombie *et al.* (2018) in Sierra Leone reported even higher contamination levels in roasted street-vended nuts which contained aflatoxins levels ranging between 0.6–1,387.0 µg/kg while Vabi *et al.* (2020) found aflatoxin B1 contamination levels ranging from 3.8 - 12.3 µg/kg in groundnut kernels and 12.3 - 99.4 µg/kg in groundnut-based products in Northwestern Nigeria. In addition, Hlashwayo (2018) found groundnut contamination of 0.0 - 72.9 µg/kg with an average of 2.7 µg/kg while studying the level of aflatoxin B1 contamination in raw peanuts sold in Maputo City, Mozambique.

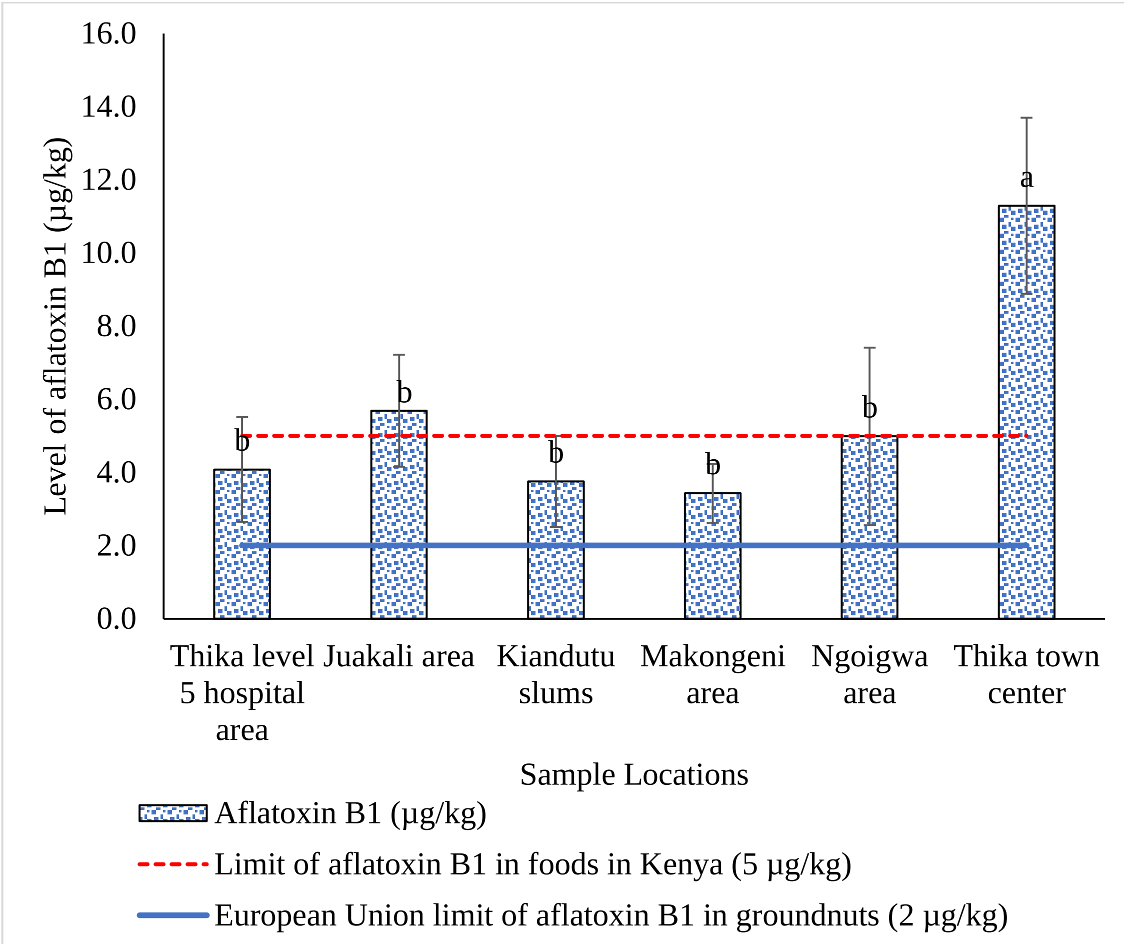


Figure 8.2: The mean aflatoxin B1 level in groundnuts from selected locations in Thika Town.

The Kenyan regulatory limit for aflatoxin B1 in food products is 5.0 µg/kg (Sirma *et al.*, 2018). On average 55.6% of groundnut samples had aflatoxin B1 levels below the regulatory limit while 44.4% of samples had aflatoxin B1 levels above the allowable limits. Compared to the 2 µg/kg limit set by the European Union (European Commission, 2006) for aflatoxin B1, all the individual samples from all study locations were above the established limits. Similar to this study, levels of aflatoxin B1 exceeding the maximum allowable limit set by the European Commission (2006) were found in 91% of groundnut and groundnut-based products in Northwestern Nigeria (Vabi *et al.*, 2020).

The high level of total aflatoxins and aflatoxin B1 reported in Thika town center as compared to the other locations could be attributed to the possible differences in handling practices and storage among street food vendors as well as the sources of raw materials. It is possible that despite the possible poor handling practices such as exposing groundnuts to moist air resulting in growth and toxin production by *Aspergillus* spp., vendors in Thika town center may have bought their raw materials from the same source which may have had high contamination levels in groundnuts and hence the high contamination levels reported in the street-vended product. In addition, it is possible that due to higher competition among the vendors in Thika town center, vendors have to sell their groundnuts for an extended time which may allow for the proliferation of fungi and toxin production in the groundnuts. Nonetheless, aflatoxin production has been reported to vary greatly depending on many physical, chemical, and biological factors such as the moisture content of the food product, the temperature of storage, the location of the street food vendors, the storage practices, and personal hygiene (Asemoloye *et al.*, 2017).

The high levels of total aflatoxins and aflatoxin B1 reported in this study could be attributed to many factors. This is because aflatoxin contamination of foods may occur at different points in the food chain depending on the time of mold invasion. It may be produced during the pre-harvest, harvest, drying, or storage period of the groundnuts although they ultimately depend on the handling method, packaging, or transport conditions of the food materials (Asemoloye *et al.*, 2017). All these factors may be different for different street food vendors from different regions. Insufficient drying and humid storage environmental conditions may result in high mold invasion and concurrent aflatoxin contamination in foods (Asemoloye *et al.*, 2017; Proietti *et al.*, 2014b). For instance, poor packaging and storage methods that are mostly applied by street food vendors may contribute to the contamination of groundnuts with aflatoxins. According to Mutegi *et al.* (2013), packaging materials used in groundnuts significantly influenced the levels of aflatoxin in the product, with 68% of groundnuts that were stored in plastic containers having more than 10 μg/kg of aflatoxin. The majority of street vendors use plastic containers for packaging or storage of groundnuts (Section 3.0). The plastic containers may retain moisture and trap heat and retain them inside thus providing a conducive environment for mold growth and eventual toxin production. Similar findings were reported by Hlashwayo (2018) who reported that the highest levels of aflatoxin B1 contamination were found in groundnuts sold in plastic containers.

These high levels of aflatoxin particularly aflatoxin B1 in groundnuts are worrying considering that aflatoxins are hepatotoxic, carcinogenic, genotoxic, nephrotoxic, teratogenic, and immunosuppressive (Omara *et al.*, 2021). Aflatoxin B1 has been reported as being the most potent of the aflatoxin compounds capable of causing the development of hepatocellular carcinoma in humans as well as many other complications including malnutrition, immunomodulation, and growth impairment (Deng *et al.*, 2018; Rushing & Selim, 2019). These high levels of aflatoxins, especially aflatoxin B1, highlight the need for Kenya to take the necessary steps to effectively manage aflatoxins in ready-to-eat foods.

8.4 Conclusion

Although aflatoxin was absent in cereal-based foods, the results revealed the presence of aflatoxin B1 in 44.4% of groundnut samples above the recommended limits (5 µg/kg) set by the Kenya Bureau of Standards (KEBs). In addition, all groundnut samples had contamination levels exceeding the EU set limits of 2 µg/kg which may pose serious food safety concerns. Aflatoxin B1 has been proven to be carcinogenic and thus, there is a great need for interventions to reduce contamination in street-vended groundnuts. These high levels of aflatoxins, especially aflatoxin B1, highlight the need for Kenya to take the necessary steps to effectively manage aflatoxins in ready-to-eat foods. Mapping the groundnut value chain in Kenya may assist in identifying avenues of contamination and developing strategies to reduce contamination.

CHAPTER NINE

GENERAL CONCLUSION AND RECOMMENDATIONS

9.1 Conclusion

In Kenya, the safety of street-vended foods continues to be a public health problem. Their consumption has the potential to cause foodborne diseases due to contamination with pathogenic microorganisms as well as the presence of toxic chemical contaminants. This study sought to determine the level of food safety knowledge and practice of street food vendors and to determine the microbial and chemical quality of ready-to-eat street-vended foods sold in selected locations within Thika town, Kiambu County, Kenya. The findings of this study demonstrate that street-vended foods sold in Thika Town, constitute a significant potential hazard to public health. The majority of street food vendors were educated at the secondary school level but had not received any formal training on food hygiene and safety. The lack of training for most of the vendors may have contributed to their unhygienic behavior and poor knowledge of food hygiene and safety. Of particular concern were the findings that almost all SFVs handled food with bare hands, and handled money and food at the same time without washing hands after. Storage and preservation practices were poor as most vendors stored the ready-to-eat food including leftovers at ambient temperature. For most vendors, the condition of the vending environment, as well as the vending structures, was also poor.

Nonlinear principal component analysis (NLPCA) is an effective procedure for analyzing data that has mixed measurement levels such as numeric, nominal, or ordinal that may have non-linear relationships with each other. This study identified seven components of food hygiene and safety knowledge and practices among street food vendors in Kiambu County which also represent the categories of concern in enhancing the quality and safety of street food. Furthermore, NLPCA was also able to group street food vendors depending on whether they had good or poor food hygiene and safety awareness and practices. These components may be used as the basis for evaluating street food quality and safety. This study further revealed that public health inspection and street food vendors' mobility were the most significant factors influencing food safety, hygiene awareness, and practices (FSHAP) among street food vendors. Public health inspection improved the chance of having a good FSHAP score while being mobile increased the likelihood of poor scores implying that public health inspection is paramount in enhancing street food safety. Efforts to reduce the movement of street food vendors should be put in place as mobility impairs the achievement of certain hygienic practices such as regular hand washing and maintenance of environmental hygiene. The education level, training in food hygiene and safety, category of street food vendors, and length of time in vending were significant in predicting at least one FSHAP score. Therefore, to improve the hygiene and safety of street food, emphasis should be placed on all the factors that have the potential to influence street food vendors' food safety and hygiene practices. These findings should be used to establish priorities for programs geared toward enhancing street hygiene and food safety.

Total viable counts, coliform, *Escherichia coli*, yeast, and mold counts in all street-vended foods were generally high, implying that most of these foods were unsatisfactory and unsafe for human consumption. The presence of *Escherichia coli* in ready-to-eat foods was indicative of poor hygiene and safety practices among street food vendors which have the potential to cause health issues to both consumers and street food vendors upon consumption. Pathogenic bacteria such as *Salmonella* spp. and *Staphylococcus aureus* were also isolated from the street-vended foods. The presence of these pathogenic bacteria in ready-to-eat foods indicates a major risk to the street food vendors as well as the consumers of street-vended foods since they can cause microbiological foodborne diseases.

The presence of heavy metals in foods is of public health concern. The lead concentrations in the majority of samples analyzed had contamination levels exceeding the maximum recommended limits suggested by the Joint FAO/WHO food standards programme. At least one of all food sample types was contaminated with lead, with the highest contamination levels being observed in groundnuts. The presence of lead and cadmium in street-vended foods poses a public health concern considering the huge population of people who consume these foods and the frequency at which this food is consumed.

Furthermore, these heavy metals can bioaccumulate in the body posing health risks later in life.

The margin of exposure to acrylamide from street-vended french fries was found to be extremely low in both adults and children in all locations. This shows that the consumption of street-vended french fries in any location within Thika town poses a great risk to the health of street food consumers. An even greater risk is posed to children who consume these street-vended french fries frequently. The high exposures reported in this study, especially in children are a major health concern and call for the development of strategies and implementation of appropriate measures to minimize the risk of exposure to acrylamide through street-vended french fries in Kenya.

The presence of aflatoxin B1 in groundnuts samples above the recommended limits set by the Kenya Bureau of Standards (KEBs) is a cause for concern considering the proven carcinogenic effect of aflatoxin B1 as well as the negative effect it has on nutritive status, growth, and development, and immune system functions in humans. These high levels of aflatoxins, especially aflatoxin B1, highlight the need for Kenyan food safety competent authorities to take the necessary steps to effectively manage aflatoxins in ready-to-eat foods.

Considering the benefits of the street vending business, including the provision of income and employment for many young people, the inclusion of these businesses in street design may not only benefit the street food vendors but also the consumers of street foods through the provision of high quality and safe foods. Continuous provision of food hygiene and safety training to the street food vendors as well as consumers, and enforcing the implementation of appropriate food hygiene and safety practices among street food vendors have the potential to improve street food quality and safety. Policies specific to the street food vending sector may streamline the sector and facilitate control and regulation by public health officials. In addition, the provision of basic infrastructure for enhancing hygiene among street food vendors has the potential to improve their food preparation and selling conditions/environments thus contributing to the production and sale of quality and safe foods.

9.2 Recommendations

The following recommendations were made from this study:

i. Poor street vending environmental conditions identified as a key characteristic of street food vendors could be solved through the inclusion of street vending businesses in the street design of towns or estates.

ii. Continuous monitoring of street-vended foods to determine the presence of pathogenic and toxic chemical contaminants should be carried out to increase awareness and the development of strategies to enhance the safety and quality of these foods.

iii. The establishment and enforcement of policies and preparation of guidelines specific to the street food sector to govern the street-vended food businesses aimed at reducing biological and chemical contaminants are recommended:

    a. A policy that recognizes street food vending as a legal business and allows for vending to be undertaken from specific fixed locations that have all required facilities to guarantee hygiene, quality, and safety.

    b. A policy outlining the minimum sanitary and hygiene conditions for street food vendors.

    c. A policy that requires street food vendors to undertake mandatory food hygiene and safety training courses and to obtain a food handlers certificate before the start of vending.

    d. A policy that requires street food vendors to undertake mandatory food hygiene and safety refresher course after a prescribed time, for instance, two years since the last course.

iv. Development and implementation of comprehensive guidelines for street food vendors to uphold the highest standards of quality and safety in the preparation and sale of street-vended foods. Analysis for other toxic contaminants such as nitrosamines, fumonisins, patulin, antibiotic residues, and pesticide residues that were not evaluated in this study is recommended.

v. Assess the impact of implementing food safety management systems such as hazard analysis and critical control points on the quality and safety of street-vended foods

vi. Mapping of the groundnut value chain in Kenya may assist in identifying avenues of contamination and developing strategies to reduce contamination.

vii. A chemical risk assessment to determine the public health risk posed to street food consumers in Thika town due to the presence of toxins such as aflatoxins and acrylamide in street foods should be carried out.

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APPENDICES

Appendix 1: Research License

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This is to Certify that Mr.. Johnson Kyalo Mwove of Chuka University, has been licensed to conduct research in Meru on the topic: Determination of the presence of toxic chemical contaminants in street vended foods and the health risk posed to street food consumers in Meru Town, Meru County, Kenya for the period ending : 29/March/2023.

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Appendix 2: Questionnaire for assessing handling practices and safety knowledge of street food vendors in Thika sub-county, Kiambu County, Kenya

Introduction: You are being asked to participate in a research study by **Johnson Kyalo Mwove**, a Ph.D. candidate at Jomo Kenyatta University of Agriculture and Technology in the School of Food and Nutrition Science. This study is designed to assess the food handling practices and safety knowledge of street food vendors in Thika Town, Kiambu County, Kenya.

Purpose of the study: To assess the food handling practices and safety knowledge of street food vendors in Thika Town, Kiambu County, Kenya.

Consent to participate in research: Participation is entirely voluntary**.** You are free to choose to participate or not to participate in this research. Nevertheless, if you choose to participate, you will be contributing to the body of knowledge on the safety of ready-to-eat street-vended foods. You are also free to pull out of the study at any time during the interview. In case any questions are asked that you would rather not respond to, you may request that we skip them. Agreeing to answer the question will indicate acceptance to participate.

Confidentiality: If you choose to participate in this research, your information will be kept safe in the hands of the researchers alone. No names or personal information will be collected or published by the researchers. The data collected will only be used to give an understanding of the handling practices and food safety knowledge of street food vendors in general, not individually.

Benefits: There may be no direct benefit to you now. However, your participation is likely to help us find out more about food hygiene practices and safety knowledge among street food vendors and may also assist the County government to learn how to improve the hygiene and safety of street foods as well as the welfare of street food vendors.

Procedures: You will be asked several questions related to your food handling practices as well as food safety knowledge. Please answer them to the best of your knowledge.

Checklist Number: __________________ **Date:** _________________________________

Interviewer: ____

Ward ____

Estate/ Street ____

Co-ordinates (Longitude: Latitude) _______________________: _________________________

Social and demographic characteristics of the street food vendors

1. Gender: (0) Male [ ] (1) Female [ ]

2. The average age in years:

(0) Below 18 Years [ ]

(1) Between 18 – 20 Years [ ]

(2) Between 21 – 25 Years [ ]

(3) Between 26 – 30 Years [ ]

(4) Between 31 – 35 Years [ ]

(5) Between 36 – 40 Years [ ]

(6) Above 40 Years [ ]

3. Level of education

(0) No formal education [ ]

(1) Primary school (In-complete) [ ]

(2) Primary School (Complete) [ ]

(3) Secondary school [ ]

(4) College Education [ ]

(5) University Education [ ]

4. What length of time have you been in this business?

(0) < 6 months [ ]

(1) 6-12months [ ]

(2) 1-2years [ ]

(3) more than 2years [ ]

5. (a) How many customers do you serve in an hour? ______/ hour

(b) Of the customers served in an hour (Question 5a), how many are young children ____/hour

6. Products sold:

(0) Foods of animal origin [ ] ____

(1) Foods of plant origin [ ] ____

(2) Both animal and plant foods [ ] ____

Food hygiene, safety, and practices

1. Where do you get supplies from? ____

2. In what quantities do you buy your supplies? ______________________________

3. How long does it take to clear the supplies? ___________________________ Days

4. a) How do you handle leftovers from the previous day?

   (0) Use them for the next day [ ]

   (1) Consume [ ]

   (2) Throw away [ ]

   (3) Refrigerate [ ]

   (4) Other(specify)_____________________

b) If you preserve, explain how? ____

5. a) What do you do when you receive your supplies?

   (0) Sorting and cleaning [ ]

   (1) Preserve [ ]

   (2) Don’t do anything [ ]

   (3) Other (specify) ______________________

b) If you **preserve**, how do you do it? ____

____

____

6. How do you wash your hands?

(0) Coldwater only

(1) Warm water only

(2) Cold water with soap

(3) Warm water with soap

(4) Other (specify) ________________________

7. How do you wash your equipment and utensils?

(0) Cold water only

(1) Warm water only

(2) Cold water with soap

(3) Warm water with soap

(4) Other (specify) ________________________

8. How do you wash fruits and vegetables meant for salads or juices or pudding preparation?

(0) Never wash

(1) Cold water only

(2) Warm water only

(3) Cold water with soap

(4) Warm water with soap

(5) Other (specify) ________________________

9. a) For the fruit juices, do you subject them to any heat treatment?

(0) Yes [ ] No (Go to 9) [ ]

b) Do you have a specific heat target? __________________________________ Degrees C

10. a) Have you received any training on food hygiene and food safety?

Yes [ ] No (if no skip to question 9 d) [ ]

b) If yes, where and when were you trained?

Institution	**Place**	**Date**

c) Was the training helpful to you?

Yes [ ] No [ ]

d) Would you be willing to receive training on food hygiene and sanitation?

Yes [ ] No [ ]

11. If food is held hot or cold, what temperatures are set for that? ______________________________

12. a) Have you ever obtained a food handler's medical certificate?

Yes (Go to 12. b) [ ] No (Go to 12. c) [ ]

b) If Yes, how often do you go to renew your food handler's medical certificate?

(0) Every 3 months [ ]

(1) Every 6 months [ ]

(2) Every 12 months [ ]

(3) Don't know [ ]

c) If No, how willing would you be to receive a food handler's medical certificate?

(0) Willing [ ]

(1) Not sure [ ]

(2) Unwilling [ ]

13. a) Have you ever been visited by a public health officer?

Yes (Go to 13. b) [ ] No [ ]

b) If yes, how often are you visited?

(0) Once per year [ ]

(1) Every month [ ]

(2) Never [ ]

(3) Other (specify) ____

14. What precautions do you take while handling food to avoid contamination?

____

____

15. a) Are you aware of any food safety standards and regulations in Kenya?

(0) Yes (Go to 15. b) [ ] No [ ]

b) If yes, which one(s)? ____

____

16. Show how much you agree with the statements below on a scale of 1 – 5, where 1 strongly disagrees and 5 strongly agree

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Street-vended foods may be sources of pathogenic microorganisms					
Training street food vendors is important to ensure the safety of consumers					
Street food vending is a major source of livelihood for many Kenyans					
There is a need for regulating the street food vending businesses					
There is a need to legalize the street food vending business					
I am willing to attend sanitation and hygiene training if offered					

Appendix 3: Checklist for assessing the handling practices of street food vendors in Thika Town, Kiambu County, Kenya

Checklist

Number: ________________ **Date:** ______________________________

Interviewer: ____

Ward ____

Estate/ Street ____

Co-ordinates (Longitude: Latitude)

_____________________:_____________________

		Hygiene and sanitary status
	General information	
1	Category of foodstuff sold (0) Plant-based only (1) Animal-based only (2) Both plant and animal-based foods	
2	List of foodstuff on site: ____________________ ____________________	
3	Vendor mobile? (0) Yes [ ] (1) No (occasionally moves around) [ ]	
4	For the food requiring heat treatment, the nature of heating ____________________ ____________________	

5	Form of storage in practice for stock (0) Store at ambient temperature [ ] (1) Store in cold temperatures [ ] (2) Other (specify) ____________________________	
	The vending environment	
1.	Vendor location (0) Near school [ ] (1) Around institutions for the elderly [ ] (2) Hospitals [ ] (3) Business Center [ ] (4) Residential place [ ] (5) Other (specify) ______________________	
2.	Place of vending (0) Cart [ ] (1) Wheelbarrow [ ] (2) Stall [ ] (3) Other (specify) ________	(0) Good [ ] (1) Average [ ] (2) Bad [ ]
3	Nature of construction material (0) Polythene bag [ ] (1) Wood [ ] (2) Iron sheets [ ] (3) Other (specify)	(0) Good [ ] (1) Average [ ] (2) Bad [ ]
4	Are building structures washable and working surfaces cleanable? Yes [ ] No [ ]	

5	A) Condition of working surfaces/ Cutting equipment/ chopping boards Yes [ ] No [ ]	
5	B) Nature of the material used for working surfaces (0) Steel [ ] (1) Wood [ ] (2) Plastic [ ] (3) Other ____________________	
6	Condition of the surrounding environment (0) Clean (Garbage absent) [ ] (1) Not clean (Garbage present) [ ]	
7	Garbage collecting bin present Yes [ ] No [ ]	(0) Good [ ] (1) Average [ ] (2) Bad [ ]
8	The garbage collecting bin covered Yes [ ] No [ ]	
9	The garbage collecting bin overfilled Yes [ ] No [ ]]	
10	Houseflies and other insects present Yes [ ] No [ ]	
11	Availability of water for washing Yes [ ] No [ ]	
12	Sufficient water for washing Yes [ ] No [ ]	
13	Adequate washing processes Yes [ ] No [ ]]	

14	Presence of a drainage system Yes [ ] No [ ]	(0) Good [ ] (1) Average [ ] (2) Bad [ ]
15	Adequate separation between raw and ready-to-eat foodstuffs Yes [ ] No [ ]	
	Personal hygiene of street food vendors	
1	Washing hands after a bathroom visit Yes [ ] No [ ]	
	If yes in 1 above, how does the vendor wash their hands? (0) Cold water only [ ] (1) Hot water only [ ] (2) Cold water with soap [ ] (3) Hot water with soap [ ]	
2	Handling money while serving food and not washing it after Yes [ ] No [ ]	
3	Washing hands before handling food Yes [ ] No [ ]	
4	Washing food before preparation/ processing Yes [ ] No [ ]]	
5	Use aprons Yes [ ] No [ ]	(0) Good [ ] (1) Average [ ]

		(2) Bad [ ]
6	Use gloves / bare hands to handle foods (0) Gloves [ ] (1) Bare hands [ ] (2) Other [ ]	
7	Short nails Yes [ ] No [ ]	
8	Nails with polish/ attached nails Yes [ ] No [ ]]	
9	The vendor's hair covered Yes [ ] No [ ]	
10	Vendor wearing jewelry Yes [ ] No [ ]	
11	Visible bruises, cuts, or boils Yes [ ] No [ ]	
12	Vendor chewing gum etc. while handling food Yes [ ] No [ ]	
13	Vendor smoking etc. while handling food Yes [ ] No [ ]	
14	Vendor spitting, sneezing, and coughing on or near food Yes [ ] No [ ]	
15	Vendor touching mouth, tongue, nose, eyes, etc while handling food Yes [ ] No [ ]	
	Nature of service	
1	Type of serving utensils/ packaging material (0) Enamel [ ] (1) Plastic [ ]	(0) Good [ ]

	(2) Disposable polythene bags [ ] (3) Metal [ ] (4) Other (specify) ________________	(1) Average [ ] (2) Bad [ ]
2	Cleaning done for utensils (0) Cold water only [ ] (1) Hot water only [ ] (2) Cold water with soap [ ] (3) Hot water with soap [ ] (4) No cleaning [ ] (5) Not cleanable [ ]	
3	Condition of utensils – scratches or rusting observed Yes [ ] No [ ]	
4	Storage of serving or packaging material (0) Exposed [ ] (1) Enclosed [ ]	
5	Separate basin for utensils and food preparation Yes [ ] No [ ]	
6	Working surfaces in good condition, crevices, cracks, etc. (0) Good [ ] (1) Average [ ] (2) Bad [ ]	
7	Drying rack for clean utensils present Yes [ ] No [ ]	
8	Dry clean wiping towels present Yes [ ] No [ ]	(0) Good [ ]

		(1) Average [ ] (2) Bad [ ]
9	Ready-to-eat prepared (cut/ sliced for fruits) food adequately enclosed Yes [ ] No [ ]	
10	Nature of enclosing material (0) Plastic [ ] (1) Metallic [ ] (2) Caramel [ ] (3) Other (specify) ______________	(0) Good [ ] (1) Average [ ] (2) Bad [ ]
11	How is food held after cooking or preparation while awaiting consumers? ______________________________ ____	

Appendix 4: A pictorial description of samples used for analysis in this study

Sample type	Picture	Description of samples
Sausages		Cured meat products containing meat and spices. Three sausages were randomly selected from the SFV's cart, prepared by SFV in the manner that they do before presenting them to customers, and bagged in a sterile sample bag as a single sample. Accompanying additives such as salt and salads were not included.
Smokies		Cured meat products containing meat and spices. Three smokies were randomly selected from the SFV's cart, prepared by SFV in the manner that they do before presenting them to customers, and bagged in a sterile sample bag as a single sample. Accompanying additives such as salt and salads were not included.

Boiled deshelled eggs		Boiled eggs without shells. Three boiled eggs were randomly selected from the SFV’s cart, their shells removed by SFV in the manner that they do before presenting them to customers, and bagged in a sterile sample bag as a single sample. Accompanying additives such as salt and salads were not included.
Cereals		Maize mixed with legumes such as beans and peas (locally referred to as ‘*Githeri*”). Products were fried containing varied additives such as onions, tomatoes, and cabbages.

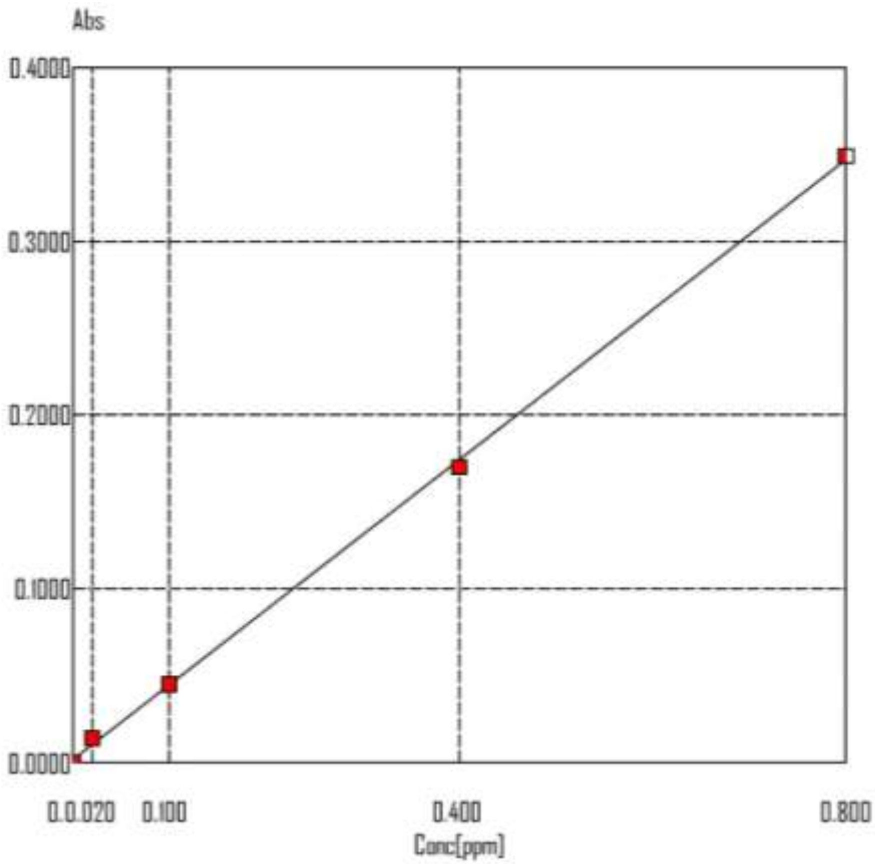
French fries		Deep-fried Irish potato chips
Groundnuts		Roasted unpeeled groundnuts

Juices		Blended fruit juice mixes. Commonly used fruits included bananas, watermelons, avocados, pineapples, mangoes, and oranges. Other uncommon additions included sugarcane juice, aloe vera juice, milk, and groundnuts.
Watermelons		Sliced watermelon fruit

Sliced Pineapples		Peeled and sliced pineapple fruit
Salads		An assortment of sliced tomatoes, and onions with or without pepper.

Arrowroots		Boiled unpeeled arrowroots
Sweet potatoes		Boiled unpeeled sweet potatoes

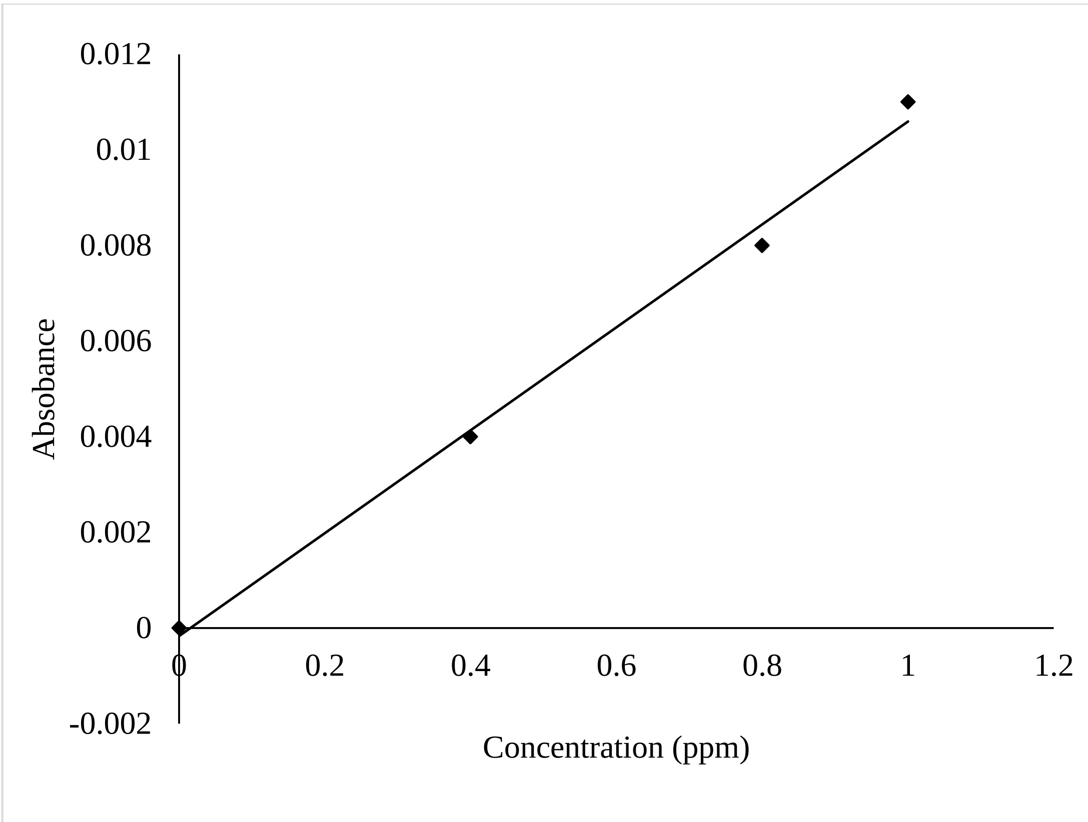
Appendix 5: The standard curve used during spectrophotometric analysis of cadmium in street-vended food samples



Curve Equation: 1st [A]=K1[C]+K0
Equation Factor: K1=0.4317, K0=0.0016,
Dependency: 0.99977

No.	Conc[ppm]	Abs
1.	0.000	0.000
2.	0.020	0.014
3.	0.100	0.045
4.	0.400	0.170
5.	0.800	0.349

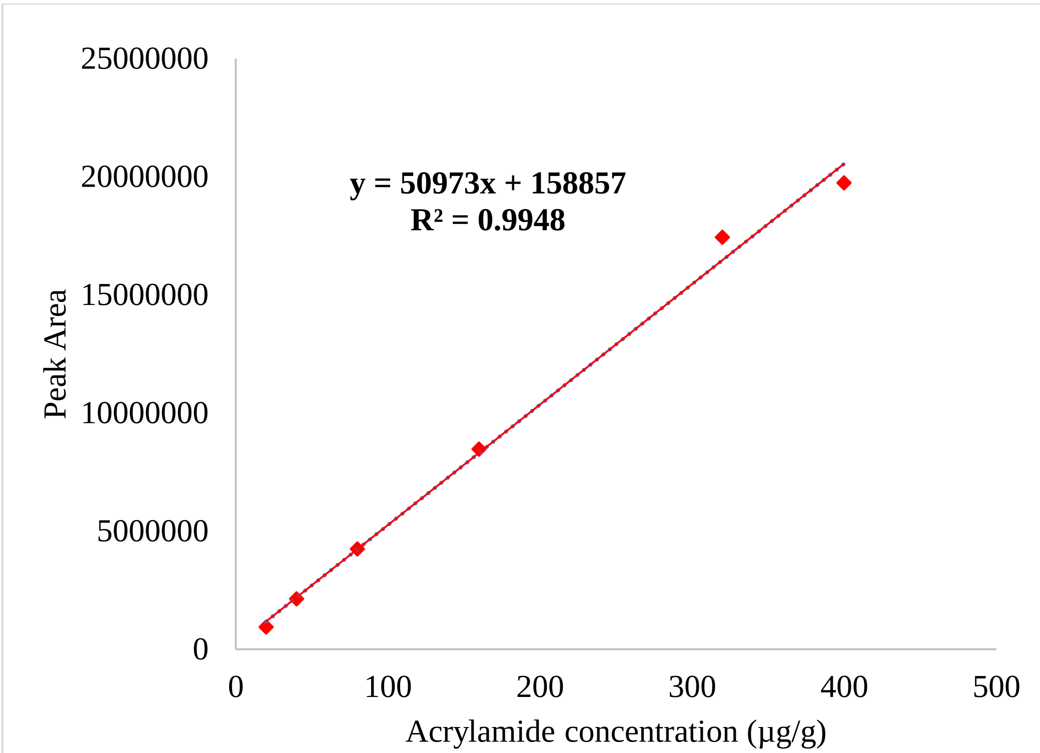
Appendix 6: The standard curve used during spectrophotometric analysis of lead in street-vended food samples



Curve Equation: Ist [A]=KI[C]+K0
Equation Factor: KI=0.0108, K0=-0.0002,
Dependency: 0.99704

No.	Conc[ppm]	Abs
1.	0.000	0.000
2.	0.400	0.004
3.	0.800	0.008
4.	1.000	0.011

Appendix 7: The standard curve used during HPLC analysis of acrylamide in street-vended food samples



Appendix 8: Publication 1: Mwove, J., Imathiu, S., Orina, I., & Karanja, P. (2020). Food safety knowledge and practices of street food vendors in selected locations within Kiambu County, Kenya. African Journal of Food Science, 14(6), 174-185.

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ACADEMIC JOURNALS

African Journal of Food Science

Full Length Research Paper

Food safety knowledge and practices of street food vendors in selected locations within Kiambu County, Kenya

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The safety of street foods remains a public health concern especially in developing countries like Kenya where foodborne illnesses associated with these foods have often been reported. This study determined the food hygiene and safety knowledge and practices of 345 street food vendors (SFVs) in selected locations within Kiambu County, Kenya. Data collection was accomplished through face-to-face interviews using structured questionnaires and extensive observation using an assessment tool for observation of personal hygiene and food handling practices of SFVs and the condition of the vending environment. The results indicated that the majority of the SFVs were male (63.2%) with 38.1% of them having attained secondary school education. About 93% of the SFVs had not received any formal training on food hygiene and safety. Majority of SFVs handled food with bare hands (96.8%) or handled money while serving food without washing hands (86.1%). Few also practiced preservation with 78.3% storing foodstuff that required refrigeration at ambient temperatures while 22.3% stored leftovers without any form of preservation and sold them the following day. Whereas public health officers' visits were found to significantly (P<0.0001) motivate SFVs to obtain a food handler's medical certificate, only about 27% had obtained it. These findings suggest that street vended foods sold in this study area may pose a significant potential hazard to public health due to the poor hygiene and handling practices reported.

Key words: Street vended food, food safety, food hygiene, public health, street food legislation.

INTRODUCTION

Street vended foods are ready-to-eat (RTE) foods and beverages that are sometimes prepared by vendors in the streets and other public places, and mostly sold to consumers for immediate or later consumption without any further preparation or processing (Imathiu, 2017). The vast growing urban population in developing

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Appendix 9: Publication 2: Mwove, J., Imathiu, S., Orina, I., & Karanja, P. (2020). Multinomial logistic regression analysis of factors influencing food safety, hygiene awareness, and practices among street food vendors in Kiambu County, Kenya. Current Research in Nutrition and Food Science Journal, 8(3), 988-1000.

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Current Research in Nutrition and Food Science

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Multinomial Logistic Regression Analysis of Factors Influencing Food Safety, Hygiene Awareness and Practices Among Street Food Vendors In Kiambu County, Kenya.

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Abstract
Street food vending is a very popular and unique part of the informal sector, particularly in developing countries. However, the safety of street vended foods is a major public health concern since poor food safety and hygiene knowledge and practices are often reported among street food vendors (SFVs). The objective of this study was to identify the factors influencing food safety, hygiene awareness and practices (FSHAP) among SFVs in Kiambu County, Kenya. Structured questionnaires and an observation checklist were administered to randomly selected 345 SFVs. Results showed that good food safety and hygiene awareness scores were significantly (P<0.05) influenced by education level, food hygiene and safety training, mobility of SFVs, public health inspection, and the category of SFVs. Public health inspection was the only factor that significantly (P<0.05) influenced all FSHAP score categories. Mobile vendors were 1.86 and 2.20 times more likely to have poor working conditions and poor food handling practices scores compared to those who were not mobile, respectively. Training and education level significantly(P<0.01andP<0.05, respectively) increased food safety and hygiene awareness score whereas the duration of time in street food vending significantly (P<0.05) improved food handling practice score. Public health inspection of SFVs was found

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Keywords

Food Safety;
Food Hygiene;
Logistic Regression;
Public Health Inspection;
Street Food Vendors.

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Appendix 10: Publication 3: Mwove J, Imathiu, S., Orina I, & Karanja, P. (2021). Microbial quality and safety of ready-to-eat street-vended foods sold in selected locations in Kenya. Journal of Food and Dietetics Research, 1, 34-40.

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Journal of Food and Dietetics Research

Original Article

Microbial quality and safety of ready-to-eat street-vended foods sold in selected locations in Kenya

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ABSTRACT

Objectives: Street-vended foods (SVFs) are a major contributor to foodborne diseases, especially in developing countries, where their sale is largely uncontrolled. Foodborne diseases have often been linked to high morbidity and mortality in some developing countries such as Kenya, demonstrating their public health and societal significance. The objective of this study was to determine the microbial quality and safety of ready-to-eat (RTE) foods sold in selected locations within Thika town in Kiambu County, Kenya.

Material and Methods: A total of 199 food samples consisting of cereals, sliced fruits, salads, groundnuts, tubers, fruit juices, boiled deshelled eggs, smokies, and sausages were randomly collected for microbial analysis. Determination of total viable count (TVC), total coliform count (TCC), yeast and molds count (YMC), *Escherichia coli* counts, *Staphylococcus aureus* counts as well as the presence of *Salmonella* spp., and *Listeria monocytogenes* were determined following standard microbiological methods.

Results: Results revealed that plant-based foods had significantly ($P < 0.01$) higher TVC, TCC, YMC, and *S. aureus* counts compared to animal-based foods. The levels of TVC, TCC, YMC, *E. coli*, and *S. aureus* ranged from 6.590 ± 1.020 to 3.377 ± 1.764, 5.567 ± 2.233 to 1.594 ± 2.299, 5.052 ± 1.201 to 1.595 ± 2.146, 2.033 ± 1.229 to 0.000 ± 0.000, and 5.972 ± 1.170 to 1.888 ± 1.660 Log_{10} CFU/g, respectively. At least nine food samples were contaminated with *E. coli* although the chance for contamination was significantly ($P = 0.0002$) higher (15 times) in plant-based foods compared to animal-based foods. At least one sample in each food type was contaminated with *S. aureus* with contamination levels above 1.888 ± 1.660 Log_{10} CFU/g. *Salmonella* spp. was only detected in boiled arrowroots (25%), boiled deshelled eggs (5.6%), French fries (5.6%), juices (5.0%), and cereals (11.1%), while *L. monocytogenes* were not detected in any food sample.

Conclusion: These findings demonstrate that RTE SVFs sold in this region constitute a potential health hazard to consumers because of the presence of *Salmonella* spp., and high counts of *E. coli* and *S. aureus*. These foods are, therefore, microbiologically unsafe and unsuitable for human consumption as they may cause foodborne disease outbreaks.

Keywords: Food Safety, Hygiene, Microbial contamination, Pathogenic microorganisms, Ready-to-eat foods, Street-vended foods

INTRODUCTION

Street-vended foods (SVFs) are ready-to-eat (RTE) foods and beverages that are mostly sold and sometimes prepared by vendors in streets and other public places. They are usually bought by consumers for immediate consumption or consumption at a later time without any further preparation or processing.[1] The vast growing urban population in the developing countries

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Appendix 11: Publication 4: Mwove, J., Imathiu, S., Orina, I., & Karanja, P. (2022). Determination of total aflatoxin and aflatoxin B1 in groundnuts and cereal-based street-vended foods sold in selected locations in Thika Town, Kenya. Journal of Food and Dietetics Research, 2(3), 1-7.

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JFDR

Research Article

ISSN 2770-0259 (Online)

Determination of total aflatoxin and aflatoxin B1 in groundnuts and cereal-based street vended foods sold in selected locations in Thika Town, Kenya

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ABSTRACT

Objective: Food contamination with mycotoxins such as aflatoxin in street vended foods is a public health concern in Kenya. The objective of this study was to determine the level of aflatoxins in street vended foods sold in six locations within Thika Town, Kenya.

Methods: A total of 36 samples consisting of cereal and cereal based foods and roasted groundnuts were randomly collected for analysis. Screening for aflatoxins was done using NEOGEN's Reveal® Q+ for Aflatoxin test kit while quantification of aflatoxin B1 and total aflatoxin was done through a competitive direct enzyme-linked immunosorbent assay (ELISA).

Results: Total aflatoxin and aflatoxin B1 in street vended roasted groundnuts averaged between 4.420 - 14.241 µg/kg and 3.431-11.289 µg/kg, respectively. Thika town center had significantly ($p=0.0012$) higher total aflatoxin and aflatoxin B1 level in roasted groundnuts. On average 16.7% and 44.4% of roasted groundnut samples had total aflatoxin and aflatoxin B1 levels above the regulatory limits of 10 µg/kg and 5 µg/kg established by the Kenya Bureau of Standards as limits for total aflatoxin and aflatoxin B1 in groundnuts, respectively. Compared with the 4 µg/kg and 2 µg/kg limit set by the European Union for total aflatoxin and aflatoxin B1, 72.2% and 100% of the samples were above these limits, respectively.

Conclusion: The high levels of aflatoxins, especially aflatoxin B1, highlights the need for Kenya to take the necessary steps to effectively manage aflatoxins in ready-to-eat street vended groundnuts.

Key words: Total aflatoxin; Aflatoxin B1; Enzyme-linked immunosorbent assay; Street vended foods; Food safety

Introduction

Mycotoxins are secondary metabolites of a variety of mold species that produce toxins with adverse health effects on humans, resulting mostly in acute and chronic illnesses called mycotoxicoses [1, 2]. Among the mycotoxins of the greatest health and economic importance are aflatoxins [1, 3]. Aflatoxins are produced by some strains of *Aspergillus flavus*, *Aspergillus parasiticus*, and *Aspergillus nomius*. There are four main aflatoxin types (B_1, B_2, G_1, G_2) and two more (M_1, M_2) that are produced by animals through milk after metabolizing the main four types [4].

A wide range of food commodities including cereals especially maize and maize products, rice, sorghum, millet, cassava, yams, beer, and animal products; dairy products, dried fish, meat, and eggs have been implicated in myco-

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Appendix 12: Publication 5: Mwove, J., Imathiu, S., Orina, I., & Karanja, P. (2023). Environmental exposure assessment of lead and cadmium in street-vended foods sold in selected locations in Kenya. Food Science & Nutrition. 11(6), 2610-2619

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REVIEW

Environmental exposure assessment of lead and cadmium in street vended foods sold in selected locations in Kenya

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Abstract
The preparation and handling practices, as well as raw materials for street food vending businesses, could be sources of toxic heavy metals in street vended foods (SVFs). The objective of this study was to assess the levels of lead (Pb) and cadmium (Cd) contamination in ready-to-eat SVFs sold in selected locations within Thika town, Kenya. A total of 199 samples consisting of cereal-based foods, sliced fruits, salads, groundnuts, tubers, fresh fruit juices, eggs, smokies, and sausages were randomly collected for analysis. The concentration of Pb and Cd in street vended foods (SVFs) was determined by atomic absorption spectrophotometry. The results indicated that at least one of the food sample types was contaminated with Pb. The level of Pb contamination in SVFs ranged between 0.271 ± 0.070 and 1.891 ± 0.130 mg/kg with groundnuts recording significantly ($p < .0001$) higher levels (1.891 mg/kg) than all other food samples. Cadmium contamination levels in the SVF samples ranged between 0.001 ± 0.001 and 0.010 ± 0.003 mg/kg. Significantly ($p < .0001$) high levels of Cd were observed in cereal-based foods (0.010 mg/kg) and fresh fruit juices (0.008 mg/kg). The Pb concentrations reported in this study are a food safety concern since they exceed the maximum recommended limits set by the Joint Food and Agriculture Organization (FAO)/World Health Organization (WHO) food standards program. There is therefore a need for the establishment and enforcement of policies to govern the street food vending businesses to reduce heavy metal contamination in the SVFs.

KEYWORDS
food safety, heavy metal exposure assessment, human health, lead and cadmium, street vended foods

1 | INTRODUCTION

The vast growing urban population in developing countries such as Kenya has stimulated the demand for affordable and readily accessible ready-to-eat (RTE) meals. This has, in turn, fueled the street vending business which offers RTE foods and beverages that are cheap, convenient, and accessible to a vast number of low-income consumers (Imathiu, 2017; Proietti et al., 2014). In addition, street food plays an important socioeconomic role by offering jobs and income for those involved in their preparation and selling thus empowering the local economy in developing countries and improving livelihoods (Proietti et al., 2014; Verma et al., 2023).

Besides these numerous advantages offered by street foods, safety concerns have been raised regarding contamination with microbial or chemical toxic elements (Arkar-Brewoo et al., 2020; Proietti et al., 2014; Verma et al., 2023). Heavy metals are among

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