

ANALYSIS OF FOOD SAFETY AND FOOD HANDLING
KNOWLEDGE AMONG STREET FOOD VENDORS IN SELECTED
LOCAL FOOD MARKETS IN WINDHOEK

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN MICROBIOLOGY

OF

THE UNIVERSITY OF NAMIBIA

BY

PAULUS NGALANGI

200202995

OCTOBER 2022

SUPERVISOR: PROF. AHMAD CHEIKHYOUSSEF (SCIENCE AND
TECHNOLOGY DIVISION, MULTIDISCIPLINARY RESEARCH SERVICE,
CENTRE FOR RESEARCH SERVICES, UNIVERSITY OF NAMIBIA)

ABSTRACT

Contaminated food leads to foodborne disease outbreaks (FDO) that cause millions of deaths among people every year. In Namibia, many low and middle-income consumers use street-vended foods (SVF) with compromised quality of raw materials, degraded handling and storage conditions that do not meet food safety standards. Therefore, this study was conducted by means of a descriptive, cross-sectional study of six Windhoek locations of Okuryangava, Katutura, Klein Windhoek, Kleine Kuppe, Prosperita, and Otjomuise. Food samples were purchased for laboratory analysis to determine pH, moisture and total plate count (TPC). Systems-Theoretic Accident Models and Processes (STAMP) was adopted, informed by data gathered based on event chain models drawn from street food handlers (SFH). Food-handlers were knowledgeable about the need for hygienic practices such as hand washing (94.6%), and cleaning of utensils (83.5%). Knowledge on food pathogens revealed that 72.1% did not know food pathogens such as *Salmonella*, *Listeria*, *Campylobacter*, and *E. coli*, meanwhile, only 28.4% did not know that parasites, fungi, and viruses act as agents to cause food poisoning. There is a none-consistent pattern of SFH knowledge with regard to hygienic practices during food handling and processing. pH values were lower (3.21 ± 0.29) for liquid beverage than all solid foods that ranged from 6.81 ± 0.10 to 7.54 ± 0.16 . The moisture percentage was higher (90.97 ± 0.85) for liquid beverage than all solid foods that ranged from 37.66 ± 1.20 to 63.28 ± 0.89 . High TPC of 5.28 ± 0.49 Log CFU/g was detected in *matangara*, followed by sausage (5.06 ± 0.99), *kapana* (3.07 ± 0.47), and *oshifima* (2.66 ± 1.99). STAMP with ready to use scenarios was introduced to deal with accidents that lead to FDO. Moreover, an assessment of the potency and appropriateness of food preservation methods and preservatives are

recommended. A robust food safety regulatory regime, including a strong component of food safety training for contamination prevention should be pursued and is recommended for SVF handlers.

TABLE OF CONTENTS

ABSTRACT.....	i
LIST OF TABLES	vi
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS	ix
ACKNOWLEDGEMENTS	x
DEDICATION	xi
DECLARATION	xii
CHAPTER ONE: INTRODUCTION	1
1.1. Background of the study	1
1.2. Statement of the problem	4
1.3. Objectives of the Study	4
1.4. Significance of the study.....	5
1.5. Limitation of the study	5
1.6. Delimitation of the study	6
CHAPTER TWO: LITERATURE REVIEW	7
2.1. Food safety systems	7
2.2. Food-borne diseases.....	10
2.3. Knowledge and perception of food safety among street food vendors.....	11
2.4. Microbial quality of street vended foods	13
2.5. Physicochemical characteristics and microbial quality of street-vended foods.....	14
2.5.1. pH Values in Food	14
2.5.2. Moisture content in foods	16
2.5.3. Microbial enumeration	17
2.5.3.1. Total Plate Count	18
2.5.3.2. Lactic Acid Bacteria (LAB) enumeration	19
2.5.3.3. Yeasts and moulds enumeration	19
2.6. Microbial food hazard scenarios and STAMP	20
CHAPTER THREE: MATERIALS AND METHODS.....	22

3.1. Research Design.....	22
3.2. Food safety knowledge survey.....	23
3.3. Samples collection	24
3.4. Physicochemical parameters and microbial analysis	25
3.4.1. Measurement of pH of food samples	25
3.4.2. Moisture content	25
3.4.3. Microbial analysis	26
3.4.4. Applying systems thinking model	27
3.5. Research Ethics	27
3.6. Statistical Analysis.....	27
3.6.1. Survey data analysis	28
3.6.2. Food samples data analysis	29
CHAPTER FOUR: RESULTS	30
4.1. Assessment of food safety related knowledge among street food vendors.....	30
4.1.1. Demographic information of street food vendors	31
4.1.2. Street food vendors' food safety knowledge	34
4.1.3. Personal hygiene practices	38
4.1.4. Perception of food safety	39
4.1.5. Response to food-borne diseases	40
4.1.6. Association of the different socio-demographic characteristics with the food safety knowledge	41
4.2. Physicochemical characteristics and microbial quality of street vended foods	47
4.2.1. Percentage moisture content of street vended foods	47
4.2.2. pH Measurements of street vended foods	48
4.2.3. Microbial quality of street vended foods	52
4.3. Food hazard scenarios and STAMP.....	61
CHAPTER FIVE: DISCUSSIONS.....	63
5.1. Assessment of food safety knowledge among street food vendors.....	63
5.1.1. Demographic information of street food vendors	63
5.1.2. Street food vendors' food safety knowledge and awareness	65
5.1.3. Personal hygiene practices	67
5.1.4. Perception of food safety	68
5.1.5. Response to food-borne diseases	69

5.2. Physicochemical characteristics and microbial quality of street vended foods	69
5.2.1. Percentage Moisture content of street vended foods.....	69
5.2.2. pH Measurements of street vended foods	70
5.2.3. Total Plate Counts.....	71
5.3. Food hazard scenarios and STAMP.....	73
CHAPTER SIX: CONCLUSIONS.....	79
CHAPTER SEVEN: RECOMMENDATIONS.....	82
REFERENCES	84
ANNEX 1: ETHICAL CLEARANCE CERTIFICATE.....	99
ANNEX 2: STUDY QUESTIONNAIRE.....	100
ANNEX 3: STATISTICAL ANALYSIS TABLES	106

LIST OF TABLES

Table 1. Components of the Food system across various systemic levels in Namibia.	8
Table 2. Demographic information of participants	32
Table 3. Responses of participants to statements based on knowledge on food hazards.....	35
Table 4. Responses of participants to statements based on personal hygiene	38
Table 5. Responses of participants to statements based on perception on food safety	40
Table 6. Responses of participants to statements based on response to foodborne disease outbreak	41
Table 7. Hypotheses relating the knowledge of street food vendors to the socio-demographic characteristics	44
Table 8. Mean percentage (%) moisture content of selected street vended foods by location.....	47
Table 9. One-way ANOVA table of percentage moisture by location	48
Table 10. Mean pH values of selected street vended foods by location	48
Table 11. One-way ANOVA table for pH of foods by location	49
Table 12. Multiple comparisons of difference in means for percentage moisture (m) and pH by food type and location	49
Table 13. Mean TPC (Log CFU/g) of the different foods on PCA by location.....	52
Table 14. One-way ANOVA table of TPC by location	53
Table 15. TPC Means (Log CFU/g) from the different foods on MRS agar by location.....	54
Table 16. One-way ANOVA table of PC on MRS agar by location	54
Table 17. PC Means from the different foods on PDA by location.....	55

Table 18. One-way ANOVA table of PC on PDA by location.....	55
Table 19. Multiple Comparisons of difference in means for PC on PCA, MRS and PDA by food type and location.....	56
Table 20. Normality test for the data of physicochemical and microbial quality of the sampled foods	106
Table 21. Homogeneity test for the data of physicochemical and microbial quality of the sampled foods.....	107
Table 22. Reliability test for the data of physicochemical and microbial quality of the foods.....	107

LIST OF FIGURES

Figure 1. Map of the City of Windhoek, showing study locations marked in circled areas.....	22
Figure 2. Flow diagram of the process followed in the study	26
Figure 3. Correct responses to knowledge on food safety related aspects; food hazards, personal hygiene, perception of food safety and response to food-borne disease outbreaks.....	30
Figure 4. Frequency and types of foods handled by street food vendors.....	33
Figure 5. Customised STAMP model. As adapted from Leveson (2011)	78

LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
CFU	-	Colony Forming Unit
FAO	-	Food and Agricultural Organization
FDA	-	Food and Drug Administration
FDO	-	Food-borne Disease Outbreaks
HACCP	-	Hazard Analysis Critical Control Point
LAB	-	Lactic Acid Bacteria
MRS	-	De Man Rogosa and Sharpe
PDA	-	Potato Dextrose Agar
PC	-	Plate Count
PCA	-	Plate Count Agar
SD	-	Standard Deviation
SFH	-	Street-food Handlers
SPSS	-	Statistical Package for Social Sciences
STAMP	-	Systems Theoretic Accident Model and Process
SVF	-	Street-vended Foods
TPC	-	Total Plate Counts
WHO	-	World Health Organization

ACKNOWLEDGEMENTS

The selfless support I received from the supervisor of this study, Prof. Ahmad Cheikhyoussef deserves my highest and sincere appreciation, hence this well-deserved first acknowledgement. The academic and general advice I received from him on the going about of day-to-day activities throughout the whole project was exemplary, and I will always apply it for the benefit of efficiency in all life endeavours. The laboratory technicians; Mr Augustinus Mbangu and Ms Kaveire Kaitjizemine at the Department of Biological Sciences of the University of Namibia were always available for assistance, their help and commitment were not in vain, worthy of acknowledgment.

A big thank you to the class mates in the Food Microbiology Stream as well, for their welcoming conduct, supporting where and when they could throughout our days together, especially in the lab. Every family member, relative and friend that knew about my sacrifices and challenges, and verbally rendered an ounce of moral support or encouragement, even criticism, deserves acknowledgement and thank you.

DEDICATION

This thesis is dedicated to my parents, for all the support and suffering they went through just for their children to get some education. They were always considerate, endlessly taught, nurtured, and from them reasonably open minded people emerged - a community to whom this is dedicated too.

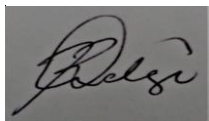
DECLARATION

I, Paulus Ngalangi, hereby declare that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

No part of this thesis may be reproduced, stored in any retrieval system, or transmitted in any form, or by means (e.g. electronic, mechanical, photocopying, recording or otherwise) without the prior permission of the author, or the University of Namibia in that behalf.

I, Paulus Ngalangi, grant the University of Namibia the right to reproduce this thesis in whole or in part, in any manner or format, which the University of Namibia may deem fit, for any person or institution requiring it for study and research; provided that the University of Namibia shall waive this right if the whole thesis has been or is being published in a manner satisfactory to the University.

Paulus Ngalangi:



Date: October 2022

CHAPTER ONE: INTRODUCTION

1.1. Background of the study

Diseases caused by consumption of contaminated foods and water lead to estimated 420,000 deaths among people worldwide every year, of which almost one third are children under the age of five (WHO, 2015). The ingestion of food items contaminated with microorganisms and chemicals can lead to food borne disease outbreaks (Webb & Morancie, 2015). Handling, preparation, and storage of food require measures that prevent food contamination. The Namibia Food Policy (2014) considers food to exist only if it is safe for human consumption. Therefore, any contamination with microbes, chemicals or physical agents renders food a risk to human health and not fit for use. A lack of systems that control and enforce food safety critically increases chances of microbial food contamination that leads to food borne diseases such as salmonellosis, listeriosis, typhoid fever, cholera and diarrhoea, among others (Sani & Siow, 2014).

Maintaining food safety can be daunting, more so for urban communities for whom where a lot of food and food products are available at affordable prices along streets (WHO/FAO, 2010). Many low and middle-income consumers depend on street vended foods, which come with a number of health and safety issues. Quality of the raw materials, preparation conditions, handling and storage conditions, as well as operating in locations that do not meet all food safety requirements contribute to the compromise of food safety among local food markets (Aluko, et al. 2014; Choudhury et al. 2011; Muyanja, et al. 2011).

Food handlers greatly contribute to the transmission of microorganisms to the food via their hands, hairs, nose and mouth during preparation, packaging, processing and

service (Assefa, et al., 2015; Moloji, et al., 2021). Additionally, the spread of microbes to food can occur when food handlers cough and sneeze (Okonko et al. (2010).

Basic food safety knowledge exists among food vendors as this is passed on through generations by means of traditions. The street food markets feature glimpses of microbial growth suppression practices to limit food poisoning and spoilage. Present on the street markets are implements for the control of temperature, pH, water activity (a_w) and aerobic or anaerobic conditions, which serve as hurdles for microbial growth. Survival of microbes in the environments created along the streets may depend on prevailing temperature, pH, water activity, preservatives (nitrite, lactic acid or carbon dioxide), and atmosphere gas (McQuestin et al. 2009). Several studies on the effects of temperature, pH, and water activity on the survival of microbes have been conducted whereby the effects of varying the conditions were confirmed. However, technical hands on knowledge of the aforementioned among the vendors may require further assessment. The continued occurrence of foodborne diseases is compounded by limited training and poor food safety and handling knowledge among vendors (Asiegbu, et al. 2016).

In Namibia, street-vended foods vary from household prepared meals to items purchased from supermarkets, which includes maize meal porridge (pap) served with varying relish, beef stew, chicken stew, or fried steak, as well as cooked macaroni, rice, spaghetti and various salads. Street-food vending in Windhoek has increased noticeably due to raving unemployment rate as is the case with other cities in developing countries (Asiegbu, et al. 2016). The street food vendors gather at high traffic areas such as construction areas in and around the Central Business District

(CBD) and at prominent assembly points like bus stations and taxi ranks to provide much needed affordable nutrition to those that flock to the areas for service. Aailed street vary from simple ingredients prepared via a range of processing conditions such as fresh-cut fruits and vegetables, to cooked foods, packed beverages, and snacks (Sseguya et al. 2020). Food outlets in and around Windhoek should be subject to regulation by relevant heath authorities, however, there is no oversight on all outlets, much so for street-food vendors who more or less operate unregulated. In Namibia, like the rest of the world, a food safety system exists which includes local government, local authorities, food business companies, and the public. The systemic interplay of components of the food supply chain ultimately delivers safe food to consumers. In general, each individual's diet is dependent on a complex interplay of social, economic and technological forces (Schlosser, 2001).

The use of a systems analysis model such as the Systems-Theoretic Accident Models and Processes (STAMP) model in Namibia provides an opportunity to analyse and assess the limitations of event chain models and critically analyse the complex interactions among various components in the complex food system (Nayak & Waterson, 2019). The potential of food-borne disease outbreaks at the level of street food handlers can be determined through application of a model built from various scenarios, to ensure accidents that may occur are approached and resolved in view of a systems approach. The scenarios, which are postulated sequences of events, related to possible accidents that may lead to food-borne disease outbreaks lead to the build-up of the STAMP model, with the focus on street vended food markets.

1.2. Statement of the problem

There is a lack of familiarity with the existence and application of key components of Food Safety such as the Hazard Analysis and Critical Control Points (HACCP) and Good Manufacturing Practices (GMPs) among street food handlers (Nkandi et al. 2017). These components are crucial in preventing food-borne infections that are a consequence of unhygienic handling of foods. Knowledge and perceptions of microbial food hazards of street food handlers are not assessed, in order to tailor mechanisms that curb on food-borne diseases. There are no systematic models to use in addressing accidents that may occur and lead to food-borne disease outbreak, therefore this research project was proposed to contribute to fill this gap in the knowledge and to strengthen the current informal food safety system in Windhoek.

1.3. Objectives of the Study

The following objectives of the study were set:

- a) To survey the food safety knowledge and microbial hazard awareness among local food vendors in Windhoek.
- b) To determine the physicochemical and microbial properties of food samples collected from the surveyed locations.
- c) To introduce ready to use scenarios that are drawn from the study findings and apply the scenarios to a STAMP model - A proactive approach, identifying the characteristics of the food system and the importance and benefits of adopting a whole system approach.

1.4. Significance of the study

The study will contribute to the formulation of strategies and guidelines aimed at informing and educating street food vendors about food safety, which leads to reducing food-borne infections that are otherwise preventable. Determining the level of knowledge and awareness will influence efforts of implementing quality control systems, ensuring safety of the raw materials used during preparation, processing, storage and selling of the foods, consequently improving public health at large.

The determined physicochemical and microbial properties of the foods are essential in indicating the susceptibility of the foods to harbouring pathogenic microbes. Disease outbreaks that may result from accidental exposure of foods to microbial contaminants cannot be minimized effectively without a systematic approach such as STAMP in place, to enable application of ready to use scenarios. The application of ready to use scenarios in dealing with microbial food hazards will contribute to the streamlining of food safety regulation in Namibia.

1.5. Limitation of the study

The street markets settings did not favour diligence of interviews during data collection, in addition to language barriers. The study did not cover all local markets and foods around Windhoek, whilst the research duration was constrained. Description of each specific accident and constraint, hierarchical levels of control and determination of inadequate control measures were not included as part of the qualitative data in the Questionnaire to the. The development of the study Questionnaire could not cover components pertaining to qualitative data collection on food value chains and interactions between various components of the food systems,

as well as vendor awareness of compliance to regulations, associated food inspections and monitoring procedures necessary for STAMP customization.

The State of Emergency declared in March 2020 by the Namibian government due to the outbreak of the Coronavirus disease (COVID -19) affected the timelines for the project. Subsequent restrictive Emergency Regulations pertaining to the pandemic caused delays in the collection of data through the rest of the year 2020. Only some physicochemical (pH and moisture content) properties and Total Plate Counts (TPC) of collected food samples were studied.

1.6. Delimitation of the study

The data collection at selected street vended food outlets around Windhoek was conducted between November 2020 and February 2021. The study focused on markets of perishable foods that are susceptible to food-borne illness causing microbes if not handled in a hygienic manner.

CHAPTER TWO: LITERATURE REVIEW

2.1. Food safety systems

The composition of food systems and their food safety cultures is inclusive of two key perspectives that need to be interrogated. These are: (1) ‘micro-perspective’ and (2) ‘macro-perspective’. According to Nayak and Waterson (2019), “factors within the micro-perspective influence the functioning and behaviours of national level food systems, whereas, factors within the macro-perspective influence the functioning and behaviours of the global food system.” Food systems within a country, as is the case in this study, are looked at from the micro-perspective, where a range of factors and stakeholders play a key role in food safety (Pennington, 2003).

In Namibia a policy was passed, which assigns different stakeholders responsibilities to ascertain food safety to the population. The Ministry of Health and Social Services, the Ministry of Industrialisation and Trade, the Ministry of Fisheries and Marine Resources, the Ministry of Urban and Rural Development, and the Ministry of Agriculture, Water & Land Reform all play a role in ensuring safe food is available to the population at large. The implementation of the policy is therefore joint that further includes stakeholders and partners of the ministries, such as local authorities and municipalities. The food system is influenced by a number of processes that vary from manufacturing of raw materials to consumption of the food products. Food safety as a principle ramifies the whole complex system, influencing the quality of food produced for consumption. The food safety system as a whole in Namibia includes involvement of three different systemic levels: (1) the government and regulatory bodies; (2) organisational management (upper-middle-lower); and (3) front-line actors (shop floor

staff and the physical work place). Table 1 summarises the components of the food system across various systemic levels in Namibia, and the roles they currently play.

Table 1. Components of the Food system across various systemic levels in Namibia.

(Adapted from Nayak & Waterson (2016).

Systemic level	Component	Role played in the food system
External	Media, Market forces, Societal values and priorities, Historic events and Global politics	Conveying new regulations and budget allocations to consumers as well as manufacturers; publicizing wrong-doings and breaches of regulation. Media are essentially the link between consumers and manufacturers, as well as consumers and the government
Government	Cabinet Committee on Legislation and The Parliament	Initiation and approval of new laws.
	Parliament	Implementation of regulations in the national food law; making decisions over how to implement directives into the country's food regulations; deciding on budget allocation.
	Food Standards Agency (Namibia Standards Institute, Ministry of Agriculture,	Protection of public health in relation to food; helping local councils understand food regulations; making decisions on how to split the allocated budget.

	Water & Land Reform, Ministry of Industrialisation & Trade, Ministry of Health & Social Services)	
	Local councils (Town councils and City of Windhoek)	Ensuring that the regulations are actually implemented; inspecting food businesses; helping food businesses establish and better themselves.
Organizational/ Workplace	Management	Conveying information from food inspectors to the shop-floor employees; ensuring that food manufactured is safe for consumption; ensuring that food safety and hygiene regulations are complied with; administration work; bringing in orders for the food business; hiring contractors (cleaning, temporary employees, full-time employees, transportation); ensuring that employees have the required training.
	Shop-floor employees	Working on the shop floor; following training provided diligently; ensuring that they follow protocols; making sure that they know what they are doing; production of

		<p>food safe for consumption; efficient cleaning of shop-floor; transporting food; storing and organizing food in stores.</p>
--	--	---

Table 1 highlight the intricacy of the vast interlinks that comprise a system and its role players (Neff & Lawrence, 2014). Negligence to hygiene practices is often attributed to individuals, even though it is, as a function largely connected to the prevailing organisational culture (Clayton & Griffith, 2008; Griffith et al., 2010). In the long run, controls and enforcement at the systemic levels, coupled with the channelling of knowledge, ultimately enhance food safety awareness and hygiene practices among street food vendors.

2.2. Food-borne diseases

Microbial contamination of foods is not a new phenomenon in communities the world over, and Windhoek is no exception to concerns of potential food-borne disease outbreaks. Pathogenic bacteria of public health concern are prevalent in street vended ready-to-eat meats in Windhoek, Namibia, as an example, and stakeholders in the food industry are recommended to provide training and continuously educate street food vendors on food hygiene and sanitation (Shiningeni, et al. 2018). There are perceptions that street vended foods are mainly unsafe because of the environment under which they are prepared, sold and consumed, which exposes the food to contaminants (Muinde & Kuria, 2005). Improper holding times or temperatures during processing of ready-to-eat foods are of particular criticality in the street market setting. The foods are often prepared in advance, well before consumption and are subjected to unfavourable temperature fluctuation during serving and distribution, allowing

bacterial growth (Sani & Siow, 2014) which leads to either food spoilage or contamination with pathogens and toxins.

Food poisoning caused by bacteria, moulds and viruses that infest food results into food poisoning, which at its worst manifests into devastating, severe inflammation of the stomach and bowels, a severe condition known as gastroenteritis (Sharif & Al-Malki, 2009). In extreme cases it may even lead to blood poisoning and kidney failure. It is important to note that food can easily become contaminated at any stage of the production process by a wide range of both waterborne and food-borne microbes such as *Salmonella* or *E. coli*. A prime example of food-borne outbreaks is one caused by *Salmonella* bacteria, the resultant infection is a major food-borne illness that causes nausea, vomiting, diarrhoea and high fever (Frank et al., 2014).

2.3. Knowledge and perception of food safety among street food vendors

General lack of knowledge about the epidemiological significance of many street vended foods, poor knowledge of basic food safety measures and inadequate public awareness of hazards posed by certain foods have severely hampered the deployment of a precise, scientific approach to the issue of public health and safety (Rane, 2011). The public needs information about health risks associated with food-borne diseases, thus authorities require to establish means to educate the existing and potential street food vendors. Important points that should be considered when devising effective risk communications, among other things, is the understanding of the target group's beliefs, perceptions and, last but not least, existing knowledge of the communication topic which is microbial food hazards in this case.

There are perceptions that street vended foods are a risk, owing to the knowledge of the suspicious environment under which they are prepared, sold and consumed, which exposes the food to contamination (Muinde & Kuria, 2005). Ensuring that knowledge of hygiene practices among street food vendors exists greatly reduces microbial food hazards. The risk declines due to the fact vendors now understand and adhere to food safety standards and protocols provided by relevant institutions and regulatory entities such as the municipality and Ministry of Health and Social Services. Capacitating street food vendors requires instilling knowledge on effective cleaning and the prevention of cross-contamination, which are essential in ensuring ready-to-eat food served by street vendors is reliably safe for consumption (Food Standard Agency (FSA), 2006).

Street food vendors can be made aware of basic principles to achieving a market that ensures safe food is available to consumers. These principles can be tailored around five keys to safe food as advised by the World Health Organization (WHO). It is vital to evaluate and subsequently ensure that knowledge and awareness exists with regards to Key 1 (Keep Clean), which explores the general cleanliness and hand washing. This further brings out the need for provisions on water availability and washing of utensils as well as raw materials for during food preparation. Furthermore, Key 2 (separate raw and cooked food), draws interest whereby street food vendors need to know about the importance of keeping raw and cooked food separately to avoid cross contamination. Vendors knowledge on Key 3 (Cook food thoroughly) need to be evaluated, since traditions of preparing food may not cater for the requirement of thorough cooking to eliminate harmful microorganisms. Key 4 (Keep food at safe temperatures), is a critical temperature component that greatly contributes to microbial

growth in foods, hence spoilage and health risk. Heating, reheating and refrigeration play a major role in the street food markets, thus knowledge on these aspects needs to exist among street vendors (WHO, 2007). Lastly, Key 5 (use safe water and raw materials) would impart knowledge that ensures vendors do not resort to reuse of water and mixing of raw materials with already prepared foods. Together, a knowledgeable community of street food vendors can be achieved by imparting the basic principles enshrined in the five keys to safe food.

2.4. Microbial quality of street vended foods

Studies have shown that in order to reduce incidences of food-borne illnesses, prevention should be implemented at all stages in the food supply chain (Sanlier, 2009; Cates et al., 2009). It is important to note that food can easily become contaminated at any stage of the production process by a wide range of both waterborne and food-borne pathogens such as *Salmonella* or *E. coli* (Sani & Siow, 2014).

Food handling can be safe from a microbial contamination perspective, provided preparation is done abiding to four main instructions: (1) avoiding cross-contamination of raw food and ready-to-eat foods, (2) maintaining high standards of hygiene, (3) cooking thoroughly and (4) preserving the cold chain when transporting and storing. Each year, up to one-third of the population of developed countries is affected by food borne illnesses (Isara, et. al., 2010).

Food can be contaminated by handlers with microorganisms prior to cooking or after it has been cooked. Food safety, hygiene and sanitation training and the subsequent licensing of food businesses is not considered by most if not all street food vendors,

who operate in makeshift, often unclean environment (FAO, 1998). Foodborne pathogens such as *Clostridium perfringens*, *Escherichia coli*, *Shigella* spp., *Campylobacter jejuni*, *Staphylococcus aureus*, *Salmonella* spp., and *Bacillus cereus* are common in street-vended foods (Nobili, et al., 2017). Frying, baking, boiling, fermenting, braising, roasting, or juicing are the usual preparation methods employed by street food vendors (Kharel, et al., 2016). Microorganisms are introduced to the foods via various modes, and the practice of dishing out food without further reheating it, particularly for cooked foods, greatly increases the likelihood of food poisoning and infections. Exploits with attempts of marketing the food such as displaying and frequent uncovering, coupled with hastened preparation procedures further render the foods more vulnerable to microbial contamination (Gitahi, et al., 2012).

2.5. Physicochemical characteristics and microbial quality of street-vended foods

2.5.1. pH Values in Food

The acidity and alkalinity, hence the pH of foods plays a role in their susceptibility to spoilage. The potency of hydrogen (pH) is a scale used to specify the acidity or basicity of an aqueous solution. Measuring the pH is a direct measurement of hydronium ion concentration or negative logarithm of the hydronium H_3O^+ concentration in an aqueous medium (Sadler, 2010). The pH scale ranges from 0 to 14, with pH 7 being neutral. The pH values below pH 7 are indicative of the acidic range while those above pH 7 represent basic range of the scale.

The techniques of fermentation or the addition of weak acids to increase the acidity of foods as a preservation method have been used over centuries among communities. Most foods such as meat, fish, and vegetables are slightly acidic in their natural state,

while most fruits are moderately acidic. Lowering the pH of a food increases the effectiveness of organic acids as preservatives. Favourable pH for acid preservation is 4.6 and below, where toxins formed by *botulinum* are inhibited.

Acids present in certain foods and beverages contribute to low pH which consequently affects the growth of microorganism to in the foods (Sadler & Murphy, 2010). Food preservation by means of lowering the pH levels of foods cannot however substitute hygiene and sanitation practices in the street food markets. Food vendors ought to adhere to the highest standards of cleanliness and protection, with a culture similar to that food manufacturers apply in adhering to GMPs at large. Foods manufactured under controlled conditions of altered pH are still susceptible to spoilage from contamination with yeasts and moulds. Therefore, further sterilization practices like heating of packaged foods that are preserved by acidification are necessary to increases the shelf lives of the foods, whereby yeasts and mould spores are killed.

The lowering of pH of foods can be augmented with factors such as added salts, temperature, redox potential, and preservatives to inhibit growth of pathogens and other organisms. Furthermore, evidence of needing less heat to inactivate microbes as a result of reduced pH has been recorded (Smelt & Brul, 2014).

In food preservation, the commercial use of organic acids to inhibit microbial growth has been exploited extensively. Organic acids are known to exist in a pH-dependent equilibrium between the dissociated and undissociated states. Studies have shown that un-dissociated and uncharged organic acid molecules are first responsible for the antimicrobial activity since their concentration increases at low pH (Theron & Lues,

2007). The undissociated molecules of organic acids are known to be lipophilic which enables them to cross the lipid cell membranes of microorganisms into their cytoplasm where they induce cell death (Hauser, et al., 2016). The H⁺ ions that build up in the cytoplasm of microbes results into a reduction in intracellular pH, causing cellular damage and unwanted modification the enzyme-substrate mechanisms, structural proteins, and DNA (Stratford, et al., 2013).

2.5.2. Moisture content in foods

Microorganisms, like all living organisms, have the need for water to grow, and they make use of water in the foods they infest. Controlling the moisture content of foods has been used as a preservation method by humans since ancient times. The need for water by microorganisms is understood in terms of water activity (a_w) of the food or environment that they find themselves in. Moisture provides for free water that is available to bacteria, fungi, and yeasts for metabolism and contributes to toxin production. Water activity is defined as a measurement of the availability of water for biological reactions and it is a ratio of water vapor pressure of the food substrate to the vapor pressure of pure water at the same temperature (Gustavo, et al., 2007).

To avoid microbial growth, the moisture content and water activity must be kept below approximately 10% and 0.60 – 0.65, respectively (Mercer, 2008), depending on the type of food. Fresh foods, which are high in moisture content often have a water activity close to 0.99 and are particularly prone to microbial growth. Moreover, the water activity values (0.97 - 0.99) of fresh foods, such as fresh meat, vegetables, and fruits, are convenient for optimum growth of most microorganisms (Jay, et, al. 2005).

It is reported that, the loss of food due to spoilage (caused by microorganisms) after it is harvested amounts to more than 30 percent of the fresh food losses in developing countries (Gustavsson, et al. 2011). The control of moisture levels and preservation of foods by means of temperature regulation is a challenge in developing countries due to high outdoor temperatures and often inadequate refrigeration and storage facilities (Sandulachi et al. 2012). Drying is the most common method of combatting food spoilage in developing countries like Namibia. Moisture available to support microbial growth is significantly reduced by drying, enhancing longevity of foods on the market.

In-depth knowledge of moisture content and water activity in foods enhances comprehension of microbial growth, with the ultimate goal of tailoring ideal food preservation methods. Furthermore, combined understanding of pH and water activity (a_w) effects, the two key parameters that influence microbial growth in the food environment, is vital in the maintenance of food quality and assurance of food security.

2.5.3. Microbial enumeration

The fact that microorganisms cannot be seen with the naked eye brings about the need to grow them using nutrient agar. Consequently, microbes grow into colonies that can be visualized and counted. Colonies are results of single microbial cells that have multiplied thousands of times, thus each colony is counted as a single microbial colony forming unit (CFU). Serial dilutions of the original sample are done to enable the counting, on average between 30 and 300 colonies of the target microbe recorded. Fewer than 30 colonies makes the interpretation statistically unsound and greater than 300 colonies often results in overlapping colonies and imprecision in the count. Average microbial counts obtained on the plates are multiplied by the dilution factor

and expressed as Colony Forming Unit per gram (CFU/g) in a specific sample (Fawole & Oso, 2001). The microbial counts are expressed in Log CFU/g in the final reporting.

The composition of the nutrient agar can be altered to include reagents that prevent growth of unwanted microbes and make the target organism easily identified. At the end of the incubation period the colonies are counted without the need for a microscope as the colonies are visible.

2.5.3.1. Total Plate Count

Total Plate Count (TPC), also known as Standard Plate Count (SPC) or Total Viable Cells (TVC) is a laboratory practice typically conducted to obtain information about the microbiological quality of foods. The TPC tests have application in the general evaluation of cleanliness of equipment and surfaces, and sanitation. Enumeration of microorganisms is an essential microbiological task for many industrial and research applications.

Examples of a viable cell count are spread plates from a serial dilution of a liquid culture and pour plates technique. With a spread plate one makes serial dilutions in liquid media and then spreads a known volume from the last tube(s) in the dilution series. In the pour plate method melted agar is poured into a petri dish and mixed with a diluted microbial sample. The colonies would be counted and the viable cell count calculated after a period of incubation. Despite limitations, TVC is one of the most common tests used to assess the microbiological quality of both water and food. TVC test regulations have been adopted by industries and health organizations of many

countries and they play an important role in validation and verification of treatment plant procedures.

Plate Count Agar, used for TPC procedures, consists of Tryptone that provides nitrogenous and carbonaceous compounds, long chain amino acids, and other essential nutrients, together with yeast extract that provides Vitamin B complex (Baird et al. 2015). Pour plate count method is recommended for higher results compared to spread plate technique.

2.5.3.2. Lactic Acid Bacteria (LAB) enumeration

To grow lactobacilli, de Man, Rogosa and Sharpe (MRS) agar is used, ensuring lactic acid bacteria are isolated from selected food sources. A range of lactic acid bacteria can be cultivated on MRS agar. The selectiveness of the agar for lactic acid bacteria is enhanced by lowering the pH to 5.7 and the addition of 0.14% sorbic acid. Tryptic digest of casein, beef extract, yeast extract, glucose, sorbitan monooleate, di-potassium hydrogen orthophosphate, magnesium sulfate, manganese (II) sulfate, ammonium citrate, sodium acetate, agar, and distilled or deionized water are combined and boiled to produce MRS agar. MRS agar is known for cultivation of good colony counts and characteristic colony size and morphology for lactobacilli and other lactic acid bacteria (Corry, et al., 2003). LAB are known to enhance organoleptic properties of various foods, in addition to health benefits imparted when introduced in foods.

2.5.3.3. Yeasts and moulds enumeration

Yeasts and molds are cultivated on Potato Dextrose Agar (PDA) medium supplemented with acid or antibiotics to inhibit bacterial growth. Fungi can be

selectively grown by the use of PDA. PDA is generally used in plate count methods for foods, dairy products and testing cosmetics. A potato infusion comprising a base supports the growth of molds and induces pigment production in some dermatophytes (Sagar, 2019). Some yeasts and molds are commercially used in foods, where they produce desired effects, contributing to organoleptic and health benefits.

2.6. Microbial food hazard scenarios and STAMP

Microbial analyses can be viewed as reactive preventative methods for maintaining safety in the food supply system in the short run (Griffith, Jackson, & Lues, 2017). These methods deal with aberrations that are able to cause widespread food poisoning, and should not be solely relied on. Therefore, systems approaches to overseeing safety in the food systems are recommended (Nayak & Waterson, 2019).

Scenarios that could lead to food-borne outbreaks need to be examined for the adoption of models that are implementable in addressing food safety; one such approach is to adopt the STAMP (System Theoretic Accident Model and Processes) accident analysis model. According to Leveson (2004), accidents are either a result of inadequate control or inadequate enforcement of safety-related constraints on the development, design and operation of the system. “Accidents occur when external disturbances, component failures or dysfunctional interactions among system components are not adequately handled by the control system” (Leveson, 2004).

In food safety, the model can be applied to suggest that one of the factors that could lead to food poisoning outbreaks is when controls such as mandatory internal Hazard Analysis and Critical Control Points (HACCP) audits are not carried out diligently, thus failing to identify faults, rectify and report them. The goal of this control structure

must be to enforce constraints on actors within the system (Nayak and Waterson 2019). The STAMP method helps analysts to identify the existing types of controls in a system or complex system and their failure points (Leveson, 2004; Salmon et al., 2016). Most accident and system analysis models define safety management in terms of preventing component failure events; however, STAMP defines safety management as a “continuous control task to impose the constraints necessary to limit system behaviour to safe changes and adaptations” (Leveson, 2004). According to this model, accidents are to be understood by identifying controls and analysing the reasons behind these controls not being effective or adequate enough to prevent or detect maladaptive changes and enforce the safety constraints in place (Nayak and Waterson, 2019). Hence, violated safety constraints also need to be identified.

Constraints, control loops, process models and levels of control are the basic concepts in STAMP (Leveson, 2004). Instead of viewing accidents as the end result of a series of events, it is viewed as the result of a lack of constraints imposed on the system design and on operations across the various socio-technical levels in the STAMP model. Accidents occur due to a lack of appropriate constraints on the interactions (Leveson, 2004).

CHAPTER THREE: MATERIALS AND METHODS

3.1. Research Design

A cross-sectional study with descriptive and analytical components was conducted in preselected Windhoek locations of Okuryangava and Katutura to the North of the city centre, Klein Windhoek to the East, Kleine Kuppe and Prosperita southward, and Otjomuise to the West. The sample collection sites are indicated on the map of the city of Windhoek in figure 1 below.

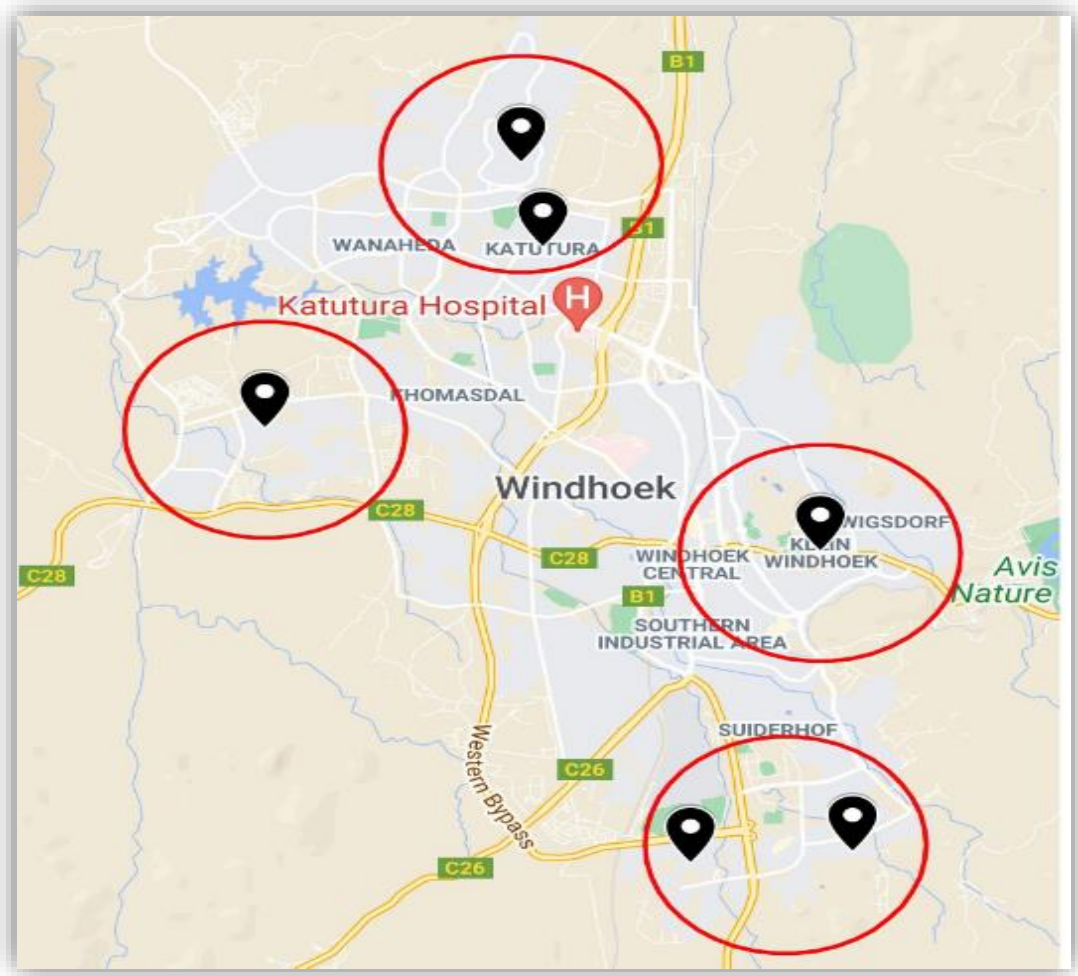


Figure 1. Map of the City of Windhoek, showing study locations marked in circled areas

(www.google.com/maps)

Quantitative data was collected using structured closed-ended questionnaires. Food samples were purchased for laboratory analysis on pH, moisture and total plate counts. Systems analysis model of STAMP was adopted and customised based on event chain models drawn from street food handlers to ensure accidents that occur as a result of inadequate controls or lack of enforcement of safety-related constraints on the design, development, and operation of the food safety system as a whole do not occur. Component failures, external disturbances, and dysfunctional interactions among system components can be adequately dealt with using STAMP in the prevention of accidents.

3.2. Food safety knowledge survey

A total of sixty (60) participants involved in street food handling were randomly selected at six (6) food markets in various neighbourhoods of Windhoek, stratified into clusters, north, south, east, and west, with fifteen (15) representatives in each stratum. A written questionnaire (Annex 2) consisting of 22 questions on microbial food hazards was designed using information from literature, and was administered in English. The structure of the questions was divided into five sections: socio-demographic, knowledge of food safety, personal hygiene, perception on food hazards and response to food-borne disease outbreak. The assessment was done by means of indicating agreement or disagreement with a 5-item scale for participants to answer different items, by choosing one of five alternatives (strongly disagree, disagree, agree, strongly agree and don't know).

Selected locations where ready-to-eat food is sold were visited for collection of data. The purpose of the study was explained to the street food handlers. Upon acceptance

to participate in the study, participants were asked to sign a prior informed consent (PIC) form (Annex 3). Association of variables was considered statistically significant at $p < 0.05$. Mean scores of responses were converted into percentages for purposes of easy interpretation of results. The significance in difference was tested at 95% confidence interval, to compare the mean scores of knowledge, hygiene practices, perception and response to food-borne disease outbreaks among the different socio-demographic characters of participants. The responses were reclassified into two categorical responses 'yes' and 'no' for correct and incorrect responses respectively. Predictive variables including age, length of employment and education level were incorporated into all models with general knowledge on food safety as the dependent variable.

3.3. Samples collection

Questionnaire data was collected with coded (to ensure anonymity) questionnaire for each participant in a once-off face-to-face interview. Available ready-to-eat food samples (cooked and prepared liquid foods) were collected for physicochemical (pH and moisture) and microbial quality (TPC) analysis. TPC was done to estimate the microbial population in order to judge sanitary quality of foods and give a hint with regards to microbial contamination risks in some foods. The ready-to-eat foods included in the study were selected based on their availability and proneness to microbial contamination.

Selected ready-to-eat food samples were randomly collected from the study sites. Sterile sample bottles placed in a cooler box were used to transfer the food samples to the Microbiology lab of the Department of Biological Sciences at the University of

Namibia. The sample bottles were kept at below 0 °C under ice cubes in a cooler box. Preparation and inoculation was done within four (4) hours, the same day of sample collection. Spare samples were stored in the fridge at -18 °C for further use if need arose. A minimum of 25g and 50ml of solid and liquid food samples respectively were purchased for the analysis.

3.4. Physicochemical parameters and microbial analysis

3.4.1. Measurement of pH of food samples

Each food sample was mixed with deionized water and turned into a slurry by use of a stomacher. The electrode of a pH meter was submerged in the sample, with a gentle stir to ensure consistent sampling, and left until a stable reading was displayed and then recorded. The electrode was rinsed and cleaned after each use. Determining the acidity or alkalinity of foods owes its basis on principles reliant on the power of Hydrogen (Karastogianni et al., 2015). The pH of solution can be measured by use of litmus paper, to determine whether it is a base or acid without revealing the pH value. Similarly, universal indicator paper with better sensitivity can be used to distinguish the pH value up to 0.5 pH scale. The use of modern pH electrode that employs a glass membrane sensitive to pH is fairly quicker and more convenient. Values in the range 0.0 to 14.0 can be detected and displayed on the pH meter (Karastogianni et al., 2015).

3.4.2. Moisture content

Moisture content of the food samples was measured using a Mettler Toledo Moisture Analyzer that gives readings of percentage moisture of a weighed food sample. The standard method as per manufacturer's instruction for measuring the percentage moisture was followed. The Moisture Analyzer uses the thermogravimetric principle,

whereby food samples are heated by a halogen dryer unit (Mettler Toledo, 1999). The equipment is tarred to ensure recalibration after each measurement. The displayed data can be stored and retrieved later on for further analysis.

3.4.3. Microbial analysis

Total plate count, total lactic acid bacteria, yeast and mould enumeration by pour plate technique was done following standard procedures as those done in similar experiments by Lefyedi, Marais, Dutton and Taylor, (2005), with the growth media prepared according to manufacturer specifications. Colonies were counted manually, and those between 30 and 300 counts were recorded, or else the counts are regarded negligible (less than 30) or too numerous to count (more than 300). The counted colonies were presented as a mean bacterial load, expressed as the logarithm (base 10) of the colony forming unit per gram of sample (CFU/g). A schematic diagram of the work involved in the study is shown in Figure 2.

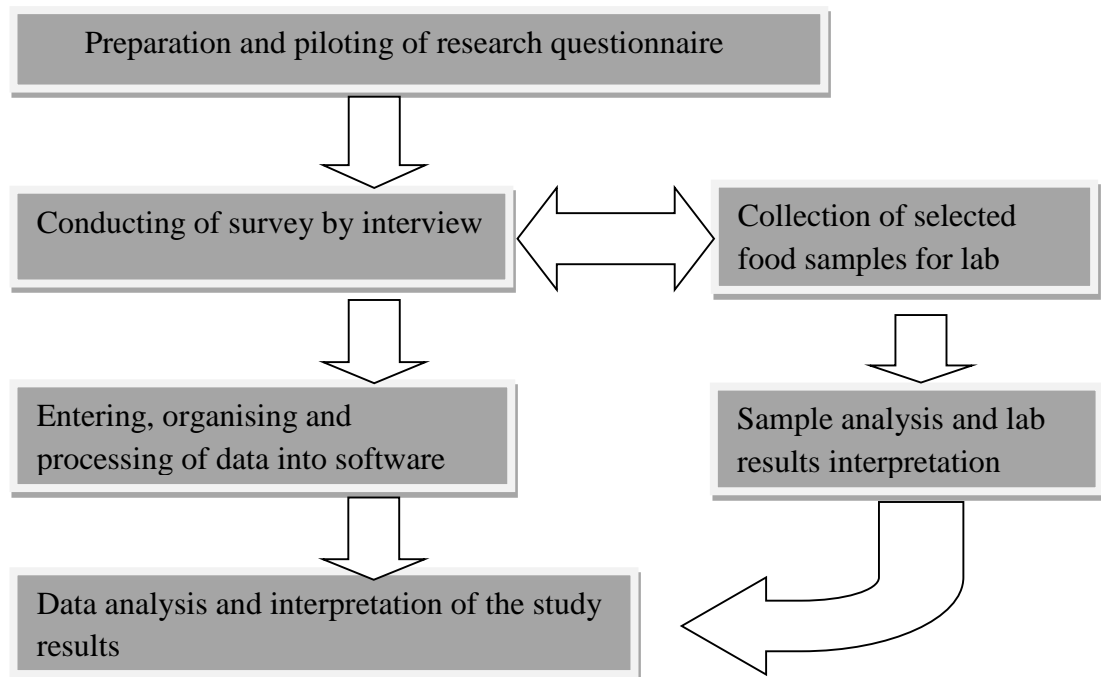


Figure 2. Flow diagram of the process followed in the study

3.4.4. Applying systems thinking model

STAMP model was adopted from Leveson (2004) to assess applicability of food safety control systems in Windhoek. Data on Knowledge of food safety, personal hygiene, perception of food hazard, and response obtained from the questionnaire, coupled with physicochemical and microbial quality data informed the adoptability of interlinks (STAMP model) that influence preparedness programmes in maintaining food safety. The ready to use scenarios were aided by deductions from the survey and the foods' physicochemical and microbial risks.

3.5. Research Ethics

Ethical clearance certificate was obtained from the University of Namibia, Research and Ethics Committee (UREC) (Annex 1), accompanied by prior informed consent and confidentiality agreement signed by the food vending participants.

3.6. Statistical Analysis

The total number of participants in the once-off questionnaire study (Annex 2) was 60; however, duplicate samples of six (6) different selected food types were collected at each cluster (north, south, east and west) for microbial assessment. The study involved the use of statistical methods like the mean, standard deviation and percentages to facilitate easy analysis and computation of the collected data. Statistics from the questionnaires and the collected food samples were summarised and presented in tables and figures.

Firstly, the data were tested for normality, homogeneity and reliability (Annex 3). Secondly, descriptive statistics were obtained using frequencies, standard deviations

and averages. Thirdly, associations between variables of interests were obtained using cross tabulation analysis. The study also performed ANOVA tests for difference between the means in physicochemical and microbial quality among the street vended foods around Windhoek.

3.6.1. Survey data analysis

The first part of the study involved Interviews with street food vendors conducted in English to collect data on knowledge of food safety, utilizing standardized structured questionnaires. Data collected includes information on demography and general information such as numbers and types of foods sold, level of experience and related information. Responses were tallied, indicating the existence or absence of food safety related knowledge. The independent samples t-test was applied in analysing the significant differences in food safety knowledge at the 95% confidence level ($P < 0.05$).

Data analysis was performed using Statistical Package for Social Science (SPSS) software (version 25). Descriptive and inferential statistics package was used to summarise the variables of interest and correlation between variables determined the differences in investigations of socio-demographic and microbial food hazards knowledge, perceptions and response. Statistical significance was tested at the 95% confidence level ($P < 0.05$). Normality, reliability and cross tabulations were applied to determine correlation and unpack information from the data (Annex 3).

Cross tabulations were used to find the following associations:

- Association between knowledge on food hazards and socio-demographic factors

- Association between hygiene practice and socio-demographic factors
- Association between Perception on Food Safety and socio-demographic factors
- Association between Preparedness to Food-Borne diseases outbreak and socio-demographic factors
- Association between Hygiene Practice and socio-demographic factors

3.6.2. Food samples data analysis

In the second part of the study, statistics on physicochemical and microbial properties of the collected food samples were compiled and summarised in tables for confirmatory determination of the means and standard deviation. Microsoft excel software was used for entering and organizing the collected data. The mean, percentage and standard deviation were the descriptive statistics carried out in the analysis of the data. Among the selected foods sampled in the study were local foods common on the street markets in Windhoek. These include, *kapana* (street vended ready-to eat beef meat) *matangara* (tripe, the cleaned digestive organs - stomach and intestines of slaughtered animals), *oshifima* (stiff porridge, a staple dish made from pearl millet flour, maize meal or a mixture of both and water), *fatcake* (a sweet, fluffy and moist deep fried dough ball) and *oshikundu* (a non-alcoholic beverage, that is a cereal product made from pearl millet and sorghum).

CHAPTER FOUR: RESULTS

The findings of the study have been divided into subsections which are discussed accordingly to address the objectives of the study. The first section is focusing on assessing the food safety knowledge among street food vendors with different components, while the second section determined few physicochemical characteristics (pH and moisture content), and microbial quality of street vended foods.

4.1. Assessment of food safety related knowledge among street food vendors

Results show that out of the four areas of concern related to food safety knowledge looked at in the study, the highest knowhow was found to be in preparedness to respond in the wake of a food-borne disease outbreak, with 95% of participants giving correct responses, while the least knowledge score was recorded for perception of food safety (59%) as shown in Figure 3. The other two food safety areas of interest revealed that 64% of participants have knowledge of food hazards, while 84% had knowledge of personal hygiene practices.

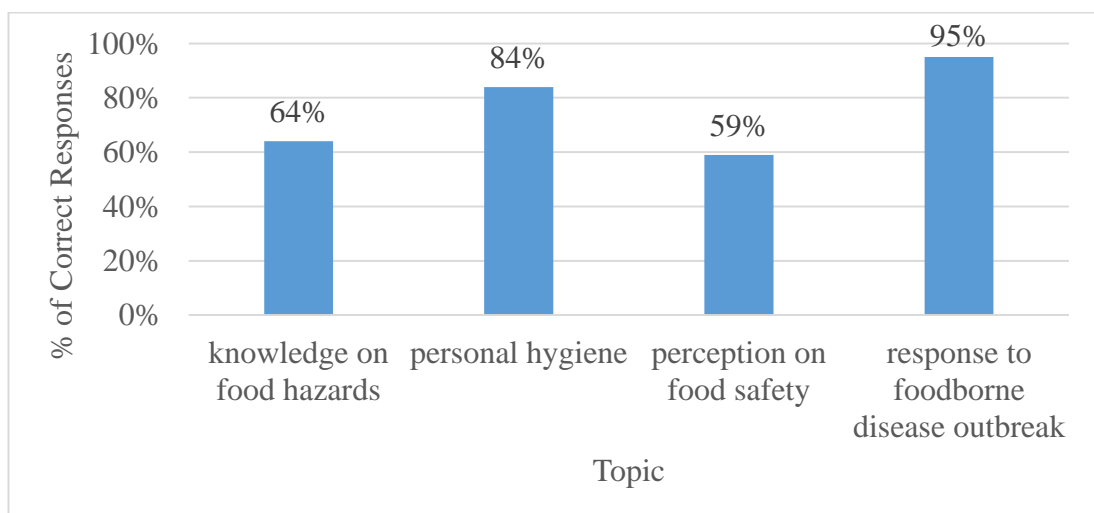


Figure 3. Correct responses to knowledge on food safety related aspects; food hazards, personal hygiene, perception of food safety and response to food-borne disease outbreaks

4.1.1. Demographic information of street food vendors

The administered questionnaire revealed information that can be used to characterise the street food vendors' demography, as shown in Table 2. The gender information of the 60 vendors who took part in the study shows that the majority 41 (71.7%) were female, with male participants being the minority 17 (28.3%), nearly a mere third of the total, as presented in Table 2. The age range of the participants was from 21 to 60 years old, majority of which were aged between 31 and 40 years old, that represents 38.3 % (n = 23). The participants who have attended school were the most, 57 (95%) in number while those who did not attend any form of school were only 3 (5%). Among those who attended school, about 61.7% of them indicated that they had secondary school education, 18.3% attended primary school and 15% had higher education. It further came to light that 35% of the participants have been employed in food vending business for more than two years, 35% for less than a year, while 30% have been involved in the business for a year to two years. The study revealed that 45% of the participants had between 1 - 5 years of some work experience, followed by 20% with more than ten years of experience and about 12% with between 6 - 10 years of experience. On average a participant was 35 years old, with the youngest being at 18 years of age and the oldest at 69 years old. Half (50%) of the participants were youth (18 - 34 years old), 46% were adults (35-59 years old) and only 3% were senior citizens (60 years old and above). On the financial front, the majority 65% of the participants make an average monthly income of up to N\$ 1000, followed by 21.7% making between N\$1000 - N\$2000, while only 13.3% reach N\$3000.

Table 2. Demographic information of participants

Variable	Item	Number	Percentage
Gender	Male	17	28.3%
	Female	43	71.7%
Age (years)	21-30	22	36.7%
	31-40	23	38.3%
	41-50	9	15.0%
	51-60	6	10.0%
Location	North	15	25.0%
	East	15	25.0%
	South	15	25.0%
	West	15	25.0%
Length of employment in the food vending business	Less than a year	21	35.0%
	1 to 2 years	18	30.0%
	More than 2 years	21	35.0%
Educational level: Attended school? <i>If yes</i> : Highest level of school attended?	Yes	57	95.0%
	No	3	5.0%
	Primary school	11	18.3%
	Secondary school	37	61.7%
	Higher	9	15.0%
Work experience	Less than one year	14	23.3%
	1-5 years	27	45.0%
	6-10 years	7	11.7%
	More than 10 years	12	20.0%

Types of food sold	1 type	17	28.3%
	2 types	19	31.7%
	More than 2 types	24	40.0%
Amount of made per month	up to N\$1000	39	65.0%
	N\$1000 - N\$2000	13	21.7%
	≥N\$3000	8	13.3%
Total		60	100

The types of foods sold on the visited street markets were recorded, with a total of 28 different foods identified. The most common occurrence is vendors involved in selling more than two types of foods, 24 (40%), followed by 19 (31%) who sell up to two types, and the 17 (28.3%) remaining deal with one type of food only. The types of foods sold by the participants involved in this study are presented in Figure 4.

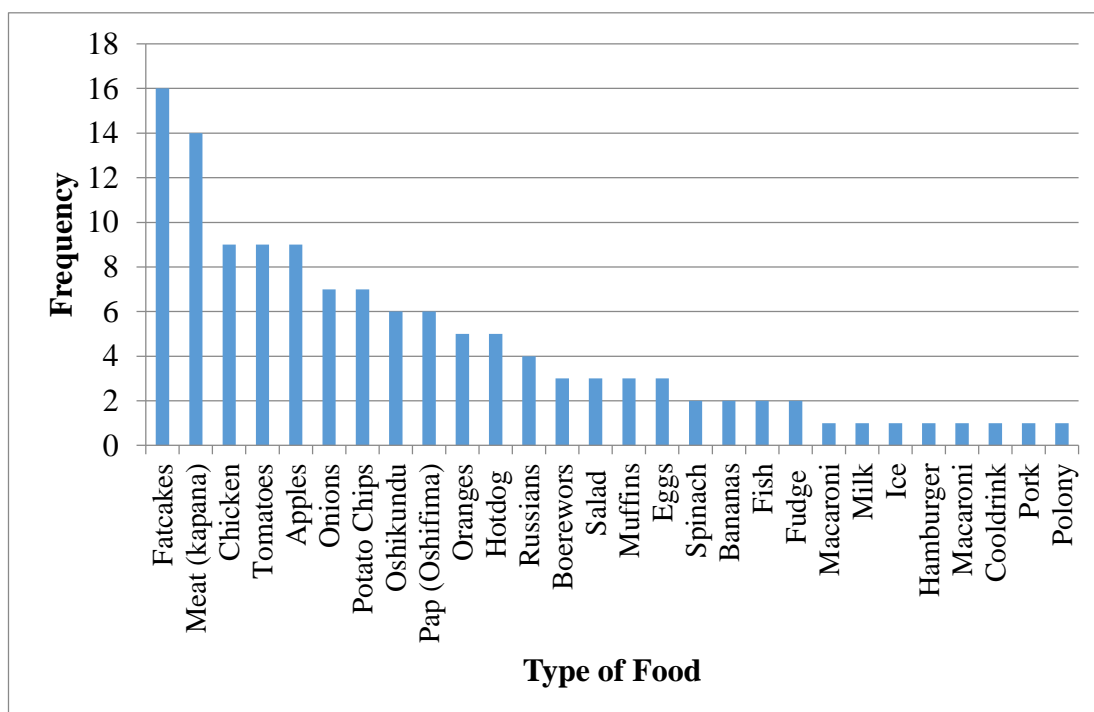


Figure 4. Frequency and types of foods handled by street food vendors

4.1.2. Street food vendors' food safety knowledge

A majority 48 (80%) of the participants in this study agreed that food hygiene requires the removal of microorganisms from food. Similarly, a greater number 59 (98%) of the participants agreed with the statement that keeping waste materials and foodstuffs separate is necessary. Storing cooked and uncooked foods separately and preparing cooked and uncooked foods with separate equipment was a notion agreed to by most, 59 (98%). The study found that a higher number 58 (96.7%) of street food vendors know that unclean equipment can transfer bacteria to food, compared to a total of 2 (3.3%) who did not get the correct response.

Table 3. Responses of participants to statements based on knowledge on food hazards

Statement	Strongly disagree		Disagree		Agree		Strongly agree		Don't know	
	f	%	f	%	f	%	f	%	f	%
1. Food hygiene requires the removal of microorganisms from food	3	5	7	12	33	55	15	25	2	3
2. It is necessary to keep waste materials and foodstuffs separate	1	2	0	0	26	43	33	55	0	0
3. Store cooked and uncooked foods separately and prepare cooked and uncooked foods with separate equipment	0	0	0	0	30	50	29	48	1	2
4. Unclean equipment can transfer bacteria to food	1	2	0	0	15	25	43	72	1	2
5. Freezing kills harmful microorganisms in food	7	11.6	9	15	13	22	15	25	16	26.6
6. Favourable temperature range of bacteria responsible for food borne diseases is 5°C - 60°C	1	2	5	8	8	13	4	7	42	70
7. It is safe to keep foods of animal origin such as meat, milk, eggs at room temperature	14	23	4	7	22	37	11	18	9	15

8. Drinkable water must be used for food preparation	0	0	2	3	22	37	36	60	0	0
9. Bacteria that that cause food poisoning multiply very quickly in the foods that are kept at room temperature	0	0	2	3	28	47	11	18	19	32
10. Cooked foods kept at room temperature for more than 2 hours before serving can cause illness	2	3.3	10	16.6	20	33.3	14	23.3	14	23.3
11. Frozen foods can be frozen again after thawed	4	6.6	5	8.3	20	33.3	8	13.3	23	38.3
12. I have heard about at least one of the following as a problem in food: <i>Salmonella</i> , <i>Listeria</i> , <i>Campylobacter</i> , and <i>E. coli</i> .	11	18	8	13	10	17	7	12	24	40
13. Parasites, Fungi, Bacteria, and Virus are the microorganism most likely to cause food poisoning	0	0	1	2	26	43	26	43	7	12
14. Diarrhoea, nausea, vomiting, fever, abdominal pain, fatigue and loss of appetite are important signs in food poisoning cases	0	0	0	0	31	51.6	28	46.6	1	1.6

f: frequency, showing the number of responses.

The majority of the participants have an understanding that freezing does not kill harmful microorganisms in food, hence the 47% that responded correctly, with 26.6% giving the incorrect response and 26.5% admitting they did not know. Majority of the participants (70%) did not know that favourable temperature range of bacteria responsible for food borne diseases is 5°C -60°C. The study revealed that the participants who did not have knowledge that it is unsafe to keep foods of animal origin such as meat, milk, eggs kept at room temperature were 55%, slightly more than those who did not give the correct response (a total 45%).

It is known to most vendors that drinkable water must be used for food preparation (97% correct response) compared to those who thought otherwise (3%). In this survey, the majority (65%) of the participants agreed that bacteria that cause food poisoning multiply very quickly in the foods that are kept at room temperature. However, only 19.3% of the participants disagreed that cooked foods kept at room temperature for more than 2 hours before serving can cause illness, with the majority 56.6% agreeing, and the remaining 23.3% not knowing the correct response.

Table 3 above further shows that a total 51 (84.9%) of food vendors did not know that it is unsafe for frozen foods to be frozen again after thawed, with a minority 9 (15%) giving the correct response. All participants, bar 17 (29%), have not heard about at least one of the following as a problem in foods: *Salmonella*, *Listeria*, *Campylobacter*, and *E. coli*, which are pathogens that can be transmitted via food. A large portion (86%) of the participants admitted that they were aware that Parasites, Fungi, Bacteria, and Virus are the microorganism most likely to cause food poisoning. Additionally, close to all participants (98.2%) agreed that diarrhoea, nausea, vomiting, fever,

abdominal pain, fatigue and loss of appetite are important signs in food poisoning cases.

4.1.3. Personal hygiene practices

Assessment of the vendors' hygiene practices revealed that 95% of those who participated believe that anyone can be a means for transportation of microbes to food. While 30% reckoned it is always safe to prepare food with bare hands, the majority 68% responded correctly in not supporting the notion. Although 87% understand that bacteria which can cause food poisoning can be found in our noses and on hands, a total minority 13% was in disagreement or did not know this fact. Majority of the participants had general knowledge about the need to cover wounds and abscesses that can transmit bacteria that cause food poisoning (90% correct responses), and avoiding of contamination by handlers where by the majority understand it is a problem for a person to serve food when suffering from flu, diarrhoea, influenza or other illnesses (80% correct responses). Table 4 shows the compiled responses given by participants on hygiene practices related to food safety.

Table 4. Responses of participants to statements based on personal hygiene

Statement	Strongly disagree		Disagree		Agree		Strongly agree		Don't know	
	f	%	f	%	f	%	f	%	f	%
1. Anyone can be a means for transportation of microbes to food	0	0	0	0	34	57	23	38	3	5

2. It is always safe to prepare food with bare hands	20	33	21	35	15	25	3	5	1	2
3. Bacteria which can cause food poisoning can be found in our nose and on hands	2	3	1	2	34	57	18	30	5	8
4. Preparing food while having an open wound or abscess can transmit bacteria that cause food poisoning	0	0	4	7	24	40	30	50	2	3
5. There is no problem for a person to serve food when suffering from flu, diarrhoea, influenza or other illnesses	33	55	15	25	7	12	3	5	2	3

f: frequency, showing the number of responses.

4.1.4. Perception of food safety

Assessment of the vendors' perception of food safety revealed that 92% of the participants had a perception that some people are more likely to get sick from food infections than others. While 95% of the participants view food infections as serious and can lead to death if untreated, a mere 5% did not agree. Although 77% of the participants regard food contamination and associated infections to be easy to prevent, 23% were not in agreement. Table 5 summarises the perception of food safety by street food vendors.

Table 5. Responses of participants to statements based on perception on food safety

Statement	Strongly disagree		Disagree		Agree		Strongly agree		Don't know	
	f	%	f	%	f	%	f	%	f	%
1. Some people are more likely to get sick from food infections than others	1	2	2	3	43	72	12	20	2	3
2. food infections are serious and can lead to death if untreated	2	3	1	2	36	60	21	35	0	0
3. food contamination and associated infections are easy to prevent	2	3	10	17	33	55	13	22	2	3

f is frequency, showing the number of responses

4.1.5. Response to food-borne diseases

The awareness on response to food-borne diseases is summarised in Table 6, which shows 93% of the vendors who understand that suspected food-borne disease outbreak must be reported to relevant Authorities. Should there be a suspected food-borne disease, 100% of the participants understand that medical attention should be sought. In the wake of suspected food contamination 93% of the participants understand the necessity to inform other vendors and food suppliers about the situation.

Table 6. Responses of participants to statements based on response to foodborne disease outbreak

Statement	Strongly disagree		Disagree		Agree		Strongly agree		Don't know	
	f	%	f	%	f	%	f	%	f	%
1. Report suspected food-borne outbreak to relevant Authorities	0	0	3	5	32	53	24	40	1	2
2. Medical attention should be sought if you suspect food-borne disease	0	0	0	0	30	50	30	50	0	0
3. It is necessary to inform other vendors and suppliers about suspected food contamination	0	0	3	5	24	40	32	53	1	2

f is frequency, showing the number of responses

4.1.6. Association of the different socio-demographic characteristics with the food safety knowledge

The hypotheses tested according to association of the knowledge with the different socio-demographic characteristics at 95% confidence interval ($p < 0.05$) are summarised in Table 7. Despite the higher knowledge recorded amongst men compared to women, the association between gender and knowledge on food hazards was not significant. Almost all, except Golgotha (71%), participants reported to have knowledge on food hazards, and the association between knowledge of food hazards

and location was statistically significant (p -values = 0.047). The study further reported that all participants who were employed for more than two years have knowledge on food hazards, followed by those employed for 1-2 years (95%). Length of employment was not significantly associated with knowledge on food hazards.

Location was significantly (p -value=0.008) associated with the knowledge of hygiene practice. Level of education was not associated with knowledge of hygiene practices. Nevertheless, the association between the different types of food sold and knowledge of hygiene practice was not significant. In the end, the association between knowledge of hygiene practices and age, as well as average monthly income was not statistically significant.

The association between perception on food safety, gender and location was however not significant. It came to light that the correlation between perception on food safety and length of employment, as well as level of education was not significant. Additionally, work experience, and the number of food items sold were not significantly associated with perception on food safety. To sum up, the association between perception on food safety and average monthly income, and age was not statistically significant.

The study also unravelled a significant association (p -value=0.022) between gender and preparedness to food-borne disease outbreak. However, the association between location, length of employment and knowledge on preparedness to food-borne disease outbreak was not significant. The association between knowledge on preparedness to food-borne disease outbreak and work experience, as well as the number of different

foods sold was not significant. To conclude, the relatedness of age and average income to preparedness in the wake of a food-borne disease outbreak was not statistically significant.

Table 7. Hypotheses relating the knowledge of street food vendors to the socio-demographic characteristics

Hypothesis		p-value	Decision
1) (a)	H ₀ : The Knowledge on Food Hazards of street food vendors differs according to gender	0.366	Reject
(b)	H ₀ : The Personal Hygiene practices of street food vendors differs according to gender	0.604	Reject
(c)	H ₀ : The Perception of Food Safety of street food vendors differs according to gender	0.142	Reject
(d)	H ₀ : The Preparedness to food-borne disease outbreak of street food vendors differs according to gender	0.022	Do not reject
2) (a)	H ₀ : The Knowledge on Food Hazards of street food vendors differs according to location	0.047	Do not reject
(b)	H ₀ : The Personal Hygiene practices of street food vendors differs according to location	0.008	Do not reject

(c)	H ₀ : The Perception of Food Safety of street food vendors differs according to location	0.624	Reject
(d)	H ₀ : The Preparedness to food-borne disease outbreak of street food vendors differs according to location	0.324	Reject
3) (a)	H ₀ : The Knowledge on Food Hazards of street food vendors varies according to length of employment in the food vending business	0.572	Reject
(b)	H ₀ : The Personal Hygiene practices of street food vendors varies according to length of employment in the food vending business	0.426	Reject
(c)	H ₀ : The Perception of Food Safety of street food vendors varies according to length of employment in the food vending business	0.250	Reject
(d)	H ₀ : The Preparedness to food-borne disease outbreak of street food vendors varies according to length of employment in the food vending business	0.572	Reject
4) (a)	H ₀ : The Knowledge on Food Hazards of street food vendors differs according to educational level	0.596	Reject

(b)	H ₀ : The Personal Hygiene practices of street food vendors differs according to educational level	0.702	Reject
(c)	H ₀ : The Perception of Food Safety of street food vendors differs according to educational level	0.557	Reject
(d)	H ₀ : The Preparedness to food-borne disease outbreak of street food vendors differs according to educational level	0.775	Reject
5) (a)	H ₀ : The Knowledge on Food Hazards of street food vendors varies according to age group	0.307	Reject
(b)	H ₀ : The Personal Hygiene practices of street food vendors varies according to age group	0.597	Reject
(c)	H ₀ : The Perception of Food Safety of street food vendors varies according to age group	0.057	Reject
(d)	H ₀ : The Preparedness to food-borne disease outbreak of street food vendors varies according to age group	0.355	Reject

4.2. Physicochemical characteristics and microbial quality of street vended foods

4.2.1. Percentage moisture content of street vended foods

The percentages moisture content for the different foods tested were as expected, higher in liquid food (90.9%) than in the solid foods (ranging from 37.31% to 64.55%), consistent in all the sampled sites. The percentage moisture content recorded is presented in Table 8.

Table 8. Mean percentage (%) moisture content of selected street vended foods by location

Food Type	Location			
	North	East	South	West
<i>Kapana</i>	42.04±4.47	40.33±4.5	43.55±3.96	42.55±1.80
Sausage	54.68±1.15	54.28±0.53	55.25±0.47	53.24±1.59
<i>Matangara</i>	63.11±1.33	63.62±0.93	63.12±1.54	63.25±1.91
<i>Oshifima</i>	64.55±0.86	64.17±0.81	64.41±0.89	64.28±1.38
Fatacake	37.31±1.27	37.60±0.46	37.04±0.82	38.70±1.73
<i>Oshikundu</i>	90.90±0.27	91.02±0.22	90.70±0.12	91.24±1.91

The results show that, *oshikundu*, was the food with the highest percentage for moisture, averaging over 90% in all locations. This was then followed by *oshifima* with an average of above 60% in all locations. While the lowest percentage moisture average was recorded for fatcake in all locations, averaging between (30% and 40%).

Table 9. One-way ANOVA table of percentage moisture by location

ANOVA	F	Sig.
North	260.152	.000
East	306.830	.000
West	361.654	.000
South	326.159	.000

F is the variation between sample means.

From the ANOVA table (Table 9) it can be seen that all the locations were significant, this implies that the means of food moisture were different within locations.

4.2.2. pH Measurements of street vended foods

Values of pH were higher (ranging from pH 6.77 to 7.53) for the solid foods tested than for the beverage (average pH 3.21, *oshikundu*). The pH measurements recorded are presented in Table 10. *Oshikundu* pH was slightly acidic, whereas that of other foods was slightly basic, and the finding was consistent within all the sampled sites in Windhoek.

Table 10. Mean pH values of selected street vended foods by location

Food Type	Location			
	North	East	South	West
<i>Kapana</i>	6.93±0.15	7.24±0.24	6.84±0.16	7.23±0.06
Sausage	7.53±0.06	7.50±0.26	7.50±0.20	7.63±0.12
<i>Oshifima</i>	7.37±0.06	7.36±0.24	7.27±0.06	7.33±0.06
<i>Matangara</i>	7.27±0.06	7.24±0.32	7.53±0.12	7.30±0.10

Fatcake	6.77±0.15	6.79±0.02	6.87±0.15	6.83±0.05
<i>Oshikundu</i>	3.33±0.45	3.10±0.16	3.37±0.29	3.03±0.11

Table 10 shows that, in the Northern locations sausage (7.53) has the highest pH, while *oshikundu* (3.33) has the lowest pH value. Equally, in the Eastern, Western and Southern locations, sausage had the highest mean pH, while *oshikundu* has the lowest pH mean.

Table 11. One-way ANOVA table for pH of foods by location

ANOVA	F	Sig.
North	175.709	.000
East	168.860	.000
South	244.810	.000
West	1236.436	.000

F is the variation between sample means.

From the ANOVA table (Table 11), it can be seen that all the locations were significant, this implies that the means of the foods' pH were different within locations.

Table 12. Multiple comparisons of difference in means for percentage moisture (m) and pH by food type and location

Food Type	Location							
	North		East		South		West	
	m	pH	m	pH	m	pH	m	pH

<i>Kapana</i>	Sausage	.038*	.038*	.735	.735	.006*	.006*	.001*	.001*
	<i>Oshifima</i>	.185	.185	.985	.985	.096	.096	.715	.715
	<i>Matangara</i>	.416	.416	1.000	1.000	.004*	.004*	.926	.926
	Fatcake	.916	.916	.215	.215	1.000	1.000	.001*	.001*
	<i>Oshikundu</i>	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
Sausage	<i>Kapana</i>	.038*	.038*	.735	.735	.006*	.006*	.001*	.001*
	<i>Oshifima</i>	.916	.916	.973	.973	.600	.600	.011*	.011*
	<i>Matangara</i>	.632	.632	.725	.725	1.000	1.000	.005*	.005*
	Fatcake	.007*	.007*	.023*	.023*	.009*	.009*	.000*	.000*
	<i>Oshikundu</i>	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
<i>Oshifima</i>	<i>Kapana</i>	.185	.185	.985	.985	.096	.096	.715	.715
	Sausage	.916	.916	.973	.973	.600	.600	.011*	.011*
	<i>Matangara</i>	.990	.990	.983	.983	.471	.471	.996	.996
	Fatcake	.038*	.038*	.078	.078	.129	.129	.000*	.000*
	<i>Oshikundu</i>	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
<i>Matangara</i>	<i>Kapana</i>	.416	.416	1.000	1.000	.004*	.004*	.926	.926
	Sausage	.632	.632	.725	.725	1.000	1.000	.005*	.005*
	<i>Oshifima</i>	.990	.990	.983	.983	.471	.471	.996	.996
	Fatcake	.100	.100	.221	.221	.006*	.006*	.000*	.000*
	<i>Oshikundu</i>	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
Fatcake	<i>Kapana</i>	.916	.916	.215	.215	1.000	1.000	.001*	.001*
	Sausage	.007*	.007*	.023*	.023*	.009*	.009*	.000*	.000*
	<i>Oshifima</i>	.038*	.038*	.078	.078	.129	.129	.000*	.000*
	<i>Matangara</i>	.100	.100	.221	.221	.006*	.006*	.000*	.000*
	<i>Oshikundu</i>	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
<i>Oshikundu</i>	<i>Kapana</i>	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
	Sausage	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
	<i>Oshifima</i>	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
	<i>Matangara</i>	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*

	Fatcake	.000*	.000*	.000*	.000*	.000*	.000*	.000*	.000*
--	---------	-------	-------	-------	-------	-------	-------	-------	-------

* shows significant difference

Findings presented in Table 12 show that when *kapana* is considered as reference (a constant in this case), almost all the percentage moisture means of the different foods differ except in Fatcake in the Northern, Eastern and Western locations. Equally, when sausage is considered as reference, all the means of foods differ irrespective of the location. Results further show that, when *oshifima* is considered as reference, only the mean of *matangara* that was reported to be not different, however for other food in all locations, the means were different. When fatcake is considered as a reference, almost all means of the foods' percentage moisture in the Northern, Eastern and Western locations were reported to be different except for *kapana* in those locations. It was concluded that when *oshikundu* was used as reference, the means for the foods in all locations were reported to be different.

Furthermore, results show that sausage and *oshikundu* pH means were different in the Northern locations, while in the Eastern location, the only difference in means was observed in *oshikundu* (p-value <0.05). In the Southern locations, difference in means was observed in sausage, *matangara* and *oshikundu*, whereas in Western locations difference in means was observed in sausage, fatcake and *oshikundu* when *kapana* was used as reference. Findings revealed that, when sausage is used as reference, difference in means of food pH was observed in *kapana*, fatcake and *oshikundu* in the Northern locations, while in the Eastern location it was observed in fatcake and *oshikundu* (p<0.05). Results show that difference (p-value< 0.05) in pH means was observed in

kapana, fatcake and *oshikundu* in the Southern locations, while in the Western locations the difference was observed in all the foods.

It was observed that when *oshifima* was used as a reference food, difference in pH in food was observed in fatcake and *oshikundu* in the Northern locations, while in the Eastern and Southern locations the difference was observed in fatcake (p-values < 0.05). On the other hand, in the Western locations, the difference was observed in fatcake and *oshikundu* respectively. Results show that in the Northern and Eastern locations, the pH mean difference was observed in *oshikundu* (p-value < 0.05). Furthermore the difference was also observed in *kapana* and fatcake in the southern locations when *matangara* is used as a reference category. When *oshikundu* is used as a reference category, the mean difference in pH among foods was present in all the food types (p-value < 0.05).

4.2.3. Microbial quality of street vended foods

High total plate count (TPC) was detected in tripe (*matangara*), followed by sausage, with unsatisfactory TPC for roasted meat (*kapana*), pap (*oshifima*), fat cake and beverage (*oshikundu*). The total plate counts were recorded and presented in Table 13.

Table 13. Mean TPC (Log CFU/g) of the different foods on PCA by location

Food type	Location			
	North	East	South	West
<i>Kapana</i>	3.02±0.5	2.44±0.08	3.36±0.16	3.46±0.07
Sausage	3.49±0.17	5.46±0.41	5.62±0.43	5.66±0.24
<i>Oshifima</i>	1.32±0	1.39±0	3.87±0.59	4.04±0.58

<i>Matangara</i>	4.70±0.16	5.37±0.45	5.32±0.49	5.75±0.12
Fatcake	0.47±0	0.37±0	0.37±0	0.43±0
<i>Oshikundu</i>	3.09±0.53	4.11±0.57	3.32±0.13	3.78±0.22

In the Northern locations, *matangara* (4.70 Log CFU/g) was reported to have the highest TPC, while in the southern locations it was sausage (5.6 Log CFU/g). Results show that in the eastern location, Sausage (5.45 Log CFU/g) and *matangara* (5.36 Log CFU/g) had the highest TPC, while Fatcake (0.37 Log CFU/g) had negligible growth (too few to count). In the end, the western locations were as well dominated by *matangara* in terms of TPC, with an average of 5.75 Log CFU/g.

Table 14. One-way ANOVA table of TPC by location

ANOVA		
	F	Sig. (p-value)
North	6.527	.004
East	11.643	.000
South	52.390	.000
West	66.255	.000

F is the variation between sample means.

The ANOVA table (Table 14) indicates significant statistical difference between sample means for all the locations, which implies that the location where the foods are sold does not influence the TPC recorded for the different foods.

Table 15. TPC Means (Log CFU/g) from the different foods on MRS agar by location

Food Type	Location			
	North	East	South	West
<i>Kapana</i>	1.08±0	1.01±0	1.02±0	1.02±0
Sausage	4.16±0.39	4.67±0.10	4.37±0.26	4.56±0.4
<i>Oshifima</i>	4.19±0.51	2.87±0.73	4.33±0.24	4.08±0.64
<i>Matangara</i>	4.65±0.25	5.32±0.17	5.56±0.39	5.40±0.07
Fatcake	0.63±0	0.47±0	0.34±0	0.35±0
<i>Oshikundu</i>	3.46±0.18	3.51±0.14	3.60±0.33	3.66±0.13

It can be observed, from table 15, that the food with the highest PC on MRS agar was *matangara* (4.65 Log CFU/g), followed by *oshifima* (4.49 Log CFU/g) and sausage (4.16 Log CFU/g) in the Northern location. In the Eastern location, *matangara*, was reported to have the highest mean (5.32 Log CFU/g) while fatcake (0.47 Log CFU/g) had the lowest, negligible (too few to count) mean. A similar trend was observed in the South and Western locations with *matangara* reported to have the highest PC, while no growth worthy of reporting was observed for fatcake.

Table 16. One-way ANOVA table of PC on MRS agar by location

ANOVA		
	F	Sig.
North	10.306	.001
East	15.729	.000
South	19.765	.000

West	18.064	.000
------	--------	------

F is the variation between sample means.

From table 16, it can be observed that all the locations had significant difference in sample means, this implies that the PC means of the different foods on MRS agar were different within each location. Thus, location does not influence PC on MRS agar.

Table 17. PC Means from the different foods on PDA by location

Food Type	Location			
	North	East	South	West
<i>Kapana</i>	1.06±0	1.01±0	1.09±0	1.13±0
Sausage	3.83±0.36	3.86±0.23	3.96±0.71	3.38±0
<i>Oshifima</i>	1.45±0	2.84±0.78	2.68±0	1.40±0
<i>Matangara</i>	4.10±0.59	5.15±0.59	4.64±0.21	4.58±0.19
Fatcake	0.34±0	0.34±0	0.35±0	0.39±0
<i>Oshikundu</i>	3.08±0.48	3.39±0.09	3.58±0.42	2.92±0.47

Findings presented in table 17 show that *matangara* had the highest PC mean on PDA in all locations, followed by sausage, while fatcake had no significant growth reported.

Table 18. One-way ANOVA table of PC on PDA by location

ANOVA		
	F	Sig.
North	4.124	.021

East	13.274	.000
South	4.954	.011
West	3.898	.025

F is the variation between sample means.

From the table (table 18) it can be seen that all the location had significant difference in the sample means, this implies that the PC means of the different foods on PDA were different in the different locations. Thus, location does not influence PC on PDA agar.

The mean total plate count of the food samples from the four different street food markets are summarised in Table 19. The overall mean TPC of the food samples from the four different outlets ranged from less than 30 colony counts (no growth) on PCA, MRS and PDA plates in *fatcake* to above unacceptable level of 5.75 Log CFU/g for *matangara* (exceeding the limit of <5 Log CFU/g). *Matangara* had the highest bacterial count, 5.75 Log CFU/g followed by sausage, 5.66 Log CFU/g, with fat cake recording the lowest, without noteworthy counts recorded at all sites. Most foods had no growth on PCA, MRS and PDA plates, which may be concluded that most street vended foods are safe for consumption.

Table 19. Multiple Comparisons of difference in means for PC on PCA, MRS and PDA by food type and location

Food Type	Location											
	North			East			South			West		
	PC	MR	PD	PC	MR	PD	PC	MR	PD	PC	MR	PD
	A	S	A	A	S	A	A	S	A	A	S	A

<i>Kapana</i>	Sausage	.993	.016 *	.188	.044 *	.002 *	.015 *	.001 *	.003 *	.152	.000 *	.002 *	.406
	<i>Oshifima</i>	.395	.015 *	.999	.834	.150	.166	.738	.003 *	.684	.548	.007 *	1.00 0
	<i>Matangara</i>	.406	.005 *	.129	.052	.000 *	.001 *	.002 *	.000 *	.054	.000 *	.000 *	.086
	Fatcake	.089	.990	.983	.247	.965	.926	.000 *	.895	.979	.000 *	.910	.984
	<i>Oshikundu</i>	1.00 0	.075	.476	.442	.032 *	.046 *	1.00 0	.019 *	.259	.925	.020 *	.629
Sausage	<i>Kapana</i>	.993	.016 *	.188	.044 *	.002 *	.015 *	.001 *	.003 *	.152	.000 *	.002 *	.406
	<i>Oshifima</i>	.185	1.00 0	.311	.006 *	.170	.693	.005 *	1.00 0	.830	.004 *	.976	.530
	<i>Matangara</i>	.709	.986	1.00 0	1.00 0	.927	.476	.960	.500	.986	1.00 0	.810	.891
	Fatcake	.036 *	.006 *	.065	.001 *	.001 *	.003 *	.000 *	.001 *	.049 *	.000 *	.000 *	.161
	<i>Oshikundu</i>	.996	.932	.979	.654	.573	.982	.000 *	.840	.999	.001 *	.762	.998
<i>Oshifima</i>	<i>Kapana</i>	.395	.015 *	.999	.834	.150	.166	.738	.003 *	.684	.548	.007 *	1.00 0
	Sausage	.185	1.00 0	.311	.006 *	.170	.693	.005 *	1.00 0	.830	.004 *	.976	.530
	<i>Matangara</i>	.018 *	.989	.220	.007 *	.036 *	.055	.019 *	.465	.483	.003 *	.417	.125
	Fatcake	.906	.006 *	.905	.846	.042 *	.035 *	.000 *	.001 *	.317	.000 *	.001 *	.942
	<i>Oshikundu</i>	.359	.920	.675	.077	.930	.964	.678	.868	.954	.969	.987	.759
<i>Matangara</i>	<i>Kapana</i>	.406	.005 *	.129	.052	.000 *	.001 *	.002 *	.000 *	.054	.000 *	.000 *	.086
	Sausage	.709	.986	1.00 0	1.00 0	.927	.476	.960	.500	.986	1.00 0	.810	.891

	<i>Oshifima</i>	.018 *	.989	.220	.007 *	.036 *	.055	.019 *	.465	.483	.003 *	.417	.125
	Fatcake	.003 *	.002 *	.043 *	.001 *	.000 *	.000 *	.000 *	.000 *	.017 *	.000 *	.000 *	.029 *
	<i>Oshikundu</i>	.444	.633	.929	.712	.167	.194	.002 *	.094	.912	.001 *	.177	.694
Fatcake	<i>Kapana</i>	.089	.990	.983	.247	.965	.926	.000 *	.895	.979	.000 *	.910	.984
	Sausage	.036 *	.006 *	.065	.001 *	.001 *	.003 *	.000 *	.001 *	.049 *	.000 *	.000 *	.161
	<i>Oshifima</i>	.906	.006 *	.905	.846	.042 *	.035 *	.000 *	.001 *	.317	.000 *	.001 *	.942
	<i>Matangara</i>	.003 *	.002 *	.043 *	.001 *	.000 *	.000 *	.000 *	.000 *	.017 *	.000 *	.000 *	.029 *
	<i>Oshikundu</i>	.079	.028 *	.197	.011 *	.009 *	.009 *	.000 *	.003 *	.089	.000 *	.004 *	.293
<i>Oshikundu</i>	<i>Kapana</i>	1.00 0	.075	.476	.442	.032 *	.046 *	1.00 0	.019 *	.259	.925	.020 *	.629
	Sausage	.996	.932	.979	.654	.573	.982	.000 *	.840	.999	.001 *	.762	.998
	<i>Oshifima</i>	.359	.920	.675	.077	.930	.964	.678	.868	.954	.969	.987	.759
	<i>Matangara</i>	.444	.633	.929	.712	.167	.194	.002 *	.094	.912	.001 *	.177	.694
	Fatcake	.079	.028 *	.197	.011 *	.009 *	.009 *	.000 *	.003 *	.089	.000 *	.004 *	.293

* shows significant difference

Results (Table 19) show that considering *kapana* as our reference food, it can be seen in the Northern locations that the TPC means were the same, as none of them were statistically significant. On the contrary in the Eastern location it can be seen that there is a difference between the TPC mean for *kapana* and sausage ($p < 0.05$). Similarly, in

the Southern location, the mean differences in comparison to *kapana* were observed for sausage ($p<0.05$), *matangara* ($p<0.05$), and fatcake ($p<0.05$).

Similar to the *kapana* grouping, among the sausage group, in the Northern group, results show that the means among food were the same except for the fatcake mean. In the Eastern location the difference in mean was observed among *kapana* ($p<0.05$), *oshifima* ($p<0.05$) and fatcake ($p<0.05$) when considering sausage as a reference. Furthermore in the Southern location the difference was observed among *kapana* ($p<0.05$), *oshifima* ($p<0.05$), fatcake, and *oshikundu* with both p-values <0.05 . It was recorded that, when *oshifima* was considered as a reference food, the difference in mean in the Northern location was observed for *matangara* ($p<0.05$), while in the Eastern location the difference was observed for sausage ($p<0.05$), and *matangara* ($p<0.05$). Furthermore means were also different among the sausage, *matangara* and fatcake in the Southern and Western locations.

Considering *matangara* as a reference, difference in means was observed for *oshifima* ($p<0.05$) and fatcake ($p<0.05$) in the Northern, Southern and Eastern locations. While in the Western location, the difference was observed among all food types with an exception of sausage. Furthermore, when fatcake was considered as reference, the difference in means was observed for sausage, and *matangara* in the Northern and Eastern locations. The Southern and Western locations had all TPC means different. It can be concluded that there was no difference in TPC means in the Northern locations, while in the Eastern location the difference was observed for fatcake ($p<0.05$), in the Southern location the difference appeared among sausage, *matangara*, and fatcake.

Findings, as seen in Table 19, further show that when *kapana* is used as a reference, the difference in means within the group of food was observed for sausage, *oshifima*, and *matangara* with p-value <0.05 in the Northern locations. The Eastern location the difference was observed for sausage, *matangara*, and *oshikundu* with p-value <0.05. In the Southern and Western locations the mean difference was observed within all food types with exception of fatcake. When sausage is considered as a reference, the mean difference was observed for *kapana*, and fatcake in all the locations with p-value <0.05. Furthermore, when *oshifima* was considered as a reference, in the northern location in the southern location the difference was observed for *kapana* and fatcake with p-value <0.05. While in the Eastern location, the difference was in *matangara* and fatcake. In the Southern and Western locations, the difference was observed for *kapana*, and Fatcake with p-value < 0.05.

It can be seen that when *matangara* was used as reference, in the Northern locations, the difference was observed for *kapana*, and fatcake with p-value <0.05. Similarly, in the Eastern, Western and Southern locations, the difference was observed for *kapana*, *oshifima* and fatcake with p-value <0.05. When fatcake was used as reference, the difference in means was observed in almost all food in all locations except in *kapana*. In the end when *oshikundu* is used as reference, in the northern location, the difference was observed in fatcake (p-value <0.05), while in the Eastern, Western and Southern locations the difference was observed for *kapana* and fatcake with p-value < 0.05.

Results show that when *kapana* was used as reference, there was no difference in the means among the different food in the northern, Southern and Western locations. On the other hand, difference in means was observed in sausage, *matangara*, and

oshikundu with p-value less than 0.05. It was also reported that when sausage was used as a reference there was no difference in food means in the Northern and Western locations. However, in the Eastern location the difference was observed for *kapana*, and fatcake, while in the Southern locations, the difference was observed in fatcake only.

Results show that when *oshifima* was considered as reference, the difference in food means was observed in fatcake in Eastern location, while in all other locations, there was no difference. It was reported that when *matangara* is used as reference, the difference in the food from the Northern locations was in fatcake, while in the Eastern location, it was in *kapana* and fatcake, while in the Southern and Western locations it was in fatcake.

It was reported that, difference in means was observed in *matangara* ($p < 0.05$) in the Northern locations, while the difference in means was observed in sausage and *matangara* in both Eastern and Southern locations. In the end, in the Western locations the difference ($p < 0.05$) was only observed in *matangara*. The study also revealed that when *oshikundu* was considered as a reference, none of the food PC means on PDA was different between the Northern, Southern and Western locations, while in the eastern location, *kapana* and fatcake means were different.

4.3. Food hazard scenarios and STAMP

Although the survey did not include a component on STAMP elements, the food safety knowledge surveyed, coupled with physicochemical properties and microbial quality

results presented above provide information that can influence the adaption of STAMP for the food safety systems in Windhoek.

It was established that the food safety Act has not been promulgated and passed by parliament in order to come into force. Individuals involved in street food vending business are not required to have licences in order to sell food along streets. There were no standards or guideline documents found in the possession of street food vendors to suggest concerted efforts by authorities to inform street food vendors on how to achieve and maintain food safety. Moreover, training and information dissemination on food safety for street-food vendors is not in existence, hence microbial food risks exist. The risk scenarios are supported by 36% who did not give correct responses to questions related to food hazards in the survey. Similarly, 16% did not give correct responses to questions on personal hygiene and 41% had the wrong perception about food safety.

CHAPTER FIVE: DISCUSSIONS

5.1. Assessment of food safety knowledge among street food vendors

5.1.1. Demographic information of street food vendors

The demographic information as shown in Table 2 can be used by authorities to make decisions on food safety with respect to the street food vending markets in Windhoek. In this study, female street food vendors outnumbered (71.7%) their male counterparts. This scenario was observed in similar studies conducted in Malaysia (Lawal et al., 2018). An anomaly was recorded in a study carried out in Nairobi, Kenya by Muinde & Kuria (2005), where majority male street vendors who constituted 60%, with 40% females was reported.

The study recorded the age range of the participants between 21 to 60 years old, with the majority between 31 and 40 years old, that represents 38.3 % (n = 23). On average a participant was 35 years old. Interestingly, similar studies done in Ghana by Akabanda et al., (2017) show a greater number (39.1%) of the participants in the age bracket of 41–50 years with average age of 41.5. The participants with formal education were the most, 57 (95%), similar to previous studies which however demonstrated that irrespective of educational level, employees' performance in food safety knowledge was not satisfactory and thus a cause for public concern (Webb & Morancie, 2015). The demographic information shows striking similarities in educational profile of street food vendors to results found in other countries (Chukuezi, 2010; Choudhury, Mahanta, Goswami & Pegoo, 2010). In a descriptive study conducted in the City of Bo, Sierra Leone (Lamin-Boima, 2017), the demographic characteristics of the vendors was not as similar.

The demographic information revealed three significant correlations, which existed between gender and preparedness in the wake of a food-borne disease outbreak, knowledge on Food Hazards and location, as well as between Personal Hygiene practices of street food vendors and location. It can be argued that gender is a factor that can affect knowledge on preparedness to respond to food-borne disease outbreaks among the vendors, whilst location can have an influence on knowledge on Food Hazards and Personal Hygiene practices among the vendors.

Low education levels and high unemployment are influencing factors for street vending businesses as shown in various studies in developing countries (Aluko et al. 2014). The findings of this study show only 14% of the food vendors did not have any formal education, whereas 16.4 % was found in Kuala Lumpur, Malaysia (Hui et al. 2017) and 14.5% in Ghana (Akabanda et al., 2017). The demographic characteristics too affect food safety knowledge of the street food vendors, for instance, age, education, or work experience (Pichler, Ziegler, Aldrian & Allerberger, 2014). A study by Garayoa et al. (2011) reported that the hygiene knowledge levels were slightly better among the people who attend higher level of education and graduated from middle-or high-school and for those who had worked 10 or more years in Food catering sector.

Augmenting training of street food vendors with regulatory interventions can greatly improve the street food sector (WHO, 1996). Regulation of street vending sectors would entail inspection and certification or licensing of the individuals who intend to practice, thus they become licensees with obligations as is the case with formal markets. Street food vendors who meet requirements would be registered with i.e. the

municipality and get approved to operate legally. The registered or licensed street food vendors would undertake a training program or receive educational material on food safety.

5.1.2. Street food vendors' food safety knowledge and awareness

This study recorded majority of street food vendors with knowledge on key general sanitary practices such as washing, keep waste materials and foodstuffs separate, storing cooked and uncooked foods separately and preparing cooked and uncooked foods with separate equipment. Although the general knowledge on all aspects of food safety was a standout feature among street food vendors, details about specific microbes of public health concern are not common knowledge. *Salmonella*, *Listeria*, *Campylobacter*, and *E. coli* are not particularly known as microbial food hazards (Table 3). Knowledge on the time-temperature controls during the handling of foods is minimal among street food vendors who participated in this study. The lack of adequate knowledge on temperature controls by food-handlers has also been reported from different countries with striking familiarity (Lawal et al., 2018).

The findings of this study are in agreement with published work where majority of the respondents did not know if Salmonella, hepatitis A and B viruses, and Staphylococcus were pathogens of concern in that can be transmitted through foods (Ekanem, 1998). Other reports (Okrend et al., 1990) show that knowledge of appropriate temperature range for foods was not adequate amongst street food vendors, as is the case in the present study. The high temperature heat of roasting meat (*kapana*) can be attributed to the minimal contamination recorded, hence reduced associated potential food-borne

infections. However, the phenomenon (minimized contamination) was not reflected in the roasted sausages findings in this study.

Notably, those street food vendors who took part in this study have good knowledge and awareness, a notion not farfetched. Education level and work experience in the food vending industry were observed not to be a contributing factor to the level of food safety knowledge of the vendors (Table 7). The study brought to light an interesting observation whereby street food vendors who had not received any formal education performed similar to those who had received primary education and secondary education ($p>0.05$; Table 7). Similar studies have reported that food safety and hygiene knowledge may exist but may not be reflected in street vendors' behavior and practices. Knowledge and skills learned need time to be internalised and used in order to impart on behavior change in safe food handling (Worsfold et al., 2004).

The Codex Alimentarius Commission (2003) outlines that sick food handlers are not allowed to work or deal with foods. Training was hailed by Soon, et al. (2012) as a means that increases knowledge on food safety. Noteworthy is the caution that more knowledge does not always lead to positive changes in food handling procedures (Park, Kwak, & Chang, 2010). Lack of knowledge, such as on the time-temperature management among street vendors can lead to scenarios such as the stimulation of growth for contaminating microorganisms by the process of refreezing thawed foods, which increases the health risk even more. According to Seaman and Eves (2010), "freezing food only slows bacterial growth and does not necessarily kill the pathogens."

5.1.3. Personal hygiene practices

Street food vendors who participated in this study from all the four areas demonstrated good knowledge of personal hygiene practices although the majority does not understand that anyone can be a means for transportation of microbes to food. Knowledge on personal hygiene is a key factor contributing to preventing the contamination that might occur during food preparation and processing, which was confirmed in the microbial total plate count analysis.

Unclean water is a major concern with regard to food safety, and more so when foods that do not have a heat step are washed in water perceived to be clean e.g. salads. Unclean (usually due to re-use) water can equally contaminate hands and surfaces during washing. Microbes are harbored in the foods as a result of time and temperature misuse leading to cross contamination as studies on cause of food poisoning have shown (Park, Kwak & Chang, 2010; WHO, 2006; Bas et al, 2006).

This study found that knowledge regarding cross contamination during preparation existed among 98% of the participants. The finding of such a high number is promising, owing to the fact that disease outbreaks are often associated with cross contamination (Park et al, 2010; Bas et al, 2006). This study found that many vendors have sufficient knowledge to ensure hygienic handling of food. These findings reflect the confirming studies that reported improved hygienic and sanitation conditions that promise relatively safe food with low bacterial counts by street food vendors in urban environments, according to Von Holy and Makhoane (2006) and Leus et al (2006). Evidence on reducing contamination by means of hygiene practices was reported in previous studies where proper hand washing by food-handlers was lauded as a means

to significantly decrease the threat of diarrheal disease in child care facilities (WHO, 1996).

The findings in this study are consistent with those of Martins (2006) who reported that street vendors do observe good hygienic practices in preparing, cooking and handling foods (Martins, 2006). The covering of foods sold along streets is critical, microbes travel through dust, including pathogens, and therefore allowing dust to settle on foods is high risk (Muinde et al, 2005). Similar studies revealed 16.1% of the vendors storing food for serving in the open (Chukuezi, 2010). Previous studies have further suggested that inadequate knowledge in food safety has a direct negative influence on hygienic practices (McLauchlin, 1997).

5.1.4. Perception of food safety

Most of the vendors do not understand that any individual is susceptible to food-borne infections (92% incorrect responses), thus they are not aware anyone can spread infections to a population at large. The perception by 92% of the participants that only some people are more likely to get sick from food infections than others is a concern and may need extensive elaboration in terms of education to clear this misconception about susceptibility to microbial infections. Food infections, however easy to prevent, are understood as serious and can lead to death if untreated, as are the reported cases in *E. coli* and *Salmonella* outbreaks worldwide. It appears the participants in the study perceive the severity of foodborne illness to be low due the fact there exist limited reported cases of food-borne disease outbreaks.

5.1.5. Response to food-borne diseases

The Ministry of Health and Social Services, in collaboration with the local municipality are tasked with carrying out health related response measures. Therefore, the reporting of suspected food-borne disease outbreaks can be viewed as a component less worrisome since the vendors' understanding of their obligations to respond correctly were observed in the study (Table 6). There were no similar reported studies in line with response preparedness among street food vendors.

5.2. Physicochemical characteristics and microbial quality of street vended foods

5.2.1. Percentage Moisture content of street vended foods

Water, being a determinant for microbiological growth on and within foods, directly affects the stability of foods in terms of spoilage (Novasima, 2005). Therefore, foods sold on the street markets are highly vulnerable to spoilage when their moisture content is high, and preservatives or temperature controls are not introduced. In this study, percentage moisture content was as expected, higher for the beverage (ranging from 90.9% to 91.2%) than in the solid foods (ranging from 37.31% to 64.55%).

The percentage moisture of foods has a direct influence on free water (water activity), which is a determining factor in microbial growth, that leads to production of toxins in foods. Sereno et al. (2000) point out that, "most thermodynamic models used to describe vapor-liquid equilibrium of osmotic solutions are based on relations involving Gibbs free energy of the system." Combining water activity controls with pH reduction is a significant hurdle in many of food products, where growth pathogenic microbes is inhibited. The other

hurdles in food preservation, for example addition of antimicrobials and thermal treatment, are secondary in assuring food safety due to the fact they mainly act against spoilage micro flora (Gustavo et al. 2007).

5.2.2. pH Measurements of street vended foods

Controlling the acidity levels of foods where there is no refrigeration greatly contributes to the extension of shelf life. A combination of controlling the acidity level (pH) of foods and the level of water activity is recommended to significantly reduce food-borne disease incidences, without relying on refrigeration. Food spoilage can be a crippling challenge among street vended food businesses, hence the need to implement several preservation techniques to save the foods. However, preservation invites scrutiny from consumer due to awareness about the effect of preservation techniques on the natural nutritional value of different foods and known organoleptic qualities that must be maintained. (Lucera et al. 2012).

Lowering pH in foods has been widely used, with extensive studies focusing on the use of organic acids and their derivative salts as biopreservatives. Organic acids such as lactic, acetic, and citric acids occur naturally in foods, prompting their study for commercial use in food preservation. Acids employ their efficacy by inhibiting the growth of several spoilage and pathogenic microorganisms, in addition to their effect in improving the sensory properties and technological functions such as the stabilisation of colour, regulation of acidity, and development of characteristic flavour of foods (Jamilah et al. 2008).

In this study, values of pH were higher (ranging from pH 6.77 to 7.53) for the solid foods tested than in beverage (pH 3.03 to 3.37, *oshikundu*). According to Deshpande et al (2015), “In general, the bioactive agents act as bacteriostatic or bactericidal molecules towards microorganisms suggesting several antimicrobial mechanisms of action.”

5.2.3. Total Plate Counts

High TPC was detected in tripe (*matangara*), followed by sausage, with unsatisfactory TPC for roasted meat (*kapana*), pap (*oshifima*), fat cake and beverage (*oshikundu*). The food samples that had exceeded the limit of total microbial plate count are relatively scarce (Figure 4) on the street food markets.

Previous studies done in Windhoek focused mostly on food handlers in the informal markets referred to as open markets (Shiningeni et al., 2018; Nkandi et al., 2017), without much focus on vendors’ knowledge of food safety. This study undertook to assess factors in the street settings, primarily along the streets, around road junctions and at street corners. This is where challenging conditions for food preparation may pose a significant risk to the consumer since there is no running water and sanitary establishments in the immediate surroundings (Campos et al., 2015).

Studies on street vended foods have in the past indicated that the foods of animal origin are the more likely to be the origin of pathogenic infections (Ntanga, 2013). The animal products of concern are dominated by beef and poultry, where foodborne diseases are influenced by the fact that the live animals roam and get into contact with various sources of microbial contamination. This can occur at water points, feeding stalls and

as they come into contact with other animals in the open pastures (in the case of cattle). Ready-to-eat meats are of significant concern with regards to the spread of contamination and infections owing to the fact there has been a high frequency of food-borne diseases with the consumption of these products observed (Abdullahi & Akunna, 2006).

TPC in the food samples analyzed in this study were found to be similar to those reported in previous studies on similar food samples, particularly in *kapana*. A study carried out by Nkandi et al. (2017) reported overall mean TPC (4.01 log₁₀ CFU/g) of beef from three outlets that was within the acceptable standard specified by the International Commission on Microbiological Specifications for Foods (ICMSF) (1986). In a study conducted in Johannesburg, South Africa, the majority of ready-to-eat street vended foods had borderline counts (below the 10⁵ CFU/g) which are the maximum acceptable limits prescribed by the Food Safety Authority of Ireland (FSAI, 2016) for ready-to-eat foods on the market (Asiegbu et al, 2020).

Similarly, studies conducted in Ethiopia reported aerobic colony counts in the range 1×10⁴ to 1.86×10⁵ CFU/g for street vended foods (Amare et al., 2019), whilst in Bangladesh a range of 1.2×10³ to 4.2×10⁹ CFU/g was reported (Hossain & Dey, 2019).

Although low levels of aerobic counts have been reported in ready-to-eat street vended foods, previous studies have revealed presence of pathogenic bacteria, with *L. monocytogenes* the most identified food-borne pathogen, followed by *S. aureus*, *Salmonella* spp., and *E. coli* O15:H7 (Asiegbu et al, 2020). A major contributor to the high bacterial counts and high incidences of foodborne pathogens can be the hygiene

practices among street food vendors, whereby foods are at times subjected to prolonged storage at room temperatures. It can further be inferred that stringent controls on microbial food hazards may not be adequate among street-food vendors and is mainly done at manufacturing and supermarket levels and less at informal markets level.

5.3. Food hazard scenarios and STAMP

A look at the knowledge with street food vendors and the contamination risks revealed through physicochemical and microbial analysis incites in-depth consideration to introduce STAMP methodology, presented in figure 5, to the food safety systems in Windhoek. The findings of the study suggest that chances of accidents that may lead to food-borne disease outbreaks are increased by a combination of inadequate or absence of training and environmental elements such as inevitable contamination posed by exposure of food to microorganisms. Targeting and minimizing these apparent risks is enhanced by systems approach, to bring street food markets on par with formal markets that get inspected and assessed with standards. Safety is assured when the components of a system are in harmony with each other resulting into accidents being viewed as only consequences of inadequate constraints on the interactions within a system (Leveson, 2004). Systems approach is the basis for establishing a model, ready to use in terms of, to curb microbial risks among food systems in Windhoek in particular, whereby controls can be placed on the street food markets who are currently not regulated. A number of scenarios can be deduced to illustrate the introduction of controls in the food system encompassing Windhoek, to systematically prepare for mitigation of microbial food risks. In this study, three scenarios are explored for the introduction of STAMP.

The first scenario (scenario 1) is whereby there is no food safety Act implementation. The Namibia Food Safety Policy mandates the Ministry of Health and Social Services with the responsibility for consumer food safety, the Ministry of Industrialisation and Trade with the responsible for the safety of processed foods, whilst the Ministry of Fisheries and Marine Resources is mandated with the responsibility for fisheries food safety. The policy further stipulates that the Ministry of Urban and Rural Development is responsible for licensing food business operators, while the Ministry of Agriculture, Water & Land Reform is responsible for the safe production of foods of animal and plant origin, including their primary processed forms (Namibian Food Safety Policy, 2014).

The joint responsibility of the ministries with their aligned stakeholders and partners to implement the policy requires concerted coordination and cooperation. In perspective, any lax in the control measures by one entity can compromise safety and lead to adverse chain of events that consequently result into food-borne disease outbreaks.

The second scenario (scenario 2) is whereby farmers are not knowledgeable about microbial food hazards and controls to alleviate the risk are inadequate at the farm level. Farmers produce various foods that are supplied to both formal and informal markets. There is heavy reliance on the farmers to ensure food is safe for consumers. Inevitably, at some stage, certain foods do not undergo minimal, essential preparation required to eliminate or reduce microbes. The consequences may be food-borne

illnesses. Lack of knowledge and awareness of microbial hazards among farmers can result into widespread contamination of plant or animal produce.

Raw fruits and vegetables produced at farms have the potential to become contaminated with microorganisms, including human pathogens. Fruits and vegetables normally carry non-pathogenic, epiphytic microorganisms; however, they have been implicated in various foodborne outbreaks. Several pathogens have been isolated from fruits and vegetables worldwide. The rate of foodborne illness caused by the consumption of fruits and vegetables is increasing, representing a significant public health and financial issue all around the world (Elias et al., 2018). Some of the notable food-borne outbreaks are associated with minimally processed plant produce, unpasteurized vegetable and fruit juices, as well as intact products.

Moreover, in animal production, microbial contamination is spread through different modes such as, carried in the digestive tracts, on hide and hooves of animals. According to Heredia & García (2018), the control of animal and animal products contamination is immensely challenging due to various factors such as the environment and human related animal handling and processing practices.

The health of employees that are involved in the harvesting matters as much as the farm tools, utensils, and packaging, for they all may contribute to contamination of the products. Good Agricultural Practices (GAPs) may exist at farms but implementation and reinforcement of the standard practices may lack, thus a lack of controls along the STAMP model, the origin of accidents that lead to food-borne disease outbreak.

Responsible ministries and regulatory authorities are therefore tasked to ensure controls exist at the level of farm production, to promote safe practices for ensuring large retailers are at ease that guidelines and associated audits of practices are implemented (FDA, 1998). Implementation of the Hazard Analysis and Critical Control Points (HACCP) programs at producing farms adds more assurance of the much needed food safety.

The third and last scenario (scenario 3) is one of inadequate information and guidelines to street food vendors. This study has revealed that there is a lack of some key knowledge among street vendors with regards to food safety. Misconception and lack of understanding of microbial food hazards for instance can lead to food-borne disease outbreaks emanating from food contamination.

The street setting exposes products to contamination since in most cases foods are displayed in the open. Major stakeholders in the fresh produce chain, both in plant and animal production, often have strict measures to prevent product contamination. This is not always the case for street food markets being at the receiving end of almost finished products, requiring final preparation for consumption. As an example, processing of meat products in unsanitary conditions and subsequent sales of the contaminated meat products can have a negative impact on public health (Miller & Griffin, 2012).

Hygiene is critical in the preparation and storage of foods, of which compromise in the storage conditions, the surrounding environment, and shortage of washing facilities,

coupled with lack of food safety knowledge among street vendors ultimately leads to food contamination, causing foodborne illnesses (Oranusi et al., 2007; Rajaseharan, 2021; Sani & Siow, 2014).

Controls can be introduced for the system encompassing street food vendors as in the STAMP model, whereby stringent measures are put in place to prevent accidents, for instance those caused by the use of unclean water, the result of which is widespread sale of contaminated food that could have been prevented by adequate information dissemination.

In conclusion, constraints characterize the safety process, hence extensive effort must be put in identifying appropriate constraints for a food safety system. There must be constraints placed at social and organisational levels in STAMP, interlinked by control loops. Nayak & Waterson (2019) emphasize that the food safety and quality constraint aspects surrounding street vended foods are maintained owing to the fact that delivering safe food to customers is the ultimate target of vendors. A lack of a documented systems model such as STAMP would lead to street vendors (and other levels in the system) to falter, hence weaknesses in the prevailing conditions of the system variables occur.

Provision of food safety knowledge and trainings on hygienic food handling practices are neglected by Government agencies and regulatory bodies (Rakha et al., 2022). Unfortunately, it was observed in the current study, whereby training in safe food handling practices for street food vendors is not offered in Windhoek, meaning the

vendors lack knowledge required to rectify errors or noncompliance in order to change the state of the system as a whole (Nayak & Waterson, 2016).

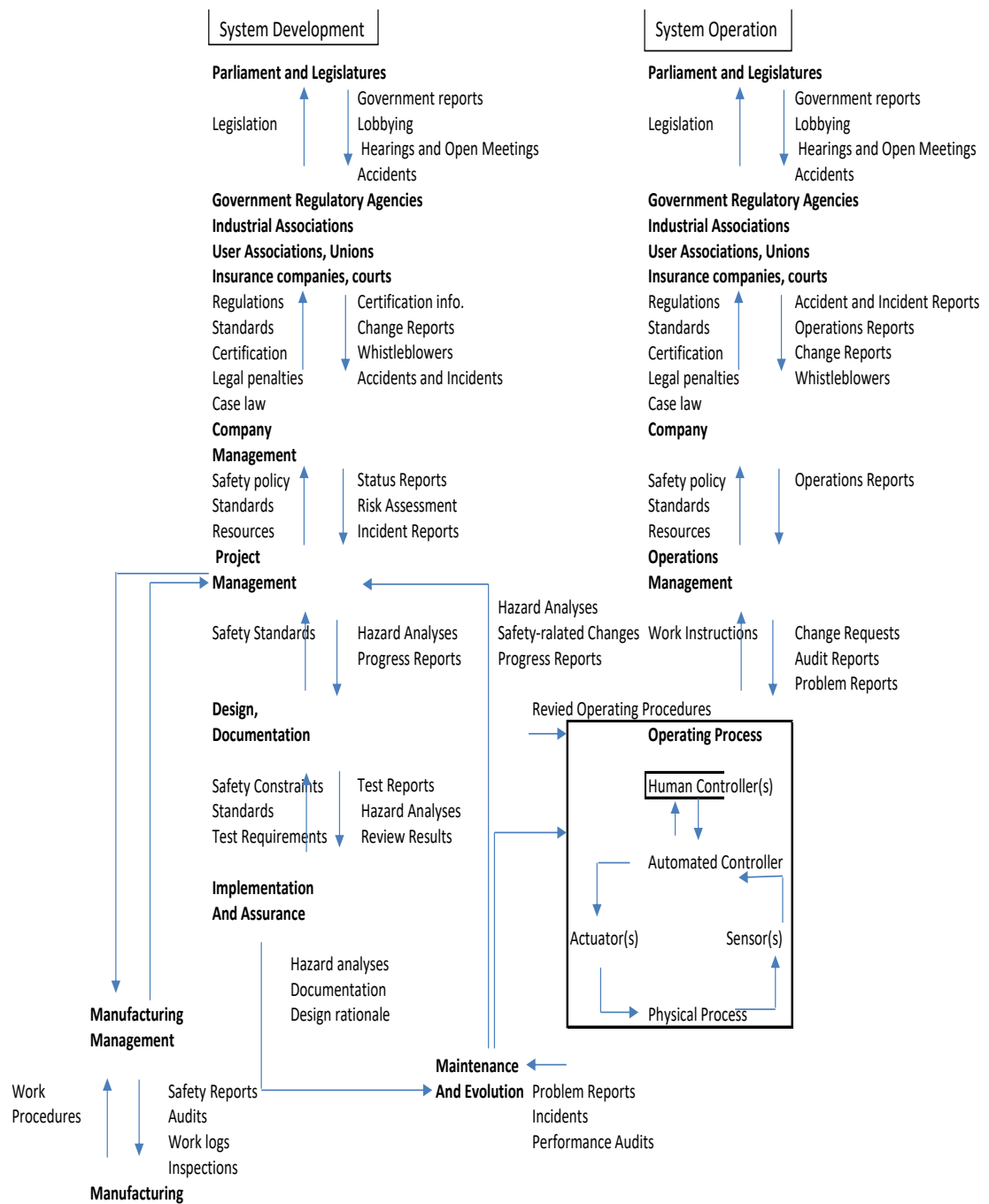


Figure 5. Customised STAMP model. As adapted from Leveson (2011)

CHAPTER SIX: CONCLUSIONS

Although food safety knowledge was remarkable among vendors who took part in the study, it was necessary to extend the study to include food sampling and analysis related to contamination, to obtain better insight into the microbial hazards on the ground. The reported good food handling practices may be contributed to by the presence of more women as street food vendors, owing to the fact that women do the routine food preparations in the home settings, thus are more experienced. On the other hand, men take interest in the roasting of meat (*kapana*) and sausages, a practice where women were not taking part in, perhaps due to the fact roasting involves repeated cutting of meat and activities done while standing most of the time. More work would be of benefit, to focus on evaluation of the effectiveness of the food safety controls and preparedness thereof that exist for street food vending business.

The physicochemical and microbiological analyses showed that there are microbial hazards existing and could be validated; therefore, there is a need for awareness training programs in food safety. Most food types that were sampled were found to have no microbial counts above the standard limits (Table 13), thus the study findings give some assurance that a street food market with an acceptable degree of food safety is in existence in Windhoek. Contamination detected through total plate counts is a signal for pathogenic microbes that may be present and that can be transmitted. Worryingly, the detected contamination was in samples from all the four clusters around Windhoek. In a bigger context, food contamination may lead to the dreaded food infections and poisoning and eventually food-borne disease outbreaks.

Conclusions can be made regarding the influence of food safety knowledge on practices that lead to food contamination. The lack in knowledge of food safety and hygiene practices of street food vendors, may be overcome by introduction of training programs, supported and maintained by means of a regulatory framework. Inspections of the street food establishments and the provision of information material related to food safety would be key components of a regulatory system that oversees the street food markets. Street food vendors showed a good level of food safety knowledge although performed poorly in the specific microbial food hazards. Confirmed contamination of some foods vended along streets could pose a threat of possible food-borne disease outbreaks resulting from cross-contamination of foods and food products. The status quo of microbial food safety regulation needs further scrutiny by the line authorities, with a closer look at the provisions to include effective wide-spread food safety awareness trainings. All in all, 60 street food vendors from selected clusters around Windhoek participated in the study, albeit only a fraction of the numerous street food vendors around the city. Although they may appear to be agents of potential food-borne disease outbreaks due to the conditions in which they prepare food, the street food vendors vitally provide nutrition and income in many developing countries. Age, education level and length of time in the food vending business, are not determining factors in the knowledge, attitude and practice of the participants. The study has brought to light information regarding the food safety knowledge amongst street vendors in Windhoek, coupled with information regarding potential food contamination risks.

To have a model like STAMP outlining the entire food system would ease preparedness and response mechanisms for intercepting food system accidents.

Continuous changes take place in the implementation of food safety at all levels of the complex food system, more so amongst street food vendors. The food system covering Windhoek possesses characteristics of a complex system. Thus, systems analysis methods were used to study the interactions between the components of the food system.

CHAPTER SEVEN: RECOMMENDATIONS

More studies that focus on factors that hinder the transfer of knowledge into food safety behaviour need to be carried out in the street vendor food markets in Windhoek so that food safety policies and guidelines can be introduced and implemented effectively. This study can be used as a baseline that can be elevated to country-wide level, to determine the relationship between food contamination risk factors and the food safety knowledge of street food handlers. Collaboration between academia and the government institutions and a larger population of street food vendors in other towns for the authorities to establish a comprehensive approach aiming at ensuring food safety is recommended.

Existence of interlinked food systems are the main reason food safety is maintained throughout the socio-technical complex food supply chain. The local food markets have been influenced by the globalisation of food networks with high complexity, yielding benefits that are unfortunately accompanied by different systemic risks. Mishaps or accidents can occur at interlinks across system levels, with impact on economic, social and political levels throughout the entire system. Food safety can be insured by the use of STAMP, a system accident model that makes use of the concept of safety constraints.

The survey conducted, together with the microbial food contamination studies would enhance efforts of providing food safety. Food travels long distances and usually reaches consumers after being handled at different functional levels; therefore, a wide scale model is required to help identify factors that occur at any point in the food system. Country-specific food systems could be designed based on the process used

on street food vendors around Windhoek as a benchmark. All in all, consumers will be protected from food-borne disease outbreaks and the stakeholders of the food industry in Windhoek would benefit from the model.

REFERENCES

- Abdullahi, Y. A., Akunna, J. C., (2006). Effect of waste type and proportions on pH control and regulation in high solids anaerobic digestion. In: Proceedings, 11th European Biosolids and Biowaste Conference, 13–15 November, Wakefield, UK.
- Akabanda, F., Hlortsi, E. H. and Owusu-Kwarteng, J. (2017). Food Safety Knowledge, Attitudes and Practices of Institutional Food-handlers in Ghana. *BMC Public Health Journal*. DOI: 10.1186/s12889-016-3986-9.
- Akabanda, F., Hlortsi, E. H., and Owusu-Kwarteng, J. (2017). Food safety knowledge, attitudes and practices of institutional food-handlers in Ghana. in *BMC Public Health*. DOI: 86-89.
- Aluko, O. O., Ojeremi, T. T., Olakele, D. A., & Ajidagba, E. B. (2014). Evaluation of food safety and sanitary practices among food vendors at car parks in Ile Ife, southwestern Nigeria. *Food Control*, 40, 165-171.
- Amare, A., Worku, T., Ashagirie, B., Adugna, M., Getaneh, A. & Dagneu, M. (2019). Bacteriological profile, antimicrobial susceptibility patterns of the isolates among street vended foods and hygienic practice of vendors in Gondar town, Northwest Ethiopia: A cross-sectional study. *BMC Microbiology* 19 (1), 120. <https://doi.org/10.1186/s12866-019-1509-4>.
- Assefa T, Tasew H, Wondafrash B, Beker J (2015) Assessment of Bacterial Hand Contamination and Associated Factors among Food Handlers Working in the Student Cafeterias of Jimma University Main Campus, Jimma, South West Ethiopia. *J Community Med Health Educ* 5:345. doi: 10.4172/2161-0711.1000345

- Ashby, W. (1999). An introduction to cybernetics (2nd ed.). London: Chapman & Hall Ltd. <https://doi.org/10.2307/3006723>.
- Asiegbu, C. V., Lebelo, S. L. and Tabit, F. T. (2016). The food safety knowledge and microbial hazards awareness of consumers of ready-to-eat street-vended food, *Food Control*, vol. 60, pp. 422–429.
- Asiegbu, C. V., Lebelo, S. L. and Tabit, F. T. (2020). Microbial Quality of Ready-to-Eat Street Vended Food Groups Sold in the Johannesburg Metropolis, South Africa. *Journal of Food Quality and Hazards Control*, Volume 7, 18-26.
- Bas, M., Ersun, A. S., Kivanc, G. (2006). The evaluation of food hygiene knowledge, attitudes, and practices of food handlers in food businesses in Turkey. *Food Control*, 17, 317-322.
- Beuchat, L. R. (1996). *Listeria monocytogenes*: incidence on vegetables. *Food Contr.* 7 (4-5), 223-228.
- Beuchat, L. R., Ryu, J. H. (1997). Produce handling and processing practices. *Emerg. Infect. Dis.* 3 (4), 459-465.
- Campos, J., Gil, J., Mourão J., Peixe L., Antunes P. (2015). Ready-to-eat street-vended food as a potential vehicle of bacterial pathogens and antimicrobial resistance: An exploratory study in Porto region, Portugal. *Int J Food Microbiology*, 206.
- Cates, S. C., Muth, M. K., Karns, S. A., Penne, M. A., Stone, C. N., Harrison, J. E., Radke, V. J. (2009). Certified kitchen managers: do they improve restaurant inspection outcomes?. *Journal of Food Protection*, 72, 384-391.
- Choudhury, M., Mahanta, L., Goswami, J., Mazumder, M., & Pegoo, B. (2011). Socio-economic profile and food safety knowledge and practice of street food vendors in the city of Guwahati, Assam, India. *Food Control*, 22(2), 196-203.

- Chukuezi, C. O (2010). Food Safety and Hygiene Practices of Street Food Vendors in Owerri Nigeria *Studies in Sociology of Science*, 1(1):12-15.
- Clarence, S. Y., Obinna, C. N. and Shalom, N. C. (2009). Assessment of bacteriological quality of ready to eat food (Meat pie) in Benin City metropolis, Nigeria. *Afr. J. Microbiol. Res.*, 3: 390-395.
- Clayton, D. A., and Griffith, C. J. (2008). Efficacy of an extended theory of planned behaviour model for predicting caterers' hand hygiene practices. *International Journal of Environmental Health Research*, 18(2), 83–98.
- Codex Alimentarius Commission. (2003). Recommended international code of practice general principles of food hygiene. CAC/RCP, Rev, 4, 1-1969.
- Corry, J. E. L., Curt, G. D. W., and Baird, R. M (2003). de Man, Rogosa and Sharpe (MRS) Agar, *Progress in Industrial Microbiology*, [https:// www. sciencedirect. com/ science/ article/pii/S0079635203800668](https://www.sciencedirect.com/science/article/pii/S0079635203800668)
- Deshpande, S. A., Yamada, R., Mak, C. M., Hunter, B., Obando, A. S., Hoxha, S., and Ja, W. W. (2015). Acidic Food pH Increases Palatability and Consumption and Extends *Drosophila* Lifespan¹. Department of Metabolism and Aging, The Scripps Research Institute, Jupiter, FL.
- Edeza, M. J., Quiroz, C. C. & Felix, J. L. (2012). Microbiological quality of beef sold in the municipal market of Culiacan, Sinaloa. *Veterinary Mexico*, 43(4), 273-284
- Ekanem, E. O. (1998). The street food trade in Africa: safety and socio-environmental issues. *Food Control* 9:211–215.
- Elias, S. O., Decol, L. T., and Tondo, E. C. (2018). Foodborne outbreaks in Brazil associated with fruits and vegetables: 2008 through 2014. *Journal of Food Quality and Safety*, Volume 2, 173–181.

- Fawole, M. O., & Oso, B. A. (2001). *Laboratory Manual of Microbiology* (1st Ed.). Ibadan, Nigeria: Spectrum Books Ltd.
- Food and Agricultural Organisation of the United Nations (FAO). (1998). *Street foods. Report of an FAO expert consultation. Jogjakarta, Indonesia, 5-9 December, 1998.* *FAO Nutr.* 1990; 46:3-30.
- Frank, C., Werber, D., Askar, M., Blümel, B., Rabsch, W., Simon, C., Sagebiel, D., Siffczyk, C., Wichmann-Schauer, H., (2014). *Catering risky food to those at-risk: Salmonella Derby outbreak among the elderly in Berlin:* <http://www.ecdc.europa.eu/en>.
- Garayoa, R., Vitas, A. I., Díez-Leturia, M., Jalón, I. G. (2011). *Food safety and the contract catering companies: Food handlers, facilities and HACCP evaluation.* Department of Food Sciences, Physiology and Toxicology, University of Navarra, Spain. C/ Irunlarre s/n, 31008.
- Gitahi, M. G., Wangoh, J. and Njage, P. M. K. (2012). “Microbial safety of street foods in Industrial Area, Nairobi,” *Research Journal of Microbiology*, vol. 7, no. 6, pp. 297–308, 2012.
- Griffith, C. J., Jackson, L. M., & Lues, R. (2017). *The food safety culture in a large South African food service complex: Perspectives on a case study.* *British Food Journal*, 119(4), 729–743. Retrieved from <https://www.scopus.com/inward/record.uri?eid2-s2.0-85015945727&doi=10.1108%2FBJ-11-2016-0533&partnerID=40&md5==e6f67c7668988b4b3654e6858c29bbdf>.
- Griffith, C. J., Livesey, K. M., & Clayton, D. (2010). *The assessment of food safety culture.* *British Food Journal*, 112(4), 439–456. <https://doi.org/10.1108/00070701011034448>.

- Gustavo, V. B., Fontana, A. J., Schmidt, S. J. (2007). Water activity in foods: fundamentals and applications, Blackwell Publishing and Institute of Food Technologists. USA. 313p.
- Gustavsson, J., Cederberg, C., Sonesson, U., vanOtterdijk, R., & Meybeck, A. (2011). Global food losses and food waste extent, causes and prevention. Study conducted for the International Congress SAVE FOOD!. Rome: Food and Agriculture Organization (FAO) of the United Nations. Retrieved from <http://www.fao.org/docrep/014/mb060e/mb060e00.pdf>.
- Hauser, C., Thielmann, J. and Muranyi, P. (2016). “Organic acids: usage and potential in antimicrobial packaging,” in *Anti-microbial Food Packaging*, pp. 563–580, Academic Press, Cambridge, MA, USA, 2016.
- Heredia, N. and García, S. (2018). Animals as sources of food-borne pathogens: A review. *Journal of Animal Nutrition*: <http://www.keaipublishing.com/en/journals/animal/> Animal Nutrition. Volume 4. 250 – 255.
- Hossain, M., Dey, B., K. (2019). Microbial contamination of handmade sauce used by street food vendors in Jashore, Bangladesh. *Journal of Food Quality and Hazards Control*, Volume 6, 115-120.
- Hui, K. L., Hishamuddin, A. H., 2, Kwai, L. T., and Lay, C. C., (2017). Assessment of Food Safety Knowledge, Attitude, Self-Reported Practices, and Microbiological Hand Hygiene of Food Handlers. *International Journal of Environmental Research and Public Health*, 14,55.
- Isara, A. R., Isah, E. C., Lofor, P. V. O., & Ojide, C. K. (2010). Food contamination in fast food restaurants in Benin City, Edo State, Nigeria: implications for food hygiene and safety. *Public Health*, 124(8), 467-471.

- Jamilah, M. B., Abbas, K. A. and Rahman, R. A. (2008). “A review on some organic acids additives as shelf life extenders of fresh beef cuts,” *American Journal of Agricultural and Biological Sciences*, vol. 3, no. 3, p. 566574.
- Jay, J. M., Loessner, M. J., & Golden, D. A. (2005). Intrinsic and extrinsic parameters of foods that affect microbial growth. In D. R. Heldman (Ed.). *Modern food microbiology* (pp.39–59). (7th ed.). New York: Springer.
- Karastogianni S, Girousi S, Sotiropoulos S. pH: Principles and Measurement. In Caballero B, Finglas PM, Toldrá F (eds): *Encyclopedia of Food and Health*. Oxford: Academic Press, 2016:333–338.
- Kharel, N., Palni, U., and Tamang, J. P. (2016). Microbiological assessment of ethnic street foods of the Himalayas, *Journal of Ethnic Foods*, vol. 3, no. 3, pp. 235–241.
- Lamin-Boima, P. T. (2017). Knowledge, Attitude and Practice of Street Food Vendors In Selected Schools within Bo City Southern Sierra Leone. *International Journal of Scientific & Technology Research*, Volume 6, Issue 12
- Lawal, G., Yarma, A. A, Hadiza A. J., Mainat A., Shuaibu I. Adamu M. T. (2018). Assessment of Knowledge, Attitudes and Practices (KAP) on Microbiological Safety among Cattle Abattoir Workers in Malaysia. Department of Microbiology, Faculty of Science, Gombe State University
- Lefyedi, M.L., Marais, G.J., Dutton, M.F., & Taylor, J.R.N. (2005). The microbial contamination, toxicity and quality of turned and unturned outdoor floor malted sorghum *Journal of The Institute of Brewing*, 111 (2), 190-196.
- Leus, F. R., Meple. R. R., Venter, P., & Theron, M. M. (2006) Assessing food safety and Association of food Handling Practices in Street Food Vending. *International Journal of environmental health research*, 16 (5): 319-328.

- Leveson, N. (2004). A new accident model for engineering safer systems. *Safety Science*, 42(4),237-270.
- Leveson, N. (2015). A systems approach to risk management through leading safety indicators. *Reliability Engineering & System Safety*, 136, 17–34. Retrieved from <https://doi.org/10.1016/j.res.2014.10.008>.
- Lucera, A., Costa, C., Conte, A. and Del Nobile, M. A. (2012). “Food applications of natural antimicrobial compounds,” *Frontiers in Microbiology*, vol. 3, pp. 287–301, 2012.
- Martins, J. H. (2006). Socio-economic and Hygiene Features of Street Food Vending in Gauteng. *South African Journal of Clinical Nutrition*, 19 (1): 18-25.
- McLauchlin, J. (1997). The identification of *Listeria* species. *Int. J. Food. Microbiol.* 38:77–81.
- McQuestin, O. J., Shadbolt, C. T. & Ross, T. (2009). Quantification of the relative effects of temperature, pH, and water activity on inactivation of *Escherichia coli* in fermented meat by meta-analysis. *Applied and Environmental Microbiology*, 75: 6963–6972.
- Mercer, D. G. (2008). Solar drying in developing countries: Possibilities and pitfalls. In G. L. Robertson, & J. R. Lupien (Eds.). *Using food science and technology to improve nutrition and promote national development International Union of Food Science & Technology* <http://www.iufost.org/publications/books/documents/Mercer.pdf>.
- Mercer, D. G. (2014). Part 2: Drying of specific fruits and vegetables. An introduction to the dehydration and drying of fruits and vegetables <http://iufost.org/iufostftp/Drying-Part2.pdf>.

- Mettler Toledo. (1999). Moisture Analyzers With Halogen Heating Technology for Fast, Precise and Reliable Results. Available on https://www.mt.com/int/en/home/products/Laboratory_Weighing_Solutions/moisture-analyzer.html.
- Miller, J. M, Griffin, P. M (2012) One Health through eyes of clinical and public health microbiology. *Microbe* 7: 23–27.
- Moloi, M., Lenetha, G. G., & Malebo, N. J. (2021). Microbial levels on street foods and food preparation surfaces in Mangaung Metropolitan Municipality. *Health SA*, 26, 1407. <https://doi.org/10.4102/hsag.v26i0.1407>
- Mossel, D.A.A., Corry, J.E.L., Struijk, C.B., and Baird, R.M. (1995). *Essentials of the Microbiology of Foods*, John Wiley & Sons Ltd., England, p. 231.
- Muinde, O. K., & Kuria, E. (2005). Hygienic and Sanitary Practices of Vendors of Street Foods in Nairobi, Kenya, *African Journal of Food Agriculture and Nutritional Development*, 5 (1): 1-14.
- Muinde, O.K. & Kuria E. (2005). Hygienic and Sanitary Practices of Vendors of Street Foods in Nairooobi, Kenay, *African Journal of Food Agriculture and Nutritional Development*, Volume 5 No 1:http://www.ajfand.net/Issue_VIIIfiles/pdf.
- Muyanja, C., Nayiga, L., Brenda, N., & Nasinyama, G. (2011). Practices, knowledge and risk factors of street foods in Uganda. *Food Control*, 22(10), 1551-1558.
- Namibia Food Safety Policy, (2014). Minister of Agriculture, Water and Forestry. Republic of Namibia
- Nayak R., Waterson P. (2019). Global food safety as a complex adaptive system: Key concepts and future prospects. Food Technology and Innovation Department, Harper Adams University, Newport TF10 8NB, UK

- Nayak, R., & Waterson, P. (2016). ‘When food Kills’: A socio-technical systems analysis of the UK Pennington 1996 and 2005 E.coli O157 outbreak reports. *Safety Science*, 86, 36–47. <https://doi.org/10.1016/j.ssci.2016.02.007>.
- Nayak, R., & Waterson, P. (2019). The Assessment of Food Safety Culture: An investigation of current challenges, barriers and future opportunities within the food industry. *Food Control*, 73, 1114–1123. <https://doi.org/10.1016/j.foodcont.2016.10.061>.
- Neff, R., & Lawrence, R. (2014). Food systems. In R. Neff(Ed.). *Introduction to the US food System: Public health, environment, and equity* (pp. 1–22). Incorporated: John Wiley & Sons. Retrieved from <https://www.planning.org/nationalcenters/health/food.htm>.
- Nkandi J., Chimwamurombe, P., and Shilangale, R. (2017). *Bacteriological Quality and Safety of Raw Beef from Selected Outlets in Windhoek (Namibia)*. University of Namibia, Windhoek, Namibia. 45-55.
- Nobili, G., Franconieri, I., La Bella, G., Basanisi, M. G., and La Salandra, G. (2017). “Prevalence of Verocytotoxigenic *Escherichia coli* strains isolated from raw beef in southern Italy,” *International Journal of Food Microbiology*, vol. 257, pp. 201–205.
- Novasima, A. G. *The Meaning of Water Activity*. (2005) Novasima. www.novassima.com. 2005.
- Ntanga, P. D. (2013). Assessment of microbial contamination in beef from abattoir to 536 retail meat outlets in Morogoro municipality, Tanzania. *Journal of Food Control*, 2(3), pp. 121 - 135.

- Okonko, I. O., Ukut, O. E., Ikpoh, I. S., Nkang, A. O., Udeze, A. O., Babalola, T. A., Mejeha, O. K., & Fajobi, E. A. (2010). Assessment of bacteriological quality of fresh meats sold in Calabar Metropolis, Nigeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 9, 89-100.
- Okrend, A. J. G., B. E. Rose, and R. Martner. 1990. An improved method for the detection and isolation of *Escherichia coli* O157:H7 from meat, incorporating the 3M Petrifilmy test kit HEC for hemorrhagic *Escherichia coli* O157:H7. *J. Food Prot.* 53:930–940.
- Oranusi, S., Galadima, M., Umoh, V., & Nwanze, P. (2007). Food safety evaluation in boarding schools in Zaria, Nigeria, using the HACCP system. *Scientific Research and Essays*, volume 2 (10), 426–433.
- Park, S., Kwak, T. & Chang, H. (2010). Evaluation of the Food Safety Training for Handlers in Restaurant Operations. *Nutrition Research and Practice*, 4(1): 58-68.
- Park, S.H., Kwak, T.K., Chang, H.J. (2010). Evaluation of the food safety training for food handlers in restaurant operations. *Nutrition Research and Practice*, 4, 58-68.
- Pennington, T. H. (2003). *When food kills: BSE, E.coli and disaster science* (1st ed.). Oxford: Oxford University Press.
- Pichler, J., Ziegler, J., Aldrian, U., Allerberger, F. (2014). Evaluating levels of knowledge on food safety among food handlers from restaurants and various catering businesses in Vienna, Austria 2011/2012. *Food Control*, 35, 33-40.
- Rajaseharan, D. (2021). Food hygiene and handling practices of street food vendors in Villupuram. *Indian Journal of Preventive and Social Medicine*, 52 (1), 4–11.

- Rakha, A., Fatima, M., Bano, Y., Khan, M. A., Chaudhary, N. and Aadil, R. M. (2022). Safety and quality perspective of street vended foods in developing countries. *Food Control Journal*. 138 Elsevier Ltd.
- Rane, S. (2011). Street vended food in developing world: Hazard analyses. *Indian Journal of Microbiology* 51(1): 100–106.
- Sadler G. D., Murphy P. A. (2010) pH and Titratable Acidity. In: Nielson S. S. (ed): *Food Analysis*. str. 219-238. Springer Science + Business Media, LLC2010. New York, USA.
- Sagar A., (2015). Potato Dextrose Agar (PDA) - Principle, Uses, Composition, Procedure and Colony Characteristics. <https://microbiologyinfo.com/potato-dextrose-agar-pda-principle-uses-composition-procedure-and-colony-characteristics/>
- Salmon, P. M., Read, G. J. M., & Stevens, N. J. (2016). Who is in control of road safety? A STAMP control structure analysis of the road transport system in Queensland, Australia. *Accident Analysis & Prevention*, 96, 140–151. <https://doi.org/10.1016/j.aap>.
- Sanders E.R. (2010): Aseptic laboratory techniques: plating methods. *J. Vis. Exp.*, 2012; 63: e3064.
- Sandulachi, E., Tatarov P. and Croitir, D. (2012). The evolution of frozen strawberries quality by studying the kinetics change of antioxidants activity, *Journal of Food Research*, Vol. 1, No. 1, Canadian Center of Science and Education, www.ccsenet.org/jfr p. 225 -238.
- Sani, N. A. & Siow, O.N. (2014). Knowledge, attitudes and practices of food handlers on food safety in food service operations at the University Kebangsaan Malaysia. *Food Control*, 37: 210-217.

- Sani, N.A., Siow, O.N. (2014). Knowledge, attitudes and practices of food handlers on food safety in food service operations at the University Kebangsaan Malaysia. *Food Control*, 37, 210-217.
- Sanlier, N. (2009). The knowledge and practice of food safety by young and adult consumers. *Food Control*, 20: 538-542.
- Schlosser, E. (2001). *Fast food nation* (1st ed.). Houghton Mifflin. [http://refhub.elsevier.com/S0924-2244\(17\)30353-9/sref84](http://refhub.elsevier.com/S0924-2244(17)30353-9/sref84)
- Seaman, P. & Eves, A. (2006). The Management of Food Safety-The Role of Food Hygiene Training in the UK Service Sector. *International Journal of Hospitality Management*, 25. (2): 278-296.
- Sereno A. M. et al. Prediction of water activity of osmotic solutions, *J. Food Engineering*, Vol.49, No2, pp. 103-114, 2001.
- Sereno, A. M., Hubinger, M. D., Comesa, J. F., Correa, A. (2000). Prediction of Water Activity of Osmotic Solutions. Department of Chemical Engineering, University of Vigo, Apd. 874, 36200, Spain.
- Sharif, L., Al-Malki, T. (2009). Knowledge, attitude and practice of Taif University students on food poisoning. Dept. of Pathology and Animal Health, Faculty of Veterinary Medicine, Jordan University of Science and Technology, Irbid 22110.
- Sharif, L., Al-Malki, T. (2010). Knowledge, attitude and practice of Taif university students on food poisoning. *Food Control*, 21, 55-60.
- Shiningeni D. W, Misihairabgwi J, Shilangale R. P, & Chimwamurombe P. M, (2018). Assessment of the prevalence of pathogenic bacteria in street vended ready-to-eat meats in Windhoek, Namibia, University of Namibia, Windhoek, Namibia. 69 -70.
- Smelt, J. P. P. M. and brul, S.. (2014). *Thermal Inactivation of Microorganisms*.

Critical Reviews in Food Science and Nutrition. Department of Molecular Microbial Physiology and Food Safety, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands. Taylor and Francis Group, 54:1371–1385.

Soares LS, Almeida RC, Cerqueira ES, Carvalho JS, Nunes IL. Knowledge, attitudes and practices in food safety and the presence of coagulase-positive staphylococci on hands of food handlers in the schools of Camaçari, Brazil. *Food Control*. 2012;27(1):206-13.

Soon, J.M., Baines, R., Seaman, P. (2012). Meta-analysis of food safety training on hand hygiene knowledge and attitudes among food handlers. *Journal of Food Protection*, 75, 793-804.

Sseguya, W., Matovu, N., Swann, J., & Draper, A. (2020). Contribution of street food to dietary intake of habitual urban consumers: A cross-sectional study in Kampala city, Uganda. *Nutrition & Health*, 26(3), 187–195.

Stratford, M., Nebe-von-Caron, G. Steels, H., Novodvorska, M., Ueckert, J and Archer, D. B. (2013). Weak-acid preservatives: pH and proton movements in the yeast *Saccharomyces cerevisiae*. *International Journal of Food Microbiology*, vol. 161, no. 3, pp. 164-171.

Swanepoel, F. J. J., C. Hobbs, P. J. Becker, and C. Ijsselmuiden. (1995). The quality of food sold by traders in central Johannesburg and factors associated with contamination. *J. Compr. Health* 6:188–190.

Theron, M. M., and Lues, J. F. R. (2007). Organic acids and meat preservation: a review, *Food Reviews International*, vol. 23, no. 2, pp. 141–158.

Von Holy, A. & Makhoane, F.M. (2006). Improving street food vending in South Africa:

Achievements and lessons learned. *International Journal of Food Microbiology*:
<http://www.sciencedirect.com>.

Webb M, & Morancie A., (2015). Food safety knowledge of foodservice workers at a university campus by education level, experience, and food safety training. *Food Control*, 50:259–64.

Westrell, T., Ciampa, N., Boelaert, F., Helwich, B., Korsgaard, H., Chriel, M., Meakelea, P.,
2009. Zoonotic infections in Europe in 2007: a summary of the EFSA-ECDC annual report. *Euro Surveill.: Bulletin Europeen sur les maladies transmissibles*¼*Eur. Commun. Dis. Bull.* 14 (3), 785e794.

World Health Organization (WHO)/Food & Agriculture Organization (FAO).
(2010). Basic steps to improve safety of street-vended food. *International Food Safety Authorities Network (INFOSAN). Information Note No. 3/2010- Safety of street-vended food*:
http://www.who.int/foodsafety/fs_management/No_03_StreetFood_Jun10_en.pdf.

World Health Organization (WHO) (1996). *Food Safety Issues, Essential Safety Requirements for Street Vended Food (Revised edition)*. World Health Organization Geneva.

World Health Organization (WHO) (2006) *Five Keys to Safer Manual*. World health Organization, Geneva. Switzerland.

World Health Organization (WHO) (2015). *WHO estimates of the global burden of foodborne diseases: foodborne disease burden epidemiology reference group 2007-2015. I*. World Health Organization, Geneva. Switzerland.

Worsfold D. Worsfold, P. M. Griffith C. J. (2004). An assessment of food hygiene and safety at farmers' markets. *Int J Environ Health Res* 14: 109-119.

ANNEX 1: ETHICAL CLEARANCE CERTIFICATE



ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: FOS-002-2020

Date: 17-12-2020

This Ethical Clearance Certificate is issued by the University of Namibia Research Ethics Committee (UREC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the Faculty/Centre/Campus Research & Publications Committee sitting with the Postgraduate Studies Committee.

Title of Project: FOOD SAFETY AND THE USE OF READY TO USE SCENARIOS TO ADDRESS MICROBIAL FOOD HAZARDS IN FOOD SYSTEMS AMONG VENDORS IN SELECTED LOCAL FOOD MARKETS IN WINDHOEK

Nature/Level of Project: HUMAN RESEARCH - NON HEALTH: RESEARCH PROJECT

Researchers: PAULUS NGALANGI

Student Nr: 200202995

Faculty: FACULTY OF SCIENCE

Supervisors: PROF. A. CHEIKHYOUSSEF

Take note of the following:

- (a) Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the UREC. An application to make amendments may be necessary.
 - (b) Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the UREC.
 - (c) The Principal Researcher must report issues of ethical compliance to the UREC (through the Chairperson of the Faculty/Centre/Campus Research & Publications Committee) at the end of the Project or as may be requested by UREC.
 - (d) The UREC retains the right to:
 - (i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,
 - (ii) Request for an ethical compliance report at any point during the course of the research.
- REC wishes you the best in your research.

REC Chairperson

A handwritten signature in black ink, appearing to read 'R Bock', written over a horizontal line.

Dr R Bock

ANNEX 2: STUDY QUESTIONNAIRE

FOOD SAFETY AND THE USE OF READY TO USE SCENARIOS TO ADDRESS MICROBIAL FOOD HAZARDS IN FOOD SYSTEMS AMONG VENDORS IN SELECTED LOCAL FOOD MARKETS IN WINDHOEK

This Questionnaire is part of a project on the above stated title in which your assistance will be of great value. All the information to be obtained will remain strictly confidential, and your answers and name will never be revealed. Note that you are not obliged to answer any question you do not want to, and you may stop the interview at any time.

The main objective of this study is to **assess the food safety situation**. Please answer the questions as honestly as possible. Feel free to answer questions at your own pace.

Do you agree to participate in this interview? Yes ___ No ___

Signature: _____

1. Demographic Information

1. Name (optional)			
2. Sex	<input type="checkbox"/> Male	<input type="checkbox"/> Female <input type="checkbox"/>	
3. Age			
4. Location			
5. Length of employment in the food vending business	<input type="checkbox"/> Less than a year	<input type="checkbox"/> 1 to 2 years	<input type="checkbox"/> More than 2 years
6. Educational level	<p>Have you ever attended school?</p> <p><i>If ye:</i> What is the highest level of school you attended?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Primary school <input type="checkbox"/> Secondary school <input type="checkbox"/> Higher	
Work experience	Less than one year	<input type="checkbox"/> 1-5 years <input type="checkbox"/> 6-10 years	

		<input type="checkbox"/> More than 10 years
Types of Foods Sold		<input type="checkbox"/> 1 type <input type="checkbox"/> 2 types <input type="checkbox"/> More than 2 types
Average Income per Month		<input type="checkbox"/> Up to N\$1000 <input type="checkbox"/> N\$1000 – 2000 <input type="checkbox"/> \geq N\$3000

2. Knowledge on Food Hazards

Food safety knowledge and awareness	Strongly disagree	Disagree	I agree	Strongly agree	Don't know
1. Food hygiene requires the removal of microorganisms from food					
2. It is necessary to keep waste materials and foodstuffs separate					
3. Store cooked and uncooked foods separately and prepare cooked and uncooked foods with separate equipment					

4. Unclean equipment can transfer bacteria to food					
5. Freezing kills harmful microorganisms in food					
6. Favorable temperature range of bacteria responsible for food borne diseases is 5°C -60°C					
7. It is safe to keep foods of animal origin such as meat, milk, eggs at room temperature					
8. Drinkable water must be used for food preparation					
9. Bacteria that cause food poisoning multiply very quickly in the foods that are kept at room temperature					
10. Cooked foods kept at room temperature for more than 2 hours before serving can cause illness					
11. Frozen foods can be frozen again after thawed					
12. I have heard about at least one of the following as a problem in food: <i>Salmonella</i> , <i>Listeria</i> , <i>Campylobacter</i> , and <i>E. coli</i> .					

13. Parasites, Fungi, Bacteria, and Virus are the microorganism most likely to cause food poisoning					
14. Diarrhoea, nausea, vomiting, fever, abdominal pain, fatigue and loss of appetite are important signs in food poisoning cases					

3. Personal Hygiene

Hygiene practice	Strongly disagree	Disagree	Agree	Strongly agree	Don't know
1. Anyone can be a means for transportation of microbes to food					
2. It is always safe to prepare food with bare hands					
3. Bacteria which can cause food poisoning can be found in our nose and on hands					
4. Preparing food while having an open wound or abscess can transmit bacteria that cause food poisoning					
5. There is no problem for a person to serve food when suffering from flu, diarrhoea, influenza or other illnesses					

4. Perception on Food Safety

Perceived safety from food illnesses	Strongly disagree	Disagree	Agree	Strongly agree	Don't know
1. Some people are more likely to get sick from food infections than others					
2. food infections are serious and can lead to death if untreated					
3. food contamination and associated infections are easy to prevent					

5. Response to Food-borne Outbreak

Preparedness to food-borne disease outbreak	Strongly disagree	Disagree	Agree	Strongly agree	Don't know
1. Report suspected food-borne outbreak to relevant Authorities					
2. Medical attention should be sought if you suspect food-borne disease					
3. It is necessary to inform other vendors and suppliers about suspected food contamination					

ANNEX 3: STATISTICAL ANALYSIS TABLES

Table 20. Normality test for the data of physicochemical and microbial quality of the sampled foods

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
& Moisture	.207	24	.009	.872	24	.006
pH	.389	24	.000	.608	24	.000
On PCA	.139	24	.200*	.909	24	.034
On MRS	.203	24	.011	.867	24	.005
On PDA	.171	24	.069	.913	24	.042

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Since the sample of the groups is equal, and less than 2000, the results of Shapiro-Wilk test are considered. Hence the following hypothesis is tested.

H₀: Data is normally distributed

H₁: Data is not normally distributed

From the normality test table, the p-value for PDA is greater than 0.05, hence the H₀ is retained, and conclude that the data is normally distributed. On the other hand, the p-value for other variables is less than 0.05, which means that the data are not normally distributed. Despite the violation of the normality test, ANOVA tests can still be, and were performed. Therefore, the test for reliability and homogeneity were conducted and they all yielded positive results below.

Table 21. Homogeneity test for the data of physicochemical and microbial quality of the sampled foods

Test of Homogeneity of Variances				
	Levene Statistic	df1	df2	Sig.
Percentage Moisture	0.004	3	20	1.000
pH	0.016	3	20	0.997
On PCA	0.38	3	20	0.769
On MRS	0.096	3	20	0.961
On PDA	0.009	3	20	0.999

H₀: The means of the groups are equal

H₁: The mean of the groups are not equal

NB: group means are *not* equal if “Sig.” or $p < 0.05$.

The homogeneity test to determine if the means of the groups are equal, on top of the sample size of the groups are equal and do not necessary require homogeneity test. Nevertheless, evidence from the homogeneity test show shat all the groups’ p-values are greater than 0.05. This implies that the means of groups are equal. Hence the data are fit for ANOVA tests.

Table 22. Reliability test for the data of physicochemical and microbial quality of the foods

Reliability Statistics

Cronbach's Alpha	N of Items
.227	5

It can be seen from the reliability statistics that the Cronbach’s value is 0.227, which shows that there is consistency in the data, meaning the data are reliable.