THE FOOD SAFETY KNOWLEDGE AND MICROBIAL HAZARDS AWARENESS OF CONSUMERS OF READY-TO-EAT STREET-VENDED FOODS AND THEIR EXPOSURE TO MICROBIOLOGICAL HAZARD

by

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DECLARATION

I, Asiegbu Chioma Vivian, hereby declare that "The food safety knowledge and microbial hazards awareness of consumers of ready-to-eat street-vended foods and their exposure to microbiological hazards" is my own work, and that all sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I have not previously submitted this work, or part of it, for any degree or examination in any other higher education institution.

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DEDICATION

I dedicate this study to the all-sufficient God, who gave me the courage, strength and wisdom to accomplish this task.

ABSTRACT

In many countries, the authorities face extreme difficulties in monitoring and ensuring that food sold on the street is safe, that is, fit for human consumption. This is particularly the case in urban areas, where people buy food on the street because it is readily available and relatively inexpensive. The objective of this study was to determine the food safety knowledge and microbial hazard awareness of street food consumers, and to assess the bacteriological quality of selected ready-to-eat foods sold by street vendors in the Johannesburg municipality. A cross-sectional survey study was conducted and a total of 402 respondents who buy and consume street-vended foods were randomly selected at various street food vending locations.

A total of 315 various street-vended samples were purchased from randomly selected street food vendors at different vending locations in Johannesburg metropolis, in order to investigate the bacteriological quality of street-vended foods. Results of the bacteriological analysis revealed that total aerobic counts ranged from $0.3*10^2$ - $0.4*10^5$ cfu/g in cereals and grain-based foods; $0.4*10^2$ - $0.5*10^5$ cfu/g in meat-, dairy- and fish-based foods and $0.7*10^2$ - $0.9*10^4$ cfu/g in fruit- and vegetable-based foods. None of the food samples tested positive for *Salmonella* spp and *Staphylococcus aureus*.

Results of the survey showed that the majority of respondents were black males younger than 35 years. Individuals of different gender, race, level of education and monthly income groups significantly ($p<0.05$) differed in their responses regarding the frequency of purchasing and confidence in the safety of street-vended food. Better taste followed closely by affordability and accessibility were the most cited reasons for purchasing street-vended food.

Keywords: Street-vended; ready-to-eat; food safety; knowledge; hazard; awareness; consumer; Johannesburg; pathogen; microbial; foodborne disease; RAPD-PCR

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA: Analysis of Variance

bp: base pair

cfu: colony forming units

DNA: Deoxyribonucleic Acid

dNTPs: Deoxy ribonucleotide Triphosphates

EHEC: Entero-Haemorrhagic *Escherichia coli*

FAO: Food and Agriculture Organisation of the United Nations

FSANZ: Food Standard Australia New Zealand

HACCP: Hazard Analysis of Critical Control Point

ICMSF: International Commission on Microbiological Specifications for Foods

LAB: Lactic Acid Bacteria

LAMP: Loop-Mediated Isothermal Amplification

$MgCl_2$: Magnesium Chloride

mPCR: Multiplex Polymerase Chain Reaction

MPF: Minimally Processed Fresh

MRA: Microbiological Risk Assessment

MRS: De Man, Rogosa, and Sharpe

NASBA: Nucleic Acid Sequence-Based Amplification

PCA: Plate Count Agar

PCR: Polymerase Chain Reaction

qPCR: Quantitative Polymerase Chain Reaction

RAPD: Random Amplified Polymorphic DNA

rpm: revolutions per minute

RNA: Ribonucleic Acid

rRNA: Ribosomal Ribonucleic Acid

RTE: Ready-To-Eat

SPSS: Statistical Package for the Social Sciences

TAC: Total Aerobic Count

TAE: Tris-Acetate-EDTA

UN: United Nations

USA: United States of America

VRBD: Violet Red Bile Dextrose

VTEC: Verocytotoxin-producing *E. coli*

WHO: World Health Organisation

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND INFORMATION

Foodborne diseases constitute a widespread and ever-increasing public health problem in both developing and developed countries (Carbas et al., 2013; Bhattacharya and Reang, 2014). They can occur because of consumers ingesting food items contaminated with microorganisms and harmful chemicals (Webb and Morancie, 2015).

The Food and Agriculture Organisation of the United Nations (FAO) estimated that up to 2 million people per year, most of whom are children, die as a result of diseases caused by contaminated food and water (FAO, 2014). According to the World Health Organisation (WHO), foodborne diseases have devastating health implications, such as kidney and liver failure, brain and neural disorders, reactive arthritis and cancer, with fatal results. The early death of people, who are active in the labour market, can also reduce the economic productivity of a country significantly (WHO, 1999a).

In many streets of developing countries, like South Africa, the sale and consumption of ready-to-eat foods and beverages are a common and normal phenomenon of everyday life (Kok and Balkaran, 2014). Different types of food items such as traditional meals, snacks, and beverages are usually prepared on the street or at home. These are then sold by vendors or hawkers on street pavements, at taxi stations, industrial areas, market places and other public sites for immediate consumption or consumption at a later stage without further processing or preparation (WHO/FAO, 2010; Muyanja et al., 2011; Samuel, 2012). Due to their unique taste, variety and accessibility, most street foods are greatly appreciated by consumers and are consumed daily by an estimated 2.5 billion people worldwide (FAO, 2007a; Kibret and Tadesse, 2013; Manguiat and Fang, 2013). In cities like Johannesburg, for example, informal food vending forms an integral part of the food supply network, and is a major contributor to South Africa's economy. About R44.7 million was spent at street food outlets in Gauteng in 1994 alone (Oguttu et al., 2015).

Regardless of the intrinsic benefits of the sale and consumption of street-vended foods, the safety of street foods can be affected by a number of factors. These include the quality of the raw materials, preparation conditions, handling and storage conditions as well as location of the vending business, which might not meet all food safety requirements (Choudhury et al., 2011; Muyanja et al., 2011; Aluko et al., 2014). Street food vendors often operate unregulated, that is without monitoring by any relevant authority (Bhattacharya and Reang, 2014). As a result, street-vended foods can become contaminated, thus exposing people who consume these foods to the potential risk of foodborne diseases, such as salmonellosis, listeriosis, typhoid fever, cholera, diarrhoea *etcetera* (Manguiat and Fang, 2013; Liu et al., 2014).

Undoubtedly, microbiological food safety hazards pose a huge challenge to the safety of street food, since potentially harmful microorganism have the ability to grow rapidly in street-vended food and cause foodborne diseases to consumers (Akinbode et al., 2011). Several researchers have identified street-vended foods as potential vectors of foodborne pathogens, such as: *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp., *Shigella sonnei*, *Proteus* spp., *Listeria* spp. and *Bacillus cereus* (Mensah et al., 2002; Lues et al., 2006; Gadaga et al., 2008; El-Shenawy et al., 2011; Gitahi et al., 2012; Odu and Imaku, 2013).

In many developing countries, the migration of people to urban centres and changes in their socio-economic status has led to an increase in the number of people who patronise street-vended foods (Omemu and Aderoju, 2008; Samapundo et al., 2015). Consequently, the rising number of people who consume these foods is matched by their heightened exposure to foodborne hazards (WHO, 2008; Adam et al., 2014). It follows that it is of crucial importance that consumers of street foods are made aware of the risks, and take precautions as safety measures. This could play an essential role in the prevention of foodborne diseases, as they constitute the last link in the "farm to fork" food chain (Losasso et al., 2012).

1.2 PROBLEM STATEMENT

Threats to food safety and foodborne disease caused by microbial pathogens remain a significant burden on public health worldwide, despite the efforts of governments towards improving food safety (WHO, 2007). A report issued by the WHO estimated that up to one-third of the populations of developed countries are affected by foodborne illnesses each year, and the problem is likely to be even more widespread in developing countries (WHO, 2002).

In Africa particularly, foodborne illness continues to be a major health threat to the African people, especially for vulnerable groups, such as infants, pregnant women and immune-compromised individuals. The mortality rate for food- and water-borne diseases like diarrhoea has recently been set at 700,000 annually for all ages in sub-Saharan Africa (Mensah et al., 2012). The FAO and the WHO estimated that 800,000 children in Africa die each year from diarrhoea and dehydration, and that 70% of these cases are probably caused by unsafe food (FAO/WHO, 2005).

Diarrhoeal disease, which is the commonest manifestation of food poisoning, remains one of the leading causes of morbidity and mortality among children, accounting for approximately 20% of under-five deaths in South Africa (Chola et al., 2015). In fact, an outbreak of foodborne disease from *Shigella flexneri* due to the consumption of unpasteurised orange juice has been reported in South Africa (Thurston et al., 1998).

In Johannesburg, street food has become an increasingly important component of the food trade system, since people from all walks of life depend on them as their source of nutrients. However, ready-to-eat foods, especially those sold on the street, are of concern, because they can be subjected to time/temperature abuses during processing and display besides poor hygienic practices by vendors. Moreover, the hot climate and environmental conditions in which street food vendors in South Africa operate, such as dusty streets, provide favourable conditions for bacterial growth (Kok and Balkaran, 2014). Consequently, this could pose a serious threat to the health of the people who consume ready-to-eat foods from these vendors.

Consumer awareness on issues concerning food safety and microbial hazards is a major issue in the promotion of healthy lifestyles and disease prevention. According to Garode and Waghode (2012), some consumers of street-vended foods are not fully aware of the hazards associated with these foods; and (whether they are aware of it or not) the majority of consumers disregard the possibility that ready-to-eat foods bought on the street can be contaminated. In South Africa, and especially in Gauteng, street food vending is one of the largest self-employment practices in the informal sector. Thousands of people, including children and adults, depend on these foods (Von Holy and Makhoane, 2006), without much cognizance to their safety, quality, and hygiene. Therefore, assessing the hazards posed by these foods as well as gaining valuable information on consumers' knowledge regarding food safety, would assist relevant authorities design and implement effective control measures aimed at protecting consumers' health.

1.3 PURPOSE OF THIS RESEARCH

The purpose of this research was to establish the extent of street food consumers' knowledge about food safety and their level of awareness of the microbial hazard such food may contain. The bacteriological quality and diversity of ready-to-eat street-vended foods were also investigated. The findings of this study will contribute in providing clarity on food safety issues associated with street-vended foods sold in Johannesburg. Hence, investigating the microbial quality and safety of food plays a key role in the prevention and recognition of problems related to public health and safety (Velusamy et al., 2010).

Given the distinctive role played by street foods for people living in Johannesburg, it was apt to conduct this study in order to determine whether there is an urgent need to strengthen existing consumer food safety programmes. These could raise awareness among consumers about hygiene and safety aspects of street foods, or target a specific consumer group that can use knowledge of food safety as a potent means of curbing serious foodborne poisoning outbreaks.

It is therefore crucial to gain a firm base of information on consumers' knowledge, attitudes and practices concerning food safety. The findings derived from this study provided valuable insights into the level of food safety knowledge and awareness of consumers of street foods in Johannesburg city. It also addressed issues affecting public health safety through investigation on the presence of food pathogens responsible for the dangerous threats to public health and national economy.

1.4 DISSERTATION LAYOUT

This study comprises six chapters, arranged as follows:

Chapter 1: Introduction

This first chapter is the introduction to the study. It provides an overview and background context for the research. This section also outlines the problem statement, the purpose of the study and explains the layout of the dissertation.

Chapter 2: Literature review

The literature review in chapter 2 provides an overview of existing literature on food safety, street-vended foods and methods of bacteria detection in food.

Chapter 3: Aims and objectives

In this chapter, the aim and objectives as well as research questions were explained.

Chapter 4: Research methodology overview

The research area, sampling method, data collection method and instruments used were outlined in this chapter. The ethical principles followed and limitations to the research were discussed.

Chapter 5: Research

The chapter outlines the research outputs emanating from the different research objectives, which were published or are under review in a peer reviewed journal. This includes results, discussion and conclusion emanating from the individual research papers.

Chapter 6: General conclusion and recommendations

This section merged the overall conclusion and recommendations emanating from the two research papers. A list of references and appendices for the dissertation then follow.

CHAPTER 2: LITERATURE REVIEW

2.1 FOOD SAFETY

Globally, issues of food safety constitute a growing concern because foodborne diseases attributable to biological, chemical or physical contamination affects the health of millions of consumers of ready-prepared food sold on the street (Velusamy et al., 2010; Aluko et al., 2014; Roesel et al., 2015). Even though the global incidence of foodborne diseases is difficult to estimate (as many cases are under-reported, especially in developing countries), a rise in the occurrence of foodborne diseases has been reported in many parts of the world (Van de Venter, 2000).

Food safety is of crucial importance not only to consumers, but also to the food industry, policy makers and economy (Jevšnik et al., 2008), as millions of people get ill and many die each year, as a consequence of consuming unsafe food (WHO, 2002; 2009). Food safety can be defined as the inverse of food risk, or the assurance that a food will not cause harm to the consumer when it is prepared or eaten in accordance with its intended use (Wilcock et al., 2004; WHO, 2009). Cruz et al. (2013) pointed out that food safety forms the basis of public health security. Therefore, providing adequate amounts of safe and nutritious food to citizens is the key to sustaining and promoting a healthy life and economy in any nation (WHO, 2014).

Nevertheless, defining what is safe or unsafe, and which processing techniques are required to make food safe, is a major issue. The chain of events involved in planting, harvesting, processing, distribution, then the final preparation of food is frequently quite long, and food safety experts have reported that foods can become contaminated at any specific point in the process (Knight et al., 2003). According to the WHO, food can become contaminated and cause foodborne illnesses due to various factors like cultural practices (such as the consumption of raw or under-cooked foods), poor standards of hygiene during food handling and preparation, and the lack of training in food safety are probably the most common causes of foodborne illnesses (WHO, 1999a). In addition, Mensah et al. (2012) mentioned human factors, such as unhygienic practices and deliberate contamination, combined with external factors, such as impure water, unsafe waste disposal, and the exposure of food to insects as well as dust, and prolonged storage of cooked food without refrigeration.

Food safety hazards could be physical, microbiological, or chemical but microbiological hazard, pose a bigger challenge to the safety of street food, since potentially harmful microorganism can grow rapidly in street-vended food and cause foodborne diseases in consumers (Akinbode et al., 2011). The food serves as a vehicle for the transfer of the pathogens to the consumer, in whom the pathogen can grow and cause a variety of diseases (Murray et al., 2003).

The rapid globalisation of the food supply system has introduced new threats to food safety, which have caused a steep rise in foodborne diseases and exacerbated the problems faced by public health systems internationally (Campbell, 2011). This deterioration in food safety is a consequence of increasing industrialisation and expansion of the food trade, rapid urbanisation, a growing number of people moving across borders, rapid changes in food production, environmental changes and the emergence of new or antibiotic-resistant pathogens (Akinbode et al., 2011; WHO, 2015).

At household level, a lack of food safety could lead to mild and adverse health conditions as well as financial burdens of medical costs, and in most extreme cases, funeral expenses and the loss of the household breadwinner. Extended to the broader context of national health, foodborne diseases not only put a strain on the government health care systems, but also impede socio-economic development, which in turn affects the country’s economy (WHO, 2014). Foodborne diseases can impede socio-economic development in two ways: it hampers productivity; and requires very costly interventions.

2.2 FOOD SAFETY MEASURES

According to Omemu and Aderoju (2008), provision of basic infrastructure and services, such as adequate supply of clean water and electricity, waste disposal services, good drainage, and toilets made available by government, is crucial in ensuring effective food safety. In a developing country, there are particular difficulties related to the production of food that is not only ‘safe’ but of good quality, because many of those producing and handling food for public consumption lack the knowledge of what is required. More specifically, they are unaware of the importance of hygiene in the handling and storage of food, and of modern practices, which ensure that the production, processing, handling and sale of food conform to health standards (FAO/WHO, 2005). It is crucial that governments, food handlers, consumers and other stakeholders cooperate in assuring food safety from farm-to-fork (WHO, 2015).

Notwithstanding the challenges mentioned above, a country can achieve acceptable levels of food quality and safety by implementing and monitoring quality assurance measures at every point along the entire food chain. Examples range from good practice in agricultural and veterinary management at farm level to the industrial sphere, where best practices in food processing entail the application of good manufacturing and hygienic principles (Whitehead, 1998). Furthermore, the management of microbial food hazards can be enhanced effectively by the use of tools, such as microbiological risk assessment (MRA) and hazard analysis of critical control point (HACCP) systems (Roesel et al., 2015). The WHO (2002), in distinguishing between these two tools, asserted that a sound MRA provides not only an understanding of the nature of the hazard, but a tool by means of which to set priorities for interventions. The HACCP, on the other hand, is best used as providing information for process management through the identification of critical control points.

However, the important part of an overall food safety strategy is the education of the public to avoid eating contaminated food (Zorba and Kaptan, 2011). This should complement the regulatory activities of the authorities regarding food safety on the part of the food producers (Nicolas et al., 2007; Webb and Morancie, 2015). Food vendors should be adequately instructed in both the role of food in disease transmission as well as their own obligations to follow the rules of personal hygiene and approved practices when handling street food. Because of this two-pronged approach, food handlers and consumers will be well informed about, and conscious of, what food safety entails. This will complement the efforts of food control agencies to encourage every link in the food industry chain to produce healthy food that is safe to eat.

Mensah (2012) advised that to ensure food safety, governments should continually include this topic in their national development plans and health policies; harmonise their legislation with international norms and standards on this aspect of public health; and strengthen the country's self-regulatory capacity through appropriate training, and the establishment of quality assurance protocols and procedures.

In order to ensure food safety in the street food industry, Das et al. (2010) suggested that the authorities should exercise strict surveillance over street food vendors, and monitor the conditions under which street foods are prepared and sold on a regular basis. This would go a long way towards reducing the risk of an outbreak of foodborne diseases.

2.3 CONSUMER'S FOOD SAFETY KNOWLEDGE

The food safety measures taken by consumers play a critical role in the prevention of foodborne illnesses, as the consumption phase is the last step of the "from farm to fork" food chain (Redmond and Griffith, 2003; Jevšnik et al., 2008; Losasso et al., 2012). However, despite an increase in consumer concern regarding food-related risks, the rise in food poisoning cases suggests that people continue to make decisions of food consumption, storage and preparation that are less than ideal from the health and safety point of view (McCarthy et al., 2007; Sanlier, 2009). The result is that they remain prone to foodborne diseases (Yilmaz et al., 2015). This is evidenced by various studies that have been carried out in different countries: these have found that consumers have insufficient knowledge of food safety and the practices involved. Most of these researchers also reported that there were gaps between the food safety knowledge of consumers and their actual practices (Bruhn and Schutz, 1999; Redmond and Griffith, 2003; Unusan, 2007; Fawzi and Shama, 2009). Unusan (2007), also pointed out, on the basis of the information yielded by previous studies that the food safety knowledge of consumers tends to increase with age and experience, as was proved by the higher food safety knowledge scores earned by older respondents, especially females.

Furthermore, the WHO has reported that not all food handlers and consumers understand their own roles in applying basic hygiene/sanitation practices when buying, selling and preparing food (WHO, 2014). Therefore, it is important that consumers' knowledge, attitudes and behaviour towards food safety be taken into consideration by researchers, to reach a full understanding of the alteration in their behaviour and beliefs necessary to help them make informed decisions about food handling and consumption (Hillers et al., 2003; Ergönül, 2013).

2.4 STREET-VENDED FOODS

Street-vended foods can be defined as different types of foods, such as traditional meals, snacks and beverages, which are usually prepared on the street or at home, and sold by vendors or hawkers for immediate consumption, or later consumption, without further processing or preparation (WHO/FAO, 2010; Muyanja et al., 2011; Samuel, 2012). These can also include fresh fruits and vegetables sold outside the authorised market areas for immediate consumption (Cho et al., 2011).

Ohiokpehai (2003) pointed out that street-vended foods could be categorised as meal components in terms of ingredients or by the processing methods used, such as boiling, frying, baking, roasting, and steaming. However, some street foods are sold raw.

According to the UN’s FAO, street food vendors usually take their wares to places where they can sell their products to their customers, and therefore set up their stalls in busy places, such as railway stations, marketplaces, motor parks, schools, street pavements, office centres, and industrial sites, where they will attract plenty customers (FAO/WHO, 2005). Street foods show considerable variation in terms of ingredients, methods of selling, and processing. They are sold on the street from "pushcarts or baskets or balance poles, or from stalls or shops having fewer than four permanent walls" (FAO, 2007b; Hiamey et al., 2015). In general, street foods are sold either from temporary or permanent structures, such as stands/stalls or on the pavement of busy streets in both urban and rural areas (Steyn et al., 2011). Tinker (1997) stated that the definition of what are considered desirable textures and sensory attributes of street food varies by country, culture and custom.

2.4.1 CONSUMERS OF READY-TO-EAT STREET FOODS

The consumption of ready-to-eat food is increasingly becoming a crucial component of the food trade system, especially in cities of developing countries. On a daily basis, approximately 2.5 billion people worldwide consume street food (FAO, 2007a; Samapundo et al., 2015). The reason is that most people prefer to eat outside their homes rather than prepare their own meals (Mensah et al., 2002; Mensah et al., 2013; Makelele et al., 2015).

In Africa, people working in the informal sector comprise a large proportion of those selling ready-to-eat foods. The making and consumption of these foods is especially common in countries where unemployment is high, urbanisation is rapidly taking place, salaries are low and there are few work opportunities (Mensah et al., 2012). Ohiokpehai (2003) reported that street foods tend to form a substantial part of the whole diet in some countries, while they serve as supplementary sources of nutrition for consumers in other countries. Those people who depend almost exclusively on these foods are more interested in their convenience than in their safety, quality, and wholesomeness (Muinde and Kuria, 2005; Sousa, 2008; Mensah et al., 2012).

People from all age groups consume street foods in Africa (FAO/WHO, 2005). However, the most frequent consumers of street foods in most countries are constituted by casual workers, labourers, and hawkers. Other categories include students, children, office workers and housewives (Khairuzzaman et al., 2014).

In terms of educational background, street food consumers also include illiterates and people who have achieved a variety of educational qualifications in schools and universities (Hiamey et al., 2015; Samapundo et al., 2015). Even though most street food consumers are from the low-income group, a small but significant number are professionals, who represent all the diverse ethnic groups in the countries concerned (FAO/WHO, 2005).

In different research studies conducted in South Africa, street food consumers were found to be mostly single and young black males (Martins, 2006; Steyn et al., 2011). Similarly, the majority of consumers of street foods in West Africa were found to be males (more than 65% of the consumers in Benin, Senegal, Togo and Côte d'Ivoire) (FAO/WHO, 2005). In Haiti, young males were also found to be the dominant consumers of street-vended food (Samapundo et al., 2015).

2.4.2 FACTORS INFLUENCING CONSUMPTION OF STREET-VENDED FOODS

Several factors are mentioned as influencing consumers' consumption of street food. These include uniqueness of flavour, freshness, the variety offered (such as traditional foods), and low price (Rane, 2011). Consumers also appreciate street food because of its nutritional value and ready availability (Kibret and Tadesse, 2013; Manguiat and Fang, 2013). Other factors include the proximity to consumers and convenience (Mensah et al., 2013), for some the opportunity to eat on credit (Tinker, 1997). Nevertheless, Steyn et al. (2011) identified socio-economic status as an important factor, which influences the consumption of street foods and fast foods in South Africa.

2.5 SIGNIFICANCE OF STREET-VENDED FOODS IN DEVELOPING CITIES

According to UN estimates, by 2050 developing countries all over the world will have experienced a massive increase in their urban populations, reaching almost 5.2 billion (UN, 2004). In cities such as Johannesburg, the rural to urban migration of people, largely owing to unemployment, is making street foods an integral part of their nutrient supply system (Lues et al., 2006).

The FAO has identified the increase in people's reliance on street food in developing countries. This is one of the characteristics of urban food distribution systems, which are driven by changes in the urban way of life and by poverty (FAO, 1998). Therefore, since the urbanisation process and unemployment are associated with the phenomenal growth of the informal food supply system, ready-to-eat street foods could represent an opportunity for the authorities to implement a food security strategy. This will support the increasing population, especially those with low incomes, while providing a varied range of commodities and assisting people to fulfil their nutritional needs (Proietti et al., 2014). In other words, street food could play a vital role as a means of securing not only the survival but also the dietary needs of the poor, by giving them food security. It would also carry the collateral benefit of creating many jobs in the street food industry, which in turn would go some way towards alleviating poverty.

Another important characteristic of street foods is the role they play in preserving the local food cultures, considering that they provide affordable traditional food to different categories of consumers, including but not limited to travellers and tourists, who cannot afford the time or the money to invest in a standard full meal (Proietti et al., 2014).

2.5.1 SOCIO-ECONOMIC BENEFITS

According to Von Holy and Makhoane (2006), the contribution of the street-vending industry to socio-economic growth is enormous. This can be attributed to the fact that street food provides a regular source of income for millions of men and women, who have low skill levels, in many of the cities and towns of developing countries (Tambekar et al., 2008; Feglo and Sakyi, 2012; FAO, 2013). Kok and Balkaran (2014) concurred, adding that the socio-economic benefits for street food hawkers extend beyond employment potential, but also provide an income for women, whether with or without education and skills. In addition, the industry supports local agricultural producers and food processors, contributing to local and national economic growth (FAO, 2013). Street food vending also offers business opportunities for developing entrepreneurs (Cho et al., 2011). Mensah et al. (2002) stated that street food vendors benefit from a positive cash flow, can often evade taxation, and can determine their own working hours.

Currently, the street food business in South Africa is considered the single largest employer in the informal sector, and possibly one of the major contributors to South Africa's economy (Von Holy and Makhoane, 2006). For instance, in 2001 the number of jobs created in the informal sectors of South Africa, through innovations such as street vending, was estimated at 911,000, as opposed to the 40,000 generated in the formal sector (Lues et al., 2006). Oguttu et al. (2015) reported that about R44.7 million was spent at street food outlets in Gauteng province in 1994 alone. In Zambia, street food trade in 2003 had an annual turnover of US$100 million in sales, and employed around 16,000 people, mostly women with minimal education (FAO/WHO, 2005).

2.5.2 NUTRITIONAL BENEFITS

Street-vended foods contribute to the nutrition of the low and middle-income sector of the population (Ohiokpehai, 2003; Khairuzzaman et al., 2014). Street foods may be the least expensive and most accessible means of obtaining nutritionally balanced meals outside the home for many low-income people, if the consumer is able to choose the healthiest combination of foods (FAO, 2013).

A study carried out in Ghana by Micah et al. (2012), reported that street food contributed to young children's nutrient intake and consequently their energy in rural communities. Overall, the researchers found out that street food contributed 35% of the energy, 43% of vitamin A, 20% of vitamin B_{12}, 30% of zinc, 34% of iron, and 54% of the calcium consumed by these young children. Street foods have also been shown to supply a substantial proportion of the daily requirements of energy and protein (25-50%) in Nigerian adolescents attending schools (Oguntona and Kanye, 1995). FAO (2004) reported that in Bangkok, Thailand, street foods contribute up to 40% of total energy, 39% of protein and 44% of iron intake for the residents; 88% of total daily energy, protein, fat and iron intake for children 4-6 years old.

2.6 MICROBIAL SAFETY OF STREET-VENDED FOODS

In many parts of the world, microbiological contamination, especially from pathogenic microorganisms, is one of the major health risks associated with street foods (FAO/WHO, 2005; FAO, 2013). This can be attributed to the unhygienic/insanitary conditions in which street foods are handled, prepared, served/sold and stored by food vendors (Nyenje et al., 2012; Manguiat and Fang, 2013; Abdulmajid et al., 2014).

Moreover, the risk of microbial contamination is influenced by the food type, its pH, the method of preparation, the availability of water, the method of handling, the temperature, and its holding time (FAO/WHO, 2005; Campbell, 2011). Besides that, a lack of knowledge about the requirements of food safety in some street food vendors also poses a notable risk (Lues et al., 2006; FAO, 2013; Tabashsum et al., 2013; Abdulmajid et al., 2014).

Several researchers (Mensah, 2002; Tambekar et al., 2008; Khairuzzaman et al., 2014) have identified the traditional processing methods used in street food preparation, inappropriate holding temperatures, and poor personal hygiene in food handlers as some of the main causes of microbial contamination in street foods. Therefore, if street-vended foods become contaminated, the people who consume them are exposed to the risk of contracting foodborne diseases, such as salmonellosis, listeriosis, typhoid fever, cholera, and diarrhoea (Manguiat and Fang, 2013; Liu et al., 2014).

Generally, foodborne diseases are caused by the consumption of food contaminated with pathogens or their toxins (Law et al., 2014). Foodborne pathogens, which include bacteria, viruses, fungi and parasites, are the causative agents of foodborne diseases (Xihong et al., 2014).

According to Chauhan et al. (2015), street foods are a major cause of several types of foodborne disease, with diarrhoea being the most common. Several researchers have identified street-vended foods as potential vectors of foodborne pathogens such as: *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp., *Shigella sonnei*, *Proteus* spp., *Listeria* spp. and *Bacillus cereus* (Mensah et al., 2002; Lues et al., 2006; Gadaga et al., 2008; El-Shenawy et al., 2011; Gitahi et al., 2012; Odu and Imaku, 2013).

Several studies in Africa have reported on the presence of theses pathogenic organisms including *Bacillus cereus*, *Escherichia coli*, *Staphylococcus aureus*, faecal coliforms, *Salmonella* and *Listeria* species street-vended foods (FAO/WHO 2005). In a study conducted in Ethiopia, Muleta and Ashenafi (2001) reported contamination of *Bacillus* spp., *Staphylococci* and *Micrococci* in street-vended food samples they analysed. Feglo and Sakyi (2012) noted the presence of high bacterial contamination (23% Coagulase negative *staphylococcus*, 18% *Klebsiella pneumonia*, 3.7% *Staphylococcus aureus*, 17.7% *Aeromonas* spp., 6.6% *Enterobacter* spp., 3.7% *Citrobacter* spp., 5.3% *Staphylococcus aureus*, 2.2% *E. coli* and 2.2% *Pseudomonas aeruginosa*) in street food samples sold in Kumasi, Ghana. Contamination of street-vended food in Egypt with *Listeria monocytogenes* and *Listeria innocua* was also reported by El-Shenawy et al. (2011). In another study, Nyenje et al. (2012)

analysed ready-to-eat foods on sale in Alice, South Africa, and discovered that the most prevalent organisms they contained were *Listeria* spp. (22%), *Enterobacter* spp. (18.6%), *Aeromonas hydrophilia* (12%), *Klebsiella oxytoca* (8%) and *Proteus mirabilis* (6.3%).

Despite the shortcomings in food hygiene and sanitation in some of the street food vending points they investigated, Mosupye and Von Holy (2000) observed that most street samples they analysed in Johannesburg were microbiologically acceptable. In the Philippines, Manguiat and Fang (2013) showed that contamination of street food was mainly caused by *Staphylococcus aureus*, *Salmonella* spp. and *Vibrio cholerae*. In Brazil, high levels of total coliform and pathogenic bacteria such as *Bacillus cereus*, *Staphylococcus aureus* and *Escherichia coli* were detected in street food samples (Hanashiro et al., 2005).

Das et al. (2010) recommended strict monitoring of the condition of street foods on a regular basis, and closer surveillance of street food vendors, to reduce the risk of foodborne disease outbreaks. On the other hand, WHO (1996) recommended the adoption of the HACCP system to improve the efficiency of the surveillance system by detecting the hazards and focusing on the critical control points. This scientific approach should be applied at every step of the food chain to identify and characterise the critical points at which contamination takes place, and to establish priorities for intervention and control. Omeme and Aderoju (2008) recommended that municipalities should provide education and training in the role of food in disease transmission for street food vendors. This would not only defend public health, but also boost consumers and vendors' confidence in the street vending industry.

2.7 RISKS ASSOCIATED WITH STREET FOODS

2.7.1 PUBLIC HEALTH RISK

Globally, street foods are perceived to be a public health risk owing to the widespread occurrence of foodborne diseases in people who consume such foods. The most common reason given for food contamination is that most of the food vendors lack knowledge of food safety requirements (Lues et al., 2006; Rane, 2011). The contaminants carried by street food can cause diarrhoea, kidney and liver failure, brain and neural disorders, reactive arthritis, cancer and ultimately death; all of which have devastating consequences for not only public health, but for productivity, and by extension, the country's economy (WHO, 1999a).

Ghosh et al. (2007) pointed out two important reasons for the perception that street foods constitute a major risk to public health. First, some, or even many, street vending operations are unsupported by basic infrastructural facilities like running water and shelter. Second, law enforcement agencies find it difficult to monitor and enforce safety regulations because of the large numbers of food hawkers, and their diversity, mobility and the temporary nature of their stalls. In addition, most street foods are not protected against insects, rodents, dust and fumes, all of which may carry foodborne pathogens (Tambekar et al., 2008; Rane, 2011).

According to FAO (2013), the health hazards associated with street foods include the improper use of additives, presence of mycotoxins, heavy metals and other contaminants. Other, more external factors are poor personal hygiene in the people who handle these foods, inadequate access to clean water and waste disposal, and unsanitary environmental conditions (such as proximity to drains and public discharge sites). All of these exacerbate the public health risk associated with street foods.

The presence of aflatoxins and/or aflatoxin-producing fungi was reported in some street-vended foods analysed in Nigeria (Ezekiel et al., 2012) and in Ghana (Annan-Prah et al., 2011), both of these in West Africa. High levels of lead, cadmium, zinc and iron have also been found in street foods sold in Lagos state, Nigeria (Opeolu et al., 2010). Heavy metals contamination poses a serious public health risk because they are known causes of various disorders such as genomic instability, endocrine disruption, neurotoxicity, carcinogenicity, immunological problems and also impaired psycho-social behaviour (Khan et al., 2013).

Potential health risks are associated with the contamination of street-vended foods by *E. coli*, *Salmonella typhi*, *Pseudomonas* spp. and *Staphylococcus aureus* during preparation, post cooking and the subsequent food handling stages (Hanoshiro, et al., 2004; Ghosh et al., 2007). Previous studies have found that a considerable proportion of street-vended foods are microbiologically unsafe, and therefore have the potential to cause foodborne diseases (Al

Mamun et al., 2013; Oguttu et al., 2014). The incidence of microbial contamination of street-vended foods has been well documented, and the source of several outbreaks of disease, including cholera, has been traced to street food consumption (Ezekiel et al., 2012).

2.7.2 SOCIO-ECONOMIC RISK

Despite the significant socio-economic benefits street-vended foods offer to consumers, it has been identified as the major source of foodborne illnesses in developing countries (Kibret and Tadesse, 2013). Such illnesses make serious inroads into a country's economic growth (WHO, 2002), both because of the costs associated with ill health and death (which carry economic implications for individuals, their families and the health care systems of their countries), and international trade relations (Mensah et al., 2012). Moreover, the expenses incurred due to illness have also to be borne by communities, and industries, as huge sums are lost through absenteeism from school and the work place, and in expenditure on medical care. On a larger scale, the country concerned has to pay the cost of investigating and controlling outbreaks of food-related diseases (WHO, 1999b).

Overall, the cost of foodborne illnesses includes not only the expense of medical treatment, but also a number of collateral harms. Setting aside the pain and suffering of individuals, illnesses cause losses in productivity, industry, and the public health sector, all of which threaten the economy (Harris, 1997). For example, the annual costs of foodborne illnesses in the US have been estimated between USD 10-83 billion (Lin et al., 2005). In 1991, England and Wales had about 23,000 cases of salmonellosis, which cost the United Kingdom about EU 40-50 million (Wilcock et al., 2004). In Nauru in the South Pacific, the amount of money spent on outbreaks associated with *Salmonella typhi* was estimated at USD 46,000 (Olsen et al., 2001).

2.8 DETECTION OF BACTERIA IN FOOD

2.8.1 CULTURAL-BASED METHODS FOR BACTERIA DETECTION

According to Ahmed et al. (2014), conventional methods based on the culturing of samples have traditionally been considered the "gold standard" for the isolation and identification of foodborne bacterial pathogens. These methods entail culturing the microorganisms on agar plates, and then making standard biochemical identifications (Mandal et al., 2011). The culture is made by mixing the samples to be analysed with an appropriate broth or agar medium, and then incubating the mixture under conditions that enable the microorganisms present in the sample to grow and produce colonies or reactions (Yousef and Carlstrom, 2003). This method of detecting bacteria may involve the following steps: pre-enrichment, selective enrichment, selective plating, biochemical screening and serological confirmation (Mandal et al., 2011).

Most of these methods are usually powerful, inexpensive and reliable. They are also very sensitive, and can give both qualitative and quantitative information on the number and the nature of microorganisms present in the food sample (Doyle, 2001). However, they also carry some disadvantages: they can be time-consuming, complex, and laborious (Jasson et al., 2010). Furthermore, viable cells that cannot be cultured may cause false negative results (Law et al., 2014).

An important advantage of the culture method lies in its ability to isolate live cells of suspected pathogens from any food product or environmental sample, to trace them back to the potential source of a foodborne bacterial pathogen. Moreover, culturing methods make it possible to recover injured or sub-lethally stressed bacteria cells that were subjected to osmotic shock, acid, alkali, heat or cold (Nannapaneni, 2011).

2.8.2 NUCLEIC ACID-BASED METHODS FOR BACTERIA DETECTION

The basic principle of nucleic acid-based assays is the specific formation of double-stranded nucleic acid molecules from two complementary single-stranded molecules under defined physical and chemical conditions (Mandal et al., 2011). This is achieved by hybridising the target nucleic acid sequence to a synthetic oligonucleotide (probes or primers) that is complementary to the target sequence (Xihong et al., 2014).

Both Deoxyribonucleic Acid (DNA) and Ribonucleic Acid (RNA) can be analysed by this method, which enables the researcher to assess the presence of specific pathogens in a sample and to determine their viability. In addition, nucleic acid-based methods can be used to quantify the amount of pathogens in food samples (Goodridge et al., 2011). Matthews (2002) noted that these methods include plasmid typing, ribo typing, polymerase chain reaction (PCR), and random amplified polymorphic DNA (RAPD) as well as restriction fragment length polymorphism. Others are multiplex polymerase chain reaction (mPCR), real-time/quantitative polymerase chain reaction (qPCR), nucleic acid sequence-based amplification (NASBA), loop-mediated isothermal amplification (LAMP) and microarray technology (Law et al., 2014).

Nucleic acid-base detection methods present a valid alternative to culture-based methods, and offer several advantages in terms of speed, specificity, and sensitivity in food and processing environment detection (Bisha and Goodridge, 2012). However, advanced technical skills are required to operate the instruments, and these methods are not useful for routine testing of food pathogens (Rijpens and Herman, 2002). This is because the procedures involved are quite complicated, costly and requires very clean environment (Mandal et al., 2011).

2.8.2.1 POLYMERASE CHAIN REACTION (PCR)

One of the most commonly used nucleic-acid based methods for bacterial detection is the PCR, probably because of its relatively low cost and its ease of use (Gorski and Csordas, 2009). PCR can be described as a molecular tool that allows for the amplification of target DNA fragments by using oligonucleotide primers in a chain of replication cycles that are catalysed by DNA polymerase (*Taq* polymerase) (Rompré et al., 2002). This is described in Figure 2.1.

In the PCR method, a specific amplification of a target DNA is obtained by successive cycles of three steps (Figure 2.2). These are the denaturation of a sample of DNA to obtain a single strand target, the annealing of short and specific primers to the target DNA, and the polymerisation of the DNA starting from the primers (Olsen, 2000). The three stages of each cycle are controlled by changing the temperature of the reaction, as each stage will occur only at a particular temperature (Blackburn and McClure, 2002).

Gorski and Csordas (2009) listed components of PCR including a thermostable DNA polymerase, deoxy ribonucleotide triphosphates (dNTPs), primers, magnesium chloride and template or target DNA. The PCR amplification products are visualised on electrophoresis gel as bands by staining with ethidium bromide (Xihong et al., 2014).

The PCR technique has been applied in areas such as DNA cloning, the identification of hereditary and infectious diseases, the identification of genetic fingerprints, and the detection and diagnosis of infectious diseases (Adzitey et al., 2013). They also play a crucial role in tracking typical bacterial strains that exist in viable but non-culturable coccoid forms, which are often overlooked when culture-based methods are, used (Magistrado et al., 2001). When using PCR methodology, it is relatively easy to accumulate a large amount of material that can be sequenced directly after the purification stage (Lukinmaa et al., 2004).

PCR is very widely used to detect microbial pathogens in food, and forms the basis for a variety of pathogen-identifying systems utilising nucleic acid. It is superior to culture-based methods, and offers the advantages of specificity, sensitivity, rapidity, accuracy and the capacity to detect small amounts of target nucleic acid in a sample (Velusamy et al., 2010).

Obstacles to the use of PCR include inhibition of the amplification reaction by components that may be present in foods, human fluids or clinical samples (Scheutz et al., 2001; Paton and Paton, 2003), or reduction in sensitivity and performance caused by components of the enrichment broth and DNA extraction solution or the concentration of the PCR mixtures (Adzitey et al., 2013). In addition, PCR cannot distinguish between live and dead cells, and hence can render false positive results (Biswas et al., 2008). It therefore becomes necessary to integrate a positive control to monitor the efficiency of the PCR reaction, especially when applied in routine laboratory conditions (Rijpens and Herman, 2002).

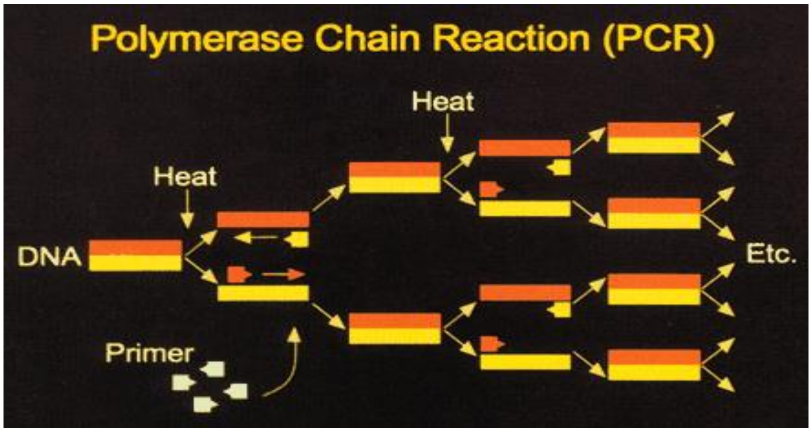

Figure 2.1: Polymerase chain reaction (PCR) (Courtesy: Powledge, 2004)

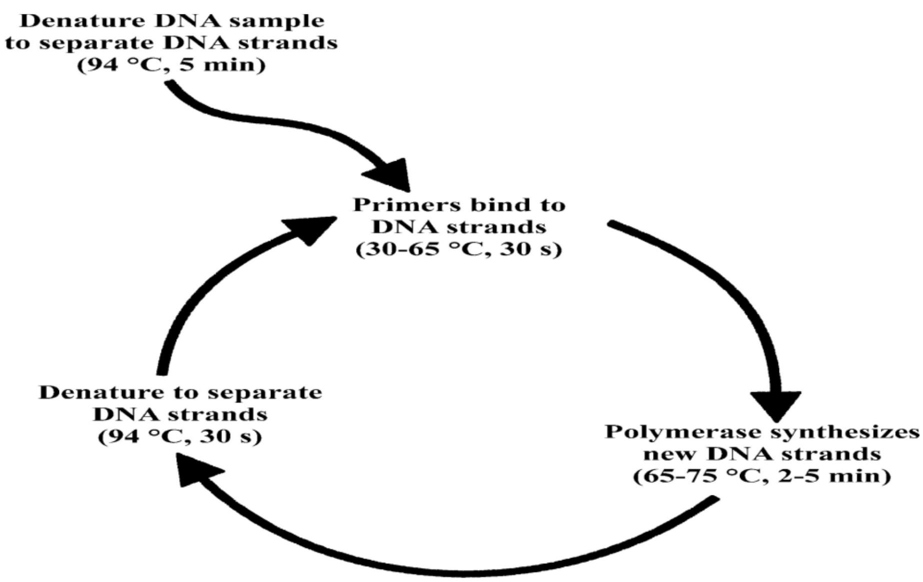

Figure 2.2: PCR reaction cycle (Courtesy: Powledge, 2004)

2.8.2.2 RANDOM AMPLIFIED POLYMORPHIC DNA (RAPD)

RAPD is a PCR-based technique that is used to distinguish between intra-and inter-specific differentiations of bacteria associated with samples, such as foods under controlled conditions (Tabit, 2015). In RAPD techniques, low-stringency PCR conditions that allow some mismatches are used to amplify random DNA fragments (Lukinmaa et al., 2004). RAPD technique uses random primers, which can be applied to any species, and do not require any prior information about the nucleotide sequence. Moreover, the amplification products of this type of analysis exhibit polymorphism, and can thus be used as genetic markers (Babalola, 2003).

The advantages of RAPD technology are that it is relatively cheap, is rapid, readily available, and easy to operate (Wassenaar and Newell, 2000; Shi et al., 2010). However, one of the disadvantages of RAPD includes its lack of reproducibility (Lukinmaa et al., 2004). The reason is largely attributable to alterations in the profiles caused by small changes in the reaction conditions. Thus, it is necessary to perform RAPD under controlled conditions (McCartney, 2002). Secondly, the efficiency of amplification, annealing and the length of the product varies with the primed site, giving rise to both weak and strong amplicons, and this makes interpretation of the results difficult (Wassenaar and Newell, 2000).

CHAPTER 3: AIM AND OBJECTIVES

3.1 AIM

The primary aim of this study was to investigate the level of knowledge about food safety and the awareness of potential microbial hazard in street foods that consumers in the Johannesburg municipality possess. Another aim was to determine the bacteriological quality and diversity of selected street foods in various areas of Johannesburg in South Africa, to obtain better insight on their safety and quality.

3.2 OBJECTIVES

This study’s objectives were:

- to investigate the food safety knowledge and microbial hazard awareness of street food consumers in Johannesburg;
- to determine how consumers’ knowledge and awareness can be affected by selected socio-demographic variables; and
- to assess the bacteriological quality of selected ready-made foods sold by street vendors in various areas of Johannesburg metropolis.

3.3 RESEARCH QUESTIONS

In view of the threat to food safety, and by extension to public health, posed by food already prepared to be sold on the street, research questions listed below were identified.

- Are consumers of street foods in Johannesburg aware of the microbial hazards associated with these foods?
- What is the level of food safety knowledge of these consumers?
- What kinds/types of bacteria can be isolated through analysis of street food samples?
- Are the levels of bacteria load within or above acceptable limits?
- How much diversity is there in the range of prepared foods sold on the streets of Johannesburg?

CHAPTER 4: RESEARCH METHODOLOGY OVERVIEW

4.1 FOOD SAFETY AWARENESS SURVEY

4.1.1 STUDY AREA

Johannesburg is a highly urbanised municipality, with a population of about 4.4 million people and an annual population growth rate of 3.18%. It is the provincial capital of Gauteng, and covers an area of 1,645 km^2 (Statistics South Africa, 2011). The city, as shown in Figure 4.1, is divided into six regions. However, for the purposes of this study Johannesburg municipality was divided into five regions: north, south, east, west, and central.

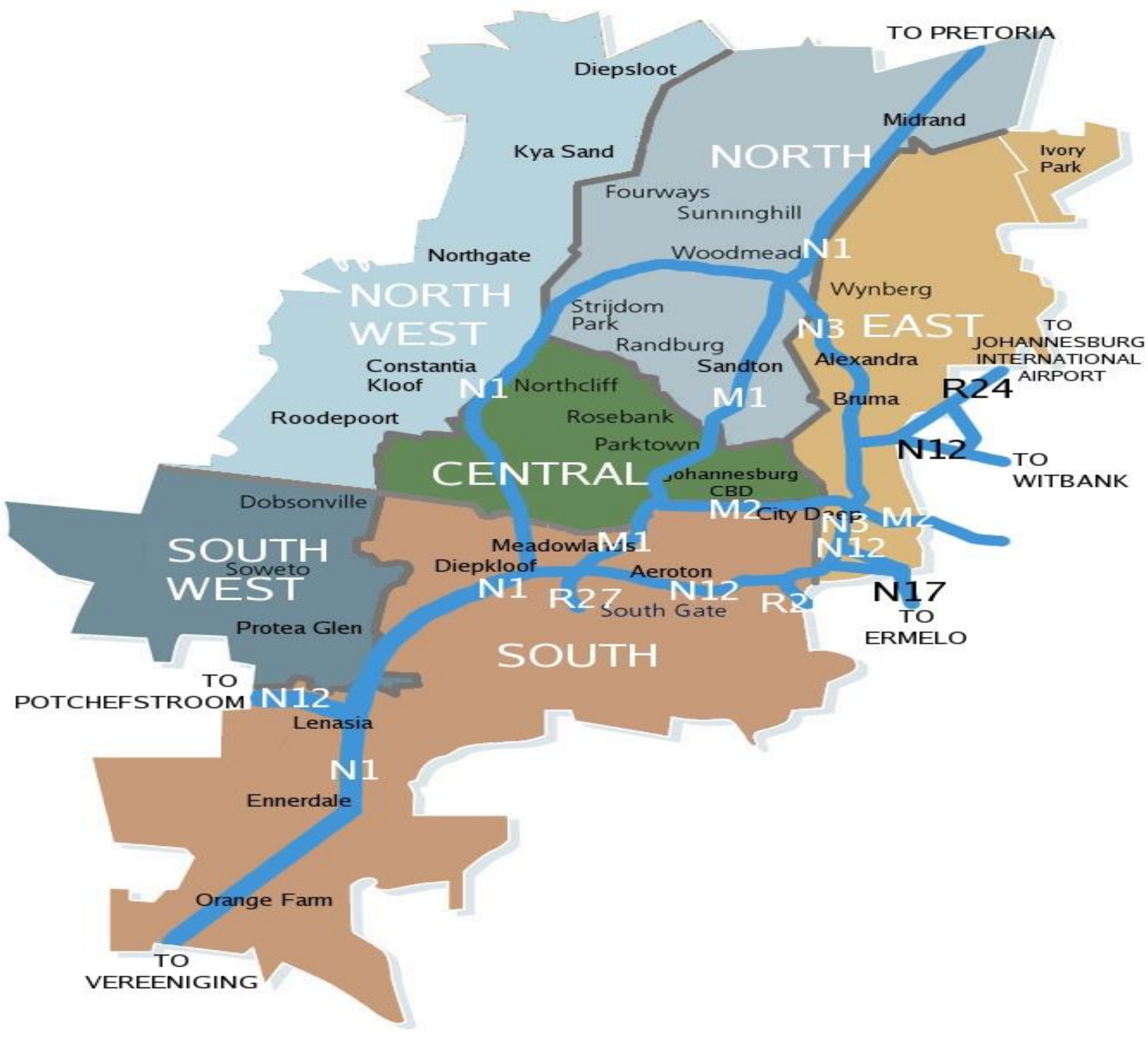

Figure 4.1: Map of Johannesburg city indicating its six regions (Courtesy: Wikipedia, 2015)

4.1.2 RESEARCH DESIGN

A cross-sectional study was conducted on individuals who buy and consume ready-to-eat street-vended foods at various street food vending locations in the different neighbourhoods in Johannesburg Municipality from May to September 2014.

4.1.3 SAMPLING OF RESPONDENTS

In this study, multiple random sampling was employed in recruiting respondents. Selected locations in the streets where ready-to-eat foods are sold were visited at different times of the day; morning, lunch time and evening and individuals who bought and consumed ready-to-eat street-vended food, were randomly approached for the purpose of this study. A total of 402 individuals (18 years and older), who buy and consume ready-to-eat street-vended foods were randomly selected at 20 street food vending points at various neighbourhoods in the Johannesburg Municipality.

4.1.4 DATA COLLECTION AND ANALYSIS

The survey data collecting instruments, data collection method and data analysis are explained in detail in research chapter 5.1.

4.2 MICROBIAL ANALYSIS

4.2.1 COLLECTION OF FOOD SAMPLES

Various street-vended food samples, as listed in Table 4.1, were purchased from randomly selected vendors at different locations in the Johannesburg area, over a period of six months (from February to August 2015). The samples were collected in their original packages and placed in separate, sterile plastic bags (Figure 4.2). The samples were then labelled and transported on ice to the UNISA Microbiology Laboratory, for sample preparation and analysis within twelve hours of purchase (Details in research chapter 5).

Table 4.1: Categories of ready-to eat street-vended foods sampled

Food sample category	Street foods sampled
Cereal and grain-based food	maize porridge (pap), semolina porridge, fried potato chips, boiled rice, fat cake (vetkoek or amagwinya), vanilla flavoured cookies, local chocolate cake, jollof rice, local bread, bean cake, roasted peanuts, boiled peanuts, coloured popcorn (skopas), boiled beans without stew, melon (egusi) soup, boiled maize, roasted maize, roasted shelled peanuts, wheat biscuit
Meat-based food	beef sausage slices (polony), cow leg stew, beef stew, fried beef derm, beef broth, fried beef tripe, fried ox liver, barbecued beef sausage (wors), biltong, samoosa, bread, potato chips, sausage sandwich (kota), hot dog
Dairy-based food	gouda cheese slices, cheese and egg burger
Poultry-based food	grilled chicken gizzard, boiled egg, fried chicken drum stick, chicken stew, grilled chicken feet, grilled chicken neck, omelette
Fish-based food	fried hake, fried snoek
Fruit/vegetables-based food	spicy vegetable relish (chakalaka), spiced unripe mango pickle (atchaar), mixed vegetable salad, spinach vegetable, onion, tomatoes mixture (gravy)

(a)

(b)

(c)

(d)

(e)

Figure 4.2: Pictorial representation of some of the street foods (a, b, c, d and e) that were analysed

4.2.2 PREPARATION OF SAMPLES

Ten grams (10g) of each food sample was aseptically weighed and mixed with 90ml of sterile peptone water (Biolab, South Africa), and then homogenised in a sterilised Waring laboratory blender for 4-8 minutes (Figure 4.3). After this, tenfold serial dilutions, up to 10^{-5} folds of the homogenate were prepared for each sample and used for bacteria analysis.

Figure 4.3: Waring laboratory blender used to homogenise the street food samples

4.2.3 MICROBIOLOGICAL ANALYSIS OF FOOD SAMPLES

Total Aerobic Counts (TACs) was done on Plate Count Agar (PCA) plates (Merck, South Africa), following the manufacturer's protocol. The detection and enumeration of bacteria isolated was conducted as described in research chapter 5.5.

4.3 STATISTICAL ANALYSIS

Statistical analysis of the data on food safety knowledge study and microbial analysis was performed using SPSS software (Statistical Package for the Social Sciences, version 11.0, SPSS Inc., Chicago, III, USA). Descriptive statistics were used to summarise the variables of interest and determine relationships between them. Analysis of variance (ANOVA) was used to investigate socio-demographic differences in food safety knowledge and microbial hazards awareness of individuals who purchase and consume ready-to-eat street-vended foods. Statistical significance was identified at the 95% confidence level ($p \leq 0.05$).

4.4 ETHICAL CONSIDERATION

Ethics approval for this study was obtained from Johannesburg municipality and the ethics committee of the College of Agriculture and Environmental Sciences, University of South Africa. Each participant in the survey was presented with a research information sheet, which explained the nature and purpose of the study, the research process and role the survey was expected to play in providing data. It also included a consent form. Written informed consent from each individual was obtained before the interview started. The basic ethical principles governing data collection, as reported by Oppenheim (1992), were strictly adhered to. The interviewers

- showed respect for the respondents' right to privacy and their right to refuse to answer certain questions;
- avoided placing undue pressure on the respondents;
- made no attempt to harass or abuse respondents; and
- treated the survey data as confidential: no unauthorised person was allowed to have access to them.

4.5 LIMITATION OF THE RESEARCH

Because the target population in this investigation consisted of street-food consumers in Johannesburg, the findings obtained from the survey may not be taken as applying to all street food consumers in South Africa. Also, the survey sample size (402 participants) may not have been large enough to yield a true representation of the actual situation in the designated areas at present.

Furthermore, because this research measured information on the food safety knowledge and awareness of microbial risk of street-food consumers through their own responses, these self-reported claims might be prone to bias. Hence, there is need for validation through further testing and observation. In addition, the number of street food samples analysed were insufficient, for various technical reasons. However, this study provided an insight on the bacteriological quality of street-vended foods in Johannesburg.

CHAPTER 5: RESEARCH

5.1 FOOD SAFETY KNOWLEDGE AND MICROBIAL HAZARDS AWARENESS OF CONSUMERS OF READY-TO-EAT STREET-VENDED FOOD

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5.1.1 ABSTRACT

Controlling and ensuring the safety of street-vended foods in many countries is a challenge considering that these foods are often less expensive and readily available. The objective of this study was to determine the food safety knowledge based on microbial hazard awareness of street food consumers in the Johannesburg municipality, South Africa. A cross-sectional survey study was conducted using a structured food safety questionnaire designed for this study. A total of 402 respondents, individuals who buy and consume ready-to-eat street-vended foods were randomly selected at various street food vending cites within the Johannesburg municipality. Data collection was by means of face-to-face interviews. The majority of respondents were black males younger than 35 years. Individuals of within different gender, race, level of education and monthly income groups significantly ($p<0.05$) differed in their responses regarding the frequency of purchasing and confidence in the safety

of street-vended food. Better taste followed closely by affordability and accessibility, were the most cited reasons for purchasing street-vended food. Although the majority of respondents were aware that certain foodborne bacteria can cause diseases that may lead to death, over 70% of them had never heard about *Salmonella* spp., *Escherichia coli*, *Listeria monocytogenes* and *Campylobacter jejuni*. Although some consumers doubt the safety of street vended foods, they are not deterred from consuming them. Gender, race, the level of education and monthly income affect the way consumers of street-vended foods perceived the safety of street-vended foods and their desire to purchase them.

5.1.2 INTRODUCTION

Annually, up to 2 million people, mostly children, die as a result of diseases caused by the consumption of contaminated food and water (FAO, 2014). Controlling and ensuring the safety of street-vended food in many countries is a big challenge considering that this food is often less expensive and is often prepared/sold in the streets by local food vendors (WHO/FAO, 2010). This food constitutes the primary source of food for many low- and middle-income consumers outside their home (FAO, 2009).

Regardless of the intrinsic benefits of the sale and consumption of street-vended food, the safety of street food can be affected by several factors. These are the quality of the raw materials, preparation conditions, handling and storage conditions. Moreover, the operation of businesses in locations that do not meet all food safety requirements may also affect quality of street food (Choudhury et al., 2011; Muyanja et al., 2011; Aluko et al., 2014). Street food vendors often operate unregulated and without monitoring by any relevant authority (Bhattacharya and Reang, 2014). As a result, street-vended food has the potential to become contaminated, thus exposing people who consume this food to the potential risk of foodborne diseases, such as salmonellosis, listeriosis, typhoid fever, cholera and diarrhoea, among others (Manguiat and Fang, 2013; Liu et al., 2014).

Foodborne diseases constitute a widespread and growing public health problem both in developing and developed countries (Carbas et al., 2013; Bhattacharya and Reang, 2014). A foodborne disease outbreak can occur because of ingesting food items contaminated with microorganisms and chemicals (Webb and Morancie, 2015). Each year, up to one-third of the population of developed countries is affected by foodborne illnesses (Isara et al., 2010). Previous studies have found that a considerable proportion of street-vended food is of poor microbiological quality and has the potential to cause diseases (Al Mamun et al., 2013; Oguttu et al., 2014).

In South Africa, Johannesburg municipality, street-vended food is often prepared and sold under improper hygienic conditions as vendors usually concentrate in overcrowded areas such as taxi ranks, railway stations and busy street pavements (Mosupye and Von Holy, 2000; Kubheka et al., 2001). Vending stands/stalls are usually located outdoors with or without roof covers (Lues et al., 2006). In some cases, the vending sites lack access to basic sanitary facilities, such as clean running water, garbage disposal and clean toilets, making it difficult for vendors to apply standard sanitary practices (Mosupye and Von Holy, 2000; Kubheka et al., 2001). Changes in the socio-economic status of many developing countries and the increase in the urban population have led to an increase in the number of people who consume street-vended food (Omemu and Aderoju, 2008; Samapundo et al., 2015). Consequently, as the number of people who consume these foods increases, so does the number of consumers who are potentially exposed to foodborne hazards (WHO, 2008; Adam et al., 2014).

With the number of street food consumers increasing, it is crucial that food safety measures be taken by consumers. This can play an essential role in the prevention of foodborne diseases, as they constitute the last link in the “from farm to fork” food chain (Losasso et al., 2012). The objective of this study was to establish the food safety knowledge and microbial hazard awareness of street food consumers in the Johannesburg municipality, as well as how this knowledge and awareness can be affected by selected socio-demographic variables.

5.1.3 MATERIALS AND METHODS

5.1.3.1 RESREARCH DESIGN AND STUDY AREA

A cross-sectional study was conducted on individuals who buy and consume ready-to-eat street-vended foods at various street food vending locations in the different neighbourhoods in Johannesburg municipality from May to September 2014.

5.1.3.2 SAMPLING PROCEDURES

A total of 402 individuals (18 years and older) who buy and consume ready-to-eat street-vended food were randomly selected at 20 street food vending points in various neighbourhoods of the Johannesburg municipality. The municipality was divided into north, south, east, west and central, and neighbourhoods were based on their location of these stratified regions. As a result of the absence of data on the total population of street-vended food consumers, this study had to rely on multiple random sampling of respondents to recruit 402 respondents.

5.1.3.3 RESEARCH INSTRUMENT

A written questionnaire consisting of 21 questions was designed for this study by a person with knowledge on food safety and quality control using information from literature. The questionnaire was tested in a pilot study consisting of 40 participants, whose data was not included in the final study. After the pilot study, the structure and sentences of the questions were revised and divided into five sections: socio-demographic, confidence in and reasons for purchasing street-vended food, food safety hazard awareness of street-vended food consumers, food safety attitude towards street-vended food and microbial food safety hazard. The reliability and validity of the different sections of the research instrument were determined during the pilot study. Cronbach's α for the different constructs ranged from 0.759 to 0.815, which implies acceptable reliability.

5.1.3.4 DATA COLLECTION

After obtaining permission from the Johannesburg municipality and ethics clearance from the University of South Africa, the principal researcher, together with five trained research assistants, visited selected locations in the streets where ready-to-eat food is sold at different times of the day, i.e. morning, lunchtime and evening. Individuals who bought and consumed ready-to-eat street-vended food were randomly approached and the purpose of the study was explained. Upon acceptance to participate in the study, respondents were asked to sign a consent form affirming their desire to participate voluntarily as well as their right to withdraw from the study if they so desired. The questionnaire of each respondent was coded to ensure anonymity. Data was collected by means of a once-off face-to-face interview using the questionnaire and the questionnaires were filled in either directly by the respondents or with the assistance of the principal researcher or research assistants, depending on the respondent's level of literacy. Each questionnaire took approximately 25 minutes to complete.

5.1.4 STATISTICAL ANALYSIS

Statistical analysis of the data was performed using SPSS software (Statistical Package for the Social Sciences, version 11.0, SPSS Inc., Chicago, III, USA). Descriptive statistics were used to summarise the variables of interest and determine relationships between them. Analysis of variance (ANOVA) was used to investigate socio-demographic differences in food safety knowledge and microbial hazards awareness of individuals who purchased and consumed ready-to-eat street-vended foods. Statistical significance was identified at the 95% confidence level ($p \leq 0.05$).

5.1.5 RESULTS

5.1.5.1 SOCIO-DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

More than half (56.5%) of the respondents were male while the rest were female (43.3%). Over 60% of the respondents were younger than 35 years with the majority falling within the 27-35 years range. The vast majority of respondents, up to 92% were African, followed by coloureds (4%), whites and Indians with 2% each (Table 5.1.1).

More than half (54%) of the respondents were either not married and lived alone (43%) or not married but living with a partner (13%). Only 33% of the respondents indicated that they were married couples. Up to 76% of the respondents had attained either a secondary or a tertiary education. Close to 49% of respondents indicated that their monthly income was below R5000 and this was followed by 27% whose monthly income was within the range R5001-R10000; only 6% had a monthly income above R10000 (Table 5.1.1).

Respondents had a very diverse employment or source of income background, with most employed as casual workers (21%) or street vendors (19%). About 14% earned an income from permanent employment; another 14% from temporal employment and 12% were unemployed. The rest were either students (13%), social grant recipients (5%) or simply house wives (2%) (Table 5.1.1).

Table 5.1.1: Biographic information of respondents (n=402)

Variables		**Frequency (%)**
Gender	Female	174 (43.3)
	Male	227 (56.5)
	Missing system	1 (0.2)
Age	18-26	98 (24.4)
	27-35	153 (38.1)
	36-44	102 (25.4)
	45-53	37 (9.2)
	54-62+	12 (3)
Race	Blacks	369 (91.8)
	Coloured	16 (4)
	White	9 (2.2)
	Indian/Asian	8 (2)
Marital status	Married	133 (33.1)
	Unmarried - living with a partner	53 (13.2)
	Unmarried - living without a partner	165 (41)
	Divorced	13 (3.2)
	Widowed	9 (2.2)
	Separated	26 (6.5)
	Missing system	3 (0.7)
Level of education	No formal education	14 (3.5)
	Junior primary education	42 (10.5)
	Senior primary	36 (9)
	Secondary education	163 (40.5)
	Tertiary education	142(35.3)
	Missing system	5 (1.2)
Average monthly income	Below R5 000	196 (48.8)
	R5001- R10 000	107 (26.6)
	R10001 - R15 000	16 (4)
	R15 001 or more	6 (1.5)
	Missing system	77 (19.2)
Employment status	Salary - permanent	58 (14.4)
	Salary - temporary	58 (14.4)
	Social grant	20 (5)
	Street vending	77 (19.3)
	Casual work	83 (20.6)
	Student	53 (13.2)
	Housewife	5 (1.2)
	Unemployed	48 (11.9)

5.1.5.2 CONFIDENCE IN AND REASONS FOR PURCHASING AND CONSUMING STREET-VENDED FOODS

About 82% of the respondents, always (29%) or often (53%), bought ready-to-eat street-vended food. Up to 58% were, always (29%) or often (29%), confident about the safety of ready-to-eat street-vended food. The top three most popular reasons for purchasing ready-to-eat street food given by respondents were better taste (35%), affordable (29%) and easily accessible (22%) (Table 5.1.2).

Table 5.1.2 (A-C): Confidence in and reasons for purchasing and consuming street-vended foods by consumers of street-vended foods (n=402)

A: The regularity of purchasing ready-to-eat street-vended foods by consumers RESEARCH QUESTION: How often do you buy ready-to-eat street-vended foods?	
Level of regularity	Frequency (%)
Always	118 (29.4)
Often	211 (52.5)
Rarely	68(16.9)
Never	4 (1)
Missing system	1 (0.2)
Total	402 (100)
B: Level of confidence in the safety of ready-to-eat street-vended foods by consumers RESEARCH QUESTION: How confident are you about the safety of ready-to-eat street-vended foods?	
Level of confidence	Frequency (%)
Always	116 (28.9)
Often	115 (28.6)
Rarely	127 (31.6)
Never	35 (8.7)
No idea	9 (2.2)
Total	402 (100)
C: The main reason for purchasing ready-to-eat street-vended foods by consumers RESEARCH QUESTION: Which of the following is the main reason for purchasing ready-to-eat street-vended foods?	
Reason	Frequency (%)
Just the food type I prefer	32 (8)
Better taste	140 (34.8)
It is affordable	115 (28.6)
Easily accessible	90 (22.4)
Liked by my household members	8 (2)
Others	17 (4.2)
Total	402 (100)

Respondents in the different subgroups within the gender, race, level of education and monthly income groups differed significantly ($p<0.05$) in their responses regarding the frequency of purchase and confidence about the safety of street-vended food. This was in contrast to respondents in the different subgroups, within the age group, who did not differ significantly ($p>0.05$) in their responses. Regarding the reason for purchasing ready-to-eat street-vended food, respondents in the different subgroups, within the level of education and monthly income groups, differed significantly ($p<0.05$) in their responses. This is in contrast to respondents in the different subgroups, within the gender, age and race groups, who did not differ significantly ($p>0.05$) in their responses (Table 5.1.3).

Table 5.1.3: ANOVA of the responses of consumers, regarding their confidence in and reasons for purchasing and consuming street-vended foods within different groups (n=402)

Descriptions	**ANOVA between groups (p-value)**				
	Gender	Age	Race	Educa-tion level	Monthly income
RESEARCH QUESTION: How often do you buy ready-to-eat street-vended foods?	0.000¥	0.282	0.000¥	0.000¥	0.000¥
RESEARCH QUESTION: How confident are you about the safety of ready-to-eat street-vended foods?	0.002¥	0.334	0.000¥	0.000¥	0.001¥
RESEARCH QUESTION: Which of the following is the main reason for purchasing ready-to-eat street-vended foods?	0.052	0.495	0.220	0.000¥	0.000¥

¥ = Significance at $p\leq0.05$

5.1.5.3 FOOD SAFETY HAZARD AWARENESS OF STREET-VENDED FOODS CONSUMERS

The majority of respondents (73%) indicated that they were, either always (53%) or often (20%), apprehensive about the bacterial safety of ready-to-eat street-vended food. Similarly, up to 60% were, either always (42%) or often (18%), concerned about the fungal safety of ready-to-eat street-vended food. Less than half (44%) were, either always (30%) or often (14%), perturbed about the chemical safety of ready-to-eat street-vended food from lead, mercury and aluminium (Table 5.1.4). The majority of respondents (57%) were, either always (27%) or often (30%), worried about foodborne diseases when they bought ready-to-eat food from shebeens compared to those who were, either always (14%) or often (33%) uneasy when they bought ready-to-eat food from street food vendors. Only 19% were, either always (7%) or often (12%) edgy about foodborne diseases when they bought ready-to-eat food from restaurants, while 20% were, either always (6%) or often (14%) bothered about foodborne diseases when they bought ready-to-eat food from supermarkets (Table 5.1.4).

Table 5.1.4: Food safety hazard awareness of street-vended food consumers (n=402)

A: The degree to which street-vended food consumers are concerned about food contamination by selected hazards(N=402) RESEARCH QUESTION: How concerned are you, about the safety of street-vended foods in terms of the following?					
Type of hazards	**Frequency of concern about hazards**				
	Uncertain	**Never**	**Rarely**	**Often**	**Always**
Bacteria	24 (6)	21 (5.2)	64 (15.9)	82 (20.4)	211 (52.5)
Fungi	37 (9.2)	37 (9.2)	87 (21.6)	71 (17.7)	170 (42.3)
Other hazards: Chemical, Lead, Mercury and Aluminium	87 (21.6)	54 (13.4)	82 (20.4)	57 (14.2)	122 (30.3)
B: The most concern regarding foodborne disease outbreaks from ready-to-eat food retail outlets (n=402) RESEARCH QUESTION: How often do you get worried about foodborne diseases when you buy ready-to-eat foods from any of the following outlets?					
Type of retail outlet	**Frequency of the concern about hazards**				
	Uncertain	**Never**	**Rarely**	**Often**	**Always**
Supermarket	24 (6)	98 (24.4)	198 (49.3)	57 (14.2)	25 (6.2)
Street food market	27 (6.7)	39 (9.7)	147 (36.6)	131 (32.6)	58 (14.4)
Restaurant	44 (10.9)	128 (31.8)	152 (37.8)	50 (12.4)	28 (7)
Shebeen[£]	78 (19.4)	40 (10)	53 (13.2)	122 (30.3)	109 (27.1)

£ = unlicensed drinking establishment

Respondents in the different subgroups within the gender, level of education and monthly income groups differed significantly (p<0.05) in their concern about the safety of street-vended food in terms of bacteria, fungi and heavy metals (lead, mercury and aluminium). This is in contrast to respondents in the different subgroups, within the age and race groups, who did not differ significantly (p>0.05) in their responses. Furthermore, respondents in the different subgroups, within the level of education group, differed significantly (p<0.05) regarding their uneasiness about foodborne diseases when they bought ready-to-eat food from supermarkets, street food vendors, restaurants and shebeens. This is in contrast to respondents in the different subgroups, within the age and race groups, who did not differ significantly (p>0.05) in their response (Table 5.1.5). Respondents in the different subgroups, within the gender group differed significantly (p<0.05) regarding their apprehension about foodborne diseases when they bought ready-to-eat food from street food vendors, but did not differ significantly (p>0.05) regarding foodborne diseases when they bought ready-to-eat foods from supermarkets, restaurants and shebeens (Table 5.1.5).

Table 5.1.5: ANOVA of the food safety hazard awareness of street-vended food consumers within different groups (n=402)

Description of hazard awareness and attitude	**ANOVA between groups (p-value)**				
	Gender	**Age**	**Race**	**Education level**	**Monthly income**
RESEARCH QUESTION: How concerned are you, about the safety of street vended foods in terms of contamination with the following?					
Bacteria	0.020¥	0.596	0.596	0.000¥	0.003¥
Fungi	0.006¥	0.286	0.341	0.000¥	0.001¥
Other hazards: Chemical, lead, mercury and aluminium	0.005¥	0.436	0.412	0.000¥	0.010¥
RESEARCH QUESTION: How often do you get worried about foodborne diseases when you buy ready-to-eat street-vended foods from any of the following outlets?					
Supermarket	0.631	0.141	0.312	0.000¥	0.800¥
Street food vendors	0.033¥	0.457	0.077	0.000¥	0.000¥
Restaurant	0.528	0.059	0.507	0.001¥	0.673
Shebeen£	0.204	0.892	0.064	0.015¥	0.114

¥ = Significance at p≤0.05, £ = unlicensed drinking establishment

5.1.5.4 ATTITUDE ABOUT THE SALE AND PURCHASE OF READY-TO-EAT STREET-VENDED FOODS

Up to 53% of respondents either strongly disagreed (24%) or disagreed (29%) with the statement that they did not always think about food safety when buying ready-to-eat street-vended food, compared with 36% who strongly agreed (8.5%) or agreed (28%). Similarly, up to 63% of respondents strongly disagreed (26%) or disagreed (37%) that they were certain they could not get foodborne diseases when they ate ready-to-eat street-vended food, compared to 19% who strongly agreed (2%) or agreed (17%). Up to 67% strongly agreed (35%) or agreed (32%) that ready-to-eat street-vended food was cheaper than ready-to-eat food from supermarkets and restaurants (Table 5.1.6).

Table 5.1.6: The attitude of street-vended food consumers on the sale and purchase of ready-to-eat street-vended foods from different outlets (n=402)

RESEARCH QUESTION: To what extent do you agree with each of the following statements regarding the selling and purchasing of ready-to-eat street-vended foods?						
Attitudes		**Level of agreement**				
	Strongly disagree	**Dis-agree**	**Neu -tral**	**Agree**	**Strongly agree**	**Missing system**
I do not always think about food safety when buying ready-to-eat street-vended foods	98 (24.4)	115 (28.6)	33 (8.2)	112 (27.9)	34 (8.5)	10 (2.5)
I am certain I cannot get foodborne illnesses when I eat ready-to-eat street-vended foods	106 (26.4)	148 (36.8)	64 (15.9)	69 (17.2)	6 (1.5)	9 (2.2)
Ready-to-eat street vended foods are cheaper than ready-to-eat foods sold in supermarkets and restaurants	35 (8.7)	43 (10.7)	40 (10)	130 (32.3)	141 (35.1)	13 (3.2)

Respondents in the different subgroups within the gender, level of education and monthly income groups, differed significantly ($p<0.05$) in their responses as to whether they always thought about food safety when buying ready-to-eat street-vended food and whether they were certain they could not get foodborne diseases when they ate this food. This is in contrast to respondents in the different subgroups within the age and race groups, who did not differ significantly (p>0.05) in their responses. Similarly, respondents in the different subgroups within the gender, race, level of education and monthly income groups, differed significantly (p<0.05) in their responses as to whether ready-to-eat street-vended food was cheaper than ready-to-eat food sold in supermarkets and restaurants. This is in contrast to respondents in the different subgroups within the age group who did not differ significantly (p>0.05) in their response (Table 5.1.7).

Table 5.1.7: ANOVA of the attitude of street-vended food consumers on the sale and purchase of ready-to-eat street-vended foods from different outlets within different groups (n=402)

Description of attitude	**ANOVA within groups (p-value)**				
	Gender	**Age**	**Race**	**Educa-tion level**	**Monthly income**
I do not always think about food safety when buying ready-to-eat street-vended foods	0.023¥	0.913	0.207	0.000¥	0.001¥
I am certain I cannot contract foodborne illnesses when I eat ready-to-eat street-vended foods	0.010¥	0.431	0.108	0.000¥	0.007¥
Ready-to-eat street-vended foods are cheaper than ready-to-eat foods sold in supermarkets and restaurants	0.005¥	0.437	0.002¥	0.000¥	0.000¥

¥ = Significance at p≤0.05

5.1.5.5 MICROBIAL FOOD SAFETY HAZARDS AWARENESS

The opinions of respondents regarding the most important food safety issues nowadays were diverse. The food safety issue of concern, most cited by consumers, was foodborne diseases caused by bacteria (28%), followed by the sale of expired food (22%), unknown food sources (21%), too much junk food (19%) and lastly the presence of allergens (10%) (Table 5.1.8). The majority of respondents (74%) were either very aware (30%) or aware (44%) that certain foodborne bacteria can cause diseases that may lead to death. However, the majority of respondents knew very little about selected food pathogens. *Salmonella* was the most known considering that 28% of respondents indicated that they knew about it. This was followed by *Escherichia coli* (23%), *Listeria monocytogenes* (18%) and lastly *Campylobacter jejuni* (10%) (Table 5.1.8).

Table 5.1.8 (A-C): Microbial food safety hazards awareness of street-vended food consumers (n=402)

<table>
<tr><td colspan="3">A: The most important food safety issue of concern at present as perceived by street-vended food consumers
RESEARCH QUESTION: Which of the following, in your opinion, is the most important food safety issue of concern at present?</td></tr>
<tr><td>Cause</td><td colspan="2">Response frequency (%)</td></tr>
<tr><td>Presence of allergens</td><td colspan="2">38 (9.5)</td></tr>
<tr><td>Foodborne diseases caused by bacteria</td><td colspan="2">113 (28.1)</td></tr>
<tr><td>Sale of expired food</td><td colspan="2">88 (21.9)</td></tr>
<tr><td>Unknown food sources</td><td colspan="2">84 (20.9)</td></tr>
<tr><td>Too much junk foods</td><td colspan="2">75 (18.7)</td></tr>
<tr><td>Missing system</td><td colspan="2">4 (1)</td></tr>
<tr><td>Total</td><td colspan="2">402 (100)</td></tr>
<tr><td colspan="3">B: The knowledge of street-vended food consumers about the risks of bacterial foodborne diseases
RESEARCH QUESTION: Are you aware that certain foodborne bacteria can cause diseases that may lead to death?</td></tr>
<tr><td>Level of awareness</td><td colspan="2">Response frequency (%)</td></tr>
<tr><td>Very aware</td><td colspan="2">121 30.1)</td></tr>
<tr><td>Aware</td><td colspan="2">178 (44.3)</td></tr>
<tr><td>Not aware</td><td colspan="2">101 (25.1)</td></tr>
<tr><td>Missing system</td><td colspan="2">1 (0.2)</td></tr>
<tr><td>Total</td><td colspan="2">402 (100)</td></tr>
<tr><td colspan="3">C: The knowledge of street-vended food consumers about selected foodborne bacteria (N=402)
RESEARCH QUESTION: Have you ever heard about any of the following foodborne bacteria?</td></tr>
<tr><td rowspan="2">Foodborne bacteria</td><td colspan="2">Response Frequency (%)</td></tr>
<tr><td>YES</td><td>NO</td></tr>
<tr><td>Escherichia coli</td><td>93 (23)</td><td>309 (76.9)</td></tr>
<tr><td>Salmonella</td><td>111 (27.6)</td><td>291 (72.4)</td></tr>
<tr><td>Campylobacter jejuni</td><td>42 (10.4)</td><td>360 (89.6)</td></tr>
<tr><td>Listeria monocytogenes</td><td>73 (18.2)</td><td>328 (81.6)</td></tr>
</table>

Respondents in the different subgroups within the level of education and monthly income groups differed significantly ($p<0.05$) in their responses regarding the following: foodborne diseases caused by bacteria, sale of expired food, unknown food sources, too much junk food and the presence of allergens. Respondents in the different subgroups within the gender, age and race groups did not differ significantly ($p>0.05$) in their response (Table 5.1.9).

Furthermore, respondents in the different subgroups within the race, level of education and monthly income groups differed significantly ($p<0.05$) in their responses as to whether they had ever heard of each of the following bacteria: *Salmonella*, *E. coli*, *L. monocytogenes* and *Campylobacter jejuni*. Respondents in the different subgroups within the gender and age groups did not differ significantly ($p>0.05$) in their responses (Table 5.1.9).

Table 5.1.9: ANOVA of the microbial food safety hazards awareness of street-vended food consumers within different groups (n=402)

Descriptions of food safety hazards awareness	**ANOVA between groups (p-value)**				
	Gender	**Age**	**Race**	**Education level**	**Monthly income**
RESEARCH QUESTION: How often do you get worried about foodborne diseases when you buy ready-to-eat street-vended foods from any of the following outlets?					
	0.036	0.807	0.043	0.000¥	0.000¥
RESEARCH QUESTION: Are you aware that certain foodborne bacteria can cause diseases that may lead to death?					
	0.000¥	0.408	0.090	0.000¥	0.000¥
RESEARCH QUESTION: Are you aware that certain foodborne bacteria can cause diseases that may lead to death?					
Escherichia coli	0.005¥	0.101	0.000¥	0.000¥	0.000¥
Salmonella	0.124	0.575	0.001¥	0.000¥	0.000¥
Campylobacter jejuni	0.362	0.496	0.000¥	0.000¥	0.000¥
Listeria monocytogenes	0.093	0.098	0.000¥	0.000¥	0.000¥

¥ = Significance at $p \leq 0.05$

5.1.6 DISCUSSION

5.1.6.1 SOCIO-DEMOGRAPHICS OF RESPONDENTS

This study revealed that the majority of respondents were black males younger than 35 years. This clearly shows that street food consumption is particularly popular among young black males. An explanation for this might be the convenience, affordability and availability of street food to young people, who may be traders, hawkers, casual workers, students, unemployed and/or workers who are busy and do not have much time to prepare meals for themselves (Khairuzzaman et al., 2014). In a similar study conducted in South Africa, Martins (2006) found that most street food consumers were unmarried black males and ranged within the 26-35 year age group. Young males were also found to be the dominant consumers of street-vended food consumers in Haiti (Samapundo et al., 2015).

In this current study, just over half the respondents were not married or were unmarried but living with a partner. This is not surprising, as one would expect unmarried and single individuals to consume street-vended food. Elsewhere, single labour workers have been found to have a high willingness to buy street-vended food, owing to a lack of food safety awareness and the reluctance to cook food at home after a day’s work (Liu et al., 2014).

The majority of the respondents were literate and had attended a secondary or tertiary institution. This shows that most of the consumers of street food in the Johannesburg municipality are adequately literate. A 2011 survey in the Johannesburg local municipality estimated that 32.4% of those aged 20 years and above had some secondary education, 34.9% had completed matric and 19.2% had some form of higher education (Statistics South Africa, 2011). One would expect respondents with a higher education level to be more knowledgeable regarding food safety issues than respondents with no or less formal education. Similar to our findings, previous studies have reported that food safety issues among higher education/graduate respondents were less than satisfactory (Lazou et al., 2012; Lee et al., 2012; Carbas et al., 2013; Hassan and Dimassi, 2014; Samapundo et al., 2015). The fact that the majority of the respondents had no salary or earned below R5000 per month indicates that most street food consumers are from the lower income groups and this reaffirms the importance of the street food trade in the provision of food at affordable prices to low- and middle-income consumers (Khairuzzaman et al., 2014).

5.1.6.2 FOOD SAFETY CONFIDENCE IN AND REASONS FOR PURCHASING AND CONSUMING STREET-VENDED FOODS

Many of the respondents regularly purchased street-vended food even though they did not have much confidence about its safety. A similar finding was made in a study conducted in Shijiazhuang city, China where only 18% of street food consumers felt that their street food purchases were completely safe (Liu et al., 2014). Better taste followed closely by affordability and accessibility were the most cited reasons for purchasing ready-to-eat street food. These findings are similar to those of Martins (2006), in which the majority of street food consumers stated better tastiness as their reason for buying and consuming street-vended food. Affordability, palatability and accessibility were found to be the major factors influencing respondents' preference for street-vended food in Manila, Philippines (Abdulmajid et al., 2014) and in Ghana (Mensah et al., 2013).

Gender, race, level of education and monthly income, unlike the age group, significantly ($p<0.05$) differed in their responses regarding the frequency of purchasing and confidence about the safety of street-vended food. The reason for this could be that age comes with experience in food safety gained through unlimited/wider exposure to food safety information over time (Worsley et al., 2013). Furthermore, educated people and high-income earners are more likely to be knowledgeable about food safety, hence more likely not to have confidence in the safety of street-vended food (Liu et al., 2014). Regarding gender, the food safety practice, behaviour and awareness skills of females have been found to be significantly higher ($p < 0.01$) than that of males (Turnbull-Fortune and Badrie, 2014). Similarly, the food safety awareness of female and older consumers from shopping to eating has been found to be stronger compared to that of their male and younger counterparts respectively (Jevšnik et al., 2008).

5.1.6.3 THE FOOD SAFETY AWARENESS OF STREET-VENDED FOODS CONSUMER

In terms of food safety hazards awareness, the majority of respondents were more concerned about bacterial and fungal hazards than they were with other food safety hazards (Boodhu et al., 2008; Abdulmajid et al., 2014). Other hazards, such as pesticide/insecticide residues, heavy metals such as lead, mercury, aluminium, arsenic, and cadmium, which are also major contaminants in the food supply chain have been found not to be well-known by respondents, yet of immense concern (Unusan, 2007; Nergiz and Ergonul, 2010). Unfortunately, street foods are susceptible to contamination by chemical/toxicological hazards at various stages in their preparation and handling cycle (Proietti et al., 2014). The high level of awareness towards bacterial and fungal hazards by many respondents may be due to previous foodborne disease outbreak experiences and extensive mass media coverage of foodborne disease outbreaks in South Africa (Niehaus et al., 2011).

Respondents were more concerned about foodborne disease outbreaks when they buy ready-to-eat foods from shebeens and street food markets unlike supermarkets and restaurants. The South African food industry comprises two distinct separate sectors, the commercial and informal sector. The National Department of Health, through the application of legislation regulates both sectors. Example, all food-handling premises have to comply with the requirements of the regulations governing general hygiene requirements for food premises, the transport of food and related matters (R962 of 2012). Section 3 of these regulations stipulates that all food premises should have a valid certificate of acceptability on display. However, a stricter level of compliance is found in the formal sector compared to the informal sector, which trades in street-vended foods. As a result, consumers perceive foodstuffs from the commercial sector to be safer to consume, compared to perceived unhygienic/unsanitary conditions prevalent in the informal sector (Abdulmajid et al., 2014). Similarly, previous studies have also reported that most consumers preferred supermarkets as the safest place for food shopping (Unusan 2007; Behrens et al., 2010; Zorba and Kaptan 2011).

5.1.6.4 FOOD SAFETY AWARENESS DURING PURCHASING AND CONSUMPTION OF STREET-VENDED FOODS

The results of this study indicate that close to half of the respondents at least agreed they did not always consider food safety issues when they bought ready-to-eat street-vended foods. This means that consumers are less conscious about food safety when they buy street food, despite being aware of food safety hazards. A few consumers are probably not aware of food safety issues related to street-vended foods but the majority, who are aware, are simply not bothered with food safety concerns when they buy and consume street-vended foods (Akinbode et al., 2011). Consumers, who buy street-vended foods are often more interested in its convenience and affordability rather than issues of food safety. Over 60% of the respondents are aware that they can fall ill as a result of eating street-vended foods yet they were not deterred from purchasing and consuming street-vended foods. These findings from a public health point of view are of concern and necessitate effective food safety training and monitoring as well as stricter enforcement of existing regulations (Knight et al., 2003).

5.1.6.5 MICROBIAL FOOD SAFETY HAZARDS AWARENESS

Foodborne diseases caused by bacteria were cited as the most important food safety concerns, followed closely by the sale of expired food, then unknown sources of food and lastly too much junk food consumption. The possible reason could be due to their knowledge from foodborne disease outbreaks caused by bacteria. Due to the news about infections and illnesses caused by foodborne pathogens, microorganisms are well-known contaminants (Ergönül, 2013). Moreover, foodborne diseases caused by microorganism are an increasingly recognised problem involving a wide spectrum of illnesses, such as the acute effects on the gastrointestinal tract as well as other symptoms such as fever, vomiting, nausea, diarrhoea as well as bloody diarrhoea, dehydration and kidney failure in severe cases (Chauhan et al., 2015).

The presence of allergens was of very little concern to the respondents in this study. This observation could be a result of lack of exposure to such occurrences and understanding that certain foodstuffs allergens may cause an allergic reaction in certain individuals (Soller et al., 2015). The majority of respondents were aware that certain foodborne bacteria can cause diseases that may lead to death but over 70% have never heard about *Salmonella*, *Escherichia coli*, *Listeria monocytogenes* and *Campylobacter jejuni*. The reason for this could be the fact that the respondents had difficulties recognising the specific names of each food pathogen. However, the high level of food safety awareness demonstrated by respondents in this study indicates that street food consumers were not completely ignorant about food safety issues.

Salmonella followed by *E. coli* were the most well-known of the foodborne pathogens in this study. This awareness could be as a result of outbreaks of *Salmonella* and *E. coli* foodborne infections reported on the TV, radio and newspaper. Akhtar et al. (2014) revealed that salmonellosis is a major health problem that prevails in South African regions, where broiler farms and slaughterhouses have been regarded as major sources of contamination. Other studies have also found street-vended food consumers to have a poor knowledge of various foodborne pathogens that are responsible for many foodborne diseases (Samapundo et al., 2015). Furthermore, Osaili et al. (2013) found that only 10% or less of the respondents in a study conducted in Jordan had heard about *Listeria monocytogenes*, *Staphylococcus aureus*, *Bacillus cereus*, *Escherichia coli O157:H7*, *Clostridium perfringens*, *Campylobacter jejuni*, and *Shigella* and only about 40% had heard about *Salmonella*. Therefore, consumers tend to be unable to distinguish between individual foodborne pathogens.

5.1.7 CONCLUSIONS

This study investigated the level of food safety and microbial hazard awareness of street food consumers in the Johannesburg municipality. The results highlighted some gaps in consumers' food safety knowledge, attitudes and practices on purchase and consumption of street-vended foods. The consumption of street-vended foods is popular among young black African males due to affordability, availability and convenience. The majority of the street-vended food consumers were unmarried, literate and belong to the lower income group. The majority of the street-vended food consumers do not have confidence in the safety of street-vended foods and this does not affect their preference for street-vended foods. Gender, race, level of education and monthly income affect the ways consumers of street-vended foods perceived the safety of street-vended foods and their desire to purchase them. Consumers are most worried when they buy ready-to-eat foods from shebeens and street food vendors, compared to supermarkets and restaurants. The majority of the consumers have very little knowledge of *Salmonella*, *E. coli*, *Listeria* and *Campylobacter*.

5.2 BACTERIOLOGICAL QUALITY AND DIVERSITY OF READY-TO-EAT STREET-VENDED FOODS

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5.2.1 ABSTRACT

The bacterial quality of ready-to-eat (RTE) street-vended food is a serious concern to the safety and well-being of those who patronise it. This study investigated the bacteriological quality and diversity of ready-to-eat street-vended foods from the Johannesburg metropolis. A total of 315 various street-vended samples were purchased from randomly selected street food vendors at different vending locations in Johannesburg metropolis and their bacterial quality and diversity were analysed. Samples were analysed for the presence of *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus* and *Listeria monocytogenes*. Results obtained revealed that total aerobic counts ranged from $0.3{*}10^2$ - $0.4{*}10^5$ cfu/g for cereals and grain-based foods; $0.4{*}10^2$ - $0.5{*}10^5$ cfu/g for meat-, dairy- and fish-based foods and $0.7{*}10^2$ - $0.9{*}10^4$ cfu/g for fruit- and vegetable-based foods. Only 16% of the 126 cereals, grain, fruit- and vegetable-based food samples were contaminated with Enterobacteriaceae, of which 95% had counts above 10^2 cfu/g. Up to 34% of the 154 meat- and dairy-based food samples were contaminated with Enterobacteriaceae, of which 50% had counts above 10^2 cfu/g.

The genus mostly detected in the different street-vended foods was *Pseudomonas*, followed by *Bacillus*, *Escherichia* and *Ralstonia*. Only 4% of the 304 cereals and grain-based foods

samples, 10% of the 368 meat-, dairy- and fish-based foods, and 5% of the 64 fruit- and vegetable-based foods tested positive for the presence of foodborne pathogens. None of the food samples tested positive for *Salmonella* spp. and *Staphylococcus aureus*. Overall, the bacterial quality of the majority of the food samples analysed was within acceptable limits, despite the presence of *Escherichia coli* and *Listeria monocytogenes* in a few samples. Therefore, the findings from this study could assist public health authorities and other relevant food control agencies to facilitate an effective food safety management system.

5.2.2 INTRODUCTION

In many streets of developing countries, like South Africa, the sale and consumption of ready-to-eat foods and beverages are a common and normal phenomenon of everyday life (Kok and Balkaran, 2014). Different types of food items such as traditional meals, snacks, and beverages are usually prepared on the street or at home. These are then sold by vendors or hawkers on street pavements, at taxi stations, industrial areas, market places and other similar places for immediate consumption or consumption at a later stage without further processing or preparation (WHO/FAO, 2010; Muyanja et al., 2011; Samuel, 2012). These foods are usually consumed where they are bought or alternatively eaten somewhere else (Mensah et al., 2002).

Generally, the street food industry plays a significant role in assuring food security especially among the low-income population, in addition to providing a wide range of food commodities and nutrients (Khairuzzaman et al., 2014; Proietti et al., 2014). These foods are greatly appreciated by consumers, because of their unique taste, nutritional value, variety and accessibility (Kibret and Tadesse, 2013; Manguiat and Fang, 2013). The majority of the street-vended food consumers seem to have little confidence in the safety of street-vended foods; however, this does not affect their preference for such foods (Asiegbu et al., 2016).

Unfortunately, the risk of contracting foodborne diseases especially from microbial contaminated street foods remains a serious threat to public health (FAO, 2013). This could be attributed to the unhygienic/unsanitary conditions in which these foods are handled, prepared, served/sold and stored by food vendors (Nyenje et al., 2012; Manguiat and Fang, 2013; Abdulmajid et al., 2014). In addition, some street food vendors are often very poor, uneducated and lack adequate knowledge about food safety issues (Lues et al., 2006; Tabashsum et al., 2013; Abdulmajid et al., 2014). Thus, it is clearly evident that street foods are one of the major causes of several types of foodborne diseases of which diarrhoea has been the most common symptom (Chauhan et al., 2015). Notwithstanding the public health concerns associated with these foods, street food purchasing has continued to increase over the years due to factors such as the urbanisation of rural communities, rural to urban migration, urban population growth and changing life styles (FAO, 2009; Khongtong et al., 2014).

In many neighbourhoods of Johannesburg, many popular street foods are being sold by vendors, who are often not regulated. Nonetheless, consumers of street-vended foods have entrusted their safety to these vendors, who cannot guarantee the implementation of food safety practices in their activities. Furthermore, many street food-vending sites lack adequate sanitary facilities, therefore providing favourable conditions for bacteria proliferation (Kok and Balkaran, 2014).

Microbiological food safety hazards pose a huge challenge to the safety of street food since potentially harmful microorganism have the ability to grow rapidly in street-vended food and cause foodborne diseases to consumers (Akinbode et al., 2011). Several researchers have identified street-vended foods as potential vectors of foodborne pathogens such as: *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp., *Shigella sonnei*, *Proteus* spp., *Listeria* spp. and *Bacillus cereus* (Mensah et al., 2002; Lues et al., 2006; Gadaga et al., 2008; El-Shenawy et al., 2011; Gitahi et al., 2012; Odu and Imaku, 2013).

Based on the popularity and the degree of consumption of street-vended foods in various neighbourhoods, the aim of this study was to investigate the bacteriological quality and diversity of selected ready-to-eat street-vended foods sold in various areas of Johannesburg metropolis, South Africa, so as to give a better insight of their safety and quality.

5.2.3 MATERIALS AND METHODS

5.2.3.1 SAMPLE COLLECTION

A total of 315 different food samples were purchased from randomly selected street food vendors at different vending locations in Johannesburg metropolis, over a period of six months from February to August 2015. The samples were collected in their original packages and placed in separate sterile containers. The samples were then labelled and transported on ice to the laboratory for sample preparation and analysis within twelve hours of purchase.

5.2.3.2 SAMPLE PREPARATION

Ten grams (10g) of each food sample was aseptically weighed and mixed with 90ml of sterile peptone water (Biolab, South Africa) and then homogenised in a sterilised Waring laboratory blender for 4-8 min. Thereafter, tenfold serial dilutions, up to 10^{-5} folds of the homogenate were prepared for each sample and used for bacteria analysis.

5.2.3.3 TOTAL AEROBIC COUNTS

Total Aerobic Counts (TACs) was done on Plate Count Agar (PCA) plates (Merck, South Africa). Serial dilutions of each sample up to 10^{-5} were plated in duplicates and incubated at 37 ℃ for 24 hours. Plates showing 30-300 colony forming units (cfu) were counted.

5.2.3.4 DETECTION OF PATHOGENS

Enterobacteriaceae

Enterobacteriaceae counts were conducted using violet red bile dextrose agar (Merck, South Africa) using the manufacturer's protocol. Serial dilutions of each sample up to 10^{-5} were plated in duplicates and incubated at 37 ℃ for 24 hours. Round, purple-pink, 1-2mm diameter colonies surrounded by purple haloes were counted.

Escherichia coli

Enrichment was done by aseptically weighing 12.5g of each food sample into sterile test tubes containing 112.5ml of E. coli HiCrome™ enrichment broth (Sigma). After enrichment at 37 ^{o}C for 21 hours, 200µl of broth culture was plated on RAPID' E. coli 2 agar plates (Biolab, South Africa), and incubated at 37 ℃ for 24 hours. Plates showing pink to violet colonies were recorded as positive plates.

Salmonella spp.

For enrichment, 12.5g of each food sample was aseptically weighed into sterile test tubes containing 112.5ml of Salmonella enrichment broth (Sigma), and incubated at 37 ℃ for 21 hours. After enrichment, 200µl of broth culture was plated on Salmonella chromogen agar plates (Sigma), and the plates were incubated at 37 ℃ for 24 hours. Plates showing magenta colonies were recorded as positive plates.

Staphylococcus aureus

Enrichment was done by aseptically weighing 12.5g of each food sample into sterile test tubes containing 112.5ml of modified Giolitti and Cantoni broth (Sigma). After enrichment at 37 ℃ for 21 hours, 200µl from broth culture was plated on RAPID' Staph agar (Biolab, South Africa), and incubated at 37 ℃ for 24 hours. Plates showing black colonies with a clear halo around the colony were recorded as positive plates.

Listeria monocytogenes

Enrichment was done by aseptically weighing 12.5g of each food sample into sterile test tubes containing 112.5ml of Listeria enrichment broth (Biolab, South Africa). After enrichment at

37 ℃ for 21 hours, 200µl from broth culture was plated on RAPID' Listeria spp. agar (Biolab, South Africa), and incubated at 37 ℃ for 24 hours. Plates showing blue-to-blue-green colonies were recorded as positive plates.

5.2.3.5 DETECTION AND ENUMERATION OF LACTIC ACID BACTERIA (LAB)

De Man Rogosa and Sharpe (MRS) agar (Merck, South Africa) was used for the enumeration of LAB using the manufacturer's protocol. Serial dilutions of each sample up to 10^{-5} were plated in duplicates and incubated at 30 ℃ for 24 hours. Plates showing 30-300 colony forming units (cfu) were counted.

5.2.3.6 PROFILING AND IDENTIFICATION OF ISOLATES USING MOLECULAR METHODS

Preparation of pure culture

Using a sterile inoculation loop, each selected bacteria colony was carefully picked and grown separately in 500µl of sterile nutrient broth (Biolab, South Africa) and incubated at 37 ℃ for 24 hours. Subsequently, 300µl of the grown bacteria culture was plated on PCA plates (Merck, South Africa) and incubated at 37 ℃ for 24 hours. The resultant bacteria cells were then harvested and centrifuged at 12000 rpm for 3 minutes. Pellets obtained were stored at -20 ℃ for later use.

DNA extraction

Bacteria genomic DNA was extracted using ZR Fungal/Bacterial DNA MiniPrep™ Kit (Zymo Research Corporation, USA) following the manufacturer's protocol. Subsequently, the concentrations of DNA were determined and adjusted between 1-1.5ug/ml using the Smart Spec™ Plus spectrophotometer (Bio-Rad Laboratories, Inc., Hercules, CA, USA) using the manufacturer's protocol.

Random amplified polymorphic DNA (RAPD) PCR analysis of isolates

Random amplified polymorphic (RAPD) DNA PCR analysis was done using a 9-mer primer with the sequence 3´-ACG CGC CCT-5´ as described by Quednau et al. (1998). All primers used for the RAPD was synthesised by Inqaba Biotechnology Company (South Africa).

Two microliter (2µl) of each genomic DNA extract was used as template for RAPD-PCR reaction. The PCR amplification was performed in a 25µl reaction volume consisting of 1µl of primer, 9.5 µl of nuclease-free water and 12.5µl of 2× PCR Master Mix [50 units/ml of *Taq* DNA polymerase supplied in a proprietary reaction buffer (pH 8.5), 400µM dATP, 400µM dGTP, 400µM dCTP, 400µM dTTP, 3mM $MgCl_2$] (Promega, Madison, USA).

The amplification was carried out in an Agilent Technologies Mx3005P Real-time PCR system (California, USA) under the following conditions: an initial denaturation at 94 ℃ for 2 minutes and 6 cycles of denaturation at 94 ℃ for 30 seconds, annealing at 36 ℃ for 60 seconds, extension at 72 ℃ for 90 seconds followed by another 30 cycles of denaturation at 94 ℃ for 20 seconds, annealing at 42 ℃ for 30 seconds, extension at 72 ℃ for 90 seconds, and a final extension at 72 ℃ for 3 minutes. Thereafter, 10µl of each amplified PCR products was analysed using gel electrophoresis (Mini-Sub® Cell GT; Bio-Rad Laboratories, Inc., Hercules, CA, USA), and run for 42 minutes at 75V on 0.75% agarose (Sigma) gels submerged in 0.5 × TAE buffer (Sigma) and stained with 1µl of ethidium bromide. Gels were visualised and photographed using the GelDoc- It™ 310 Imaging System (California, USA).

Identification of isolates by 16S rRNA gene sequencing

Prior to DNA sequencing, the primers ENV1 (5´-AGA GTT TGA TII TGG CTC AG-3´) and ENV2 (5´-CGG ITA CCT TGT TAC GAC TT-3´) were used to amplify the 16S rRNA gene of bacteria isolates as describe previously by Olsson et al. (2003). Twenty five microliter (25µl) reaction volume consisting of 2µl of each DNA, 1.5µl of each primer, 7.5µl of nuclease free water and 12.5µl of 2× PCR Master Mix [50 units/ml of *Taq* DNA polymerase supplied in a proprietary reaction buffer (pH 8.5), 400µM dATP, 400µM dGTP, 400µM dCTP, 400µM dTTP, 3mM $MgCl_2$] (Promega, Madison, USA).

The amplification was carried out in an Agilent Technologies Mx3005P Real-time PCR system (California, USA) under the following conditions: an initial denaturation at 94 ℃ for 2 minutes and 6 cycles of denaturation at 94 ℃ for 30 seconds, annealing at 36 ℃ for 60 seconds, extension at 72 ℃ for 90 seconds followed by another 30 cycles of denaturation at 94 ℃ for 20 seconds, annealing at 42 ℃ for 30 seconds, extension at 72 ℃ for 90 seconds, and a final extension at 72 ℃ for 3 minutes. Thereafter, 10µl of each amplified PCR products was analysed using gel electrophoresis (Mini-Sub® Cell GT; Bio-Rad Laboratories, Inc., Hercules, CA, USA) run for 42 minutes at 75V on 0.75% agarose (Sigma) gels submerged in 0.5 × TAE buffer (Sigma) and stained with 1µl of ethidium bromide. Gels were visualised and photographed using the GelDoc- It™ 310 Imaging System (California, USA).

The purification of the PCR products was carried out using the MinElute PCR Purification Kit (Qiagen) following the manufacturer's protocol. Purified PCR products were sequenced using the BigDye® Terminator v1.1 Cycle Sequencing Kit (Applied Biosystems) as directed in the manufacturer's protocol. Sequence reactions were electrophoresed using the Applied Biosystems 3500xl Genetic Analyser. The resulting sequences were initially aligned using ClustalW in BioEdit (vision 7.0.9.1) and manually edited. The edited sequences obtained were then blasted in the EMBL nucleotide sequence database (Maidak et al., 1999).

5.2.4. RESULTS

5.2.4.1 TOTAL AEROBIC COUNT FOR CEREALS, GRAIN AND RELATED STREET-VENDED FOODS

Total aerobic count for the different food groups analysed ranged from $0.3*10^2$ - $0.4*10^5$ cfu/g, local chocolate cake and coloured popcorn (skopas) were the most frequently contaminated. This was followed by vanilla flavoured cookies, local bread, bean cake, roasted peanuts, melon soup, boiled and roasted maize and wheat biscuits. On the contrary, maize porridge (pap), semolina porridge, fat cake, boiled peanuts, boiled beans and roasted shelled peanuts were the least frequently contaminated of the cereals and grain-based foods. Only boiled rice and jollof rice had no growth in all the samples analysed (Table 5.2.1).

Table 5.2.1: Total aerobic count for cereals and grain-based foods

Food groups	**Total Positive sample**	**Number of sample in the indicated interval**				**Range of counts (cfu/g)**
		<10^1	**10^1 - 10^2**	**>10^3 - 10^4**	**>10^4**	
Maize porridge (Pap)	3			2	1	$0.6{*}10^3$ - $0.2{*}10^4$
Semolina porridge	2			2		$0.7{*}10^2$ - $0.4{*}10^3$
Fried potato chips	3			3		$0.1{*}10^3$- $0.6{*}10^3$
Fat cake (Amagwinya)	2	1			1	$0.1{*}10^4$- $0.3{*}10^4$
Vanilla flavoured cookies	4		1	3		$0.3{*}10^2$- $0.6{*}10^3$
Local chocolate cake	7			3	4	$0.3{*}10^3$- $0.3{*}10^4$
Local bread	5			2	3	$0.1{*}10^3$- $0.1{*}10^5$
Bean cake	5			1	4	$0.4{*}10^3$- $0.2{*}10^5$
Roasted peanuts	5			2	3	$0.8{*}10^3$- $0.3{*}10^5$
Boiled peanuts	5				5	$0.8{*}10^4$- $0.4{*}10^4$
Coloured popcorn (Skopas)	7			2	5	$0.2{*}10^3$- $0.2{*}10^5$
Boiled beans without stew	5			3	2	$0.1{*}10^3$- $0.1{*}10^5$
Melon (Egusi) soup	5			3	2	$0.4{*}10^2$- $0.4{*}10^5$
Boiled maize	5			1	4	$0.7{*}10^3$- $0.4{*}10^5$
Roasted maize	5			1	4	$0.4{*}10^3$- $0.1{*}10^5$
Roasted shelled peanuts	5				5	$0.1{*}10^4$- $0.3{*}10^5$
Wheat biscuit	5			4	1	$0.1{*}10^3$- $0.7{*}10^3$
Total	78	1	1	32	44	$0.3{*}10^2$ - $0.4{*}10^5$
NB: Number of foods with no aerobic plate count for all samples = 2 (boiled rice, jollof rice), number of sampling times = 7, total number of samples analysed = 133						

5.2.4.2 TOTAL AEROBIC COUNT FOR MEAT, DAIRY, FISH AND RELATED STREET-VENDED FOODS

Up to 70% of the 154 food samples analysed had aerobic growth. Of these, 46% had counts above 10^4 cfu/g. The TAC results of these food groups indicated that beef stew, boiled eggs, grilled chicken feet and cheese/egg burgers were the most frequently contaminated. On the contrary, the least frequently contaminated foods were beef broths, fried chicken drumsticks and fried hakes. Only omelettes had no growth in all the samples analysed (Table 5.2.2).

Table 5.2.2: Total aerobic count for meat-, dairy- and fish-based foods

Food groups	**Total positive sample**	**Number of sample in the indicated interval count (cfu/g)**				**Range of counts (cfu/g)**
		$<10^1$	**10^1-10^2**	**$>10^2$-10^4**	**$>10^4$**	
Beef-based foods						
Beef sausage slices (Polony)	5			1	4	$0.5{*}10^3$-$0.3{*}10^5$
Cow's leg stew	5				5	$0.3{*}10^4$-$0.2{*}10^5$
Beef stew	7				7	$0.2{*}10^4$-$0.1{*}10^5$
Fried beef derm	5			3	2	$0.4{*}10^2$-$0.1{*}10^3$
Beef broth	3		1	2		$0.4{*}10^2$-$0.1{*}10^3$
Fried beef tripe	5			4	1	$0.3{*}10^3$-$0.4{*}10^4$
Fried ox liver	5			3	2	$0.2{*}10^3$-$0.3{*}10^4$
Barbecued beef sausage	5		1	2	2	$0.9{*}10^2$-$0.2{*}10^4$
Biltong	5			1	4	$0.3{*}10^3$-$0.9{*}10^4$
Samoosa	5				5	$0.1{*}10^4$-$0.4{*}10^5$
Bread, potato chips, sausage sandwich (Kota)	5			2	3	$0.2{*}10^3$-$0.8{*}10^4$

Dairy-based foods						
Gouda cheese slices	5			4	1	$0.2*10^3$-$0.9*10^3$
Cheese/egg burger	6			2	4	$0.8*10^3$-$0.2*10^5$
Poultry-based food						
Grilled chicken gizzard	5		1	1	3	$0.9*10^2$-$0.1*10^5$
Boiled egg	7				7	$0.1*10^4$-$0.3*10^5$
Fried chicken drum stick	3			1	2	$0.7*10^3$-$0.3*10^4$
Chicken stew	5			1	4	$0.8*10^3$-$0.4*10^4$
Grilled chicken feet	7			1	6	$0.4*10^3$-$0.3*10^5$
Grilled chicken neck	7			3	4	$0.2*10^3$-$0.3*10^4$
Fish-based products						
Fried hake	3				3	$0.9*10^4$-$0.5*10^5$
Fried snoek	5		1	1	3	$0.5*10^2$-$0.2*10^4$
Total	108	-	4	32	72	$0.4*10^2$ - $0.5*10^5$
Number of foods with no aerobic plate count for all samples = 1 (omelette), Number of sampling times = 7, total number of samples analysed = 154						

5.2.4.3 TOTAL AEROBIC COUNT FOR FRUIT, VEGETABLE AND RELATED STREET-VENDED FOODS

Up to 93% of the 154 food samples had aerobic growth, of which 61% had counts above 10^4 cfu/g. The most frequently contaminated foods under this category were spiced unripe mango pickle (atchaar), spiced vegetable relish (chakalaka) and mixed vegetable salad (Table 5.2.3).

Table 5.2.3: Total aerobic count for fruit- and vegetable-based foods

Food groups	**Total positive sample**	**Number of sample in the indicated interval count (cfu/g)**				**Range of counts (cfu/g)**
		$<10^1$	**10^1 - 10^2**	**10^3 - 10^4**	**$>10^4$**	
Fruit- and vegetable-based products						
Spinach vegetable, onion, tomato mixture (Gravy)	7		1	3	3	$0.7{*}10^2$-$0.9{*}10^4$
Spiced unripe mango pickle (Atchaar)	7			3	4	$0.3{*}10^3$-$0.5{*}10^4$
Spicy vegetable relish (Chakalaka)	5				5	$0.1{*}10^4$-$0.6{*}10^4$
Mixed vegetable salad	7			2	5	$0.2{*}10^3$-$0.5{*}10^4$
Total	26		1	8	17	$0.7{*}10^2$ - $0.9{*}10^4$
Number of sampling times = 7, total number of samples analysed = 28						

5.2.4.4 ENTEROBACTERIACEAE COUNTS

Only 28% of the 161 cereals, grain, fruit- and vegetable-based food samples were contaminated with Enterobacteriaceae of which up to 96% had counts above 10^2 cfu/g. Chocolate cake, local bread, bean cake, coloured popcorn (skopas) and roasted maize were cereals and grain related foods with the most incidences of Enterobacteriaceae contamination, while chakalaka and mixed vegetable salad were the fruit- and vegetable-based foods with the most incidences of Enterobacteriaceae contamination. Maize porridge (pap), semolina porridge, fried potato chips, boiled rice, vanilla flavoured cookies, jollof rice, melon (egusi) soup, boiled maize and roasted shelled peanuts were the cereals and grain-based food with no incidence of Enterobacteriaceae contamination. Furthermore, spinach, onion and tomato gravies as well as atchaar were the fruit- and vegetable-based foods with no incidence of Enterobacteriaceae contamination (Table 5.2.4).

Table 5.2.4: Enterobacteriaceae count for cereals, grain, fruit- and vegetable-based foods

Food groups	Total Positive sample	Number of sample in the indicated interval (cfu/g)				Range of counts cfu/g)
		$<10^1$	**10^1 - 10^2**	**$\geq 10^2$ - 10^4**	**$>10^4$**	
Fat cake (Amagwinya)	2		1	1		$0.1{*}10^3$-$0.7{*}10^3$
Chocolate cake	4			1	3	$0.5{*}10^3$-$0.2{*}10^5$
Local bread	4			2	2	$0.7{*}10^3$-$0.1{*}10^5$
Bean cake	5				5	$0.2{*}10^4$-$0.1{*}10^5$
Roasted peanuts	2			2		$0.7{*}10^2$-$0.2{*}10^3$
Boiled peanuts	3				3	$0.7{*}10^4$-$0.3{*}10^5$
Coloured popcorn (Skopas)	4		1	2	1	$0.2{*}10^2$-$0.1{*}10^4$
Boiled beans without stew	2			2		$0.1{*}10^2$-$0.1{*}10^3$
Roasted maize	5			4	1	$0.1{*}10^4$-$0.2{*}10^4$
Wheat biscuit	3				3	$0.4{*}10^4$-$0.1{*}10^5$-
Chakalaka	4			1	3	$0.6{*}10^3$-$0.2{*}10^5$
Mixed vegetable salad	7			2	5	$0.9{*}10^3$-$0.3{*}10^4$
Total	45	-	2	17	26	$0.1{*}10^2$-$0.3{*}10^5$
Cereals and grain-based foods with no growth on violet red bile dextrose agar: maize porridge (pap), semolina porridge, fried potato chips, boiled rice, vanilla flavoured cookies, jollof rice, melon (egusi), boiled maize and roasted shelled peanuts						
Fruit- and vegetable-based foods with no growth: spinach, onion and tomato gravies, atchaar						
Number of sampling times = 7, total number of samples analysed = 161						

Only 34% of the 154 meat- and dairy-based food samples were contaminated with Enterobacteriaceae of which 50% had counts above 10^2 cfu/g. Beef stew, boiled egg, grilled chicken feet and cheese/egg burger were the meat- and dairy-based foods with the most incidence of Enterobacteriaceae. Stewed cow's leg, beef broth, fried ox liver, grilled chicken gizzard, biltong, grilled chicken gizzard, fried chicken, omelette and hot dog were the meat- and dairy-based foods with no incidence of Enterobacteriaceae (Table 5.2.5).

Table 5.2.5: Enterobacteriaceae count for meat-, dairy- and fish-based foods

Food groups	**(%) Total Positive sample**	**Number of sample in the indicated interval count (cfu/g)**				**Range of counts (cfu/g)**
		$<10^1$	**10^1 - 10^2**	**$\geq10^2$ - 10^4**	**$>10^4$**	
Beef-based foods						
Beef sausage slices (Polony)	4			2	2	$0.5*10^4$-$0.3*10^5$
Beef stew	6			6		$0.2*10^4$-$0.4*10^4$
Fried beef derm	3			3		$0.3*10^3$-$0.7*10^3$
Fried beef tripe	2			2		$0.2*10^3$-$0.5*10^3$
Barbecued sausage (Wors)	2			2		$0.8*10^3$-$0.9*10^3$
Samoosa	3			1	2	$0.5*10^4$-$0.3*10^5$
Kota	3		2		1	$0.2*10^2$-$0.1*10^3$
Dairy-based foods						
Gouda cheese	3		1	1	1	$0.7*10^2$-$0.5*10^4$
Cheese/egg burger	5			2	3	$0.5*10^3$-$0.5*10^5$
Poultry-based food						
Boiled egg	7			3	4	$0.6*10^4$-$0.5*10^5$
Chicken stew	1			1		$0.1*10^3$-$0.2*10^3$
Grilled chicken feet	4			2	2	$0.4*10^4$-$0.3*10^5$
Grilled chicken neck	3			3		$0.9*10^3$-$0.3*10^4$
Fish-based products						
Fried hake	3			1	2	$0.5*10^4$-$0.4*10^5$
Fried snoek	3			1	2	$0.5*10^4$-$0.5*10^5$
Total	52	-	3	30	19	$0.2*10^2$-$0.5*10^5$
Dairy- and fish-based foods with no counts: stewed cow's leg, beef broth, fried ox liver, grilled chicken gizzard, biltong, fried chicken, omelette and hot dog. Number of sampling times = 7, N = 154						

5.2.4.5 LACTIC ACID BACTERIA (LAB) COUNT FOR CEREALS, GRAIN AND RELATED STREET-VENDED FOODS

LAB was detected in 27% of the 133 samples of which 78% had counts above 10^4 cfu/g. The cereals and grain-based foods with the most LAB count above 10^4 cfu/g were local bread, roasted peanuts, boiled shelled peanuts, melon (egusi soup) and wheat biscuits. Those with the most frequent incidence of LAB were local bread and bean cake. The following cereals and grain-based foods with no LAB incidence in all samples analysed were semolina porridge, fried potato chips, boiled rice, vanilla flavoured cookies, chocolate cake, jollof rice, boiled beans, boiled maize, roasted maize and roasted shelled peanuts (Table 5.2.6).

Table 5.2.6: Lactic acid bacteria (LAB) count for cereals and grain-based foods

Food groups	**Total Positive sample**	**Number of sample in the indicated interval (cfu/g)**				**Range of counts (cfu/g)**
		$<10^1$	**$10^1 - 10^2$**	**$\geq 10^2 - 10^4$**	**$>10^4$**	
Cereals, grain and related foods						
Maize porridge (Pap)	3		1	1	1	$0.6*10^2$-$0.2*10^3$
Fat cake (Amagwinya)	2			2		$0.4*10^3$-$0.5*10^3$
Local bread	4				4	$0.2*10^4$-$0.4*10^5$
Bean cake	5			1	4	$0.4*10^3$-$0.5*10^4$
Roasted peanuts	5				5	$0.1*10^4$-$0.2*10^4$
Boiled shelled peanuts	5				5	$0.3*10^4$-$0.1*10^5$
Coloured popcorn (Skopas)	3			3		$0.3*10^3$-$0.6*10^3$
Melon (Egusi) soup	5				5	$0.2*10^4$-$0.1*10^5$
Wheat biscuit	4				4	$0.4*10^4$-$0.2*10^5$
Total	36		1	7	28	$0.6*10^2$-$0.4*10^5$
Cereals and grain-based foods with no lactic acid bacteria growth: semolina porridge, fried potato chips, boiled rice, vanilla flavoured cookies, chocolate cake, jollof rice, boiled beans, roasted maize and roasted shelled peanuts						
Number of sampling times = 7, total number of samples analysed = 133						

5.2.4.6 LACTIC ACID BACTERIA (LAB) COUNT FOR MEAT, DAIRY, FISH AND RELATED STREET-VENDED FOODS

LAB was detected in 43% of the 154 samples of meat- and dairy-based foods, of which 74% had counts above 10^4 cfu/g. The meat- and dairy-based food with the most LAB count above 10^4 cfu/g was Gouda cheese slices. This was followed by beef sausage slices, beef stew, grilled chicken feet and kota. Those foods with the most frequent incidence of LAB were Gouda cheese slices, boiled eggs and cheese egg burgers. These were followed by beef sausage, beef stew, chicken stew, grilled chicken feet, fried snoek and kota. The meat- and dairy-based foods with no lactic acid bacteria incidence in all samples analysed were stewed cow's leg, beef broth, fried ox liver, grilled chicken gizzard, omelette, hotdog and fried hake (Table 5.2.7).

Table 5.2.7: Lactic acid bacteria (LAB) count for meat- and dairy-based foods

Food groups	**Total Positive sample**	**Number of sample in the indicated interval (cfu/g)**				**Range of counts (cfu/g)**
		$<10^1$	**10^1 - 10^2**	**$\geq 10^2$ - 10^4**	**$>10^4$**	
Beef-based foods						
Beef sausage slices (Polony)	1				1	$0.9{*}10^4$- $0.7{*}10^6$
Stewed cow's leg	5				5	$0.2{*}10^4$- $0.1{*}10^5$
Beef stew	5				5	$0.4{*}10^4$- $0.3{*}10^5$
Fried beef derm	2			1	1	$0.4{*}10^3$- $0.1{*}10^4$
Fried beef tripe	3			2	1	$0.5{*}10^3$- $0.7{*}10^3$
Fried ox liver	3			2	1	$0.3{*}10^3$- $0.7{*}10^3$
Barbecued sausage (Wors)	3			1	2	$0.4{*}10^3$- $0.2{*}10^4$
Biltong	3				3	$0.4{*}10^4$- $0.2{*}10^5$
Kota	5				5	$0.3.10^4$- $0.2{*}10^5$

Dairy-based foods						
Gouda cheese	7				7	$0.6*10^{3}$-$0.5*10^{5}$
Cheese/egg burger	6			5	1	$0.1*10^{4}$-$0.7*10^{5}$
Poultry-based foods						
Boiled egg	6			3	3	$0.1*10^{3}$-$0.5*10^{5}$
Chicken stew	4			1	3	$0.5*10^{3}$-$0.3*10^{4}$
Grilled chicken feet	5				5	$0.3*10^{4}$-$0.3*10^{5}$
Grilled chicken neck	3				3	$0.2*10^{4}$-$0.4*10^{4}$
Fish-based food						
Fried snoek	5		1	1	3	$0.5*10^{2}$-$0.3*10^{5}$
Total	66		1	16	49	$0.5*10^{2}$-$0.7*10^{6}$
Meat- and dairy-based foods with no incidence LAB: beef broth, fried ox livers, grilled chicken gizzards, omelettes, hotdog and fried hake						
Number of sampling times = 7, total number of samples analysed = 133						

5.2.4.7 LACTIC ACID BACTERIA (LAB) COUNT FOR FRUIT, VEGETABLE AND RELATED STREET-VENDED FOODS

LAB was detected in 75% of the 28 samples of fruit- and vegetable-based foods, of which 81% had counts above 10^{4} cfu/g. The fruit- and vegetable-based foods with the most LAB count above 10^{4} cfu/g were mixed vegetable salad, followed by atchaar and chakalaka. Furthermore, fruit- and vegetable-based foods with the most frequent incidences LAB were mixed vegetable salads, atchaar and chakalaka. No fruit- and vegetable-based foods had a negative LAB growth for any of the sample analysed (Table 5.2.8).

Table 5.2.8: Lactic acid bacteria (LAB) counts for fruit- and vegetable-based foods

Food groups	**Total positive sample**	**Number of sample in the indicated interval count (cfu/g)**				**Range of counts (cfu/g)**
		<10^1	**10^1 - 10^2**	**≥10^2 - 10^4**	**>10^4**	
Spinach vegetables, onion, tomatoes mixture (Gravy)	3				3	$2.0*10^3$-$9.6*10^3$
Atchaar	7		1	1	5	$1.0*10^2$-$1.8*10^4$
Chakalaka	4			1	3	$6.9*10^2$-$3.1*10^4$
Mixed vegetable salad	7			1	6	$9.6*10^2$-$8.5*10^3$
Total	21		1	3	17	$1.0*10^2$-$3.1*10^4$
Number of sampling times = 7, total number of samples analysed = 28						

5.2.4.8 PROFILING AND IDENTIFICATION OF AEROBIC PLATE COUNT BACTERIA ISOLATES OF STREET-VENDED FOOD

Based on their PCR-RAPD profiles (Figure 5.2.1), bacteria isolates from the different street foods were grouped in to 25 RAPD types and a representative isolate for each RAPD type was identified. A total of 25 bacteria species representing 22 different genera were identified.

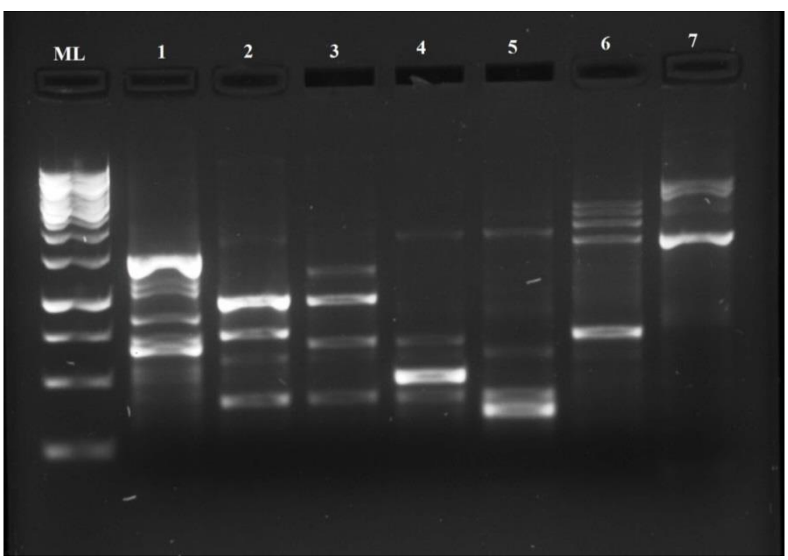

Figure 5.2.1: RAPD profiles of selected food isolates: ML = 1 kb molecular ladder (Sigma), 1 = *Escherichia vulneris*, 2 = *Pseudomonas aeruginosa*, 3 = *Pseudomonas japonica*, 4 = *Renibacterium Salmoninarium*, 5 = *Bacillus pumilus*, 6 = *Stenotrophomonas maltophilia*, 7 = *Ralstonia pickettii*

The genus that was detected the most in the different food samples was *Pseudomonas*, followed by *Bacillus*, *Escherichia* and *Ralstonia*. *Pseudomonas aeruginosa*, *Pseudomonas japonica*, *Bacillus atrophaeus*, *Bacillus subtilis*, *Bacillus pimulus* and *Lactobacillus florum* were the various psychrotrophs species isolated from the analysed food samples. *Pseudomonas aeruginosa* was detected in cookies, coloured popcorn, boiled maize, atchaar, samoosa, chicken stew, chicken gizzard, chicken neck, fried hake, fried snoek and cheese. *Bacillus atrophaeus* was detected in wheat biscuit; *Bacillus subtilis* in local bread and coloured popcorn; *Bacillus pimulus* in roasted maize, beef stew, chicken stew, chicken neck and fried snoek (Table 5.2.9).

Seven species belonging to the *Enterobacteriaceae* family were identified and they include *Escherichia vulneris*, *Pantoea ananatis*, *Citrobacter freund*i, *Serratia proteamaculans*, *Enterobacter aerogenes*, *Erwinia billingiae* and *Shimwellia blattae*. The most abundant, *Escherichia vulneris*, was identified in the following 6 different food types: local bread, bean cake, boiled shelled peanuts, coloured popcorn, melon soup and stewed cow's leg (Table 5.2.9).

Pantoea ananatis was identified in 3 different food types: roasted maize, coloured popcorn and beef stew. *Citrobacter freundi* was also identified in 3 different food types: boiled peanuts, beef stew and boiled egg. *Serratia proteamaculans* was identified in 3 food types: chicken feet, boiled egg and fried snoek. *Enterobacter aerogenes*, *Erwinia billingiae* *Shimwellia blattae* were identified only in boiled egg, roasted maize and polony respectively.

The following five species of lactic acid bacteria were identified in the ready-to-eat street-vended foods: *Weissella cibaria* (boiled peanuts, cheese),

Leuconostoc citreum (gravy),

Leuconostoc mesenteroides (polony, mixed vegetable salad),

Lactobacillus florum (roasted maize) and

Lactococcus lactis (bean cake).

Other bacteria species identified were *Stenotrophomonas maltophilia*, *Serratia proteamaculans*, *Ralstonia pickettii* and *Terriglobus roseus* (Table 5.2.9).

Table 5.2.9: Bacteria identified in RTE street-vended foods

Genus	Bacteria species detected	Total no of foods types
Pseudomonas	*Pseudomonas aeruginosa* (cookies, coloured popcorn, boiled maize, atchaar, samoosa, chicken stew, chicken gizzard, chicken neck, fried hake, fried snoek, cheese) *Pseudomonas japonica* (kota)	12
Bacillus	*Bacillus atrophaeus* (wheat biscuit); *Bacillus subtilis* (local bread, coloured popcorn); *Bacillus pimulus* (roasted maize, beef stew, chicken stew, chicken neck, fried snoek)	8
Escherichia	*Escherichia vulneris* (local bread, bean cake, boiled shelled peanuts, coloured popcorn, melon soup, stewed cow's leg)	6
Stenotrophomonas	*Stenotrophomonas maltophilia* (local bread, cookies, atchaar, stewed cow's leg, kota)	5
Ralstonia	*Ralstonia pickettii* (coloured popcorn, mixed vegetable salad, polony, stewed cow's leg, boiled egg)	5
Pantoea	*Pantoea ananatis* (roasted maize, coloured popcorn, beef stew)	3
Weissella	*Weissella cibaria* (boiled peanuts, cheese)	3
Citrobacter	*Citrobacter freundi* (boiled peanut, beef stew, boiled egg)	3
Leuconostoc	*Leuconostoc citreum* (gravy); *Leuconostoc mesenteroides* (polony, mixed vegetable salad)	3
Serratia	*Serratia proteamaculans* (chicken feet, boiled egg, fried snoek)	3
Lactobacillus	*Lactobacillus florum* (roasted maize)	1
Terriglobus	*Terriglobus roseus* (roasted maize)	1
Erwinia	*Erwinia billingiae* (roasted maize)	1
Burkholderia	*Burkholderia cenocepacia* (mixed vegetable salad)	1
Rubidibacter	*Rubidibacter lacunae* (stewed cow's leg)	1
Entomoplasma	*Entomoplasma luminosum* (beef stew)	1
Shimwellia	*Shimwellia blattae* (polony)	1
Enterobacter	*Enterobacter aerogenes* (boiled egg)	1
Renibacterium	*Renibacterium Salmoninarium* (chicken stew)	1
Delftia	*Delftia acidovorans* (fried snoek)	1
Lactococcus	*Lactococcus lactis* (bean cake)	1

5.2.4.9 INCIDENCE OF FOODBORNE PATHOGENS

Only 4% of the 304 cereals and grain-based food tested positive for the presence of foodborne pathogens. *L. monocytogenes* and *E. coli* were the only foodborne pathogens detected of which *L. monocytogenes* was the most frequently detected. *L. monocytogenes* was detected in boiled beans in all the 4 tested samples, bean cake and wheat biscuit in 2 out of 4 samples each and coloured popcorn and roasted maize in 1 out of 4 samples each. *E. coli* on the other hand was detected only in boiled beans in 3 out of 4 samples (Table 5.2.10).

Table 5.2.10: Incidence of foodborne pathogens; *E. coli*, *Salmonella* spp., *Staphylococcus aureus* and *L. monocytogenes* in cereals, grain and related street-vended foods

Food groups	**Incidence of foodborne pathogens**				
	Number of positive samples	*E. coli*	*Salmonella* spp.	*Staphylo-coccus aureus*	*L. monocyto-genes*
Cereals and grain-based foods					
Maize porridge (Pap)	0/16	0/4	0/4	0/4	0/4
Semolina porridge	0/16	0/4	0/4	0/4	0/4
Fried potato chips	0/16	0/4	0/4	0/4	0/4
Boiled rice	0/16	0/4	0/4	0/4	0/4
Fat cake (Amagwinya)	0/16	0/4	0/4	0/4	0/4
Vanilla flavoured cookies	0/16	0/4	0/4	0/4	0/4
Chocolate cake	0/16	0/4	0/4	0/4	0/4
Jollof rice	0/16	0/4	0/4	0/4	0/4
Bread	0/16	0/4	0/4	0/4	0/4
Bean cake	2/16	0/4	0/4	0/4	2/4
Roasted peanuts	0/16	0/4	0/4	0/4	0/4
Boiled peanuts	0/16	0/4	0/4	0/4	0/4
Coloured popcorn (Skopas)	1/16	0/4	0/4	0/4	1/4
Boiled beans without stew	7/16	3/4	0/4	0/4	4/4
Melon (Egusi) soup	0/16	0/4	0/4	0/4	0/4
Boiled maize	0/16	0/4	0/4	0/4	0/4
Roasted maize	1/16	0/4	0/4	0/4	1/4
Roasted shelled peanuts	0/16	0/4	0/4	0/4	0/4
Wheat biscuit	2/16	0/4	0/4	0/4	2/4
Total	13/304	3/76	0/76	0/76	10/76

Only 10% of the 368 meat, dairy, fish and related food samples tested positive for the presence of foodborne pathogens of which *L. monocytogenes* was the most detected. Beef sausage slices (polony) and fried beef derm had the highest incidence of *L. monocytogenes* as it was detected in 4 out of 4 tested samples, followed by cheese/egg burger, grilled chicken neck and fried hake in 3 out of 4 tested samples (Table 5.2.11).

Table 5.2.11: Incidence of foodborne pathogens; *E. coli*, *Salmonella* spp., *Staphylococcus aureus* and *L. monocytogenes* in meat, dairy, fish and other related street-vended foods

Food groups	**Incidence of foodborne pathogens**				
	Number of positive samples	*E. coli*	*Salmonella* spp.	*Staphylococcus aureus*	*L. monocytogenes*
Beef-based foods					
Beef sausage slices (Polony)	4/16	0/4	0/4	0/4	4/4
Stewed cow's leg	0/16	0/4	0/4	0/4	0/4
Beef stew	1/16	0/4	0/4	0/4	1/4
Fried beef derm	7/16	3/4	0/4	0/4	4/4
Beef broth	0/16	0/4	0/4	0/4	0/4
Fried beef tripe	4/16	2/4	0/4	0/4	2/4
Fried ox liver	0/16	0/4	0/4	0/4	0/4
Barbecued beef sausage (Wors)	0/16	0/4	0/4	0/4	0/4
Biltong	0/16	0/4	0/4	0/4	0/4
Samoosa	0/16	0/4	0/4	0/4	0/4
Kota	2/16	0/4	0/4	0/4	2/4
Hot dog	0/16	0/4	0/4	0/4	0/4
Dairy-based foods					
Gouda cheese	1/16	0/4	0/4	0/4	1/4
Cheese/egg burger	3/16	0/4	0/4	0/4	3/4
Poultry-based foods					
Grilled chicken gizzard	0/16	0/4	0/4	0/4	0/4
Boiled egg	3/16	1/4	0/4	0/4	2/4

Fried chicken	0/16	0/4	0/4	0/4	0/4
Chicken stew	2/16	1/4	0/4	0/4	1/4
Grilled chicken feet	2/16	0/4	0/4	0/4	2/4
Grilled chicken neck	3/16	0/4	0/4	0/4	3/4
Omelette	0/16	0/4	0/4	0/4	0/4

Fish-based foods					
Fried hake	3/16	0/4	0/4	0/4	3/4
Fried snoek	3/16	1/4	0/4	0/4	2/4
Total	38/368	8/92	0/92	0/92	30/92

Only 0.05% of the 64 fruit, vegetable and related food samples tested positive for the presence of foodborne pathogens and *L. monocytogenes* was the only foodborne pathogens detected. The foods implicated were chakalaka and mixed vegetable salad. None of the food samples tested positive for the presence of *Salmonella* spp. and *Staphylococcus aureus* (Table 5.2.12). Overall, boiled beans, fried beef derm, fried beef tribe, boiled egg, chicken stew and fried snoek had samples that tested positive for both *L. monocytogenes* and *E. coli*.

Table 5.2.12: Incidence of foodborne pathogens; *E. coli*, *Salmonella* spp., *Staphylococcus aureus* and *L. monocytogenes* in fruit, vegetable and related street-vended foods

Food groups	**Incidence of foodborne pathogens**				
	Number of positive samples	*E. coli*	*Salmo-nella spp*	*Staphylo-coccus aureus*	*L. monocyto-genes*
Fruit- and vegetable-based food					
Spinach vegetables, onion, tomato mixture (Gravy)	0/16	0/4	0/4	0/4	0/4
Atchaar	0/16	0/4	0/4	0/4	0/4
Chakalaka	2/16	0/4	0/4	0/4	2/4
Mixed vegetable salad	1/16	0/4	0/4	0/4	1/4
Total	3/64	0/16	0/16	0/16	3/16

5.2.5 DISCUSSIONS

5.2.5.1 TOTAL AEROBIC COUNTS (TACS)

The food samples studied represent the different varieties of foods sold on the streets of the Johannesburg metropolis, South Africa. Looking at the TAC results, boiled rice and jollof rice were the only cereals and grain-based foods that had no growth on PCA throughout the study. An explanation for this could be that these foods were sufficiently cooked and held at appropriate holding temperatures above 60 ℃ (El-Sherbeeny et al., 1985; Muyanja et al., 2011).

The TAC for the cereals and grain-based foods ranged from $0.3*10^2$ to $0.4*10^5$ cfu/g. These counts are below the maximum limits ($5*10^5$ cfu/g) prescribed by the European Commission Regulation, regarding TAC microbial criteria for food testing (European Commission Regulation, 2005). Furthermore, the fact that only close to 32% food samples of the114 analysed had TACs above 10^4 cfu/g implies that the vast majority of street-vended foods had acceptable microbial levels at the time of purchase. This could be attributed to good sanitary practices, adequate cooking and holding temperatures by street food handlers.

This finding was similar to that of a study conducted in Bloemfontein, South Africa (Lues et al., 2006), and in Bangalore, India (Das et al., 2010), in which street-vended food were found to contain total viable plate counts $<10^5$ cfu/g.

It was established that cooked ready-to-eat street-vended foods generally contained bacterial counts higher than those of uncooked foods (Mosupye and Von Holy, 2000). The contamination of ready-to-eat cooked street-vended food is principally due to cross-contamination because of poor personal and environmental hygiene, poor waste disposal systems, and exposure to dust, wind, fumes and flies (Liu et al., 2014). The subsequent growth of bacteria in food could be due to the warmth and rich nutrients in the food in which the organisms find themselves (Asiegbu et al., 2016). Furthermore, insufficient cooking, cooling, use of contaminated utensils, equipment and raw ingredients are other notable source of contamination (Kothe et al., 2015). In contrast to the findings of this study, unsatisfactory aerobic count levels have been found in some street-vended food in Hong Kong; 1.97-6.84

log cfu/g (Ng et al., 2013), Korea; 0-7.43 log cfu/g (Cho et al., 2011) and Portugal; > 10^5 cfu/g (Campos et al., 2015).

Chocolate cake and coloured popcorn (skopas), followed by vanilla flavoured cookies, local bread, bean cake, roasted peanuts, melon soup, boiled maize, roasted maize and wheat biscuits were the most frequently contaminated of all the cereals and grain-based food in this study. This might be attributed to risk factors such as poor hygiene practices by the food vendors and cross-contamination during food handling, preparation, serving or display as some street foods, such as snacks, roasted or boiled maize and peanuts are commonly displayed uncovered from environmental and human contamination. Unfortunately, the uncovering of these foods and utensils promotes a real risk of contamination from dust (Muyanya et al., 2011). Moreover, the polyethylene material used for packaging may also contribute in contaminating street foods if they are not aseptically handled and stored. It is crucial that vendors clean their hands at short intervals for the purpose of minimising cross-contamination and recontamination (Mankee et al., 2003). Therefore, food vendors should be encouraged to use clean tongs, forks, spoons or disposable gloves when handling, serving or selling street food (Omemu and Aderoju, 2008).

The most frequently contaminated fruit- and vegetable-based products were spicy vegetable relish (chakalaka) spiced unripe mango pickle (atchaar) and mixed vegetable salad. This could be attributed to the fact that these foods undergo minimal processing, hence increasing the likelihood of bacteria proliferation. Contamination of minimally processed fresh (MPF) fruit and vegetables occurs at every stage of the food chain, from cultivation to processing (Nguyen-the and Carlin, 1994).

5.2.5.2 ENTEROBACTERIACEAE COUNTS

Enterobacteriaceae were detected in only 30% of samples for the cereals, grain, fruit- and vegetable-based foods as well as the meat- and dairy-based foods. Overall, only close to 3% of cereals, grain, fruit- and vegetable-based foods and 9% of meat- and dairy-based foods had Enterobacteriaceae counts $\geq 10^4$ which is an unacceptable limit for most regulatory agencies, such as Food Standard Australia New Zealand (FSANZ, 2001), Food Safety Authority, Ireland (2014), Centre for Food Safety, Hong Kong (2014). Nevertheless, the $\geq 10^4$ microbiological criteria do not apply to fresh fruit and vegetables or to sandwiches containing salad vegetables because fresh fruit and vegetables often carry high levels of these organisms as part of their normal flora (Gilbert et al., 2000).

The detection of unacceptable levels of Enterobacteriaceae in few of the samples analysed is of economic importance since Enterobacteriaceae are opportunistic pathogens that are responsible for majority of infections including that of the urinary tract (Livermore and Woodford, 2006).

Other studies have reported low Enterobacteriaceae contamination in foods. A study conducted on ready-to-eat street-vended food in the Porto region of Portugal, also reported counts that are generally below 10^4 cfu/g (Campos et al., 2015). Similarly, a study conducted on ready-to-eat foods and ready-to-bake frozen pastries from university canteens in Thessaloniki, Greece, detected Enterobacteriaceae at counts between 10^3 and 10^4 cfu/g in 35.3% of samples analysed (Kotzekidou, 2013). Furthermore, less than 30% of samples were found to contain unacceptable Enterobacteriaceae levels in plant-based foods obtained from food service establishments analysed (Sospedra et al., 2013).

The presence of Enterobacteriaceae in ready-to-eat food could be attributed to factors such as inadequate cooking, cross-contamination, poor hygiene practices and the use of contaminated water and/or ingredients at various stages of food preparation (Balzaretti and Marzano, 2013; Tabashsum et al., 2013). For fruit- and vegetable-based foods, exposure to various conditions during growth, harvest, preparation, packaging, display and sale creates conducive environments and opportunities for the contamination and growth of Enterobacteriaceae (Abadias et al., 2008). The low level of Enterobacteriaceae in the majority of samples could be attributed to adequate cooking and holding temperature at the point of sale.

5.2.5.3 LACTIC ACID BACTERIA COUNTS

Lactic acid bacteria are non-motile bacteria characterised by their capability to ferment sugar to lactic acid. They include Heterofermentative LAB of the *Carnobacterium*, *Leuconostoc* and *Weissella* genera, which are often involved in meat spoilage compared to the homofermentative *Lactobacillus* and *Pediococcus* genera (Swetwiwathana and Visessanguan, 2015). Cross-contamination of the final retail food products could be responsible for the high incidence of LAB present in the street food groups, which are susceptible to fermentation (Pothakos et al., 2015; Dušková et al., 2016).

Meat- and dairy-based foods had higher LAB level counts above 10^4 cfu/g with the beef sausage slices (polony) sample having the highest counts $0.7{*}10^6$ cfu/g. According to Dušková et al. (2016), lactic acid bacteria are known as the main bacterial group associated with the spoilage of thermally processed meat products. In sausage fermentation, lactic acid bacteria contribute to texture formation and in the acid taste (Landeta et al., 2013). Even so, the presence of high LAB communities does not necessarily result in quality defects (Pothakos et al., 2015).

LAB microflora forms part of the normal flora in cheese and plays an important role in the acidification of curd, as well as in other physical and chemical transformations that affect the curd development and flavour in cheese, hence an explanation for the high LAB count in Gouda cheese slices and cheese/egg burger (Gala et al., 2008).

5.2.5.4 PRESENCE OF FOODBORNE PATHOGENS IN READY-TO-EAT STREET-VENDED FOODS

Only 4% of the 304 cereals and grain-based foods, 10% of the 368 meat-, dairy- and fish-based foods and 5% of the 64 fruit- and vegetables-based foods tested positive for the presence of foodborne pathogens. This is an indication of a low incidence of foodborne pathogens in the street-vended foods analysed. This is contrary to a study conducted in Dhaka, Bangladesh, in which 41 to 100% school-based street foods were found to contain unacceptable (102 cfu/100g) levels of foodborne pathogens (Al Mamun et al., 2013). The reason behind the different result when compared to the Bangladesh study may be attributed to the type of food sampled, sampling technique and method of food storage, processing, handling and display.

L. monocytogenes and *E. coli* were the only foodborne pathogens detected of which *L. monocytogenes* was most frequently detected. However, the virulence of the *E. coli* isolated in this study was not tested. *L. monocytogenes* is a facultative anaerobic bacterium, capable of surviving in the presence or absence of oxygen as well as growing in adverse environmental conditions, hence the high probability of cross-contamination during the handling of food (Yu and Jiang 2014). The presence of *L. monocytogenes* and *E. coli* in boiled beans, fried beef derm, fried beef tripe, boiled egg, chicken stew and fried snoek could only be attributed to post contamination of these pathogens during food handling. This is because high cooking temperatures, which usually exceed 80°C, can kill vegetative forms of most bacteria, including foodborne pathogens (Mosupye and Von Holy, 2000). *L. monocytogenes* and *E. coli* are commonly found in soil, water, plant matter, animals and humans; they can easily recontaminate previously safe foods of animal origin (Gebretsadik et al., 2011; Lambertz et al., 2012). The relatively high prevalence of *L. monocytogenes* in the examined food samples is a cause for concern considering that it is the causative agent of listeriosis and can cause gastroenteritis, sepsis, meningitis, and abortion in pregnant women (Yang et al., 2016).

None of the food samples tested positive for the presence of *Salmonella* spp. and *Staphylococcus aureus*. Since the human body is the normal ecological habitat of *Staphylococcus aureus*, their non-detection in this study indicates good hygiene practices by the street food vendors. This is similar to previous studies conducted by Campos et al. (2015), in which *Salmonella* spp. and *Staphylococci* spp. were not detected in any of the ready-to-eat street-vended food in Portugal. In another study, Nyenje et al. (2012) also reported that *Salmonella* spp. was not present in any of the street food samples investigated in South Africa.

5.2.5.5 IDENTIFICATION OF TOTAL AEROBIC COUNT BACTERIAL ISOLATES

The genus detected the most in the different street-vended foods was *Pseudomonas*, followed by *Bacillus*, *Escherichia* and *Ralstonia*. Unlike *Ralstonia* and *Escherichia* species, *Pseudomonas* and *Bacillus* species are psychrotroph, which are ubiquitously distributed in water, soil, plant and animal environment, thus, explaining their prevalence in street-vended foods (Rajmohan et al., 2002).

5.2.5.5.1 *Pseudomonas aeruginosa*

The detection of *Pseudomonas aeruginosa* in vanilla flavoured cookies, coloured popcorn, boiled maize, atchaar, samoosa, chicken stew, chicken gizzard, chicken neck, fried hake, fried snoek and cheese may be attributed to cross-contamination during handling especially biofilms from food contact surfaces such as cooking utensils, tables or vendor's hands to food. *Pseudomonas aeruginosa* is widely recognised as a ubiquitous bacterium with minimum survival requirements and adaptability potentials to survive extreme environmental situations often due to biofilm formation (Casanovas-Massana et al., 2010; Adetunji et al., 2014). The high prevalence of *Pseudomonas aeruginosa* in these foods could pose public health risks since they have been implicated as contributors to food spoilage and foodborne diseases including pneumonia, urinary tract infections, wound and burn infections, bacteraemia and septicaemia in susceptible hosts (Weiser et al., 2014).

5.2.5.5.2 *Bacillus* species

The high prevalence of *Bacillus* spp. is attributed to their ability to produce endospores that can survive extreme environmental conditions (Kotzekidou, 2013). *Bacillus atrophaeus* are non-pathogenic bacteria that are virtually identical to *Bacillus subtilis* except for the production of a pigment on media containing an organic nitrogen source (Burke et al., 2004). Spores of *B. subtilis* have been found to be able to germinate in the gastrointestinal tract of animals upon ingestion (Tam et al., 2006). *B. pumilus* can cause infections, ranging from skin infection to life threatening bacteraemia in immunocompromised individuals (Parvathi et al., 2009).

5.2.5.5.3 *Ralstonia* species

The presence of *Ralstonia* species are likely due to environmental contamination and/or inadequate hygiene practices particularly with regards to food contact surfaces since they are primarily environmental organism with strong potential for surviving harsh environmental conditions through formation of biofilms (Ryan et al., 2011). *Ralstonia pickettii* is a non-fermenting gram-negative bacillus that can create a significant problem in clinical settings, being a widespread cause of nosocomial infections (Ryan et al., 2005).

5.2.5.5.4 Enterobacteriaceae

The Enterobacteriaceae are natural habitants of a wide variety of environments including human and animal gastrointestinal tract and they are causative agents of many foodborne infections in humans (Wawire et al., 2013). *Escherichia* species like most other Enterobacteriaceae are often ingested by the consumption of foods, which has been contaminated by human and/or animal faeces, especially via water sources (Kostyla et al., 2015).

Seven species belonging to the Enterobacteriaceae family were identified and they include *Escherichia vulneris*, *Pantoea ananatis*, *Citrobacter freundi*, *Serratia proteamaculans*, *Enterobacter aerogenes*, *Erwinia billingiae* and *Shimwellia blattae*. *Pantoea ananatis* has been found to cause disease in to a wide range of economically important agricultural crops and forest tree species worldwide and it is regarded as an emerging pathogen based on the increasing number of reports of diseases occurring on previously unrecorded hosts in different parts of the world (Coutinho and Venter, 2009).

Citrobacter freundi is often considered as a commensal in the intestinal tracts of both humans and animals and some isolates have acquired virulence traits and have caused diarrhoea and other infections in humans (Bai et al., 2012). *Serratia proteamaculans* has been found not to be capable of causing diseases (Stock et al., 2013).

Shimwellia blattae has been isolated from the hindgut of a cockroach and has been found not to be pathogenic to humans (Brzuszkiewicz et al., 2012). *E. billingiae* are epiphytic and are common agent of hospital-acquired infection, which when resistance to β-lactam antibiotics, they results to a high fatality rate among infected patients (Thiolas et al., 2005; Kube et al., 2010).

Contamination of irrigation water has been associated with the prevalence of faecal indicator bacteria in agricultural produce especially during seasons of heavy rainfall because of poor quality water (Holvoet et al., 2014). Hence, an explanation for the presence of *Escherichia vulneris* in the street food samples analysed. *Escherichia vulneris*, which is an environmental organism that colonises humans and animals, especially human wounds, was very prominent in the street-vended foods (Kilani et al., 2008).The high prevalence of *Escherichia* in street-vended foods could be attributed to cross-contamination because of poor hygiene practices at various stages of food preparation (Balzaretti and Marzano, 2013; Tabashsum et al., 2013).

Therefore, the detection of these organisms in this study is of great significance from a food safety point of view and in terms of the public health risk posed by them.

5.2.5.5.5 Lactic acid bacteria

Most of the LAB identified, were not renowned probiotic bacteria and this could be attributed to the fact that most of the street-vended food analysed were not the ideal medium of growth and survival of probiotic bacteria (Saarela et al., 2000). Nevertheless, *Weissella cibaria* has been found to possess probiotic properties, which include anticancer activity, immune modulating activity, anti-inflammatory activity and antioxidant activity (Kwak et al., 2014). LAB play an important role in the food fermentation process through formation of acids such as lactic acid, hence are important for their antimicrobial effect and sensory development properties (Cizeikiene et al., 2013). *Leuconostoc citreum* and *Leuconostoc mesenteroides* have been associated with kimchi fermentation (Choi et al., 2003). Strains of *Lactobacillus florum*, which can metabolise citrate, have been isolated from South African grape and wine samples (Mtshali et al., 2012). *Lactococcus lactis* is a non-pathogenic lactic acid bacterium that is most commonly used in a cheese starter and it occupies a niche related to plant or animal surfaces and the animal gastrointestinal tract (Bolotin et al., 2001).

5.2.6 CONCLUSION

The results of this study revealed that the TACs of the tested food samples were within acceptable levels with counts ranging from $0.3{*}10^2$ - $0.5{*}10^5$ cfu/g; Enterobacteriaceae counts ranged from $0.1{*}10^2$ - $0.5{*}10^5$ cfu/g, while lactic acid bacteria counts ranged from $0.5{*}10^2$ - $0.7{*}10^6$ cfu/g. However, lactic acid bacteria counts were higher in the different food groups analysed when compared to other bacteria groups.

On the whole, L. *monocytogenes* and *E. coli* were the only foodborne pathogens detected, of which *L. monocytogenes* had the highest prevalence. It can then be concluded that the presence of *L. monocytogenes* and *E. coli* in the analysed street-vended food samples could be as a result of defective handling and storage practices and/or poor hygiene practices by vendors. Nevertheless, none of the food samples tested positive for the presence of *Salmonella* spp. and *Staphylococcus aureus*.

Overall, this study demonstrated that the majority of ready-to-eat street-vended foods sold in Johannesburg were within acceptable food safety limits.

CHAPTER 6: GENERAL CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

Safe food is essential to life, not only for good health, but also because contaminated food strains health facilities and poses economic risks in affected communities. Therefore, it is imperative to assess and understand consumers' food safety awareness levels, because a large number of people eat daily meals outside their home. Consequently, they could be exposed to foodborne illnesses that could originate from shebeens, restaurants, street stalls and other food outlets.

This study had the primary objective of investigating the food safety knowledge, attitude and practice of street food consumers in Johannesburg. It also had the objective of determining the bacteriological status of the diversity of selected street foods in various areas of Johannesburg.

The results of the present study showed that street-vended food consumers in Johannesburg had an acceptable knowledge level of food safety awareness and attitudes, but an unsatisfactory knowledge level of foodborne pathogens. This emphasises the need for improvement through creating awareness on microbial food hazards.

The study further demonstrated that although some street-vended food consumers doubt the safety of street foods, they are not deterred from consuming these foods. Gender, race, level of education and monthly income were the factors that affected the ways consumers perceived the safety of street-vended foods and their desire to purchase them.

The results also highlighted the presence of low counts of bacteria, excluding lactic acid bacteria, which were detected in higher counts. In addition, the occurrence of two pathogens (*L. monocytogenes* and *E. coli*) was found in this study. This raises some serious health concerns and points out to the need for improvement on food handling and hygiene practices, despite the non-detection of *Salmonella* spp. and *Staphylococcus aureus* observed throughout this study.

A limitation of this study was that it relied on self-reported claims, a method known to be subject to reporting bias, therefore implementing observational studies would allow for validation of these results and a more accurate representation of consumer food safety knowledge and attitudes.

Another limitation was that the number of street food samples analysed were insufficient due to sampling limitations such as time and resources.

6.2 RECOMMENDATIONS

Based on the findings from the food safety knowledge study, we recommend that consumer food safety awareness intervention strategies should cover awareness on food pathogens microbiology and hazards associated with microbial contamination of foods so that the public are greatly informed about food safety when they purchase, handle and consume foods. Additionally, a comprehensive food safety programme should be designed to target street food vendors and shebeen food vendors considering food safety awareness alone might still not deter consumers from purchasing street-vended foods.

Based on the findings of the bacteriological diversity study, we recommend the need for a structured framework aimed at improving and sustaining the food safety practices of food vendors via implementation of strict food safety laws and infrastructural development especially at street vending sites. Food safety and quality control measures also need to be strengthened, for example through regular monitoring and inspections. There is further need to educate street food vendors and consumers continuously on appropriate food handling, preparation and safe storage practices.

Future research work investigating the sanitary and hygiene conditions of street food vendors at the point of sale will be beneficial in clarifying issues relating to vendors' food safety practices, and can assist with interventions to tailor food safety messaging to those vendors who most likely need them.

Moreover, investigations on the presence of other pathogens such as *Clostridium perfringens*, *Campylobacter jejuni*, *Bacillus cereus*, *Vibrio cholerae* and *Shigella* in street foods should be assessed; their contamination levels and routes of transmissions in street foods should also be analysed, since it will contribute significantly in the control and/or prevention of any future outbreaks.

Lastly, future studies should develop research methodologies based on this present survey in order to benefit from the existing baseline knowledge and to allow comparisons over time to assess the effectiveness of food safety interventions on the reduction of foodborne illnesses.

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APPENDIX A: RESEARCH INFORMATION SHEET

Department of Life and Consumer Sciences

School of Agriculture and Life Sciences

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Private Bag X6

FLORIDA

1710

RESEARCH INFORMATION

Title of the Research

The food safety knowledge and microbial hazards awareness of consumers of ready-to-eat-street-vended foods and their exposure to microbiological hazards.

Aims of the Research

The aim of this study is to assess the level of food safety knowledge and microbial hazard awareness of consumers of street-vended foods in Johannesburg municipality. It also aims to determine the bacteriological quality of some selected street-vended foods in Johannesburg.

Significance of the Research Project

The findings of this research will give an insight on the current level of consumers food safety knowledge about street-vended foods sold in Johannesburg. It will also facilitate the development of an effective consumer education programme by the relevant government departments as well as to emphasise, if there is need, to target a specific consumer group as a potent means of curbing foodborne diseases. As a result, the burden on public health system will be minimised and the heavy economic cost incurred by government and the public daily, due to foodborne diseases, will be significantly reduced.

Additionally, the findings from this research will play a positive role in addressing public health safety and food security through the demonstration of the likely presence of food pathogens. It will also indicate if there is necessity to implement strict food safety measures. This in turn will minimise health risks and the mortality rate associated with street foods, especially among vulnerable groups, and it will significantly boost their economic growth.

Thank you for taking the time to read this information.

[Asiegbu Chioma Vivian] **(Researcher)**

[Dr FT Tabit] **(Supervisor)**

APPENDIX B: CONSENT FORM

CONSENT FORM

TITLE OF RESEARCH PROJECT

THE FOOD SAFETY KNOWLEDGE AND MICROBIAL HAZARDS AWARENESS OF CONSUMERS TO READY-TO-EAT STREET-VENDED FOODS AND THEIR EXPOSURE TO MICROBIOLOGICAL HAZARDS

Dear Mr/Mrs/Miss/Ms ______________________________ Date....…/..…...../20......

***************NB: To be signed by each participant*****************

NATURE AND PURPOSE OF THE STUDY

The aim of this study is to assess the level of food safety knowledge and microbial hazards awareness of consumers of street-vended foods in Johannesburg municipality. It also aims to determine the bacteriological quality of some selected street-vended foods sold in Johannesburg.

For this purpose, a trained researcher will interview respondents face-to-face using a structured questionnaire. The questionnaire will capture data on demographics and consumers' food safety knowledge in relation to ready-to-eat street-vended food and participants will be expected to complete the questionnaire, which will take about 25 minutes to complete. The research study will identify gaps in food safety knowledge and microbial hazard awareness among consumers of street-vended foods in Johannesburg.

RESEARCH PROCESS

This research will take place at various street food vending sites in different neighbourhoods of Johannesburg municipality.

There will be two sessions for each day and data gathering session will last for about four hours per session; twenty five minutes for each respondent at one sitting. Research sampling will be formed from 20 street food-vending points at various neighbourhoods in Johannesburg city. The questionnaire instrument consists of five sections: socio-demographic, confidence in-and reasons for purchasing street-vended foods, food safety hazard awareness, food safety attitude toward street-vended foods and microbial food safety hazard awareness will be used to collect data. Respondents will fill in the questionnaire or be interviewed when necessary at their own convenience.

NOTIFICATION THAT TAPE RECORDINGS WILL BE REQUIRED

Tape recording may be used when deemed necessary by the researcher.

CONFIDENTIALITY

Your ratings and assessments of any of the research instruments as well as your opinions are viewed as strictly confidential, and only members of the research team will have access to the information.

No data published in dissertations and journals will contain any information by means of which you may be identified. Your anonymity is therefore ensured.

WITHDRAWAL CLAUSE

I understand that I may withdraw from the study at any time. I therefore participate voluntarily until I request otherwise.

POTENTIAL BENEFITS OF THE STUDY

The findings of this research will be beneficial to the South African public in the sense that the relevant government department will draw conclusion from the results and act accordingly.

FURTHER INFORMATION

If there is any question concerning this study contact DR Frederick Tabit on 0114712080, Department of Life and Consumer Sciences, UNISA.

CONSENT

I, the undersigned, ………………………………………………………………….… (full name) have read the above information relating to the project and have also heard the verbal version, and declare that I understand it. I have been afforded the opportunity to discuss relevant aspects of the project with the project leader, and hereby declare that I agree voluntarily to participate in the project.

I indemnify the university and any employee or student of the university against any liability that I may incur during the course of the project.

I further undertake to make no claim against the university in respect of damages to my person or reputation that may be incurred because of the project/trial or through the fault of other participants, unless resulting from negligence on the part of the university, its employees or students.

I have received a signed copy of this consent form.

Signature of participant:...................................at (place)…………………on ……/……/2014

WITNESSES

1 .... 2 ....

APPENDIX C: QUESTIONNAIRE

QUESTIONNAIRE

Mark an **x** in the column containing your response

Section 1: Socio-demographics of respondents

1 Gender

Male	Female
2	1
☐	☐

2 Age (years)

18-26	27-35	36-44	45-53	54-62+
5	4	3	2	1
☐	☐	☐	☐	☐

3 Ethnicity

Black	White	Coloured	Indian/Asian
4	3	2	1
☐	☐	☐	☐

4 Marital status

Married	6	☐
Unmarried - living with a partner	5	☐
Unmarried - living without a partner	4	☐
Divorced	3	☐
Widowed	2	☐
Separated	1	☐

5 What is your average monthly income?

Less than R5000	R5001-R10000	R10001-R15000	Above R15000
4	3	2	1
☐	☐	☐	☐

6 How do you generate your income?

Salary - permanent	8	☐
Salary - temporary	7	☐
Social grants	6	☐
Street vending	5	☐
Casual work	4	☐
Student	3	☐
Housewife	2	☐
Unemployed	1	☐

7 What best describes your level of education?

No formal education	5	☐
Junior primary education	4	☐
Senior primary	3	☐
Secondary education	2	☐
Tertiary education	1	☐

Section 2: Confidence in and reasons for purchasing and consuming street-vended foods

1 How often do you buy ready-to-eat street-vended foods?

Always	Often	Rarely	Never
4	3	2	1
☐	☐	☐	☐

2 How confident are you in the safety of ready-to-eat street-vended foods?

Always	Often	Rarely	Never	No Idea
5	4	3	2	1
☐	☐	☐	☐	

3 Which of the following is the main reason for buying ready-to-eat street-vended foods?

Just the food type I prefer	6	☐
Better taste	5	☐
It is the affordable	4	☐
Easily accessible	3	☐
Liked by my household members	2	☐
Others	1	☐

Section 3: Food safety hazard awareness of street-vended food consumers

1 How concerned are you, in the safety of street-vended foods in terms of the following?

Variables	Always	Often	Rarely	Never	Uncertain
	5	4	3	2	1
Bacterial contamination	☐	☐	☐	☐	☐
Fungi contamination	☐	☐	☐	☐	☐
Lead, mercury and aluminium contamination	☐	☐	☐	☐	☐

2 How often do get worried about foodborne illnesses when you buy ready-to-eat foods from the following outlets?

Variable	Always	Often	Rarely	Never	Uncertain
	5	4	3	2	1
Supermarket	☐	☐	☐	☐	☐
Street food market	☐	☐	☐	☐	☐
Restaurant	☐	☐	☐	☐	☐
Shebeen	☐	☐	☐	☐	☐

Section 4: Attitude on the sale and purchase of ready-to-eat street-vended food from different outlets

1 To what extent do you agree with each of the following statements regarding the sale of foods?

Variable	Strongly disagree	Disagree	Neutr al	Agree	Strongly agree
	5	4	3	2	1
I do not always think about food safety when buying ready-to-eat street-vended food.	☐	☐	☐	☐	☐
I am certain I cannot get foodborne illnesses when I eat ready-to-eat street vended food.	☐	☐	☐	☐	☐
Ready-to-eat street-vended foods are cheaper than ready-to-eat foods sold in supermarkets and restaurants.	☐	☐	☐	☐	☐

Section 5: Microbial food safety hazards awareness of street-vended food consumers

1 Which of the following in your own in opinion is the most important food safety issue nowadays?

Presence of allergens	5	☐
Foodborne diseases caused by bacteria	4	☐
Sale of expired food	3	☐
Unknown food sources	2	☐
Too much junk foods	1	☐

2 Are you aware that certain foodborne bacteria can cause diseases that may lead to death?

Very aware	Aware	Not aware
3	2	1
☐	☐	☐

3 Have you ever heard of *Escherichia coli*?

YES	NO
1	0
☐	☐

4 Have you ever heard of *Salmonella*?

YES	NO
1	0
☐	☐

5 Have you ever heard of *Campylobacter jejuni?*

YES	NO
1	0
☐	☐

6 Have you ever heard of *Listeria monocytogenes?*

YES	NO
1	0
□	□

THANK YOU FOR YOUR PARTICIPATION