Participatory risk analysis of street vended chicken meat sold in the informal market of Pretoria, South Africa

By

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Submitted in partial fulfilment of the requirements of the degree of Philosophiae Doctor (PhD) in the Department of Paraclinical Sciences, Faculty of Veterinary Sciences, University of Pretoria

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Informal food outlets at a taxi rank in one of the suburbs of Tshwane

"Some is known and much is assumed when talking about street food and street food vendors…." (FAO, 2012)

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DEDICATION

This work is dedicated to the following:

- Firstly in memory of three very important people who helped shape my life, but are not here to celebrate this achievement with me:
    - My father (**Mr William, W. Muruya, Oguttu**), who taught me the value of education, and right from an early age instilled in me a work ethic and desire to study. This achievement would have brought much joy to him he had been here to see me reach another milestone.
    - My late paternal grandmother (**Mrs Faith, Najjabi, Muruya**), who sacrificed so much and ensured that her three sons (**William, W. Muruya, Oguttu; John, Muruya, Mageni; and James, Muruya, Oundo**) were educated. This paved a way for my siblings and I to get an education. I will forever be grateful for her foresightedness.
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    - To my children (**Jonathan, Abigail** and **Timothy**) for the sacrifice on their part that allowed me to be away for long hours in the field and laboratory, plus the ceaseless prayers they (notably **Timothy**) said for me.
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Above all, this work is dedicated to my Heavenly Father – the giver of wisdom – to whom all the glory and honour are due. Without His divine grace, this work would not have been accomplished.

DECLARATION

I **James Wabwire Oguttu**, declare that this thesis, which I hereby submit for the degree Philosophiae Doctor (PhD) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other university.

Signed:

Date: 30 March 2014

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS USED IN THE TEXT

ALOP:	Acceptable Level of Protection
AHT:	Animal Health Technicians
CAC:	Codex Alimentarius Commission
CBD:	Central Business District
CP:	Control Point
CCP:	Critical Control Point
EFSA:	European Food Safety Authority
EHO:	Environmental Health Officer
EPA:	United States Environmental Protection Agency
EU:	European Union
FAO:	Food and Agriculture Organization
FSO:	Food Safety Objectives
HACCP:	Hazard Analysis and Critical Control Point
ICMSF:	International Commission on Microbiological Specifications for Foods
IUM-ICFMH:	International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene
KZN-DOH:	Kwa-Zulu Natal Department of Health
MC:	Microbial Criteria
NACMCF:	National Advisory Committee on Microbiological Criteria for Foods
NRI:	Natural Resources Institute
NRIL:	National Resources International limited
OIE:	World Organisation for Animal Health
PC:	Performance Criteria
PO:	Performance Objectives
SAVC:	South African Veterinary Council
SE:	Staphylococcal enterotoxins
SFP:	Staphylococcal food poisoning
SMEs:	Small and Micro-Enterprises
WHO:	World Health Organization

PUBLICATIONS

a) Full articles published from thesis

- **Oguttu, J. W**., McCrindle, C.M.E., Makita, K., Grace, D. (2014). Investigation of the food value chain of ready-to-eat chicken and the associated risk for staphylococcal food poisoning in Tshwane, Metropole, South Africa. Food Control 45: 97-94, http://dx.doi.org/10.1016/j.foodcont.2014.04.026

b) Abstracts from thesis presented at conferences and/or seminars

- **Oguttu, J.W**., McCrindle, C.M.E., Makita, K, Grace D. (2013). Investigation of food value chain and associated risk for staphylococcal food poisoning due to consumption of ready-to-eat chicken sold by informal vendors in Tshwane, South Africa. 94th CRWAD Annual meeting, Chicago, IL, USA. December 8, 9, & 10 2013.
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- **Oguttu, J.W**., McCrindle, C.M.E., Fasina, F.O., Grace, D. (2014). Predictors for contamination of informally traded ready-to-eat (RTE) chicken with generic (Biotype I) *Escherichia coli*. 95th CRWAD Annual meeting, Chicago, IL, USA. December 7, 8, & 9 2014.
- **Oguttu, J.W**., McCrindle, C.M.E., Fasina, F.O., Grace, Delia. (2014). Contamination of ready-to-eat chicken sold by informal vendors: What are the risk factors? Seminar presentation: Epidemiology group meeting, University of Tennessee, TN, USA. December 10th 2014.

c) Chapter in a book published from thesis

- **Oguttu, J**., Roesel, K., McCrindle, C., Hendrickx, S., Makita, K. & Grace, D. (2015), "Arrive alive in South Africa: chicken meat the least to worry about" in *Food safety and Informal Markets: Animal products in sub-Saharan Africa*, eds. K. Roesel & D. Grace, Routledge, Oxford, UK, pp. 206.

SUMMARY

Title: Participatory risk analysis of street vended chicken meat sold in the informal market of Pretoria, South Africa

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Degree: Philosophiae Doctor (PhD)

Background and motivation

Informal food vending has many benefits that range from food security for the urban poor, to contribution to local economies. Yet, the street food sector is not recognized and is treated as a major public health risk. This is based partly on perceptions of local authorities that street food vendors are undesirable, or are a temporary phenomenon that will disappear in due course as a result of development. Moreover, a number of studies have documented contamination of street foods with pathogenic microorganisms like *Staphylococci aureus* and enteric organisms. The former can grow and express virulence in foods such as meat and meat products post cooking. To date no participatory risk analysis methods have been applied to informal markets in Tshwane, to study the food value chain of ready-to-eat (RTE) chicken and quantify the risk of exposure to selected foodborne diseases, or to determine predictors for contamination of RTE chicken sold by informal vendors.

Methodology

A cross-sectional analytical study design was adopted to achieve the objectives of the present study. The study area was city of Tshwane, Gauteng Province, South Africa. The study population was informal vendors selling RTE chicken to commuters at taxi and bus stations and the sampling design involved cluster sampling. Markets were the sampling units and the informal vendors the units of concern. All clusters (n=13) that were identified were included in the study and all informal vendors located within the markets were invited to be part of the study. A total of 237 vendors agreed to be interviewed, have checklists filled in for their vending stalls, and provided a sample of RTE chicken (n= 237) for laboratory analysis. Participatory Risk Analysis, a novel approach to understanding food safety in data scarce

environments, was used to collect data for analysis. Participatory research methods employed in this study included: check-lists and structured interviews with informal vendors, proportional piling and focus group discussions. Enumeration of bacterial colonies from RTE chicken samples was performed using 3M™ Petrifilm™ plates (3M, St. Paul. Mn, USA). Data for the demographic profile of vendors (n=237) was analysed using descriptive statistics to establish means and proportions. Thematic analysis combined with descriptive statistical analysis was used to establish and quantify the food value chain of informally traded RTE chicken. Stochastic risk analysis using @Risk 4.5 (Palisade Corp., Ithaca, N.Y.), was used to estimate the risk of staphylococcal food poisoning from consumption of street-vended RTE chicken. Univariable and multivariable regression models were developed using Stata 9.0 (StataCorp, College Station, Texas, USA) to determine predictors for contamination of RTE chicken with *E. coli* and coliform bacteria respectively.

Results

The majority of vendors in the markets studied were females (92%), and were between 25-50 years of age. Very few young people (< 25 years) were involved. More than half of the vendors (69.47%) ran the informal food outlet as a personal business. The minority were long term employees (15.04%) or were hired to help out for a short period of time (0.88%). A high level of literacy was observed among informal vendors. Assessment of hygiene practices showed a low level of compliance with regard to possession of a certificate of acceptance, washing of hands and utensils in the same container and controlling flies at the vending site.

The environment in which informal vendors operated was not conducive to production of safe food. This means that Key 1 of the WHO five keys to safer food that requires that food production takes place in a clean environment was violated. Contamination of RTE chicken was associated with the use of water collected and supplied in containers of questionable microbiological status. This was because vendors also violated Key 5 of the WHO five keys to safer food, which requires that raw materials, including water used to prepare food should be of a high microbiological quality. However, high compliance was observed with regard to the following aspects: not wearing jewellery while preparing food, using cutlery to pick up RTE chicken, washable floors (concrete slabs and cemented floors), use of potable municipal water, preparing food in a closed structure (temporary or permanent) and locating vending stalls within 30m from the toilets.

Four food value chains for RTE chicken, sold by informal vendors, were identified showing extensive cross-over from the formal to informal sector. This extensive cross-over, was corroborated by the fact that over 79.3% of the RTE chicken sold on informal markets in Tshwane metropolis, was sourced from formal markets such as supermarkets or wholesalers. The food value chain for RTE chicken was short, meaning that it involved very few stages from farm to fork. Furthermore the tendency was for the RTE chicken to be purchased, cooked and consumed the same day.

Although the prevalence of contamination of RTE chicken with *S. aureus* was high (44%), the risk of staphylococcal food poisoning was estimated to be only 1.3% (90% CI: 0% - 2.7%) for each meal of RTE chicken consumed. The mean *S. aureus* counts in the RTE chicken was $10^{3.6}$ (90% CI: $10^{3.3}$ – $10^{3.9}$). This level was lower than the 10^5 CFU/g needed to induce staphylococcal food poisoning. While contamination of RTE chicken with *E. coli* (6.32 %) was low, contamination with coliforms (23.21 %) was moderate. This suggests a moderate level of food hygiene. The fly population at the stalls where the RTE was on display, intermittent washing of hands, the location of the stall >30 m from the toilets and holding RTE chicken at <70 C were identified as important predictors of contamination with *E. coli*. Whereas, the use of potable toilets without hand washing facilities and poor hand washing practices were a positive predictor for contamination with coliforms.

Conclusions

The informal trade in food in Tshwane is dominated by women and for the majority of these vendors the informal trade in food, is the main source of employment. A risk communication strategy needs to take this into consideration. There is need for intervention to improve the hygiene in the informal markets and ensure that informal vendors observe the WHO five keys to safe food. The high level of literacy observed among informal vendors is good news, as it presents a situation of educated vendors; a fertile ground for initiatives aimed at improving their lives and the service they offer to their customers. There is neither a food policy aimed at ensuring food security for the urban poor nor evidence it is being implemented. This is supported by the high number of vendors operating in temporary structures. There is a need for the municipal authorities to intervene, to provide appropriate structures. Planning of new taxi ranks should include a proper food market, with facilities that meet the legal requirements for production of safe food. Informal vendors have demonstrated an awareness of the need to practice good food hygiene as proved by the compliance with certain hygienic food handling practices. The link between the formal and informal markets suggests that the informal market of RTE chicken is well-established with a reliable source of raw chicken. Furthermore, the strong inter-linkage between the formal and informal value chain for RTE chicken, further confirms the informal sector as a potential market for locally produced product. It also emphasizes its potential to impact on the economy of the city. In addition, this strong inter-linkage, suggests that the risks associated with the formal sector might be mirrored in the informal. Therefore, as the supermarket proliferation takes root in the rest of Africa, this food value chain and its associated risks might become the norm on the continent.

The present study shows that participatory risk analysis is a good way to obtain data on informal markets. Such data can then be subjected to quantitative microbial risk analysis using sophisticated biostatistical techniques, to determine and quantify the microbial risks. The low risk of staphylococcal food poisoning proved that despite the poor working conditions under which the informal food vendors prepare food, they are able to produce food that is unlikely to result in food poisoning. However, due to the high prevalence of contamination of RTE chicken with *S. aureus*, there is a need for the informal vendors in these markets to be trained to improve hygienic food handling practices. On the positive side, the present study demonstrated that high prevalence of contamination does not always translate into high risk. The relatively low to moderate level of contamination with *E. coli* and coliforms respectively, suggests a low risk of enteric foodborne diseases from ingestion of RTE chicken. Given that some and not all hygiene practices were significantly associated with contamination of RTE chicken, monitoring authorities should emphasise identified predicators to reduce the risk of contamination and the subsequent risk of contracting foodborne diseases. The difference in hygiene scoring highlights that the one-size-fits all approach to monitoring of informal markets may not be effective. These need to be tailored to suit the individual informal markets.

Key words: Participatory Risk Assessment, Ready-to-eat chicken, Staphylococcal foodborne poisoning, Foodborne diseases, Food safety, Predicators for contamination, Informal food markets.

CHAPTER 1

INTRODUCTION

1.1 Background

Informal markets and street vended foods are linked to access to affordable ready-to-eat (RTE) food by resource-poor groups in urban and peri-urban areas (Ekanem 1998, Codjia 2000, Estrada-Garcia et al. 2004, Barro et al. 2007, National Resources Institute 2011, National Resources International limited (NRIL) 2010, International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005, Dawson, Canet 1991). In South Africa, it is estimated that 98.9% of the people who patronize street food vendors are people of colour who form the majority of the urban poor in the country (Martins 2006).

Preparing and selling foods informally is universal and occurs in both developing and industrialised countries. However, the role played by foods sold on the informal markets differs between the developed and developing countries (Dawson, Canet 1991).

Worldwide, the informal food markets as small and micro-enterprises (SMEs) are increasingly recognized as role players in the creation of employment and income generation (Martins 2006, FAO 2012). Therefore, street food vending is an indispensable component of the food distribution system and is a major economic activity in many cities in developing countries (Codjia 2000, KZN-DOH 2001, Rane 2011, FAO 2012). This informal industry feeds millions of people each day through provision of RTE food. In addition, this informal trade impacts on agricultural production and the nutritional status of urban populations (Dawson, Canet 1991, Mensah et al. 2012, FAO 2012).

With rapid urban population growth, there has been a corresponding increase in the number of poor people living in the cities. It is estimated that between one-fourth and one-third of all urban households in the world live in poverty. In the next 10-15 years 50% of the world's population will be living and working in urban situations. Unfortunately, the formal sector of the economy cannot develop as quickly to match the growth rate of urbanization. This has led to informal markets emerging as a livelihood strategy for the many poor households who have migrated to the cities, but cannot be absorbed into the formal organized labour market (Division of Prevention and Control of Non-communicable Diseases (DNC) 2004, Martins 2006, Dawson, Canet 1991, FAO 2012). The result has been an increase in the demand for non-traditional services, which include self-employment and/or small scale income generating activities, both legitimate and illegitimate, which make up the informal sector, also called the tertiary sector or bazaar economy (Ekanem 1998, Khubeka, Mosupye & Von Holy 2001, Codjia 2000, Gadaga et al. 2008, Lues et al. 2006, Martins 2006, Rane 2011).

With the surge in urban populations, there has been an increase in the demand for convenient RTE food (Schelin et al. 2011, Badrie, Joseph & Chen 2011). In many developing countries, the main source of this food is the informal sector, especially street food vendors (Mensah et al. 2012, Badrie, Joseph & Chen 2011). In some cities on the African continent such as Abidjan, 20% of meals are taken outside of home and most of these are purchased from street vendors. In Ghana, it is reported that 40% of the total household food budget, is used to purchase street foods in the lowest expenditure quintile, with 2% in the high-income households (Division of Prevention and Control of Non-communicable Diseases (DNC) 2004). In Bamako, it was estimated that the household expenditure on street vended foods varied between 19 and 27% (FAO 2012).

The popularity of street foods can be attributed to availability near the places they are consumed, such as factories, schools and universities, transit points and market places (Dawson, Canet 1991, Badrie, Joseph & Chen 2011, Mensah et al. 2002, FAO 2012), and/or convenience (Rane 2011). The unique flavour is another reason street vended foods are popular (Rane 2011). Lack of proper housing and cooking facilities, in addition to increasing costs and the difficulty of procuring fuel, are additional reasons why street foods are becoming the alternative source of food for urban dwellers. With more people joining the workforce and working far from home, street foods are the most accessible source of food (Dawson, Canet 1991). As more women start working outside the home to earn a livelihood, many hardly have time to cook and street foods provide a convenient source of nourishment (Dawson, Canet 1991). Other reasons explaining the popularity of street vended foods include: being able to provide variety to the different ethnic groups within cities (Dawson, Canet 1991); and street foods representing a unique source of healthy foods, especially fruits and vegetables for the under-privileged (FAO 2012). It can therefore be deduced that street vended foods play a role in both the cultural and social heritage of societies (Rane 2011, FAO 2012).

Growth in the informal markets has been fuelled by the fact that most developing countries have experienced faltering economic development, due to factors related to natural disasters, poor governance and unfair trade practices (Gadaga et al. 2008, National Resources International limited (NRIL) 2010). In Harare Zimbabwe, harsh economic conditions have made cooked food vending an industry, with more than 1,000 vendors identified around the city (National Resources International limited (NRIL) 2010).

In South Africa and elsewhere, food vending as a part of the informal sector, is a major contributor to job creation. It is estimated that 911,000 employment opportunities were generated in the informal sectors of South Africa, through innovations such as street vending, in contrast to just 40, 000 generated in the formal sector in 2001 (Lues et al. 2006). The street food sector is a significant contributor to employment, especially for women who often are the first victims of increased poverty (Ekanem 1998, Codjia 2000, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004, Lues et al. 2006, Rane 2011, FAO 2012). A study done in South Africa showed that the vast majority (90.5-98.5%) of the people involved in street food vending are females (Martins, Anelich 2000, Martins 2006). The street food industry is a vast business involving millions of people and employs a large sector of populations, which might otherwise be unemployed (Dawson, Canet 1991).

The informal sector employs millions of semi-skilled and unskilled workers (Dawson, Canet 1991). Generally in Africa, it is estimated that the informal food sector employs more than 37% of the labour force; and contributes about 38% to total GDP (FAO 2012). In Lusaka-Zambia, it is reported that informal food vendors employ over 16,000 people (National Resources International limited (NRIL) 2010). In Ghana a mini-census and a survey of 334 street vendors in Accra, revealed that the street food sector employed over 60,000 people (Codjia 2000). Reports (Dawson, Canet 1991) of employment in the street food industry showed that in Malaysia, 100,000 people were employed in the sector. In China, 1 million people are employed in various aspects of street vended food business. In countries like India, Nigeria, Indonesia, Thailand and Peru, it is known that large numbers of people work in the street food sector (Dawson, Canet 1991). Based on the National Policy for Urban Street Vendors/Hawkers, street vendors constituted approximately 2% of the population of a metropolis (Rane 2011). According to Cohen (1987), as cited in the publication "International activities in street foods" (Dawson, Canet 1991), in Senegal, while the street food sector employed 40,000 - 50,000 people, modern agribusiness and the food industry, provided only 6,800 jobs. It is estimated that in developing countries, employment related to street food vending makes up 6-25% of the total labour force (Dawson, Canet 1991).

The street food industry involves large amounts of money (Dawson, Canet 1991). For example, the yearly turnovers of $100 million have been recorded in Calcutta and Ghana, while in Cotonou a yearly turnover of $20 million has been reported for the street food vending trade (Codjia 2000, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004). In Lusaka-Zambia, informal vendors collectively made an annual profit of approximately £5.5 million, with individual profits ranging from £0.10 to £17 per day (National Resources International limited (NRIL) 2010). A study referred to by the Food and Agriculture Organization (FAO) (2012), showed that the majority of street food vendors who operated at night had an income that exceeded that of a secondary school teacher.

Studies on street food vendors in South Africa showed that street food vending is also a multi-million rand business. In 1994 it was estimated that 44.7 and 8 million rand respectively, were spent on street food outlets in Gauteng and the Western province. In 1998, over 18 million rand was spent on street vended foods in the Durban metropolitan area (Martins 2006, International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005). A study of food vendors showed that 99.5% indicated that their street food business was the main source of household income (Martins 2006).

In view of this, the informal food sector is regarded as a significant “economic crisis absorber” with potential to make a significant contribution to the urban economy, through its ability to provide decent income and employment for those who otherwise might have been unemployed (i.e., women and entire families) (National Resources Institute 2011, Codjia 2000, Dawson, Canet 1991). The income from street food vending is usually or often three to ten times higher than the prevailing minimum wage (Codjia 2000, Dawson, Canet 1991). A study (Martins 2006) in South Africa showed that the average net income for the informal street food vendors who participated was R1, 659, which at the time was 19% higher than the average minimum living wage level of R1, 389. In Penang, Malaysia, the net profit for street food workers was M$6.14 per day, which was higher than the minimum wage for food handlers. Studies done by FAO and Department of Human Nutrition (1987), as cited by Dawson and Canet (1991), showed that in Ecuador, 68% of the street food vendors earned the equivalent of, or more than, the minimum wage. In Nigeria, 74% of the vendors made the equivalent of, or more than, the minimum wage (Dawson, Canet 1991). Street food vendors earning higher than the minimum wage have also been reported in countries like Morocco, Nigeria, Colombia, Peru and other Asian countries (Dawson, Canet 1991).

Due to the relatively higher income from street food vending (as demonstrated in the paragraphs above), coupled with the fact that as little as R400 capital (with an average start-up capital of R1, 403) is needed to start an informal street food vending business in South Africa, growth of the sector can be anticipated (Martins 2006). In South Africa the period between 1990 -2000 saw a downsizing in the non-Agricultural formal sectors by almost a million jobs. As a result, many of the unemployed people in need of survival started their own informal activities like the 'easy-to-enter' businesses, where a small capital layout is all that was needed (Martins 2006, Lues et al. 2006).

Although the level of urban poverty is lower in Africa than in Asia and Latin America, the growth in urban poverty is highest in Africa (Division of Prevention and Control of Non-communicable Diseases (DNC) 2004). There is therefore likely to be an increase in the demand for cheap food for the urban poor. Given that state-owned and state aided organizations are willing to contribute funds towards investigating and implementing proposals to improve the informal sector (Wellings, Sutcliffe 1984), coupled with the World Health Organization (WHO) declaration that access to food is a basic human right (Mensah et al. 2012), the informal sector (including street food vending) is anticipated to develop in such a way that it will cease to be an informal sector.

Despite the recognized benefits accrued to informal food vending that include food security for the urban poor; meeting the socio-economic and cultural needs of the community; and contribution to local economies; the street food sector is not recognized in many countries and continues to be treated as an "informal sector" and a major public health risk (Dawson, Canet 1991, Rane 2011). This is associated with the perception by governments, local bodies or city officials, that street food vendors are undesirable; that do not need to exist, or are a temporary phenomenon that will disappear in due course as a result of development (Dawson, Canet 1991). The situation is not helped by the fact that a number of studies have documented potential contamination of street foods with pathogenic microorganisms (Division of Prevention and Control of Non-communicable Diseases (DNC) 2004, Dawson, Canet 1991). Also that improperly handled food can be a medium for disease transmission (Mensah et al. 2012). Convenient food present a real risk to food poisoning because it offers a suitable growth environment for toxin producing bacteria like *Staphylococcus aureus*, that can grow and express virulence in foods such as dairy products, mixed foods, meat and meat products, eggs and egg products, cakes and ice cream (Schelin et al. 2011, IFT. 2004).

Based on the role street vended foods play as a source of nutritious food for urban dwellers, the FAO of the United Nations has taken special interest in street foods (Dawson, Canet 1991, Badrie, Joseph & Chen 2011). The major contributing factors to food-borne disease associated with street vended foods include: contamination of food (from raw food, infected handlers and inadequately cleaned equipment) and time-temperature abuse (Martins 2006, IFT. 2004, Mensah et al. 2012).

A study conducted in the United States of America, found *Salmonella* and *Campylobacter* in about two-thirds of raw chicken tested (Montague-Jones 2009), both of which are important food borne pathogens of faecal origin. In a study by the European Food Safety Authority (EFSA), it was demonstrated that poultry meat is an important source of exposure to the two most commonly reported food borne pathogens in the European Union (Harrington 2010). In the same study, it was found that 71% of the flocks surveyed carried *Campylobacter* in their intestines, while still alive and cross contamination occurred during processing. It has also been shown that the prevalence of both *Campylobacter* and *Salmonella* spp. in poultry in the European Union varied from one state to another (Harrington 2010). This suggests a generally high level of contamination of poultry flocks. If this is the case, then street vended chicken may pose a serious health risk to vulnerable groups (National Resources Institute 2011, Barro et al. 2007, Rane 2011) in developing countries.

Throughout the world, food safety is considered an important issue and was one of the WHO's thirteen strategic objectives for 2008-2013 (Schelin et al. 2011). There is evidence that there is high potential for serious health problems related to the preparation of and handling of street foods contaminated by both chemical and microbial contaminants (Dawson, Canet 1991, Rane 2011). In South Africa, although it is recognized that for most part, food served on the informal market is relatively safe for consumption, there is evidence to suggest that potential risks of contracting food-borne diseases by consumers exists. Therefore, serious consequences following consumption of contaminated street vended foods are a real possibility among consumers (Lues et al. 2006, Rane 2011). Furthermore, available epidemiological evidence confirms the association between street-vended foods and sickness (Ekanem 1998, Rane 2011).

Although street food vending is a major contributor to the economies of cities, the question of safety of street vended foods, particularly RTE chicken, has not been fully addressed in South Africa. Central to this, is government intervention, which is important to guarantee access to wholesome, safe and nutritious food, while growing the economy (Division of Prevention and Control of Non-communicable Diseases (DNC) 2004). Proper food control measures have the potential to reduce food losses, stimulate trade in food products, create employment, increase incomes and improve nutritional well-being. Therefore where government intervention is lacking, the risk of contracting foodborne diseases is heightened and informal vendors fail to reap the full benefits of participation in the informal trade of RTE food.

In Africa, laboratory analysis of food samples is not always affordable and there is a tendency to concentrate on formal rather than informal markets for monitoring food. In South Africa, regulations governing microbiological standards for food-stuffs (Department of Health 1997), prescribe standard traditional microbiological methods for use in food microbiology to indicate the presence of faecal contaminants and poor hygiene practices. These methods might be out of reach for most laboratories in African countries. Conventional in-house microbial methods for analysing foods by enumeration of aerobic bacteria and coliforms can also be time-consuming (requiring media preparation) and difficult to perform (Mizuochi et al. 1999). One of the objectives of participatory risk analysis is to make the monitoring techniques affordable and accessible to developing countries. There is thus a need to appropriate technology for microbiological analysis of food from street vendors. Recent advances in food microbiology have resulted in the invention of readymade, disposable bacterial analysis kits which can be processed in a rudimentary laboratory. In view of this, there is a need to demonstrate the applicability of this technology in a simple food laboratory, such as those found in Africa's resource poor countries.

Microbial risk analysis has greatly contributed to improved food safety in developed countries. Unfortunately, this has not been the case in developing countries for various reasons, including insufficient data and lack of human resources; and the dominance of formal markets (Makita et al. 2012). However, risk assessment, the current best practice for evaluating health risks associated with food and developing meaningful food safety standards; is yet to be applied to the informal markets in South Africa (Grace et al. 2008, FAO/WHO 1995). It has been proven that the application of risk assessment to informal markets in developing countries, where the majority of poor people buy and sell their livestock products, is possible (Grace et al. 2008, Makita et al. 2012). Application of sound risk analysis is now being advocated to provide a scientific base for risk management options, which regulating bodies can use to ensure public health and food safety (Rane 2011).

In South Africa, the cross-over between the informal and formal food value chain, for products of animal origin sold on the informal markets, is known to exist. However, it has not been fully studied (Van Zyl, McCrindle & Grace 2008). There is no information on the food value chain for chicken meat that is used to prepare RET chicken and chicken by-products, sold in the informal markets. As seen elsewhere (Ekanem 1998), there is a need for studies to establish value/food chains for informally vended chicken and chicken by-products sold on informal markets.

A number of studies, that have involved identification of microbiological hazards associated with street foods sold in informal markets in South Africa, have been conducted. Associated microbiological hazards are therefore known to a certain extent (Masupye, von Holy 2000, Masupye et al. 2002, Masupye, Von Holy 1999, International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005, Martins 2006). Six previous studies quoted in one Journal article (Martins 2006) showed the following:

- Vendors maintained a high standard of hygiene during preparation of and serving of foods.
- The prevalence of pathogens in informally sold food is relatively low.
- Although conditions under which the informal vendors operated did not meet hygiene standards prescribed for food outlets, it was not a major determinant to the quality and safety of RTE street vended foods.
- The number of organisms detected in different foodstuffs yielded very low or low colony counts.
- Microbiological quality of foods from which samples were taken, was within acceptable safety limits.

All these studies have gone as far as identifying the hazards. To date there have not been any studies done in South Africa that have considered the estimation of the risk associated with eating street vended food and more so RTE chicken as its objective.

This study therefore seeks to quantify the risk associated with eating RTE chicken sold in informal markets associated with taxi ranks in Tshwane. The study also seeks to describe the food value chain and the risk factors for contamination of the RTE chicken and chicken by-products sold in the informal markets, with a view to establish points or activities along the food value chain where control measures were critical for the safety of street vended RTE chicken and chicken by-products.

1.2 Problem statement

Cooked RTE chicken is commonly sold by vendors in informal markets in Tshwane. This kind of meat is known to have a high potential for food poisoning, but has not been previously investigated in South Africa. The WHO has guidelines to improve food safety in street foods but it is unknown whether these are adhered to by street vendors in South Africa. There have been a number of publications on street foods in Tshwane, however none of these have quantitatively analysed the risk to consumers. Risk analysis includes risk assessment (including magnitude of risk), risk mitigation and risk communication.

1.3 Assumptions/hypothesis

Use of participatory risk analysis and microbial evaluation of RTE chicken will assist in identifying mitigation strategies to reduce health risks in consumers.

1.4 Purpose/thesis statement

The purpose of this research project is, through participatory risk analysis together with rapid microbial analysis methods, to quantify the risk associated with RTE chicken and identify variables during sourcing, preparation, and sale of RTE chicken that could increase/decrease the risk of foodborne diseases in consumers.

1.5 Research questions

a) What is the demographic profile of vendors of RTE chicken and how could this increase or decrease risk of foodborne diseases to consumers?
b) What is the food chain for RTE chicken and does it increase or decrease risk of foodborne diseases in consumers?
c) What is the level of microbiological contamination of RTE chicken sold by vendors?
d) Which variables during preparation and sale of RTE chicken could increase/decrease risk of foodborne disease to consumers?
e) What could be done to mitigate the risk to consumers of RTE chicken?

f) How could risk mitigation strategies be communicated to street vendors and consumers of RTE chicken?

1.6 Aim

The aim of this study is to apply participatory risk analysis methods to study the food value chain of RTE chicken, assess the risk of exposure to selected foodborne diseases and to determine predictors for contamination of RTE chicken sold by informal vendors.

1.7 Objectives

The objectives of this study include the following:

a) Conduct literature survey to collect data needed to supplement data from laboratory analysis, and as part of hazard identification and hazard characterisation;
b) Develop a sampling frame for the study area;
c) Apply participatory, observational research methods plus interviews and focus group meetings to obtain demographic and observational data on vendors of RTE chicken and the conditions at informal markets in Tshwane, South Africa;
d) Use rapid microbiological analysis techniques such as 3M technology to analyse RTE chicken from informal markets in Tshwane;
e) Apply qualitative and quantitative assessment of data obtained to estimate the risk of foodborne diseases; and
f) Formulate risk mitigation and communication strategies.

1.8 Anticipated benefits from the study

a) The food chain (chicken meat pathway) in the informal market will be modelled for the first time in South Africa. This information will be available for use in the future to develop a food safety assurance model for the informal vendors dealing in RTE chicken and chicken by products.
b) The probability of occurrence and severity of known or potential adverse health effects that may be associated with the presence and numbers of pathogens in RTE chicken sold in the informal markets for immediate consumption will be estimated for the first time in South Africa.

c) Information from participatory risk analysis will be available to relevant authorities for use to develop a risk communication and management strategy to enhance the safety of street vended RTE chicken and chicken by-products.

d) Information obtained in this study will be available for future use in risk modelling, and prioritization of risk management to improve the ability of the relevant authorities to deal positively and cost effectively with the growth of the informal food sector.

e) This study could be used by health authorities to develop performance objectives (along the food value chain) that have been shown to be effective in terms of guidance to microbial hazard control for the street food industry.

f) This study will provide the authorities tasked with monitoring the production and selling of street vended RTE chicken and chicken by-products with suggested areas for focused inspection operations.

g) Experience gained from this study could be used to design a small scale, affordable food laboratory using appropriate technology (3M technology) for monitoring microbiology of foods in informal or rural markets in developing countries, where there is a shortage of laboratory infrastructure.

h) This study will provide an appraisal on the status of the infrastructure of the informal markets associated with taxi ranks in Tshwane.

i) This study will show the benefits of participatory risk analysis as a scientifically justifiable, cost effective way to evaluate food safety in informal markets such as the market for RTE chicken at taxi ranks in Tshwane.

1.9 Ethical considerations

Ethical approval for this research project (Ref V010/10) was first sought from the Research Committees of the Faculty of Veterinary Science, University of Pretoria before work commenced (Annexure IX). This study did not involve taking biological samples from humans (street vendors) or live animals (poultry). Consequently, there was no need to seek ethical clearance from the Human Medical Ethics Committee and the Animal Use and Care Committee of the Faculty of Veterinary Science, University of Pretoria.

The chairpersons of the informal vendors were consulted to explain the purpose of the project before sampling commenced. Written informed consent was obtained from all food vendors invited to participate in this study. As required by the Ethical Code of Primary Research and Research Committee of the Faculty of Veterinary Science, University of Pretoria, each vendor filled in a consent form (Annexure III) after its contents had been read and explained to each vendor.

Research assistants used to gather data for this study were Animal Health Technicians (AHTs) registered with the South African Veterinary Council (SAVC), either as students or professionals. They were chosen because they were familiar with principles of data gathering using questionnaire and checklists, as it forms part of their training as AHTs. However, before they could go out to the field, they were given the opportunity to practice administering questionnaires so they would be familiar with the questionnaire and the checklist used in this study. Furthermore, a pilot study was conducted using the same research assistants to test both the questionnaire and checklist. The later offered the assistants the opportunity for further training on data gathering.

Throughout the study, the researcher and the assistants hired to assist with data collection, committed themselves to treat each respondent with respect and dignity, and to ensure confidentiality of all information gathered during the study. To ensure anonymity, no name of any vendor was recorded, but instead each vendor was allocated a code for identification purposes.

Although the questionnaires and checklists used in this study had been designed in the English language, the interviewers (research assistants) were encouraged to interview the respondents in the language of their preference since some of the vendors were not conversant with English.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter considers the universally accepted definition of street vended foods, and discusses the various ready-to-eat (RTE) foods sold by informal vendors. It also provides a brief overview of the poultry industry in South Africa, the social economic impact of the informal food trade, the public health issues associated with the informal trade of food plus the regulations of the food trade. The application of risk analysis in food safety and the food safety assurance system HACCP (Hazard Analysis and Critical Control Points) are also handled. Monitoring and sampling strategies for informal markets are also discussed. The chapter concludes with a review of microorganisms isolated from street vended chicken and chicken by-products.

2.2 Defining street vended foods

Street foods are mass consumer RTE foods that include beverages intended for immediate consumption or consumption at a later time, without further processing or preparation (Ekanem 1998, Khubeka, Mosupye & Von Holy 2001, Codjia 2000, Estrada-Garcia et al. 2004, FAO 2012). They also include foods prepared at home but consumed on the street, or food that is prepared in the market and sold in the market and/or on work premises without further preparation (Gadaga et al. 2008, Rane 2011, FAO 2012).

The distinguishing characteristics of street vended foods include (Martins 2006, Dawson, Canet 1991, FAO 2012):

- food sold on the street;
- food prepared in small or cottage-scale factories and brought to the street food stall for sale;
- food prepared at home by the vendor and brought to the street food stall for sale; and
- food prepared and sold at the street food stall and several other public places such as lorry stations, parks, schools, and construction sites.

Street vended foods include a variety of products such as diverse meats, fish, fruits, vegetables, grains, cereals, frozen products and beverages. In Africa, popular street foods include roasted meat, fried snails and fish, fried bean cake, roasted and fried yam and plantain, coked/roasted maize, cassava chips, boiled eggs, broken-out coconut, roasted African okra, peeled oranges and other fruits, sugar cane, groundnuts, kolanuts, melon cake, fermented sorghum drink, soya bean milk, non-alcoholic cereal products, fermented East and Central African milk, and all types of RTE street meals. In addition to this, an array of traditional and homemade products, many modern factory products (e.g. biscuits, bread, confectionaries, soft drinks, fruit juices, ice cream, and yoghurt) also form part of street vended foods (Ekanem 1998).

In South Africa, a typical dish bought from the informal vendors consists of maize porridge served with either chicken or beef pieces or stew, tomato and onion gravy or salad (Lues et al. 2006, Martins 2006). Based on a study on a group of 200 street vendors in South Africa, approximately 64.9% of the total sales of the outlets for informal street food vendors were made up of porridge and meat (Martins 2006). Literature searches conducted during this study did not yield any report on types of chicken products that were sold on the informal market in South Africa. However, it is possible that there were several chicken byproducts that could be purchased on the informal market in South Africa.

2.3 The poultry industry in South Africa: overview and potential

According to the South African Poultry Association (SAPA), the poultry industry in South Africa is mature, efficient and a highly productive industry consisting of small scale, emerging and larger commercial poultry farmers in four sub-sectors. The four sub-sectors are: the day-old chick supply industry, the egg industry, the broiler industry, as well as small scale and developing farmers (SAPA 2011).

It has been estimated that the poultry industry in South Africa produced 1,773,447 tons of poultry meat and placed 6,503,000 broiler breeders in 2011. The industry produced slightly fewer than 1,036,000,000 broilers and was capable of hatching 20.3 million chicks per week. This translated into 18.773 million broilers slaughtered per week at 1.40 kg dressed mass. Of this, it was estimated that the informal sector produced only 1 million broilers per week (SAPA 2011).

In addition to the broiler industry (the traditional source of poultry meat), there were 400 000 grandparents and great-grandparents that produced 6.521 million female parents and a commercial progeny of 1.036 billion chicks for the broiler industry per annum. There were also layer-breeder-parent stocks, estimated at 300,000, reared in the country, per annum. As of 2011 there were 25 million hens reared as layers for egg production in South Africa (SAPA 2011). At the end of their laying period, the grandparents, the great-grand parent and layers, were slaughtered and thus contributed to the poultry meat available to the South African public.

Besides providing employment, the poultry industry also supports many peripheral businesses downstream in the value chain, including informal food vendors who sell RTE chicken (SAPA 2011).

2.4 Informal markets: socio-economic and environmental impacts

Street food vendors are regarded as small-scale operators or micro-entrepreneurs. They are part of the informal sector, which is distinct from the formal sector (Martins 2006, Makita et al. 2012).

Like their counter parts in the formal food markets (e.g., restaurants), the street vendors in the informal market play an important socioeconomic role. In some developing countries the informal vending sector has in recent years grown into a lucrative trade that competes with the formal sector (Lues et al. 2006).

Street vended foods are affordable and as a result are an important and essential part of maintaining the nutritional status of sections of the urban population such as workers, shoppers, travelers, and school children in addition to low income groups (Rane 2011, Mensah et al. 2012, Badrie, Joseph & Chen 2011). In 1991, studies showed that in Morocco, through consumption of street vended food consumers were able to obtain their daily requirements for a mere US$2 (Dawson, Canet 1991).

At a global level, informal vendors provide inexpensive nutritious food to those in transit who otherwise would not be able to afford food sold on the formal market. This includes people like construction and office workers (Ekanem 1998, Khubeka, Mosupye & Von Holy 2001, Codjia 2000, Estrada-Garcia et al. 2004, Lues et al. 2006, Dawson, Canet 1991), (National Resources International limited (NRIL) 2010, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004).

In South Africa, it has been shown that it is mainly black males between 26-35years (half of whom are single) who consume food sold on the informal market (Martins 2006). In Morocco, it was also observed that 60% of the street food consumers were less than 30 years old single and that a total of 30% of consumers in Morocco ate street vended foods on a daily basis (Dawson, Canet 1991). Dawson and Canet cite a study by TNO (1989) that showed that among students of Bogor Agricultural University (Indonesia), who depended on street vended foods for most of their nutritional intake, the majority came from lower and middle socio-economic classes of the population of Java and Sumtra (Dawson, Canet 1991).

The reasons why street vended RTE food is popular were discussed in detail in Chapter 1. Furthermore, why street vended foods are popular among city dwellers is also discussed in the following publications: "International Activities in Street Foods" (Dawson, Canet 1991) and "Public Health and Food Safety in the WHO Africa Region" (Mensah et al. 2012). The tastiness, nutritional value, proximity to work, convenience and cleanliness, in that order played a role in why street vended foods were popular with urban dwellers (Martins 2006).

Given the phenomenal rate at which urbanization is taking place in the developing world, many cities have been turned into melting pots of ethnic groups who bring along their own food habits that only the informal sector is able to meet and provide food that these different ethnic groups are used to consuming. In cities with large ethnic populations, consumption of the traditional street foods is seen as a social benefit among the urban poor and those feeling alienated by virtue of being different (Dawson, Canet 1991, Rane 2011, FAO 2012).

Participatory rapid appraisal studies have shown that the street food business is both economically viable and a good source of income (Ekanem 1998, Lues et al. 2006). The sector offers business opportunities for developing entrepreneurs (Rane 2011, SAPA 2011) that benefit the vendors through positive cash flow and offer the opportunity to own a business with minimum outlay of capital, that is not taxed (Codjia 2000, Estrada-Garcia et al. 2004, National Resources International limited (NRIL) 2010, National Resources Institute 2011, Barro et al. 2007, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004, Martins 2006, Lues et al. 2006). This low cost opportunity for self-employment is important for poverty alleviation, the major causative factor of food insecurity among urban dwellers (Codjia 2000, Lues et al. 2006).

With the prevailing harsh economic conditions and the HIV/AIDS pandemic, many poor households have no male bread winner, and in extreme cases, no adult breadwinner to maintain the household. As a result, women and adolescent girls, often with little formal education and only limited opportunities for earning livelihoods within the city, resort to using their limited capital assets to produce and sell street foods as a source of income (National Resources International limited (NRIL) 2010, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004, Lues et al. 2006, Martins 2006).

Locally-produced agricultural products represent a large portion of the vendor's raw material purchases. It is reported that this trade represents millions of United States dollars daily (Codjia 2000, Dawson, Canet 1991, FAO 2012). Therefore, the sale of street foods can make a sizeable contribution to the economies of developing countries (Rane 2011). Moreover, there is potential for the sector to grow, considering that by 2020, the developing world's urban population will have grown to 3.4 billion (National Resources Institute 2011). In light of this, if the informal food sector was to be able to produce safe, sound and wholesome food, it has the potential to contribute to the growth of other sectors of the economy, such as agriculture.

Despite the positives associated with the informal food traded mentioned in the preceding paragraphs, from a social perspective some problems have been identified such as food vendors being children and youths who should be in school. Moreover the highly itinerate nature of the street food trade, exposes young people to social vices leading to high rates of juvenile delinquency (Ekanem 1998).

In Africa the bad habit of throwing waste around that results in littering with street food wrappers and containers, is a serious environmental problem (Ekanem 1998). However, failure to dispose of waste water and refuse, including garbage, is almost a universal problem with informal traders. For example, studies have reported that in Bombay, India there was no system for garbage disposal available to informal vendors. As a result, all leftover materials were thrown into the nearby gutters or on the road side. In Peru, about 30% of the garbage disposal was in the street, as well as nearly 40% of the waste water. In Nepal, 35% of the areas used by street vendors had no waste disposal containers in which to dispose of the waste (Dawson, Canet 1991).

Other environmental health issues associated with the street food trade that adversely affect daily life, relate to its unlimited and unregulated growth. This phenomenon places severe strain on city resources, leading to overcrowding, inadequate sanitation, possible environmental pollution, congestion, disturbance to traffic, and interference with city planning (Barro et al. 2007, Masupye, Von Holy 1999, Moy, Hazzard & Käferstein 1997, Masupye, von Holy 2000, Rane 2011).

According to Ekanem (1998), sustainability is a key consideration in development. A sustainable system is one that is economically viable, socially just, and ecologically sound. In view of this, it is imperative that environmental and social maladies associated with the informal food trade be addressed to make the street food trade sustainable. This means that provisions to control socio-environmental problems, during the development of codes of practice for street foods in Africa, are necessary, if the trade is to be sustainable. Street food consumers and vendors need to be continuously enlightened on proper waste (including food remains) disposal methods. The inefficient public garbage collection systems in Africa must be revamped to protect the environment. A dual pricing system where the market (selling) price of the product is displayed alongside the socio-environmental shadow price has also been suggested. The socio-environmental shadow price should be the market price plus the cost of socio-environmental damage brought about by producing the street food. The government could then collect the difference between the two prices and use these funds for socio-ecological restorative activities to offset the damage caused by producing the product. However, this, dual pricing would probably be difficult, where informal trading is outside the ambit of state control, as mentioned earlier and in other publications (Barro et al., 2007; Codjia, 2000; Division of Prevention and Control of Non-communicable Diseases (DNC), 2004; Estrada-Garcia et al., 2004; Lues et al., 2006; Martins, 2006; National Resources Institute, 2011; National Resources International limited (NRIL), 2010).

According to the WHO, every effort should be made to preserve the benefits provided by the varied, inexpensive, and often nutritious street food, so that street vended foods may continue to play an important role in the diets of socially disadvantaged urban populations. This requires the authorities concerned with street vended food management to balance efforts aimed at reducing the negative aspects on the environment and human health, with the benefits of street food and its important role in the community (Moy, Hazzard & Käferstein 1997, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004).

2.5 Public health issues associated with street vended RTE foods

Rapid urbanization in many developing countries has not only led to considerable expansion of street vended foods as mentioned earlier, but has also led to other problems associated with unplanned urbanization such as overcrowding and inadequate sanitation and other infrastructure. These create challenges to the assurance of food safety of street vended foods (Ekanem 1998, Codjia 2000, Masupye, von Holy 2000, Masupye, Von Holy 1999, Barro et al. 2007, National Resources International limited (NRIL) 2010, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004). Furthermore and as mentioned earlier, people who depend on street vended food are more interested in its convenience than in issues of safety, quality and hygiene (Mensah et al. 2012, Mensah et al. 2002, Badrie, Joseph & Chen 2011).

The following has been observed with respect to basic food hygiene among street food vendors (Masupye, von Holy 2000, Lues et al. 2006, Dawson, Canet 1991): hand and dish washing is usually done in one or more pans sometimes without soap; waste water and garbage are discarded in the street providing food and harborage for flies and rodents; foods not effectively protected from dust and flies may harbor food borne pathogens; and safe food temperatures cannot be maintained or are frequently violated. As long as there are no facilities for liquid drainage, and waste water and garbage are left in the streets, rodent infestation is encouraged and the breeding of flies takes place. This makes the food sold in such environments susceptible to contamination by flies, which is likely to lead to diarrhoeal diseases (Dawson, Canet 1991).

Several authors have been able to show that street food vendors in South Africa are capable of producing foods with low bacterial counts (International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005, Masupye, von Holy 2000, Lues et al. 2006, Martins 2006). However, the majority of vendors are not aware of training programmes available to them. This is corroborated by Martins (2006), who found that only 18% of the vendors who participated in their study had heard about training programmes for informal street traders in South Africa. The same study also showed that only 31.5% of the vendors interviewed had some knowledge of the 10 golden rules for healthy food preparation which include not wearing jewelry and washing hands after handling money. In addition, studies in South Africa have shown that micro-organisms occur on meat and in gravy, as well as on the surfaces where food is prepared. These same studies also showed that a degree of ignorance regarding proper hygienic practices on the part of informal food vendors was evident (Lues et al. 2006).

Throughout the developing world, informal methods of processing and packaging, improper holding temperatures and poor personal hygiene of food handlers occur (Barro et al. 2007, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004). The use of raw materials from uncertain or contaminated sources, as well as poor handling practices and mixing raw and cooked foods, play an important role in food safety (Dawson, Canet 1991, Food-Info.net Organisation 2014).

Food is a major source of exposure to several different chemical or biological hazards affecting human health, in both developing and developed countries (KZN-DOH 2001, Fahrion et al. 2014). Contaminated food continues to cause devastating outbreaks in the African region and the main aetiological agents are bacteria, viruses and parasites (Mensah et al. 2012). Food that is contaminated, irrespective of whether it has unacceptable levels of pathogens or chemical contaminants or other hazards, imposes substantial health risks to consumers and severe economic burdens on individual communities and nations (KZN-DOH 2001, Mensah et al. 2012, Fahrion et al. 2014).

Foodborne illnesses of microbial origin are a major international health problem associated with food safety (Fahrion et al. 2014, Barro et al. 2007, Förster et al. 2007, Badrie, Joseph & Chen 2011), and are an important cause of death in developing countries (Barro et al. 2007). It is estimated that approximately 2 billion global episodes of diarrhea occur annually, resulting in 1.9 million deaths among children under the age of five, the majority of which occur in developing countries. Contaminated foods are known to play a significant role in the occurrence of diarrhea (World Gastroenterology Organisation 2012).

Thus, informal street foods contaminated with pathogens, can negatively impact on the health of a large segment of the urban population (Rane 2011, Legnani et al. 2004). Unfortunately, outbreaks of foodborne diseases are not always recorded on medical databases, due to the fact that their symptoms are often moderate and self-limiting. Affected consumers may not even visit doctors or clinics. Consumers may not recognize that symptoms are due to foodborne diseases and as a result, unhygienic or risky practices during the preparation and preservation of street food are ignored (Legnani et al. 2004, Badrie, Joseph & Chen 2011). In view of this, lack of consumer pressure towards better hygiene makes street food vending an important public health issue (Rane 2011).

It is reported (Ekanem 1998) that food, such as poultry among others, sold in the street are vehicles of disease transmission in countries that have surveillance programmes. In the United States and the UK, chicken (Figure 2.1), turkey and other poultry are the leading cause of food related death and/or outbreaks (Armour 2013, Hubbert et al. 1996):

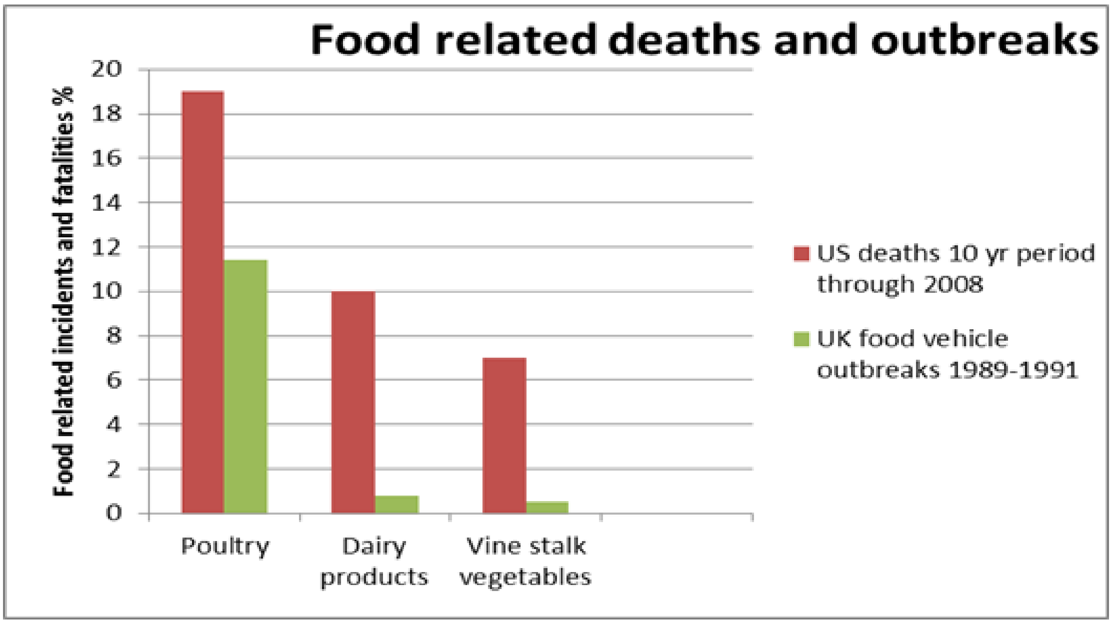

Figure 2.1: Role of poultry in food related deaths in the UK and US (Armour 2013)

Studies done elsewhere concluded that purchasing street food is an independent risk factor for paratyphoid compared to eating from restaurants (Vollaard et al. 2004). Contaminated food has been recognized as playing a major role in the epidemiology of cholera and other forms of epidemic diseases (KZN-DOH 2001). In many developing and industrialized countries, trends suggest a rise in the number of foodborne diseases, such as salmonellosis, campylobacteriosis and infections caused by *E. coli* over the last few decades (KZN-DOH 2001, World Gastroenterology Organisation 2012).

According to Barro et al., (2007) and Dawson and Canet (1991) there is ample evidence to suggest an epidemiological link between street foods and illness among the consumers. This is supported by the fact that there are recorded cases where street vended foods have been implicated in outbreaks of foodborne diseases. For example, in Malaysia, 14 people died as a result of eating rice noodles bought from street vendors. A cholera outbreak in Pune, India, was related to street vended sugar cane juice containing ice that was contaminated with *Vibrio cholera*. In Senegal, over 200 cases of food poisoning were traced to street foods made from dairy products. In the mountain region of Pakistan, tourists are reported to have complained of diarrhea after reportedly eating snacks or prepared meals sold by informal vendors. While in western Cuba, 14 people died and 49 were hospitalized due to food poisoning after eating fried food from a street vendor who also died (Masupye, Von Holy 1999, Dawson, Canet 1991).

Estrada-Garcia et al., (2004) refer to microbiological studies that reported street vended food containing human faecal pathogens in sufficient quantities to cause disease. The same authors also quote studies that reported that street vended food has been associated with traveler's diarrhea. In 2001, two serious cases of food poisoning associated with consumption of informally traded food were reported in Harare (National Resources International limited (NRIL) 2010). In Ghana, a study on the microbial quality of street foods in Accra found evidence of *Shigella sonnei*, enteroaggregative *Escherichia coli* and *Salmonella arizonae* in some food samples (Division of Prevention and Control of Non-communicable Diseases (DNC) 2004). In Nigeria, purchasing of breakfast and lunch as well as water from vendors is a risk factor for diarrhoeal illness (Mensah et al. 2012).

Available evidence shows that the majority of outbreaks of foodborne diseases results from inappropriate food handling practices. As a result food handlers play an important role in food safety and in the occurrence of food poisoning due to the introduction of pathogens into food during production, processing, distribution and/or preparation (Githiri, Okema & Kimiywe 2009, Dawson, Canet 1991, Mensah et al. 2012). Ignorance on the part of the vendors specifically has been cited as being a significant contributor to contamination of street vended foods (Ekanem 1998, International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005, Barro et al. 2002, National Resources International limited (NRIL) 2010).

Other real risk factors for contamination of food include the practice of under heating to avoid shrinkage of meat (Ekanem 1998), initial contamination of raw materials with pathogenic bacteria and/or subsequent contamination by the vendors themselves during preparation, post-cooking handling, and cross-contamination (Barro et al. 2007, Estrada-Garcia et al. 2004, Masupye, von Holy 2000). Githiri et al., (2009) cite studies that suggest that microorganism get transferred to the hands of food handlers in the process of handling food due to poor personal hygiene after visiting the lavatory. This is bound to lead to the contamination of food with enteric pathogens. Prolonged food storage has also been identified as risk factors for contamination of food (Mensah et al. 2012).

Although street food vending has been associated with serious outbreaks of food poisoning (Barro et al. 2007), in South Africa (like in other developing countries) where street vended food is common, information regarding the risks (the likelihood and severity) associated with eating street vended foods, and the incidence of street food related diseases has not been established. Studies that have been conducted in South Africa have had microbial hazard identification as their main objectives (Masupye, von Holy 2000, Masupye, Von Holy 1999). Studies by Masupye & von Holy (2000) that were done in South Africa showed that street vended foods became contaminated with microbial hazards.

According to Masupye & Von Holy (1999), microbiological studies that have been done in other parts of the world like the USA, Asia and other African countries also showed that street vended foods tended to be contaminated with high bacteria counts and there is a high incidence of food borne bacterial pathogens. For example, a study done in Addis Ababa by Muleta & Ashenafi (2001) revealed that over 70% of the street vended food samples had aerobic mesophilic counts higher than 10^7 cfu g^{-1}. In the same study, out of a total of 1552 bacterial strains isolated from the different food samples, 29.1% were *Bacillus* spp., 22.8% staphylococci, 15.4% were micrococci, and members of *Enterobacteriaceae* were encountered in 14.5% of the samples. Studies done in Nigerian cities (Ekanem 1998) reported levels of coliforms and total plate counts that exceeded the recommended tolerable levels of 10^2 CFU/g total count and the 10^2 CFU/g coliforms recommended for delicatessen products.

The problems encountered by informal traders that influence the safety of the foods, include lack of infrastructure and lack of understanding of basic food hygiene principles (Muleta, Ashenafi 2001, Estrada-Garcia et al. 2004, International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005, Masupye, Von Holy 1999, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004, Lues et al. 2006).

Based on the investigations by the FAO of the United Nations into street vended food, a number of activities have been done to improve street vended foods. But it is further recommended that periodic review and analysis is needed and that studies to quantify the risk of eating street vended food are conducted worldwide (Codjia 2000, Estrada-Garcia 1997). Unfortunately, South Africa has tended to lag behind in the generation of scientific data not only on the microbiological quality, but also on the risk associated with street vended foods.

Until the late 1990's very little information on street foods was available on South Africa but much was available about other developing countries such as Zambia, Nigeria, Pakistan and the Dominican Republic. The first comprehensive studies into the safety of street vended foods in South Africa where by Masupye and von Holy in 1999. The objective of these studies were to give an overall indication of the microbiological status of RTE street vended foods sold on a typical South African setting of a major taxi rank in Johannesburg central business district. Following that, there have been other studies, with the most recent in the Free State Province, in Bloemfontein (International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005, Masupye, Von Holy 1999, Lues et al. 2006).

Despite overwhelming evidence that informal markets are an integral part of the food supply for the urban poor, in some African countries, street food vending is considered illegal and vendors are frequently harassed by being evicted and their property destroyed by the authorities. Even in countries like Zambia where vending sites are legally recognized, vendors operate in contravention of Zambian food laws out of ignorance. These circumstances render street food vending an unstable and unsustainable source of income. This is despite the fact that little solid evidence of contamination of street vended foods exists. As such, the existence of street food vending is threatened whenever the perception by the authorities is that informally traded foods are a high risk from a food safety perspective (National Resources International limited (NRIL) 2010).

The perception that street vended foods are a major public health risk is at times merely based on the fact that the environment in which street foods are prepared is of a poor hygiene status, and it is difficult to control the large numbers of vending operations due to their diversity, mobility and temporary nature (Rane 2011).

In conclusion, for markets selling food to assure safety and improve the perception of the regulatory bodies towards informal food markets and the food they sell, there is a need to regulate their activities. Therefore, regulation of food markets including informal food markets is the focus of the next section.

2.6 Regulating for food safety

Food safety in general has been a concern to human kind since the dawn of history and many of the problems encountered in our food supply date back to the earliest recorded years. The many rules and recommendations advocated in religious or historical texts are evidence for the need to protect people against food borne diseases and food adulteration (Motarjemi et al. 1996). With the increase in the number of serious incidents of foodborne diseases observed in recent years, organizations like the Food and Drug Administration (FDA) have stepped up efforts to ensure that food supply chains deliver food for consumers that is safe (Schelin et al. 2011).

Production and marketing of food that is safe is the shared responsibility of industry, government, and the consumer (Cliver 1990). In South Africa, the responsibility of ensuring that food is safe is the shared responsibility of the different government agencies, industry and consumers. Therefore, collaboration between these various bodies is essential for the formulation of monitoring systems and implementation of the same (KZN-DOH 2001).

In South Africa, the administrative structure responsible for food safety is as follows. At the national level the Directorate of Food Control of the National Department of Health is responsible for all matters relating to food safety, while provincial food health control is the responsibility of the nine provincial health authorities. At the community level, it is the District Health Departments which include the local authorities that oversee food safety issues. The authorities charged with ensuring food safety (i.e., the Directorate of Food Control and the Provincial Food Health Control), achieve their objective through, inter-sectoral collaboration, encouraging community participation and the rendering of environmental health services to communities (Martins, Anelich 2000).

There are a total of thirteen acts (national laws) in addition to bylaws enforced by the different local authorities that regulate street food vending in South Africa (Martins, Anelich 2000). These laws and regulations are enforced by Environmental Health Officers (EHO) tasked with ensuring that food safety standards are adhered to. A summary of legislation in South Africa pertinent to informal markets and food safety is shown in Table 2:1.

The duties of EHO include general inspections, sampling and analysis. According to KZN-DOH (2001), once they have completed these activities, the two remedial measures that can be implemented include corrective action or legal actions. However, as has been suggested by some authors (Moy, Hazzard & Käferstein 1997), for the street food trade to be preserved and in the process prevent the aggravation of hunger and malnutrition among the urban poor that would follow its abolition, corrective actions should be the emphasis and not legal action.

Table 2.1: Food safety legislation applicable to informal markets in South Africa

Institution	Food hygiene management standard	Legislation
SABS	Food hygiene management standard	SANS 100049
DoH	Regulations governing general requirements for food premises and the transport of food	R918
DoH	Regulations regarding processed foodstuffs	R723
SABS	Drinking water	SANS 241
SABS	Guidelines on the application for ISO 9000:2001	SANS 15161
SABS	Handling of chilled and frozen foods	SANS 10156
DoH	Foodstuffs Cosmetics and Disinfectants Act, covering product labelling, ingredient declaration, the uses of additives etc.	Act No. 54 of 1972
DAFF	Agricultural Product Standards Act	Act No. 119 of 1990
GFSI	Guidance Document	Belgium law
CFA	High-risk area-Best practices Guidelines	

This is where the scientific rationale for food safety that is incorporated into the framework of risk analysis becomes relevant. The scientific rationale for food safety involves a structured approached whereby risks to human health are assessed and the best means for their control identified as a basis for the formulation of regulations (Henson, Caswell 1999). It is for this reason that food safety standards are increasingly becoming risk based. In light of this, both the World Organisation for Animal Health (OIE) and WHO emphasize risk analysis for promoting and maintaining food safety and also emphasize the "farm-to-fork" approach for food supply chains and monitoring systems (Van Zyl, McCrindle & Grace 2008).

Therefore, national food control systems that are designed to ensure a safe food supply and hence promote good health of the local populations should require conducting a risk analysis and introduce measures necessary to ensure production of safe food (National Resources Institute 2011, Henson, Caswell 1999).

2.7 Recent developments the informal food trade in South Africa

There have been initiatives in South Africa by food control authorities to improve street food vending by adopting regulations that address food safety rather than outlaw street food vending (International Union of Microbiological Societies, International Committee on Food

Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005). For example, the EThekwini Metropolitan Municipal Council in KwaZulu-Natal province developed the Durban Informal Policy to provide a strategy the Metropolitan region could follow, to achieve its economic development goals. The goal of the program was to ensure that vendors in the Metro received essential food hygiene training prior to receiving a certificate of acceptability that allows them to operate a food outlet. In addition, the EThekwini Metro street food vendors would operate in designated areas thus minimizing the problem of public nuisance in the city of Durban and surrounding towns (International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005).

In the Ehlanzeni District (International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005), the municipality has compiled the Nelspruit street vending by-laws, which upon implementation would allow the Municipality to register all street vendors in its area of jurisdiction, and designate specific sites as strictly vending sites. The benefits of this exercise would include: the establishment of control over the number of vendors per area and the municipality being able to provide basic facilities for the vendors such as cleaning services, running water, washbasins, storage facilities and toilets. In addition, vendors would be required to comply with minimum requirements as stipulated in the National Hygiene Regulations. Furthermore, the municipality would be able to continue training vendors and also conduct inspections as part of compliance monitoring.

In Gauteng, the Department of Health has been able to develop an informal food training programme to promote safe food handling in the food-trading sector in the province. The objectives of the programme include: providing street vendors with general knowledge and awareness of good hygienic practices, regulations, and by-laws; encouraging street food vendors to become responsible and conscientious in providing safe food for their clients. The purpose of this is to reduce the risk of food contamination and the incidence of foodborne disease outbreaks. The Johannesburg Metropolitan council took the initiative to register street food vendors in its area of jurisdiction and allocated space for them with facilities such as shelter, running water, toilets and, in some instances, electricity to operate.

The North West province has developed a policy that contains minimum requirements requiring vendor compliance. In the Western Cape, local authorities regulate street food vending in terms of the National Hygiene regulations (R 918 of July). In terms of this regulation, street food vendors are required to be in possession of a certificate of acceptability before they are permitted to run a food outlet. In addition, the local authorities perform regular inspections of street food vending premises and collect samples for analysis.

2.8 Risk analysis

While it is true that microbial foodborne disease may occur when a susceptible individual consumes a food contaminated by a viable microbial pathogen(s), and/or microbial toxin(s), not every exposure to a pathogen or its toxins in food, will result in infection or illness, and not all individuals in a population are equally susceptible to all pathogens (Rajkovic 2014, Lammerding, Fazil 2000). The risk of acquiring foodborne diseases is a combination of the likelihood of exposure to a pathogen in a food, the likelihood that the exposure will result in infection or intoxication and subsequently illness (Lammerding, Fazil 2000, Rajkovic 2014).

In light of the prevalence of contamination of street vended foods cited in several studies, there is a need to quantity the risk associated with street vended foods. Risk assessment specifically is needed due to its ability to provide an estimate of the probability and impact of adverse health effects attributable to potentially contaminated foods (Lammerding, Fazil 2000).

On a population basis, the calculation of risk can predict the expected number of specific cases or deaths per 100 000 populations per year attributable to the pathogen/food in question or the probability of a specific adverse outcome per exposure to the food (Lammerding, Fazil 2000).

To ensure that food safety is prioritized, risk analysis and food safety assurance systems are essential. Although the later have been implemented in the formal sector, methods to assure food safety in informal markets remain problematic (Van Zyl, McCrindle & Grace 2008).

2.8.1 Definitions of risk analysis

To foster a uniform understanding of the various risk analysis terms, the joint FAO/WHO expert consultation on the application of risk analysis to food standards issues has proposed definitions for the following terms (FAO/WHO 1995): food, hazard, risk, risk analysis, risk assessment, hazard identification, hazard characterization, exposure assessment, risk characterization, risk management, risk communication, dose-response assessment and scenario set. Therefore, wherever these terms are used in this document, unless expressed, the definitions given in the document "Application of risk analysis to food standards issues" (FAO/WHO 1995) apply.

2.8.2 Components of risk analysis

According to Rosenquist et al., (2003) the use of risk analysis as a tool for the control of biological hazards in foods is increasingly becoming accepted worldwide. Risk analysis is a process consisting of three components: risk assessment, risk management and risk communication (Rosenquist et al. 2003, WHO 2009, CAC (Codex Alimentarius Commission) 2004, Lammerding& Fazil 2000, Henson & Caswell 1999).

a) Risk assessment

Risk assessment is primarily seen as a method of systematically organizing and analyzing scientific and technical information, and its associated uncertainties, to answer specific questions about health risk (FAO/WHO 1995, Lammerding & Fazil 2000). It requires the evaluation of relevant information, and the selection of models to be used in drawing inferences from that information. Furthermore, risk assessment requires explicit recognition of uncertainties and, when appropriate, acknowledgment that alternative interpretations of the available data may be scientifically plausible (FAO/WHO 1995).

Therefore risk assessment is defined as the scientific evaluation of known or potential health effects resulting from human exposure to foodborne hazards, and consists of four distinct steps (FAO/WHO 1995, WHO 2009, Lammerding & Fazil 2000, Henson & Caswell 1999, Makita et al. 2012, Schelin et al. 2011, Rajkovic 2014) that are discussed below:

i) Hazard identification

This is the first step in a formal risk assessment. It involves performing a qualitative evaluation of the risk issue and identification of known or potential health effects associated with a particular agent. In microbiological risk assessment (MRA) for food, hazard identification is performed by collection, organization and evaluation of all information about a pathogen.

In traditional fields of risk assessment such as toxicology and environmental health, the major focus of the hazard identification process is to determine if there is sufficient evidence to consider a substance (e.g., a chemical) as the cause of an adverse health effect (e.g., cancer). However, in microbial risk assessment the hazard is in most cases already known even before the onset of risk analysis. But where there is a need to identify the agents known to cause foodborne diseases, it is done using epidemiological and other data to link the organism and its source to illness. In MRA, the cause-and-effect relationship for microbial hazards can often be measured over a short time (hours, days or weeks) compared to chemical hazards are in most cases, the time frames are usually in the order of years or lifetimes. Therefore, the hazard identification process is much easier and faster in MRA. This is because of the short time it takes for the cause-and-effect relationship to be observed and likelihood for an adverse effect exhibited in a population to be positively associated with a pathogen/food combination. Further still, microbial pathogens are also easily often isolated from the individual that exhibit(s) the adverse health effect(s) which provides more evidence for a causal-and-effect relationship.

ii) Hazard characterization

This stage entails the qualitative and/or quantitative evaluation of the nature of the adverse effects associated with the biological, chemical, and physical agents which may be present in food. In MRA hazard characterization involves determining the relationship between a pathogen in the food and any adverse effects. Therefore, this stage provides a qualitative and/or quantitative estimate of the severity and duration of adverse effects due to the presence of a pathogen in food. In the risk assessment model adopted by the United States Environmental protection Agency (EPA), this stage (hazard characterization stage) is replaced with the dose response assessment. The latter describes how the likelihood and severity of adverse health effects (the responses) are related to the amount of and condition of exposure to an agent (United States Environmental Protection Agency, (EPA) 2012).

iii) Exposure assessment

This involves the qualitative and/or quantitative evaluation of the degree of intake likely to occur. In the case of microbiological risk assessment (MRA), exposure assessment involves determining the quantity of the pathogen likely to be ingested in a serving of food. That is to say, exposure assessment gives an estimate of either the number of pathogenic bacteria or the level of bacterial toxin consumed in food. According to Schelin et al. (2011), exposure assessment can also be conducted by developing predictive microbiology models to quantify growth, inactivation and toxin production. However, where quantitative data to develop an exposure assessment are lacking, a qualitative indication of the likely risk to the consumers could be arrived at by measuring hazard levels at particular process steps, or segments of the production chain. Comparative studies on biological hazard levels and qualitative estimates of the likely effects to human health can also be used to assess the likely risk to consumers (FAO/WHO 1995). Just as in quantitative risk assessment, the basic steps are the same and the quality of information developed during the risk assessment process is very important (FAO/WHO 1995).

iv) Risk characterization

This step involves the integration of hazard identification, hazard characterization and exposure assessment into estimation of the risk and the nature of the adverse effects likely to occur in a given population, including attendant uncertainties.

b) Risk management

Risk management is a distinct process from risk assessment that involves weighing policy alternatives in consultation with all interested parties. Here factors relevant for the protection of the health of consumers are considered to promote fair trade practices and selecting appropriate prevention and control options (CAC (Codex Alimentarius Commission) 2004). Simply put, risk management entails making decisions regarding acceptable risk and measures to control the risk (Henson & Caswell 1999). In the context of street vended foods, decision makers need to understand the harms and benefits of informally marketed food to determine appropriate regulations and management strategies (Grace et al. 2008). According to Lammerding (2006), quantitative modelling of the sources, prevalence, numbers, and behavior of food borne pathogens, such as *Salmonella*, and of the host/pathogen interaction and consequences do provide scientific information and insights useful for decisions related to managing the safety of the food supply. The same author states that the only basis for justifying the introduction of increased stringency in safety standards for foods in trade should be based on scientific assessment of risk.

c) Risk communication

Risk communication is defined by the Codex Alimentarius Commission (2004) as "*the interactive exchange of information and opinions throughout the risk analysis process concerning hazards and risk, risk-related factors and risk perceptions, among risk assessors,* *risk managers, industry, the academic community and other interested parties, including the explanation of risk assessment findings and the basis for risk management decisions*."

According to Henson and Casewell (1999), risk communication entails the communication of decisions made regarding the acceptable risk amongst interested parties.

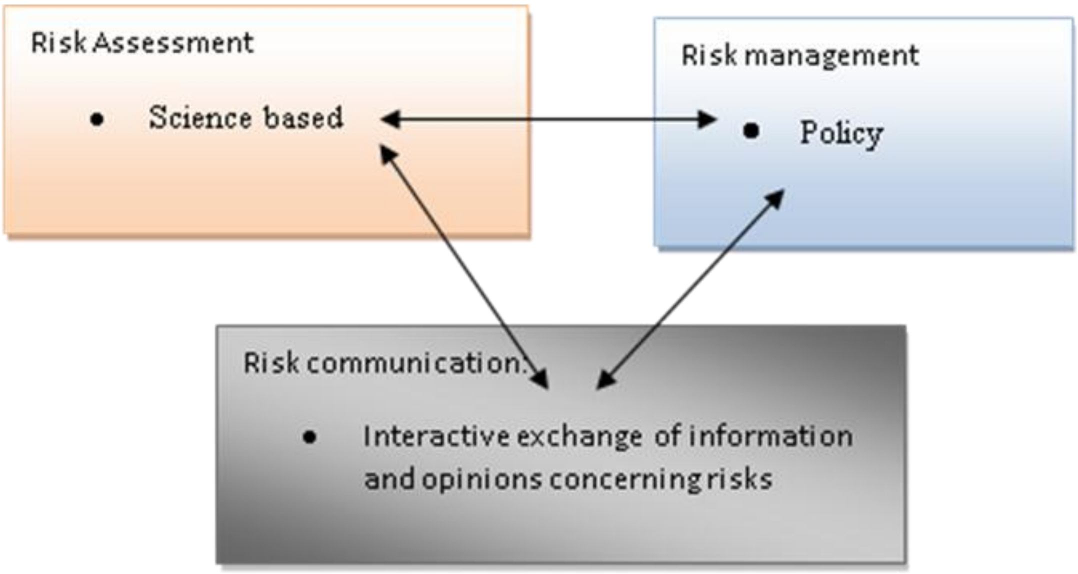

Figure 2.2: Risk analysis framework (Henson & Caswell, 1999; WHO, 2009)

According to Rosenquist et al., (2003), the 3 elements of risk analysis (risk assessment, risk management and risk communication) should form the basis for establishing Food Safety Objectives (FSO) by governmental agencies and industry.

Furthermore, risk analysis as a means of organizing available information, identifying data gaps, quantifying risk for specific pathogens and foods, and presenting strategies for improvement is needed for education (Lammerding & Fazil 2000, Barro et al., 2007).

2.8.3 Risk assessment: methodologies and associated limitations

The first three steps; hazard identification, hazard characterization and exposure assessment are usually combined during risk assessment when assessing the health risk in relation to the specific risk questions being addressed. Determining dose-response relationship is crucial in the hazard characterization stage (Schelin et al. 2011). For further reading on how dose response assessment is conducted including applicable models, reference should be made to the documents by the United States Environmental Protection Agency, (EPA) (2012), and FAO/WHO (2003).

The need to implement risk assessment in the management of public health is widely supported. This is because to effectively manage food safety, a systematic system like risk assessment is necessary to examine variables and unknown factors that affect food safety (Lammerding & Fazil 2000, Lammerding 2006). Risk assessment can aid the determination of the magnitude of public health impacts and identify factors that contribute to increased risk from hazards in the food supply, and also provide objective information on the effectiveness of various intervention options. Furthermore, the scientific assessment of risk can be used as the basis to justify the introduction of increased stringency in safety standards for foods in international trade. Through the risk assessment process, it is possible for commodities, sources, and factors considered the largest contributors to increased public health risk to be prioritized by the risk managers (Lammerding 2006). It is thus argued that if risk assessment is used to supplement epidemiological data, it can provide invaluable food safety assurance information to help prevent foodborne illness (Toh, Birchenough & Smalley 2000).

According to FAO/WHO (1995), risk assessment for foodborne pathogens can be achieved by probabilistic scenario analysis, fault tree analysis, event tree analysis and the quantitative paradigm proposed for chemicals. On the other, Lammerding et al., (2000) proposed two general approaches to risk assessment namely qualitative and quantitative. Qualitative risk assessment involves descriptive or categorical treatment of information, while quantitative risk assessment involves mathematical analyses of numerical data.

Although qualitative risk assessments involve descriptive or categorical treatment of data, it is more than simply a literature review or summary of the available information about an issue. It follows the same systematic approach used in the quantitative approach and includes sections dealing with hazard identification, exposure assessment, hazard characterization and risk characterization. Therefore, the qualitative approach includes a frame work for translating qualitative information from different aspects of a risk issue into an objective evaluation of the overall risk. The structured frame work assists in reducing the bias associated with the risk assessor’s interpretation of qualitative information and helps ensure that descriptive statements are not misinterpreted by risk managers or others that might make use of the assessment (Lammerding & Fazil 2000).

Quantitative risk assessment can be deterministic or stochastic (Lammerding & Fazil 2000). The two are descriptively referred to as “point –estimate” and “probabilistic” risk assessment, respectively. The difference between the two approaches lies in the description of inputs for a risk assessment. The point estimate approach makes use of single values such as the average or the 95th percentile to represent "worst-case" events as inputs to a risk assessment. For example, to estimate the average number of a pathogen that an individual may be exposed to, the average level of contamination of a food is combined with the average amount of food consumed by an average consumer. Therefore the point-estimate approach, produces a single (average, or if selected, worst-case scenario) value for the risk estimate. The probabilistic approach considers all of the data available and uses probability distribution, as opposed to single values to describe the parameters that contribute to the risk. This approach produces a distribution of risk that characterizes the range of risk that might be experienced by an individual or population.

The probabilistic approach despite being more complex compared to the point-estimate approach, is becoming the method of choice for quantitative risk assessment. This is because it is increasingly being recognized that risk characterizations includes the variability and uncertainty in the information used to derive the risk estimate. Variability is essentially a property of nature, a result of natural random processes, and represents the diversity in a well-characterized population or parameter. Each step in the production, processing and marketing of a food has variability, and both the microbial pathogen and the human host responses are highly variable. On the other hand, uncertainty results from lack of knowledge about a phenomenon or parameter and the inability to characterize it. Recognizing and characterizing variability and uncertainty are important since they have different implications on the results of a risk assessment and for the risk management decisions to be pursued. For example, if variability in a parameter is the driving force for the large risk estimate, then better control of the process or factor may be needed to reduce the risk. But if the large risk estimate is the result of uncertainty in one or more parameters, then the management decision may be to focus research activities on collecting more data to better characterize the important uncertain parameters. However, if action has to be taken under circumstances where uncertainty is significant and additional data are not readily available, then a conservative (cautious) decision might be opted for with the understanding that more information would allow a better risk management strategy (Lammerding & Fazil 2000).

For more details on probabilistic versus point-estimate assessments the reader is referred to an article by Lammerding and Fazil (2000).

The dilemma is when is it appropriate to use qualitative and not quantitative risk assessment and vice versa? Quantitative risk assessment is difficult for pathogenic bacteria associated with foods as far as hazard identification, hazard characterization, exposure assessment, and risk characterization are concerned. The reasons for this view are detailed in the document "Application of Risk Analysis to Food Standards Issues" (FAO/WHO 1995), and are briefly discussed below:

i) Hazard identification

Limitations associated with the hazard identification stage include:

- the process being expensive and the difficulty involved in outbreak investigations,
- the lack of reliable or complete epidemiological data, and
- the inability to isolate and characterize new pathogens.

ii) Hazard characterization

Dose response data are useful when addressing toxigenic bacteria. However, when characterizing hazards from invasive strains of pathogenic bacteria, such information may be of little utility. Furthermore, for many foodborne pathogenic bacteria dose-response data are limited or non-existent and information on which to base dose-response estimates is difficult to obtain and/or may also be inaccurate for a variety of reasons, such as:

- host susceptibility to pathogenic bacteria is highly variable;
- attack rates from a specific pathogen vary widely;
- virulence of a pathogenic species is highly variable;
- pathogenicity is subject to genetic variation resultant from frequent mutation;
- antagonism from other bacteria in foods or the digestive system may influence pathogenicity; and
- foods have the potential to modulate the ability of bacteria to infect and/or otherwise affect the host.

iii) Exposure assessment

While levels of chemical agents in food may change slightly due to processing, populations of bacterial pathogens are dynamic and may increase or decrease dramatically in food matrices. Changes in populations of bacteria are affected by complex interactions of factors such as:

- ecology of the bacterial pathogen of concern;
- processing, packing and storing of food;
- preparation steps, such as cooking, which may inactivate bacterial agents; and
- cultural factors relating to consumers.

iv) Risk characterization

Analysis of risk associated with bacterial pathogens presents unique challenges. For example, any method used to assess the risk of hazards from foodborne bacteria will be complicated by factors resulting from methods used in the growth process, storage and preparation of food for consumption. These can vary greatly depending on cultural and geographical differences. Such factors describe the scenario set for a given food and are an essential element in a risk assessment for bacterial hazards (FAO/WHO 1995). Because of this, FAO/WHO have since recommended that further research be conducted to permit more accurate and quantitative assessments in the future (FAO/WHO 1995).

A view is held that it has not yet been determined whether a quantitative risk assessment approach is possible and appropriate for characterization of risk associated with foodborne bacterial pathogens. As a result, a qualitative approach to characterizing risk may be the best current alternative for risk assessment (FAO/WHO 1995).

On the contrary, Lammerding and Fazil (2000) are of the view that where quantitative information and resources are available, quantitative risk assessment is the preferred choice. However, when data, time and/or other resources are limited, the only option available may be to conduct a qualitative risk assessment. These same authors argue that qualitative assessment could be undertaken as a first evaluation of a food safety issue to determine if the risk is significant enough to warrant a more detailed analysis. In the publication "Application of Risk Analysis to Food Standards Issues" (FAO/WHO 1995), it is suggested that where it is possible to quantify threshold levels for concern (e.g., intoxications and other biological agents), a quantitative risk assessment may be possible. However, when considering hazards from pathogenic bacteria, a qualitative risk assessment may be the only feasible method to derive an assessment of the severity and the likelihood of harm associated with exposure through ingestion of a food. It is argued that quantitative risk assessment in such cases is often rendered impractical due to the following reasons: (1) the analyst may not be able to obtain all the necessary information needed to develop a mathematical estimate of the probability and/or severity of an adverse consequence, and (2) there are many uncertainties associated with how and when an organism may express pathogenic potential.

2.8.4 The role of risk analysis in food safety

Food will always present some minimal biological risk (FAO/WHO 1995). *Salmonella* and *Campylobacter* from food sources infect 3.4 million people a year, resulting in 25 500 hospital cases in American alone (Montague-Jones 2009). Furthermore, foodborne diseases caused by bacteria present a constantly evolving challenge, and even though a lot is known about them we are still not able to control them (Schelin et al. 2011). In the case of organisms like *S. aureus* predictive models for their growth and SE production could be powerful tools for microbial risk assessment in the food industries (Le Loir & Baron & Gautier 2003). In view of this, bodies concerned with food safety should use risk analysis to determine realistic and achievable risk levels for foodborne hazards and to base food safety policies on the practical application of the results of these analyses (FAO/WHO 1995, Schelin et al. 2011). Risk analysis has been incorporated by the Codex Alimentarius Commission (CAC), and other international organizations in the management of public health risks associated with hazards in food. To manage the risk associated with food, it is important to identify the foods, pathogens, or situations that lead to foodborne illness, and also to determine the magnitude of the impact these have on human health. Without such information, it is difficult to make rational decisions about whether or not resources should be allocated for increased management or regulation of any one hazard over another, and to decide on the kind of interventions which would be most effective in reducing food borne diseases (Lammerding & Fazil 2000).

If a food borne hazard is to be managed so as to control risk at an appropriate level of protection (ALOP), a risk assessment procedure to determine the risk to health has to be developed. This necessitates that the ALOP be translated into a metric or a safety level useful for setting limits that producers can relate to. Metrics that can be adopted include Food Safety Objectives (FSO), Performance Objectives (PO), Performance Criteria (PC) and Microbial Criteria (MC) (Schelin et al. 2011).

Biological agents (hazards) of concern to public health include pathogenic strains of bacteria, viruses, helminthes, protozoa, algae, and certain toxic products that they may produce. Of these hazards, the presence of pathogenic bacteria in foods currently presents the most significant problem internationally (FAO/WHO 1995, Fahrion et al. 2014).

Biological hazards act through two general mechanisms in causing illness. One mode of action is organisms producing toxins which may cause effects that range from mild symptoms of short duration to severe intoxications that can have long-term or life threatening consequences. The second mode of action is to produce pathological responses that result from ingestion of viable organisms capable of infecting the host (FAO/WHO 1995).

However, not every exposure to a pathogen in food will result in infection or illness, and not all individuals in a given population are equally susceptible to all pathogens. Therefore as indicated earlier on, risk of food borne disease is a combination of the likelihood of exposure to a pathogen in a food, the likelihood that exposure will result in infection or intoxication and subsequently illness and the severity of the illness (Lammerding & Fazil 2000). In view of this, the application of risk analysis in the production of microbiologically safe food products is a necessity (Notermans & Teunis 1996, Le Loir, Baron & Gautier 2003). Much that is true, for some organisms, like that many factors affect their growth and toxin production in foodstuffs, there is a need for further studies to develop accurate predictive models (Le Loir, Baron & Gautier 2003).

2.8.5 What to consider before embarking on risk analysis

The scope of risk assessment is dependent on the risk management question and the reason for doing the assessment. Therefore developing an unambiguous statement of the problem and its context is a critical initial phase of the process (Lammerding & Fazil 2000).

The problem could arise from any one of the following sources (Lammerding & Fazil 2000):

- Regulators;
- Public health sector;
- The food industry;
- Scientists; or
- Consumers.

Although background information about the problem necessary to provide a risk profile that describes the food safety problem and its context is usually assembled by risk managers or decision makers, a high degree of consultation between the risk manager(s) and risk assessor(s) to ensure a common understanding of the problem and its scope need to be considered (Lammerding & Fazil 2000).

Right at the beginning of the assessment process, it is important that the general analytical approach is adopted, the available resources and time frame, the desirable form of risk estimate (per exposure or per year, individual or population risk, or risk to a specific segment of the population), and other information that is useful for decision-making should be discussed (Lammerding & Fazil 2000). This will provide guidance to the direction and selection of information and also ensure that the questions that are asked and answered during risk assessment are the right ones.

2.8.6 Microbial risk assessment for *Staphylococcus aureus*

There has been an increase in the amount of information and consequently an increased understanding of the biology of *S. aureus* and the associated staphylococcal food poisoning (SFP), brought about by novel molecular techniques that have led to the improved understanding of virulence and survival mechanisms of *S. aureus*. However, this is not fully reflected by the developments in risk assessment and as a result several challenges remain (Schelin et al. 2011).

Risk assessment for *S. aureus* can be performed by using any of the following approaches (Schelin et al. 2011):

- Illustrative examples;
- Partial risk assessment; and
- Quantitative microbial risk assessment (QMRA) based on probabilistic modeling.

Foods for which *S. aureus* risk assessment has been conducted are varied and include: milk, skim milk, unripen raw-milk cheese, pork-based Korean food, kimbab, home cooked foods and cream-filled baked goods (Schelin et al. 2011).

Risk assessments for *S. aureus* focus on enterotoxigenic strains of the species so as to estimate hazard strength, and does not discriminate (sub) types based on serology, toxin genes or on molecular markers commonly used in epidemiology (Schelin et al. 2011). It normally involves the identification of the organism *S. aureus* in general, or enterotoxigenic strains specifically and/or the enterotoxin (SEA or not specified) (Schelin et al. 2011).

Although growth of and subsequent *S. aureus* toxin production can be prevented by storing "potentially hazardous" foods below 7 °C and 10 °C, respectively, poor personal hygiene and handling practices and inadequate refrigeration of foods have been identified as the main factors contributing to staphylococcal foodborne disease. This is demonstrated by risk assessments that have shown that foods not stored below growth temperatures for sensory reasons or whose processing includes steps with growth permissive conditions, such as cheese, and milk are a great concern (Schelin et al. 2011).

The hazard characterization step of risk assessment of *S. aureus* normally focuses on food poisoning symptoms and does not address the issues of susceptible populations or immunity. Furthermore, for toxigenic microorganisms dose-response relations are essentially that of a chemical toxin (i.e., threshold model). However, due to knowledge gaps, various levels of enterotoxin have been used as the threshold. For example, in several studies levels of *S. aureus* required for the detection of enterotoxin levels of bacteria in the food have been used as proxy for potentially hazardous doses, while in others, threshold levels for enterotoxin of 20, 94 and 20 or 100 ng per serving have been used. These thresholds are based on outbreak data. Where the numbers of *S. aureus* have been used, the threshold levels of expressed numbers of *S. aureus* bacteria of 5 to 8 log CFU per g have been used (Schelin et al. 2011). In their review article, Scheline and colleagues refer to a study that used a constant relation between toxin production and cell numbers under the conditions they evaluated using an equation developed from milk data (Schelin et al. 2011):

$$Tox = 0.9300751 \times C - 6.662092$$

Where Tox is the toxin production (log ng ml^{-1}) and C is the number of cells (log cfu ml^{-1}).

Exposure assessments for *S. aureus* tend to put emphasis on the initial contamination of the starting ingredients and their changes, mostly growth but also inactivation, due to cooking and during production, holding and storage. On the contrary, less emphasis if any is put on consumer handling and consumption, and hence these have not been described in any detail. Exposure is assessed per g or per serving (Schelin et al. 2011).

Although it is more common to rely on initial data of *S. aureus* levels and prevalence followed by modeling of the effect of processes on changes in the *S. aureus* levels (Schelin et al. 2011), there are examples where exposure assessment has been based on enterotoxins in the food with subsequent calculations (Schelin et al. 2011). This allows for assessment of enterotoxin production based on predicted numbers of *S. aureus* using either the model proposed by Fujikawa and Morozumi with 15 °C as the temperature limit for toxin production, or by using the equation developed by Schelin et al.(2011).

Risk characterization of *S. aureus* is based on the number of *S. aureus* (CFU) or the concentration of enterotoxin (ng) per g or per serving. Sensitivity and scenario analyses in risk characterization of *S. aureus* have identified the initial contamination levels together with temperatures and storage/holding times and pH as having the greatest impact on the assessment endpoints (Schelin et al. 2011). Assumptions concerning the threshold level for the number of *S. aureus* cells required for hazardous levels of enterotoxin to be produced has also been shown to contribute most to the uncertainty in the risk estimate, which highlights the importance of studies to highlight further the relationships between growth, survival and enterotoxin production in various foods and in dose-response relationships. The knowledge gap highlighted here could be the reason for the lack of predictive models for risk assessment and evaluation of process safety. In view of this, safety of food with respect to *S. aureus* is commonly evaluated based on predicted levels of *S. aureus* that have been associated with enterotoxin production level and more seldom in terms of the predicted enterotoxin level or the actual measured value. According to Schelin et.al., this may be a limitation given the dynamic and complex interplay between growth, gene expression, metabolism and enterotoxin levels and the potential uncoupling between cell numbers and the amount of enterotoxin produced (Schelin et al. 2011).

The ideal models with the greatest impact on estimates of risk for SFP are those that describe production of enterotoxin in conditions that correspond to food matrices (Schelin et al. 2011).

2.9 Hazard Analysis Critical Control Points (HACCP) system

In this section, the development of HACCP and its use as a food safety assurance measure, and its short comings are discussed.

2.9.1 Development of HACCP and some milestones in its implementation

The HACCP system was first developed by the Pillsbury Company together with NASA and the US army's research, development and engineering center at Natick to ensure the safety of astronauts' food. NASA wanted a "zero defects" program assurance against contamination by microbial hazards that could cause illness to astronauts while out in space. Although from its inception, HACCP was developed to ensure microbiological safety of foodstuffs, it has since been broadened to include chemical and physical hazards in foods (Motarjemi et al. 1996, Doménech, Escriche & Martorell 2008).

The HACCP programme was not publically discussed until the 1970s, but since then, HACCP as a food safety assurance system has grown to become the universally recognized and accepted method for food safety assurance, capable of dealing with safety hazards which may arise in the food production process (Motarjemi et al. 1996, Bertolini, Rizzi & Bevilacqua 2007, Doménech, Escriche & Martorell 2008). This has been acknowledged and is why the Codex text on the HACCP system by the CAC (Motarjemi et al. 1996, KZN-DOH 2001, FAO/WHO 1995, Doménech, Escriche & Martorell 2008).

In 1993 the adoption of the Codex Guidelines for the Application of the HACCP system by the CAC of FAO/WHO was a milestone in the history of the HACCP system. The adopted Codex guidelines provided the basis for the recommendation to review the Codex Code on General Principles of Food Hygiene and the recommendations for the application of the Codex HACCP guidelines (Motarjemi et al. 1996). As result, all relevant Codex guidelines have had to be revised to include HACCP. In the same year (1993), the European Union, through the Directive 93/43/CEE, made the need to implement self-checking in agro-food companies based on the HACCP principles compulsory (Doménech, Escriche & Martorell 2008).

The successful completion of the General Agreement on Trade Tariffs (GATT) Uruguay Round of multilateral Trade Negotiations in April 1994 was another highlight in the application of HACCP. Following the successful completion of the said GATT meeting, Codex standards, guidelines (including guidelines for the application of the HACCP system) and recommendations became the reference for food safety requirements in international trade. Experiences gained in some countries indicate that application of HACCP systems leads to more efficient prevention of foodborne diseases (Motarjemi et al. 1996, Buchanan, Whiting 1998). A notable example is the USA where application of HACCP by the fish processors is estimated to have averted some 20-60% of cases of seafood associated foodborne illnesses (Motarjemi et al. 1996).

In developed countries, it has become mandatory for food business operators to establish and operate food safety programmes and procedures based on HACCP principles. For example, in the European Union, to reinforce public health security, the EU started forcing the implementation of full HACCP in all food businesses (Bertolini, Rizzi & Bevilacqua 2007). This requirement was implemented because the HACCP system has the potential to help food business operators attain a higher standard of food safety (Doménech, Escriche & Martorell 2008).

2.9.2 HACCP as a food safety assurance system

While end-product sampling to determine compliance to legal requirements has its place in determining the safety of foods, there is a need to promote the introduction of food safety assurance systems that are preventive in nature such as HACCP to ensure food safety (KZN-DOH 2001, Schelin et al. 2011). Increasing concern about food safety and the lack of resources, coupled with the recognition of the limitations of traditional approaches to assuring food safety have accentuated the need for HACCP, a cost effective food safety assurance method (Motarjemi et al. 1996, KZN-DOH 2001).

The HACCP system is a scientific, rational and systematic approach to identifying, assessment and control of hazards during production, processing, manufacturing, preparation and use of food to ensure that food is safe (does not present an unacceptable risk to health) when consumed. Unlike the traditional food safety assurance systems that rely on end product testing, the HACCP system integrates end-product testing into the design of the process of food safety control, providing a preventative and thus a cost effective approach to food safety (Motarjemi et al. 1996). Barro and others argue that HACCP and pre-requisite systems, like good manufacturing practices (GMP), combined with good hygiene practices (GHPs) are essential for food safety management (Barro et al. 2007).

Hazard Analysis and Critical Control Points, as a food safety system, involves identification of hazards and their preventative measures. When developing a specific HACCP plan, it is important to determine all potential hazards which are "*of such a nature that their elimination or reduction to acceptable levels is essential to the production of a safe food*". This gives rise to the list of the significant hazards to be addressed within the HACCP plan (FAO/WHO 1995, Doménech, Escriche & Martorell 2008). After the list of potential hazards has been drawn, the next thing is to determine the potential hazards that are "*essential*" to control, and to overcome some of the weakness inherent in the HACCP. This requires the adoption of a risk-based hazard assessment, quantitative microbiological risk assessment (QMRA) (FAO/WHO 1995, Ekanem 1998, Buchanan, Whiting 1998).

The HACCP system is based on the following seven principles (Motarjemi et al. 1996, Doménech, Escriche & Martorell 2008):

- conduct hazard analysis (this entails identifying hazards and specifying control measures);
- identify critical control points (CCPs);
- establish critical limits at each CCP;
- establish monitoring procedures;
- establish corrective actions;
- establish verification procedures; and
- establish documentation procedures.

The application of these seven principles is a mandatory requisite in the food production chain so as to prevent exposure of the final consumer to food safety hazards (Bertolini, Rizzi & Bevilacqua 2007). The implementation of these seven principles in a HACCP-based program enhances food safety by ensuring adequate process controls accompanied by periodic verification and corrective actions (Doménech, Escriche & Martorell 2008).

Furthermore, with the HACCP system, the business operators are the ones responsible for applying the food safety assurance system to ensure production of safe food. The details of how this should be done, more so how to implement principle 1-4 has been described in details by Doménech and others (Doménech, Escriche & Martorell 2008).

Although HACCP requirements should take into account the seven principles prescribed by CAC (Doménech, Escriche & Martorell 2008), some authors have proposed flexibility in its implementation. For example, the principles applied among EU countries are different from those of Codex and no mention is made of the need for formal HACCP plans (Bertolini, Rizzi & Bevilacqua 2007).

2.9.3 The HACCP system: its short comings and critics

While it is acknowledged that HACCP is a cost effective food safety assurance system, its implementation can be challenging. Mortimore as quoted by Bertolini & Bevilacqua (2007) has this to say: "*HACCP as a common-sense approach to food safety management, its implementation is quite demanding*". Further to this, even large companies, with their resources of money and expertise, face significant hurdles in developing successful HACCP systems. It can, therefore, be concluded that trying to implement HACCP in small and medium sized companies is likely to face insurmountable issues that would jeopardize the efficiency and effectiveness of the implementation of the system (Bertolini, Rizzi & Bevilacqua 2007).

Among the factors that have been identified that may act as a hindrance to practical implementation of HACCP especially among small micro enterprises (SMEs) are lack of: time; expertise; training; motivation; commitment and funding (Bertolini, Rizzi & Bevilacqua 2007). Bertolini quoting other authors suggests that lack of experienced, technically qualified people, is the most important factor influencing the implementation of the HACCP system among SMEs. This lack of skilled personnel is likely to lead to the following (Bertolini, Rizzi & Bevilacqua 2007):

- inability to prioritize risks from physical, microbiological and chemical hazards;
- inability to discriminate between the relative risks of different pathogens on a given food;
- a lack of focus on the hazard identification stage that causes an inability to make critical technical decisions.

According to Bertolini (Bertolini, Rizzi & Bevilacqua 2007), despite efforts by numerous authors to define procedures aimed at simplifying the hazard analysis, there is no effective straight forward path for hazard assessment. Even with the use of specific software systems which make it easier to analyze/compare the different risks which may stem from production processes, still there is no effective straight forward and "automated" path for hazard assessment. As a result hazard assessment is still based on the traditional approach such as a simple evaluation of hazards a "brainstorming" session as recommended by the National Advisory Committee on Microbiological Criteria for Foods (NACMCF). Furthermore, HACCP planning has several areas where its application is limited due to reliance on qualitative consideration of hazards and their control. Specifically, HACCP planning is limited both conceptually and practically by its inability to quantify the potential combined influence of multiple control-point deviations and to relate the successful operation of a HACCP system to a measurable public health impact (Buchanan & Whiting 1998). In spite of the high reliability of the HACCP system which allows for guaranteeing a high food safety level, through process control and management systems, inherent failures do occur due to unavoidable and inherent process variation from normal performance for which no specific causes can be identified. Furthermore, little attention is given to the fact that a HACCP system can only minimize the probability or risk of food hazards from occurring (Doménech, Escriche & Martorell 2008).

2.9.4 Overcoming weaknesses associated with the HACCP system

Quantitative microbiological risk assessment (QMRA) offers a means to overcoming shortcomings relating to the inability of the HACCP planning process to quantify potential combined influences of multiple control point deviations. It also offers a means to relate a successful HACCP operation to a measurable public health impact (Buchanan & Whiting 1998).

To overcome shortcoming associated with HACCP as described above, a new methodological approach to handling a structured hazard analysis has been suggested. This methodology considers hazards as the failures of a food production process in a fuzzy fault tree. For each step of the production process, the fault tree analysis makes it possible to define whether that stage will be or will not be a critical control point, depending on the hazard's likelihood of occurrence and on its severity (measured in terms of detectability by processes downstream) (Bertolini, Rizzi & Bevilacqua 2007).

In conclusion, the integration of HACCP plans with the development of dynamic risk assessment models offers a means for considering the entire farm-to-table continuum and for relating food-manufacturing operations to public goals. This is critical to establishing equivalence among HACCP systems (Buchanan & Whiting 1998). Implementation of the HACCP plan should be viewed as a system for controlling risks. In terms of risk analysis terminology, HACCP is a quantitative risk management system developed on the basis of a qualitative risk assessment. Basing HACCP planning on qualitative hazard analysis is a limiting factor on its effectiveness as discussed above, which means further development of HACCP concepts and applications is needed to realize its full potential as a risk management system for controlling food-borne pathogens and assuring the safety of foods (Doménech, Escriche & Martorell 2008).

2.10 Monitoring food safety and sampling strategy for monitoring

In line with the FAO/WHO Expert Committee on Food Safety, South African government views pre-employment and routine medical examinations of food handlers as being unreliable and not cost-effective in the prevention of foodborne diseases. Therefore, sampling and testing of food handlers pre-employment is not part of the strategy the health authorities employ to provide safe food to the public. Instead, emphasis is placed on regular monitoring and surveillance, and management of the food handling process (Department of Health 2007).

An effective food control structure includes adequate laboratory facilities and various types of skilled staff like analytical chemists, microbiologist, technicians and environmental health officers (EHO), and support personnel. In South Africa, the EHO are considered the eye and ears of their agencies and are expected to be able to recognize, collect and transmit evidence when violations have occurred (KZN-DOH 2001).

To decide on the design and size of a food control programme, a thorough survey to assess needs has to be conducted to determine the kind of resources that are available to meet these needs and to decide whether re-organization of laws, staff and facilities could lead to the basic structure of an effective food control system. This can then be followed by establishment of the appropriate priorities (KZN-DOH 2001).

A food monitoring system should consist of the following aspects (KZN-DOH 2001):

- identifying hazards and assessing their severity and risk;
- determining critical control points;
- specify criteria to ensure control;
- monitor criteria to ensure control;
- take corrective action whenever monitoring criteria are not met;
- verify that the system is functioning as planned.

In South Africa, the following two methods of food sampling have been suggested and these are (KZN-DOH 2001):

a) **Random selective sampling**: here specific or certain (i.e., a single food or a group of foods) foods are selected for sampling and testing (food run) that occurs on a monthly basis. This monthly based system can incorporate certain foods that are sampled and analyzed for that specific month covering all districts/regions participating in the food run. The same products are re-sampled until the desired results and provided corrective measures are achieved. This method is said to provide a rational approach to the control of microbiological hazards in food and avoids the many weaknesses inherent in the inspectional approach and circumvents the draw backs of reliance on microbiological testing.

b) **Random sampling**: here food products are randomly selected on a weekly basis and analyzed. These samples are obtained on general inspections of premises so as to examine any foodstuffs found upon such premises to assess if they are hazardous or pose a health risk.

It is also possible to have the two methods run concurrently. For example this could be the case if there is a need for more food samples to be analyzed besides the set food run. The food product in question may be sampled for further analysis in order to take further action. That is to say even if a food run has been supplied, any food items that may be of concern can be sampled and submitted for analysis (KZN-DOH 2001).

Where certain samples frequently pose a health risk, the food product in question can be sampled in the entire region and may be listed on the selected food run. This would help establish if similar problems arise in other regions providing a justification for implementation of stricter food control measures (KZN-DOH 2001).

The choice of places to be evaluated is based on several factors namely: food property; food operation; volume of food preparation; and susceptibility (KZN-DOH 2001).

2.11 Microbiological organisms isolated in the present study

Foodborne diseases are a major concern worldwide, with over 250 different types of foodborne diseases described to date. Among foodborne diseases, biological hazards and especially bacteria are the leading causes. It is postulated that two-thirds of foodborne disease outbreaks that occur worldwide are caused by bacteria (Le Loir, Baron & Gautier 2003, Rane 2011, Fahrion et al. 2014).

Staphylococcus and *E. coli* as pathogens have been linked with foodborne illness and even the death of many people each year (Githiri, Okema & Kimiywe 2009, Rane 2011). As a result, these two organisms form the focus of the next section together with coliforms.

2.11.1 Coliforms

In this section a brief description is given of what makes up coliforms and the implication of their presence in ready-to-eat food.

Coliform bacteria are non-sporulating, facultatively anaerobic and Gram-negative rods that produce acid and gas from lactose during metabolic fermentation. They are not a species as such, but are a group of organisms defined by tests that are used to identify them (Department of Agriculture, Forestry and Fisheries 2012, Hall, Brown & Lewis 1967, Gilbert et al. 2000).

Coliform bacteria include genera that originate from faeces such as *Escherichia* as well as genera that are not of faecal origin. The later can be found in plant, soil material, and can grow in water distribution systems (Hall, Brown & Lewis 1967, Martins 2006, Department of Agriculture, Forestry and Fisheries 2012, TSC's Water Treatment Engineering Team 2009).

The use of coliforms (of both faecal and none faecal origin) as indicator organisms is based on the fact that they are relatively easier to identify and are usually present in larger numbers compared to the pathogenic organisms of faecal origin. In addition, coliforms respond to the environment, wastewater treatment, and water treatment like many pathogens (Hall, Brown & Lewis 1967, Department of Agriculture, Forestry and Fisheries 2012).

a) Non-faecal coliforms

This group of organisms includes organisms like *Enterobacter, Klebsiella, and Citrobacter* that are not of faecal origin. The presence of non-faecal coliform bacteria in water or food provides an indication of the sanitary quality of food and water (Department of Agriculture, Forestry and Fisheries 2012, TSC's Water Treatment Engineering Team 2009).

b) Presence of non-faecal coliforms in food and water

All foods contain some level of coliform. Unavoidable contamination of RTE food results in contamination with coliforms at the level of 10^1 to 10^2 per gram of food (Badrie, Joseph & Chen 2011). Therefore up to 10^2 CFU/g contamination level is acceptable in RTE food (Githiri, Okema & Kimiywe 2009). But if RTE food contains >10^2 CFU/g or mL total coliforms, such food is considered potentially hazardous (Mamun, Rahman & Turin 2013, New South Wales Food Authority (NSWFA) 2009, International Commission on Microbiological Specification for Foods. 2006).

A total coliform level of more than 10^2 CFU/g suggests that a food item has become contaminated or may have been inadequately cooked or processed. Such food is likely to lead to gastrointestinal infection due to enteric organisms. As a result, it is not suitable for human consumption. This is confirmed by both the International Commission on Microbiological Specifications for Food (ICMSF) and the USA Food and Drug Administration (FDA) (International Commission on Microbiological Specification for Foods

2006). Based on this, the recommended number of coliforms in RTE food is set at <10^2 CFU/g (Ekanem, Otti 1997, NSW Food Authority 2010, NSW Food Authority 2009, New South Wales Food Authority (NSWFA) 2009).

The number of coliforms in a food sample does not give an estimate of the number of *E. coli* in a food sample. Therefore, to get an indication or estimate of the number of *E. coli* in a food sample, confirmatory tests for faecal coliforms of which *E. coli* is the major species in the faecal coliform group are necessary. If confirmation is not done, a large number of food samples could end up erroneously suspected of being contaminated with faecal coliforms when actually their presence in food or water does not automatically mean one is at risk of contracting water borne illness (Hall, Brown & Lewis 1967, TSC's Water Treatment Engineering Team 2009).

Therefore, while the presence of coliforms in a food does not necessarily mean that the food is harmful, it is an indication that a food item may have (Hall, Brown & Lewis 1967):

- been stored out of a refrigerator for a prolonged period;
- not been properly cooked; or
- been contaminated following cooking.

2.11.2 *Escherichia coli*

A brief description of faecal coliforms and the implication of their presence in RTE food plus their relevance to health are discussed here.

Escherichia coli were first discovered in the human colon in 1885 and are the most studied free living organism (Marler 2014). This organism occurs in the faeces and intestinal tract of humans, and all warm blooded animals including poultry (Taulo et al. 2009, Feng et al. 2014). Unlike *Staphylococcus aureus* that resides on the skin of humans, *E. coli* are considered transient bacteria on the hands of food handlers. While *E. coli* have limited ability to survive on hands and in the environment, they can occur on the hands in sufficient numbers to allow transmission to other surfaces (Taulo et al. 2009).

a) Presence of *Escherichia coli* in food and water

Transmission of *E. coli* is via the faecal oral route and its presence in food is used as an indicator of recent faecal contamination (Ingham 2007, Feng, Weagant & Grant 1998, Feng et al. 2014, Taulo et al. 2009). Unlike non-faecal coliforms, *E. coli* do not occur in other niches (Feng et al. 2014). Therefore, if *E. coli* is detected in any food sample, it is a sign that human contact with the RTE food took place, and potential pathogenic microorganisms of enteric origin from either humans or other warm-blooded animals are present in the food (Taulo et al. 2009, Badrie, Joseph & Chen 2011).

The maximum acceptable levels of *E. coli* in RTE food lies between 10^2 CFU/g and 10^4 CFU/g (Gilbert et al. 2000, New South Wales Food Authority (NSWFA) 2009). Food that contains $>10^4$ CFU/g of *E. coli* is likely to lead to gastrointestinal infection due to enteric organisms. However, in some guidelines the classification of such food as being unacceptable/potentially hazardous has been discontinued because a prosecution based solely on indicator organisms without other criteria of unacceptability cannot succeed (Gilbert et al. 2000).

With regard to water, generally a high level of faecal coliforms is a warning of failure of the water treatment system, a break down in the integrity of the distribution system and possible contamination with pathogens. Therefore, if water tests positive for faecal coliforms, boiling the water used for drinking is advised, more so if there is no other means of disinfecting the water to render it safe for human consumption (Hall, Brown & Lewis 1967).

b) Health effects of *Escherichia coli*

Although most strains of *E. coli* are harmless, some serotypes that produce shiga toxins like *E. coli* O157:H7 are pathogenic and can cause serious illness (Taulo et al. 2009, TSC's Water Treatment Engineering Team 2009, Department of Agriculture, Forestry and Fisheries 2012, Pietrangelo 2012, Marler 2014). The obligatory pathogenic *E. coli* include the enterohaemorrhagic *E. coli* (EHEC), enteroaggregative *E. coli* (EAEC), entropathogenic *E. coli* (EPEC) and enterotoxic *E. coli* (ETEC) (Förster et al. 2007).

In healthy adults, these diseases are not life-threatening, and generally following ingestion of *E. coli* the effects are usually self-limiting, and symptoms last from a few days to more than a week. Symptoms include abdominal cramps and diarhoea. However, some types of *E. coli* especially *E. coli* 0157:H7 can cause intestinal infection characterized by hemorrhagic colitis that results in severe abdominal cramps, watery diarrhea, lower intestinal bleeding accompanied with vomiting and fever, and in some instances haemolytic uremic syndrome (HUS) or renal failure. Particularly in children, the elderly and immunocompromised individuals, infections with the obligatory *E. coli* can be fatal (Pietrangelo 2012, TSC's Water Treatment Engineering Team 2009, Förster et al. 2007).

2.11.3 *Staphylococcus aureus*

The discussion of *S. aureus* here constitutes the first two stages of risk assessment, and these are hazard identification, and hazard characterization.

Staphylococcus aureus strains belong to five biotypes according to their human or animal origin. The different biotypes; non-β-heamolyitic human, avian, bovine, ovine, and nonspecific, can be distinguished using a biotype scheme based on biochemical characteristics (Le Loir, Baron & Gautier 2003).

On the basis of a coagulase test (tests for ability to coagulate plasma), traditionally the genus *Staphylococcus* is subdivided into two groups of strains (Normanno et al. 2005, Eley 1996, Le Loir, Baron & Gautier 2003):

- the coagulase positive *Staphylococcus* (CPS) which includes *S. aureus*, *S. intermedius*, *S. hycus* and *S. delphini*, and
- the coagulase negative which includes *S. epidermidis*, *S. cohnii*, *S. xylosus* and *S. haemolyticus*

Staphylococcus aureus are Gram-positive, facultative anaerobic, non-motile, none-spore-forming cocci which are catalase, coagulase and deoxyribonuclease (DNase) positive (Normanno et al. 2005, Eley 1996, Le Loir, Baron & Gautier 2003). They occur singly or as paired cocci, or form grape like irregular clusters and produce a carotenoid pigment resulting in golden-coloured colonies which explains the origin of the species name aureus (meaning gold) (Schelin et al. 2011, Le Loir, Baron & Gautier 2003).

a) *Staphylococcus aureus* as a pathogen

Foodborne diseases caused by the consumption of food or water can be infectious or toxic in nature. Infection are caused by various types of disease-causing pathogens that can contaminate foods, while the foodborne intoxication due to toxins are caused by poisonous chemicals, or other harmful substances that are present in food (Le Loir, Baron & Gautier 2003, Rajkovic 2014).

The bacteria most commonly incriminated in foodborne intoxications are the gram positive bacteria such as *Bacillus cereus*, *Clostridium botulinum*, *Clostridium pefringens* and *Staphylococcus aureus*. These bacteria are also referred to as toxigenic bacteria. Toxins produced by the group account for 10% of the foodborne outbreaks reported in the European Union(EU) annually (Rajkovic 2014, Dablool & Fouad 2014).

The ability of toxigenic bacteria to cause foodborne poisoning depends on their capacity to produce toxins after ingestion in the digestive tract (causing toxico-infection) or before ingestion with toxins preformed in foodstuff (causing intoxication) (Le Loir, Baron & Gautier 2003, Rajkovic 2014, Sihto et al. 2015). The production of these toxins can occur at any stage of the food chain and persist in the food and remain biologically active even after the vegetative forms of the bacteria have been destroyed or rendered inactive (Rajkovic 2014).

In milk, *S. aureus* starts producing staphylococcal enterotoxins (SEs) when the population density reaches about $10^{6.5}$cfu/ml (Fujikawa, Morozumi 2006). In food, it is a population density of 10^5 - 10^6 CFU/g of *S. aureus* that is able to produce sufficient amounts of SEs to cause staphylococcal food poisoning (SFP) (Rajkovic 2014, Min et al. 2013). This is confirmed by the fact that in many cases SFP is usually confirmed when the population density is at least 10^5 CFU/g in the food in question (Hennekinne, De Buyser & Dragacci 2012). In low a_w (water activity) conditions, such as in salted RTE chicken, *S. aureus* accumulate low molecular weight compounds called compatible solutes, which stimulate not only growth but also toxin synthesis (Qi & Miller 2000). Therefore, in the present study it is assumed that SFP occurs following consumption of RTE chicken contaminated with *S. aureus* with a concentration that is higher than 10^5cfu/g.

Staphylococcal enterotoxins (SEs) belong to a family of toxins referred to as pyrogenic toxins that originate from both *Staphylococcus* and *Streptococcus* species. Pyrogenic toxins also include Toxic Shock Syndrome toxins, exfoliatins A and B and streptococcus pyrogenic toxins. All these share the same function and structural and sequence similarities (Le Loir, Baron & Gautier 2003).

According to one classification, staphylococcal enterotoxins are a family of nine thermostable (capable of withstanding boiling for up to 30 minutes), pepsin-resistant exoproteins forming a single chain with a molecular weight ranging from 26,000 to 29,600 Da. All the nine SEs identifiable serologically are designated: SEA, SEB, SEC, SED, SEE, SEG, SEH, SEI and SEJ. While the rest present a single antigenic variant, SEC presents several antigenicvariants namely SEC_1, SEC_2 SEC_3 SEC_{ovine}, SEC_{bovine} that feature minor epitome differences (Normanno et al. 2005, Eley 1996, Makita et al. 2012, Schelin et al. 2011). There is also SEF, however, this one is identical biochemically to Toxic Shock Syndrome Toxin, which produces toxic shock syndrome commonly associated with the use of tampons during menstruation (Eley 1996). In another classification of the members of the SE family, some authors (Le Loir, Baron & Gautier 2003) instead of reporting the nine (9) families of staphylococcal enterotoxins with the five antigenic sub-variants of SEC as mentioned above, report the existence of 14 different types of SEs that share structure and sequence similarities.

Studies on SEA to SEE demonstrate a good correlation between the occurrence of the *sea* to *see* genes and the production of the corresponding SEs. This is not the case for other SEs (Le Loir, Baron & Gautier 2003).

In any given population of *S. aureus*, not all isolates are enterotoxigenic (i.e., not all are able to produce SEs). Estimates of *S. aureus* isolates in a population that are likely to be enterotoxigenic vary from one food to another and also between different populations (Le Loir, Baron & Gautier 2003). For example, Normanno et al. (2005) showed that the number of isolates in a population of *S. aureus* that are enterotoxigenic ranged from 21.4% to 100% with the most likely (mean) number being 57%. While the figure for human *S. aureus* isolates that are likely to be enterotoxigenic is lower estimated to be 15-20%. Other authors estimate that the number of *S. aureus* isolates associated with food that are likely to be enterotoxigenic is around 25% (Le Loir, Baron & Gautier 2003). In a study done in France where 61 isolates were isolated from raw milk cheeses, 15.9% were enterotoxigenic. In Denmark researchers found that only 1 of 414 strains of *S. aureus* carried an SE gene. A similar study conducted in Brazil found that 54 of 127 (43%) *S. aureus* isolates from bovine mastitis were SE producers. More detailed examples of such variation and explanations for this variation have been published (Le Loir, Baron & Gautier 2003).

Characteristics of SEs include solubility in water and saline solutions in addition to being highly stable. They are resistant to most proteolytic enzymes such as pepsin or trypsin. They are also resistant to chymotrypsin, rennin and papain (Le Loir, Baron & Gautier 2003). The ability to resist digestive enzymes enables SEs to remain active in the digestive tract after ingestion. Furthermore, staphylococcal enterotoxins are highly heat resistant, and they are thought to be more heat resistant when in foodstuffs than when in laboratory culture medium. But if present in food at low concentrations, it is possible for them to be inactivated by the heat treatment used in the sterilization of canned foods. This means that SEs have the ability to resist conditions (heat treatment, low pH) that could easily destroy the vegetative bacteria that produced them (Le Loir, Baron & Gautier 2003).

Serological types SEA to E and SEH have clearly been demonstrated as the only superantigens capable of emetic activity. The new SEs seem not to possess emetic properties, and available experimental evidence suggests that they are merely superantigenic (i.e., cause immunosuppression and nonspecific T-cell proliferation) (Le Loir, Baron & Gautier 2003, Omoe et al. 2002). It is important to note that the superantigens and emetic activities of SEs are two separate functions localized on separate domains of the protein. Nonetheless, a high correlation between the two activities exists and it has been shown that genetic mutations resulting in a loss of antigen activity are likely to result in the loss of emetic activity of SE (Le Loir, Baron & Gautier 2003).

Toxins produced by *Staphylococci aureus* that either do not have emetic properties or have not been tested but have the proposed designation of staphylococcal enterotoxin-like (SEI) superantigens include the following: SEIJ, SEIK, SEIL, SEIM, SEIN, SEIO, SEIQ, SEIR, and SEIU. These together with SFP associated SE are linked to toxic shock syndrome toxin-1 (TSST-1) (Makita et al. 2012, Schelin et al. 2011). A detailed description of the superantigenic activity of SEs that results from the direct interaction between SEs and T-cell antigen receptor and the major histocompatibility complex (MHC) of antigen presenting cells (APC), which results in SEs activating T-cells at the order of magnitude above antigen-specific activation has been described (Le Loir, Baron & Gautier 2003).

Staphylococcus aureus rely on the production of SEs to cause SFP (Le Loir, Baron & Gautier 2003). Most strains of *Staphylococcus aureus* are capable of producing one or more enterotoxins which can cause the gastrointestinal symptoms observed during intoxication (Normanno et al. 2005, Makita et al. 2012, Schelin et al. 2011).

The main regulatory system controlling the gene expression of virulence factors in *S. aureus* is the accessory regulator *agr* that acts in combination with the staphylococcal accessory regulator *sar*. However, not all SE genes are controlled by the agr system. The genes that have been demonstrated to be *agr* dependent for their expression are: *seb*, *sec*, and *sed* genes. Those that are not *agr* dependent are *sea* and *sej* (Le Loir, Baron & Gautier 2003).

The *agr* expression is tightly linked to quorum sensing, which means that production of *agr* –dependent SEs in food stuffs is dependent on the ability of *S. aureus* to increase to a high cell density (estimated to be 10^6 CFU/g) in the foodstuffs. This is confirmed by Makita and colleagues (2012), quoting Fujikawa and Morozumi (2006), who noted that *S. aureus* starts producing SE when the population density in milk reaches about $10^{6.5}$ cfu/ml. In addition to quorum sensing, environmental factors also play an important role in SE gene expression (Le Loir, Baron & Gautier 2003). For example, findings of the study by Sihto et al. (2015) suggest that there is a high strain-specific variation in the *sed* gene expression under NaCl stress.

The emetic activity of SEs is not well characterized as superantigen activity. Unlike superantigens, enterotoxins activity is unique in that it has the ability to cause emetic responses when administered orally to monkeys (Le Loir, Baron & Gautier 2003). Compared to the cholera toxin, the SEs do not fall in the category of classical toxins. This is because unlike classical toxins, SEs act on the receptors in the intestines with the stimulus reaching the vomiting center in the brain via the vagus nerve and not directly on the cells of the intestines. In view of this, SFP toxins are considered neurotoxins (Eley 1996, Normanno et al. 2005, Le Loir, Baron & Gautier 2003).

The pre-formed toxins secreted by the bacteria tend to be produced in protein-rich food such as meat and dairy products (Makita et al. 2012, Schelin et al. 2011, Le Loir, Baron & Gautier 2003, IFT. 2004). Toxin production takes place during the active growth of the bacteria, often during storage (Eley 1996). However, this does not mean that toxin production is always accompanied by growth. For example, toxin production has been observed in non-replicating cell cultures in ham products (Schelin et al. 2011).

Staphylococcal food poisoning is one of the most common foodborne diseases worldwide that affects hundreds of thousands of people each year (Makita et al. 2012, Le Loir, Baron & Gautier 2003, IFT. 2004, Taulo et al. 2009). For example, in 1998 a *Staphylococcus* food poisoning outbreak affected 4000 individuals of whom 20% were hospitalized (Githiri, Okema & Kimiywe 2009). In 2009, a total of 5,550 outbreaks of foodborne illnesses that affected almost 49,000 people (of whom 46 died) were reported in Europe; in 293 of these outbreaks, *Staphylococcus* spp and bacterial toxins (produced by *Bacillus*, *Clostridium* and *Staphylococcus*) were noted as the fourth most common causative agents in the foodborne outbreaks (Schelin et al. 2011). A few decades ago in the United States of America, *S.*

aureus was responsible for 25% of all foodborne illnesses. Although SEs are widely considered the third most cause of reported food borne diseases, it is possible given the high prevalence of contamination of food with *S. aureus*, that it is the most common foodborne disease, (Makita et al. 2012, Eley 1996, Le Loir, Baron & Gautier 2003).

Although the majority of reported SFP outbreaks are associated with the classical staphylococcal enterotoxins (SEA-SEE), staphylococcal enterotoxin A (SEA) is the most common cause of SFP (Schelin et al. 2011, Dablool & Fouad 2014). This means that SEA is most frequently involved in food poisoning, and it is invariably (approximately 75%) isolated from foods associated with out breaks of SFP. The toxin SED is the second most important cause of food intoxication outbreaks. Available evidence suggests that organisms producing enterotoxins other than SEA tend to occur more frequently in clinical specimens than in food (Eley 1996, Normanno et al. 2005).

Some authors report that an intake of 100-200 ng of SEA is sufficient to cause illness. However, intake as low as 20 -100 ng of the same SEA toxin has been associated with a large scale outbreak (Makita et al. 2012). According to Le Loir et al. (2003), the infective dose of SEs required to induce SFP in humans is estimated to be around 0.1 µg. All these confirm that the infective dose required to induce SFP in humans is quite low. However, this could vary with patient sensitivity.

b) Clinical features of intoxication and prognosis

Staphylococcus aureus food poisoning is characterized by a sudden and rapid onset of symptoms consistent with diseases caused by preformed toxins. The symptoms normally set in within 1-6 hours after ingestion of food contaminated with as little as 20-100 ng of enterotoxin (Schelin et al. 2011, Eley 1996, Makita et al. 2012, Sihto et al. 2015).

The symptoms of SFP include nausea, copious vomiting, abdominal pain/cramps and prostration, often with diarrhea, but without a fever. The severity of the resultant illness depends on the amount of food ingested, the amount of toxin present in the food, and the general health of the victim (Eley 1996, Makita et al. 2012, Schelin et al. 2011, Sihto et al. 2015).

Staphylococcal food poisoning is a self-limiting disease, which is attributed to the fact that ingested bacteria do not produce toxins, and as a result most patients usually recover completely within 24 hours without specific therapy. The disease is associated with a low overall case-fatality ratio and hospitalization of approximately 10% of the cases (Eley 1996, Makita et al. 2012, Schelin et al. 2011).

Staphylococcal food poisoning still represents a considerable social burden in terms of hospital expenses, loss of patients' working days and productivity, coupled with the difficulty plus cost of disposing of the contaminated food. In the United States of America, the burden of staphylococcal intoxication is estimated to be 1.5 billion dollars annually (Normanno et al. 2005, Eley 1996).

c) Epidemiology

Staphylococcus aureus does not form spores like the other Gram-positive bacteria (i.e., *Bacillus cereus, Clostridium perfringenes, Cl. Botulinum*) that are also associated with foodborne diseases (Le Loir, Baron & Gautier 2003). Therefore, SFP caused by *S. aureus* are associated with SEs. This is because the vegetative form of *S. aureus* can easily be killed off by heat treatment (Le Loir, Baron & Gautier 2003).

Staphylococcus aureus remains a major cause of foodborne diseases because it can easily contaminate food products during preparation and processing (Le Loir, Baron & Gautier 2003). Furthermore, these organisms can survive on hands, knives, chopping boards and dish clothes for hours to days following initial contamination (Taulo et al. 2009).

Staphylococcus aureus occurs as a commensal on the skin and in the anterior nares of the nose, throat, hair and skin of healthy people, and occurs in large numbers in cuts, pustules and abscesses. They also occur in the air, in milk, sewage, and the environment (Eley 1996, Makita et al. 2012, Schelin et al. 2011, Le Loir, Baron & Gautier 2003, Taulo et al. 2009). This together with their ability to grow under a wide variety of conditions explains the high incidence of *S. aureus* in foodstuffs that require manipulation during processing such as fermented food products like cheese (Le Loir, Baron & Gautier 2003).

Like *E. coli*, *S. aureus* are amongst the most common pathogens found on the hands of food handlers, and are usually associated with poor hygiene practices (Taulo et al. 2009). It has been reported that up to 35-50% of the human population are carriers of *S. aureus* (Le Loir, Baron & Gautier 2003). According to Taulo et al. (2009), in any given human population, 60% of people are carriers of SA. In South Africa, a study on the contamination levels of the fingers of food handlers showed that the contamination level ranged from 58- 69 % (Lues et al. 2006). In general, 20 – 60% of normal healthy adults carry *S. aureus*. Specifically, it is estimated that about 20% of healthy adults are persistent carriers of *S. aureus* in their noses, 30% are intermittent carriers, and 50% are non-carriers. This explains why food handlers are considered the primary source of food contamination with *S. aureus* (Normanno et al. 2005, Githiri, Okema & Kimiywe 2009, Makita et al. 2012, Schelin et al. 2011, Lues et al. 2006), and why food that requires manipulation is likely to be associated with a high incidence of staphylococcal intoxication (Le Loir, Baron & Gautier 2003).

Besides humans, most domesticated animals also harbour *S. aureus*. For example, in cattle, it is known to cause contagious bovine mastitis (Makita et al. 2012, Lues et al. 2006). *Staphylococcus aureus* can also be endemic in the food processing environment (Schelin et al. 2011). Many different foods have been reported to be good growth medium for *S. aureus*, and these include: meat and meat products, chicken, milk and dairy products, fermented food items (i.e., sausages), canned meat, vegetables, fish products and RTE meals. Salted food products like ham are suspected to be responsible for about 24% of all the cases of staphylococcal intoxication (Normanno et al. 2005, Makita et al. 2012, Lues et al. 2006, Le Loir, Baron & Gautier 2003).

Most of the *S. aureus* strains responsible for food poisoning (enterotoxin-producers) belong to types within phage group III. This makes it easier to monitor the spread of infection in comparison to a situation where pathogenic strains belong to several phage groups (Eley 1996).

Since in most cases, *S. aureus* are transmitted to food from a human source (e.g. food handlers) or by cross contamination from another source (e.g., utensils previously contaminated by humans), food products usually become contaminated during or after processing. This is an important route of transmission from an epidemiological point of view (Makita et al. 2012, Eley 1996, Lues et al. 2006).

Once production of toxins has taken place in food, unlike the vegetative form that get killed by cooking toxins are able to retain their activity (Eley 1996, Schelin et al. 2011, Rajkovic 2014). Furthermore, toxins are also resistant to low pH conditions at which the vegetative bacteria that produce them are easily destroyed. As a result, toxins in re-cooked food or food whose pH is acidic are able to retain activity in the digestive tract if ingested (Makita et al. 2012).

Outbreaks of SFP will occur when food and food ingredients get contaminated, as is the case when there are no measures to prevent contamination, leading to formation of toxins that cannot be removed later by processing or preparation of food (Le Loir, Baron & Gautier 2003).

In areas where SFP outbreaks are common, they are linked to dietary habits (Eley 1996, Le Loir, Baron & Gautier 2003). For example, in the USA SFP is frequently associated with the widespread consumption of commercially prepared foods and large communal meals (Eley 1996).

Foods that are commonly involved in SFP differ between countries. For example, in the United Kingdom, between 1969 and 1990, 53% of the cases of SFP were associated with meat products (i.e., ham), while 22% were due to poultry and poultry-based products, and the rest due to other types of foods. In France, among SFP poisoning cases reported in the period 1999-2000, milk and milk products accounted for 32% of the cases, while poultry contributed to 9.5%, with the other foods accounting for the rest. In the United States of America, from 1975 to 1982, 36% of SFP cases were due to red meat, 12.3% due to salads, 11.3% due to poultry and the rest to other types of foods (Le Loir, Baron & Gautier 2003).

The majority of staphylococcal food intoxications are due to *S. aureus* (coagulase-positive). However an outbreak linked to *Staphylococcus epidermidis* (coagulase-negative), which normally does not produce enterotoxins, has been recorded. In view of this, coagulase-negative staphylococci should not be ignored especially if present in large numbers in food. However, while *S. aureus* and *S. epidermidis* have been associated with foodborne intoxications, the significance of *S. hyicus* and *S. intermedius* in food poisoning is unknown (Eley 1996). *Staphylococcus epidermidis* is a normal skin commensal and its presence in food may be a reflection of poor levels of hygiene practices (Eley 1996).

d) Growth of *Staphylococcus aureus* in foodstuffs

Although some authors have reported that *S. aureus* have no particular nutritional and environmental requirement for growth (Schelin et al. 2011), Le Loir et. al. (2003) state that valine is required for growth of *S.aureus*, while arginine and cysteine are needed for both growth and toxin production in strains of *S. aureus* that produce SEA, SEB, or SEC. The same authors also state that glucose on the contrary has an inhibitory effect on SE production.

This is attributed to the drop in pH associated with glucose metabolism (Le Loir, Baron & Gautier 2003).

Staphylococcus aureus can grow over a wide range of temperature, pH, sodium chloride concentration, and water activity (Schelin et al. 2011). The robustness of this organism enables it to grow in many types of foods and still produce staphylococcal enterotoxins (SE) that are responsible for SFP. For example, *S. aureus* can grow at a water activity (a_w) of 0.86 and pH above 4.8 (Normanno et al. 2005, Eley 1996, Dengremont, Membré 1995, Schelin et al. 2011, Le Loir, Baron & Gautier 2003). The minimum pH at which staphylococci is able to produce detectable SE is 5.1 (below this SE production is inhibited), while the optimal pH for toxin production is between 6.5 and 7.3 (Makita et al. 2012, Le Loir, Baron & Gautier 2003). In view of this, SE production is optimal in neutral pH and decreases in acidic pH (Le Loir, Baron & Gautier 2003). Of note, is that at a given pH, the substance used to acidify the medium influences the production of SE. For example, acetic acid has a greater inhibitory effect than lactic acid on SE production (Le Loir, Baron & Gautier 2003).

Growth and toxin production by staphylococci is enhanced by high oxygen tension. While growth can take place at temperatures between 7 and 48 ºC, production of enterotoxins takes place between 10 and 48 ºC. The optimum temperature for toxin production is between 40 – 45 ºC, and 8/9 °C is considered the minimum temperature requirement for growth of *S. aureus* (Normanno et al. 2005, Eley 1996). However, some authors have shown that only a few strains (D and E) can grow at such low temperatures and that other strains grow best at temperatures not less than 14 °C (Dengremont & Membré 1995).

Worth noting, is that *S. aureus* is salt tolerant albeit with differences between the strains. Therefore, unlike temperature that has a strong inhibitory effect on the growth rate of *S. aureus*, the organisms are able to grow in the presence of salt. In a study by Dengremont and colleagues, it was shown that while 5% NaCl (sodium chloride) decreased growth of *S. aureus*, 2% NaCl had a positive effect on its growth. This means that *S. aureus* growth rate tends to increase with low quantities of NaCl (Dengremont, Membré 1995). The inhibitory action of NaCl in foods is associated with a decrease in the growth and biochemical activities (Dengremont & Membré 1995). The increasing concentration of NaCl increases the inhibitory effect of acidic pH, with no SE production taking place at salt concentrations of 12% (Le Loir, Baron & Gautier 2003).

Other factors that influence *S. aureus* growth and production of SEs are alkaline pH and microbial competition. Alkaline pH decreases the production of SEB, SEC and SED via decreased expression of *agr*. With competing organisms, it has been shown that the higher the concentration of competing microorganisms in milk, the lower the rate of growth of *S. aureus* and SE production. Competition with lactic acid bacteria in cheese and fermented sausage production has been cited by several researchers. Competition with lactic acid starters is most likely linked to production of lactic acid, lowered pH, oxygen peroxide production, competition for nutrients and/or due to production of substances such as bacteriocins (Le Loir, Baron & Gautier 2003).

Studies show that the formation of SEs in food is different in many respects from that in cultures of pure *S. aureus*. This could be associated with the marked differences in the behavior of bacteria in the planktonic state and immobilized bacteria found in multicellular communities as is the case with food. Therefore, if production of high-quality microbiologically safe food for human consumption is to be achieved, in situ data on enterotoxin formation in food environments are required to complement existing knowledge on the growth and survivability of *S. aureus* (Schelin et al. 2011).

e) Control of *Staphylococcus aureus* in food

Staphylococcal food poisoning is a worldwide public health problem (Le Loir, Baron & Gautier 2003). One of the major problems associated with the control of *S. aureus* food poisoning is the high carriage rate of the organism in humans, which accounts for the high risk of contamination of food by the food-handlers. In view of this, it is advisable that food should be cooked and eaten immediately after handling, to prevent the growth of contaminating bacteria. Keeping food at ambient temperatures before heating allows the formation of toxin which, may not be destroyed by normal cooking (Makita et al. 2012, Eley 1996, Le Loir, Baron & Gautier 2003). This is supported by the fact that in all cases of SFP, the foodstuff or one of the ingredients was subjected to contamination with an SE-producing *S. aureus* strain and was exposed at least for a while to temperatures that allow growth of *S. aureus*. For food to reach such temperatures there has to be a failure in the refrigeration process or a permissive temperature is required in processing as is the case with cheese production (Le Loir, Baron & Gautier 2003). Therefore, care should be taken to minimize handling and keeping foods refrigerated before serving (Eley 1996). Particularly processed foods, which include RTE foods, should not be kept for prolonged periods at temperatures that favor growth of *S. aureus* as it could lead to the formation of toxic doses of SE in such foods (Makita et al. 2012).

Although it is generally known that SE cannot be inactivated by heat treatment because it is thermal stable (Makita et al. 2012), there are studies that have demonstrated that boiling of food decreases the amount of SEA and SED, and can lead to the apparent disappearance of SEA in broth, meat, minced food, and raw and pasteurized milk. However, some authors have associated the apparent disappearance of toxins in boiled food with a loss of serological recognition when using immune-based methods such as ELISA. It is therefore possible that the boiling does not inactivate the toxins in the food following their production. It has also been proposed that proteases produced by lactic acid bacteria cause a decrease in SEA levels. With this too, it has been postulated that the decrease in the SEA levels could be due to the fact that the toxins become cell associated and hence cannot be detected (Schelin et al. 2011).

There is also evidence to the effect that the presence of other organisms such as Lactic Acid Bacteria (LAB) in a food can cause a decrease in the enterotoxin level observed under certain conditions due to extra-cellular protease activities (Schelin et al. 2011).

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CHAPTER 3

MATERIALS AND METHODS

3.1 Study area/setting

This section provides a description of the study area including the local climate. It also provides a brief description of why the area was considered to be suitable for the present study.

3.1.1 Location and population

The study area, Tshwane Metropolitan Municipal area (Figure 3.1), is located in the Gauteng province of South Africa, toward the northern edge of Gauteng Province approximately 1 370 m above sea level. It is situated within the valleys of the Magaliesburg mountain range, which accounts for its weather conditions described below. Tshwane has various suburbs shown in Figure 3.1 (Dining OUT Web Services CC 2015).

Figure 3.1: Map of Tshwane showing study area (Dining OUT Web Services CC 2015)

It is estimated that of the 8,837,178 people living within the Gauteng Province, between 1 982 235 and 2 345 908 live in the Tshwane Metropolitan Municipality where the study was conducted (Brinkhoff 2012).

3.1.2 Weather patterns of Tshwane

The annual precipitation for the Pretoria area is shown in Fig 3.2 (EL Dorado Weather 2014).

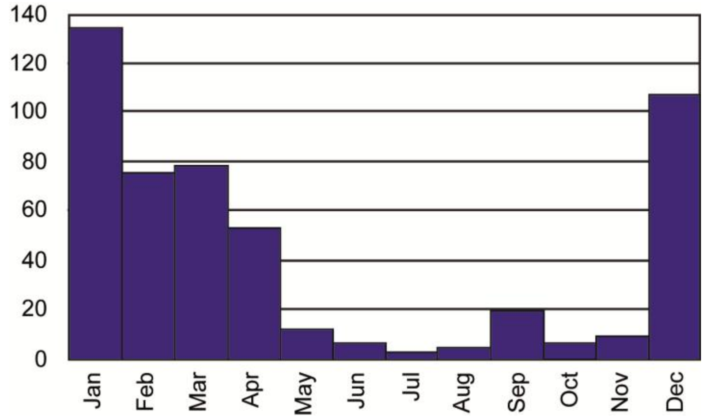


Figure 3.2: The annual Pretoria precipitation (mm)

As shown in Figure 3.2, the rain season occurs during the summer (October to March), autumn (April to May), and the spring (September) seasons. However, most of the rain tends fall between Dec-April during the afternoon periods. The city receives an estimated 700mm of rainfall per annum.

According to Figure 3.3 the annual temperature in Tshwane fluctuates throughout the year and is lowest during the June and July months which is the winter period (EL Dorado Weather 2014)

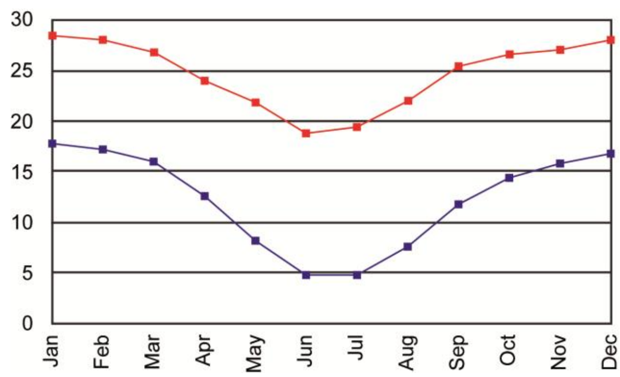


Figure 3.3: The annual temperature for Pretoria

The Tshwane weather is similar to that of Johannesburg but since the former lies at a lower altitude; its air temperatures on average are 2 °C higher than that of Johannesburg. The average summer temperatures of the Pretoria area range from 15-28 °C. The winter months tend to have sunny skies and are moderately cold with the average temperatures ranging from 6-23 °C.

Based on the temperature and rainfall patterns of the city of Tshwane, it was decided that sampling would be conducted during the summer months when it was wet and relatively warmer. This was the time when conditions that favour growth of microorganisms prevailed and thus a time that presented the highest risk of contamination of food sold by informal vendors.

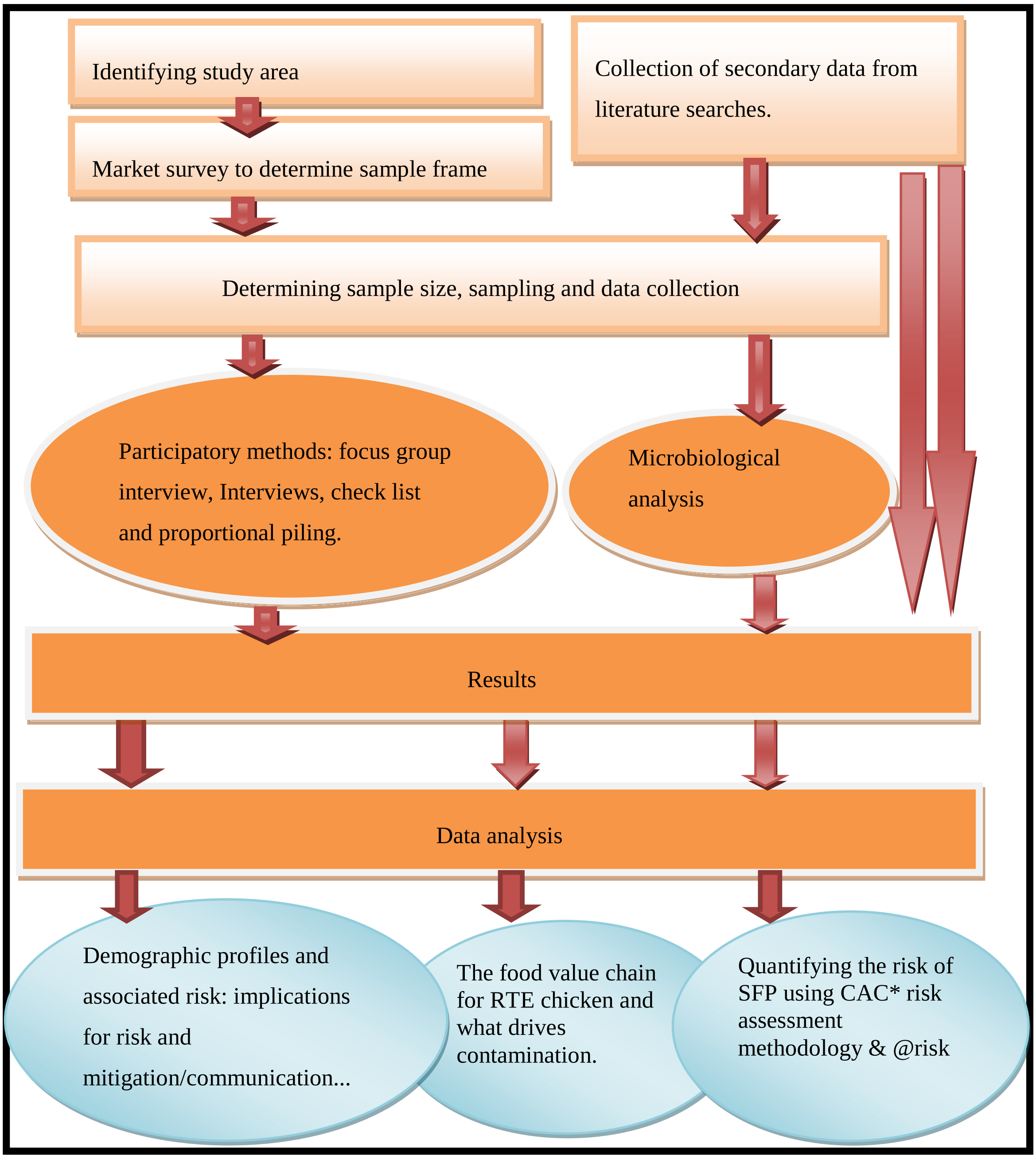
3.1.3 Suitability of the study area

Although informal vendors tend to be conveniently situated in living areas, near the workplaces or en route for thousands of commuters (Lues et al. 2006), in South Africa, they tend to congregate mainly in the Central Business District (CBD) and at major points of transit (e.g., railway station, bus stations and taxi ranks), enabling commuters to quickly pick up a meal to eat as they wait for their transport or while traveling (Masupye & Von Holy 1999, Masupye & von Holy 2000, Martins 2006). In a report on improving street foods in South Africa, the authors observed that 74,5% of all the vendors in Gauteng were situated near transport areas (i.e., taxi ranks and stations) (Martins, Anelich 2000). In view of this, the city of Tshwane was selected for this study on the basis that it has many taxi ranks located along its many streets in addition to a railway network, construction sites, and street vending points where street vended foods are sold.

It is estimated that 1,6 million people travel in Tshwane alone, and of these 500,000 use public transport (trains, buses and taxis) (City of Tshwane webpage). Considering that Johannesburg alone, another city within Gauteng and about 45 km from Pretoria, has in excess of 15,000 food street vendors (Masupye, Von Holy 1999), it was considered reasonable to assume that a large number of people in South Africa do eat food sold by the informal food vendors located at taxi and bus ranks plus railway stations.

3.2 Conceptual framework for the methodology

The different research methods adopted for the present study are summarised in Figure 3.4.



*Codex Alimentarius commission systems frame work for risk assessment.

Figure 3.4: Methodological framework of the present study

Figure 3.4 shows how conventional research methods (i.e., microbiological analysis and literature review) and participatory research methods were used to collect data. The results were then integrated to realise the objectives of the present study.

3.3 Study design

A cross-sectional study design which is explanatory in nature was considered to be more suitable for the present study as opposed to a survey. While surveys are well suited for collecting either exposure or outcome data and not both, a cross-sectional study design which is analytic in nature, allows for collection of both exposure and outcome data of subjects at a point in time, and allows for comparison between groups to be made. These comparisons in turn, allow the investigator to make inferences about relationships between the explanatory and outcome variables (Dohoo, Martin & Stryhn 2003).

Participatory risk assessment was also applied in the present study following procedures of the codex Alimentarius commission systems frame work. According to Grace et al. (2008), and Makita et al. (2012), participatory risk assessment research methods have been proved to be effective in studying informal markets. Participatory risk assessment is not distinct from the conventional risk assessment frameworks such as CAC methodology, but builds on existing risk assessment knowledge especially where sophisticated data gathering techniques like random sampling of large populations by questionnaires/interviews are impractical.

3.4 Data collection

According to Grimes et al., (2002), and Lacy et al., (2001) a combination of both quantitative and qualitative research methods is well suited to answer the ‘why’, ‘what’, or ‘how’ questions. In view of this, data collection in this study was conducted using both qualitative and quantitative data collection tools (i.e., questionnaires, focus group interviews, and laboratory microbiological analysis of ready to eat (RTE) chicken sold by informal vendors in the study area).

According to Grace et al., (2008), participatory research methods are well suited where there is a need to improve understanding of issues and yet data is scarce. Participatory research methods have been described in details by Bergold & Thomas (2012), and can be classified into four main categories:

- Participatory Observer and Personal Interviews;
- Rapid Rural Appraisal (PRA);
- Participatory Rural Appraisal (PRA); and
- Participatory Action Research (PAR).

The present research made use of Participatory Observer and Personal Interviews, and Rapid Rural Appraisal (RRA). Participatory Observer and Personal Interviews techniques that were adopted included the use of checklists to record observations and questionnaires for personal interviews. While the following aspects of RRA were adopted:

- Review of secondary sources;
- Direct observation, familiarization, and participation in activities;
- Interviews with key informants, group interviews, workshops;
- Mapping, diagramming; and
- Ranking and scoring.

3.4.1 Market survey

Use was made of geographical information systems (GIS) data from the Pretoria Tshwane metropolitan municipality and a map of Tshwane to determine the location of taxi and bus ranks, and railway stations in the area of study. A research assistant visited each taxi rank, bus station, and railway station to assess the number of stalls selling cooked and or uncooked chicken meat and the availability of toilets, potable water, toilets, and washing facilities.

3.4.2 Sampling frame and strategy

Establishing a sampling frame for street vendors proved difficult as was the case in previous studies. In the absence of a sample frame, a judgmental[1] sample of a study population is considered appropriate (Martins 2006). Dohoo et al. (2003) are of the view that where it is easier to get a list of clusters than it is to get a list of individuals, cluster sampling is the preferred sampling method. Therefore, based on the views expressed by Dohoo et al. (2003) and Martins (2006), cluster sampling was considered as the most suitable for the present study since it was easier to get a list of markets than to get a list of the individual vendors selling chicken in each of the markets. Using the definition by Dohoo et al. (2003), the markets associated with taxi ranks and bus stations were considered the sampling units and the vendors selling ready to eat chicken the unit of concern.

Preliminary studies mentioned above indicated that the target population (the number of vendors selling RTE chicken) in all the identified informal markets (clusters) was

[1]A type of sampling also known as purposive sampling or authoritative sampling that involves purposely hand picking individuals from the population based on the authority's or the researcher's knowledge and judgment. This type of sampling design is usually used when a limited number of individuals possess the characteristics of interest (Explorable.com. 2009).

approximately 400 vendors. In view of this, it was decided that all markets (clusters) be considered as the target population and all the vendors who operated in the identified markets and sell RTE chicken or chicken byproducts be included in the study. The purpose of this was to ensure that a reasonable sample size was obtained for the study.

Data collection was conducted during the summer months (October 2011 to April 2012) when it is humid and relatively warmer. This is the period when prevailing conditions favour growth of microorganisms and the risk of contamination of RTE food with high numbers of microorganisms is high.

According to Martins (2006), there are three main categories of street vendors, and these include: mobile vendors, semi-mobile vendors (who might be stationary or move from one site to another) and 'stationary' vendors, who sell their food at the same site each day. In the present study, no attempt was made to differentiate the three categories. All vendors who qualified to be categorized as the unit of concern and were located in the identified clusters were invited to participate in the study.

3.4.3 Administering questionnaires and checklists

The questionnaires (Annexure I) used for interviewing were developed in consultation with a statistician. A content validity test was performed on the questionnaire, which was then pilot tested on 10 people before the study could commence. Questions in the questionnaire included dichotomous and multiple-choice questions, and open-ended questions.

The issues dealt with in the questionnaire included: demographic information on vendors, hygiene food handling practices, available infrastructure to the informal food vendors and food value chain.

To make provision for information that is best captured through observation and not interviews, a checklist (Annexure II) was developed in consultation with a statistician. The checklist was used to capture nonverbal occurrences as was the case in a study done in Kenya, Nairobi (Githiri, Okema & Kimiywe 2009). The nonverbal occurrences observed included keeping long nails, wearing protective clothes, hand washing, using of different utensils for washing hands and plates, and the environment in which food is prepared, all of which have been identified as risk factors for microbial contamination (Rane 2011).

The ethical code of primary research was adhered to during data collection. For example, before conducting interviews or collecting data using checklists, each vendor was made to understand why he or she had been chosen to be part of the study. The objectives of the study and confidentiality of the results was also explained to the vendors prior to interviews. The vendors were informed that their participation in the study was on a voluntary basis and they had the right to pull out of the study at any stage. The consent to participate in the study was confirmed by the vendors signing or by providing verbal consent (Annexure III) after the contents of the consent form had been read or explained to them.

The enumerators were Animal Health Technicians (AHTs) registered with the South African Veterinary Council (SAVC), either as students or professionals. Although some of the enumerators enlisted for the present study had previous exposure to data collection using questionnaires, they were retrained on interviewing techniques before the study commenced. To oversee the process and ensure that every market was visited and all identified vendors interviewed, the researcher accompanied the enumerators throughout the process of conducting interviews and/or carrying out observations.

Focus group interviews were used to triangulate the data collected on the food value chain. The resultant data were recorded as focus group transcripts and researcher memos and reflections.

3.4.4 Collection and preparation of sample for microbiological analysis

After each interview and a checklist for each stall had been completed, a sample of RTE chicken and chicken byproducts from such a vendor was collected using the vendor's utensils. The sample was then carried either in sterile whirl pack® bags (Nasco, USA) or the plates supplied by the vendor and any other serving items normally used to serve their customers. Each sample was labelled by indicating the location, date, sample number and type of sample including the method of preparation. The food sample, checklist and questionnaire that came from the same vendor were given the same code.

Immediately after collection, the sample was placed in a cooler box with at list five packs of ice to keep the temperature of the sample at ±7 ^{0}C. This was to limit bacterial multiplication during transportation to the food microbiology laboratory in the Department of Paraclinical Sciences, Veterinary Public health Section.

A total of 266 food samples were collected from the 13 markets/clusters. The number was higher than the number of people (n=237) interviewed because in instances where a vendor sold more than one type RTE chicken, more than one sample was collected. Due to budgetary constraints, only 100 samples from 6 major markets/clusters were used to isolate *S. aureus*. The data were then used for assessing the risk of contracting staphylococcal food poisoning (SFP).

In the laboratory, each chicken sample was weighed to determine the overall weight of each sample that was collected, and thereafter, an aliquot of 20 g of each sample was obtained using sterilized forceps and scissors. The aliquot was placed in a marked sterile whirl pack® bag (Nasco, USA), and one hundred and eighty milliliters (180 ml) of Buffered Peptone-saline [0.1% peptone water (Oxoid) + 0.85% NaCl (Biolab, Midrand, South Africa)] was added. The sample was homogenized in the sterile whirl pack® bag (Nasco, USA) for 1-3 min using a stomacher lab blender (Colworth 400) at a speed of the "low" switch position (approximately 8000 rev/min). The homogenate was then used to inoculate the 3M™ Petrifilm™ (3M, Saint Paul. Mn, USA) to culture and enumerate bacteria as described in the next section.

3.4.5 Culturing and enumeration of bacteria

It is the norm for chicken bought off the streets to be cooked in most cases to a sufficiently high temperature, resulting in a reduction of the number of cells that might be consumed (Lues et al. 2006). However, food can become microbiologically hazardous to the consumer when the basic principles of hygiene are not adhered to post cooking/preparation. Since lack of knowledge of hygienic food handling is prevalent among street vendors there is a risk of consumers of such food contracting a foodborne pathogen. Based on this premise, the present study was designed to assess the microbiological quality of chicken bought from the informal vendors. The data could then be used to establish the associated risk of eating such food.

The need to assess the safety of foods and to a lesser extent the quality of food is increasingly being recognized (KZN-DOH 2001). Risk assessment in foodstuffs relies on classical microbial detection and quantification of organisms like coagulase positive *Staphylococcus* on a selective Baird-Parker medium (Le Loir, Baron & Gautier 2003). These conventional methods are known to be both time consuming and entail several steps (Table 3.1), which may not be easily carried out in a simple microbiology laboratory such as operated in most developing countries.

Table 3.1: Traditional methods of detecting and identifying bacteria (Eley 1996)

	Culture media		Identification criteria
Bacteria	Enrichment	Solid (selective differential media)	Presumptive identification
S. aureus	Trypticase soy broth (+/- salt)	Baird-Parker agar (sodium lithium chloride & egg yolk-tellurite emulsion)	DNase positive, coagulase positive
E. coli	Tryptose phosphate broth	MacConkey	Indole-positive, lactose- positive
Salmonella spp.	Selenite F or Rappaport-Vassiliadis	Deoxycholate citrate agar	Lactose negative, H_2S production

However, recent advances in food microbiology have resulted in the invention of readymade, disposable bacterial analysis kits which can be processed in a rudimentary laboratory and enable rapid identification of food borne bacteria (3M Food Safety 2015). These rapid methods detect bacteria by measuring specific physiochemical changes resulting from their growth or metabolic changes. For example the nucleic acid and antibody-based assays are now used to rapidly and reliably detect pathogenic bacteria in food (Swaminathan & Feng 1994, 3M Food Safety 2015). This technology would be very suitable for Africa.

The Petrifilm™ concept, one of the rapid methods for detection of bacteria, has been shown to possess high specificity and sensitivity for both Gram-positive and Gram-negative bacteria. For example, Mansion-de Vries et al., (2014) demonstrated using mastitis causing organisms that the sensitivity of the Petrifilm™ concept for Gram-positive and Gram-negative organisms was 85.2% and 89.9% respectively, while the specificity for Gram-positive and Gram-negative was 75.4% and 88.4% respectively. Another study by Silva et al., (2005), reported that the sensitivity of the Petrifilm™ concept for isolation of *S. aureus was* 87.5%. The same study using experiments to test the specificity and repeatability of the Petrifilm™ concept for isolation of *S. aureus* observed that the specificity and repeatability for the methodology was 98.5% and 96.9% respectively.

Past studies show that street vended foods sold on the informal market in South Africa tend to carry low bacterial counts (Lues et al. 2006). Therefore, in such circumstances when testing for microbiological quality, greater dilutions would give false results (Frankhauser 2008). In light of this, a concentration of 10^{-1} of the homogenized sample was used for bacterial counts as described below. Otherwise where samples are highly contaminated it is advisable to make serial dilutions of up to 10^{-3}.

In the paragraphs that follow, the laboratory techniques used to assess the microbiological quality of the chicken are described in details.

a) Enumeration of *E. coli*, and coliforms from chicken samples

Enumeration of *E. coli* and coliforms was performed on 3M™ Petrifilm™ *E. coli*/Coliform count (EC) (3M, Saint Paul. Mn, USA) plates that are able to grow and differentiate *E. coli* and coliform colonies. The ability to differentiate coliforms and *E. coli* colonies is based on the plates containing Violet Red Bile (VRB) nutrient, a cold-water-soluble gelling agent that is an indicator of glucuronidase activity. This indicator system facilitates colony enumeration in that most *E. coli* (97%) on this media are able to produce beta-glucuronidase which produces a blue precipitate. The latter is then used to differentiate *E. coli* from other coliforms. However, both coliforms and *E. coli* do produce gas that is trapped by the top film. Therefore blue or red-blue colonies associated with entrapped air on the Petrifilm EC plate (within approximately one colony diameter) are confirmed *E. coli* colonies (Fig 3.5) (3M Food Safety 2015).

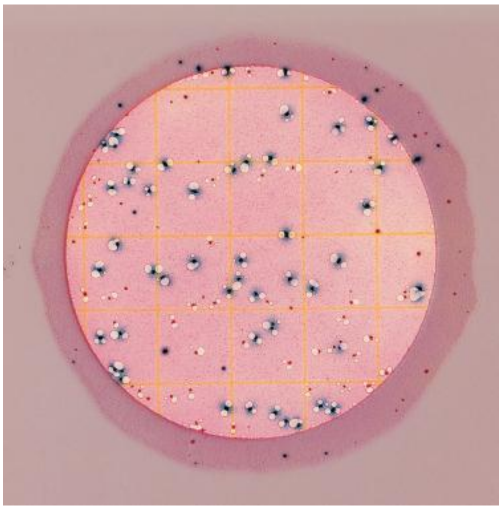


Figure 3.5: *E. coli*/coliform 3M™ Petrifilm™ plates with *E. coli*/coliform colonies

Coliforms are Gram-negative rods which produce acid and gas as they ferment lactose. Therefore, on Petrifilm EC plates, coliforms make the pH indicator to turn the gel colour dark red due to acid production. As a result, red colonies on Petrifilm EC plates associated with entrapped gas are confirmed coliforms (Fig 3.5) (3M Food Safety 2015).

A volume of 1 mL of the 10^{-1} of the homogenized sample in Peptone-saline was -plated on duplicate Petrifilm™ *E. coli*/Coliform count plates (3M, Saint Paul. Mn, USA), and the Petrifilm strips incubated in a Merck incubator at 37^0C for 24 hrs. The reading of the plates was done according to the manufacturer's instructions (Figure 3.5) (i.e. blue colonies associated with entrapped gas were counted as *E. coli* colonies, while red colonies associated with entrapped gas were counted as other coliforms). The detection limit for *E. coli* was set at 0.083 CFU/cm^2, the detection limit for Petrifilm (Ingham 2007). Therefore, if at least one cell could be counted from a sample of the RTE chicken, such a sample was scored as ≥ 0.083 CFU/cm^2 while a sample where no cells are detected was scored as < 0.083 CFU/cm^2. The counting range for the total population on Petrifilm EC count plates was set at 1-150 CFU/ml. Hence plates with more than 150 colonies are recorded as too numerous to count (TNTC).

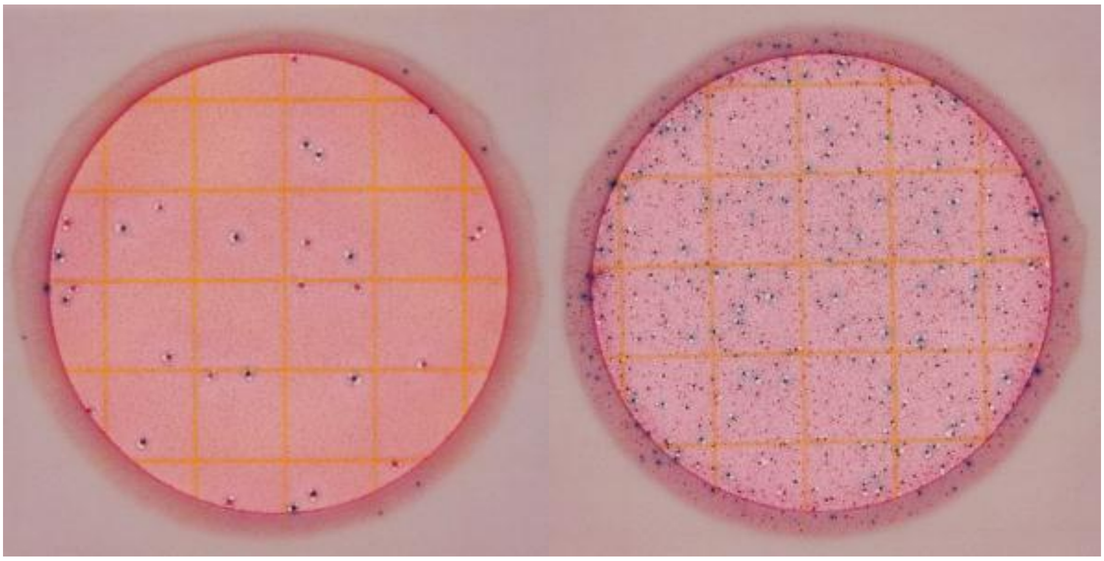


Figure 3.6: The 3M™ Petrifilm™ EC count plates[2]

[2] Petrifilm EC count plate on the left shows *E. coli* count=13 and coliform count = 15. The plate on the right = TNTC. The counting range for the total population on Petrifilm EC count plates is 15-150, hence plates with more than 150 colonies are recorded as too numerous to count (TNTC).

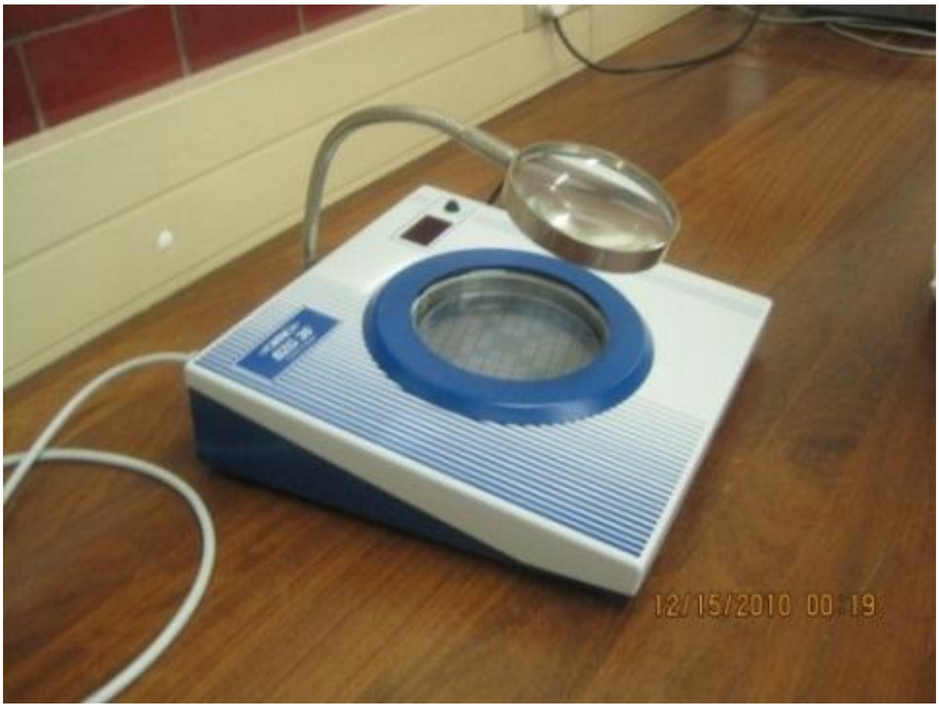


Figure 3.7: Coulter counter used to count bacteria on 3M^{TM} plates

Bacterial counts were expressed as colony forming units per gram (CFU/g) of food. The counting of colonies was done using a coulter counter (Figure 3.7).

The total number of colonies was recorded as CFU/mL, which was then converted to CFU/g. Two methods of computing the CFU/g were explored and the one suggested by Frankhauser was considered ahead of that used by Githiri and her colleagues (Githiri, Okema & Kimiywe 2009, Frankhauser 2008). This is because Githiri and her colleagues do not consider the aliquot factor in the computation of the number of CFU/g (Githiri, Okema & Kimiywe 2009).

The number of CFU/g was thus computed using the formula shown below (Frankhauser 2008):

- CFU/Plate X meat suspension factor X dilution factor X aliquot factor = CFU/g chicken.
- The meat suspension factor in this study = 20g in 180 mL (i.e., 20 gm in 200 mL), which gives 10 mL/g
- The dilution factor used was 1 to 10
- Aliquot factor = 1 ml that was inoculated on each PetrifilmTM.

Therefore CFU/g = CFU/Plate X 10 (meat suspension factor) X 10 (inverse of the dilution) X 1 (mL/amount inoculated on each Petrifilm).

b) Enumeration of *Staphylococcus aureus* from chicken samples

Enumeration of *S. aureus* was performed on 3M^{TM} Petrifilm^{TM} Staph Express Count Plate (3M, Saint Paul, Mn, USA). This is ready culture medium system that contains cold-water-soluble gelling agent. The medium in the plate is a chromogenic modified Baird-Parker medium which is selective and differential for *S. aureus* (3M Food Safety 2015).

As described for *E. coli* and coliforms in the preceding section, 1 ml of 10^{-1} dilution was plated out on 3M^{TM} Petrifilm^{TM} Staph Express Count Plates (3M, Saint Paul, Mn, USA). The 3M^{TM} Petrifilm^{TM} plates with inoculums were then incubated at 37^{0}C for 24 hrs. The red violet colonies on the plates are *Staphylococcus aureus* (Figure 3.8) (3M Food Safety 2015).

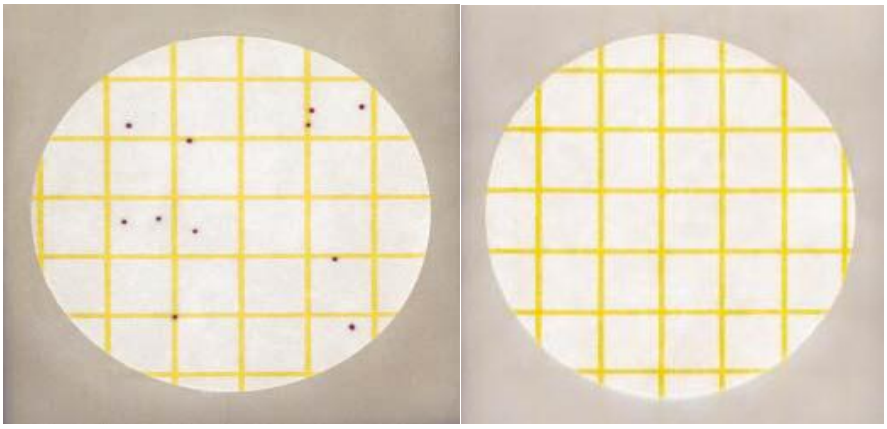


Figure 3.8: 3M^{TM} Petrifilm^{TM} Staph Express Count Plate (3M, Saint Paul. Mn, USA)[3]

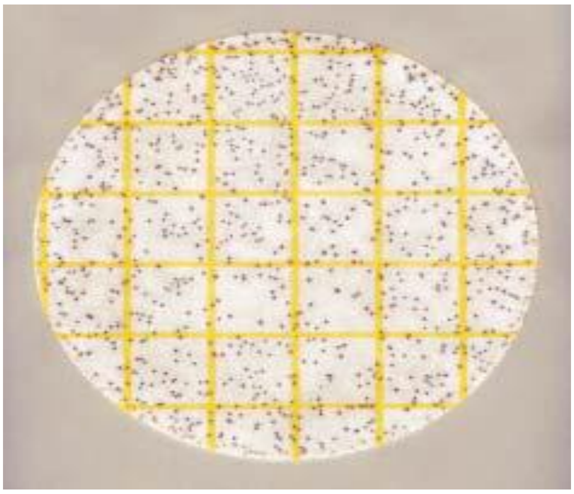


Figure 3.9: 3M^{TM} Staph Express Count Plate (3M, Saint Paul, Mn, USA)[4]

[3] To the right of Figure 3.8 is a 3M^{TM} Petrifilm^{TM} (3M, Saint Paul, Mn, USA) with 11 *S. aureus* colonies after incubating for 24 hours. To the left is a 3M^{TM} Petrifilm^{TM} (3M, Saint Paul, Mn, USA) with no growth after 24 hrs (3M Food Safety 2015).

[4] 3M^{TM} Staph Express Count Plate (3M,Saint Paul, Mn, USA) with more than 150 colonies (TNTC)

Where background flora, colonies besides the red-violet colonies (i.e., black colonies or blue-green colonies), were encountered on the Petrifilm™ Staph Express Count Plate (Figure 3.10), the 3M Petrifilm™ Staph Express Discs were used to identify *S. aureus* from all suspect colonies (with obscured *S. aureus*) (Figure 3.10). The plates with the discs (left part of Figure 3.11) were re-incubated for 1 to 3 hours at 37 °C.

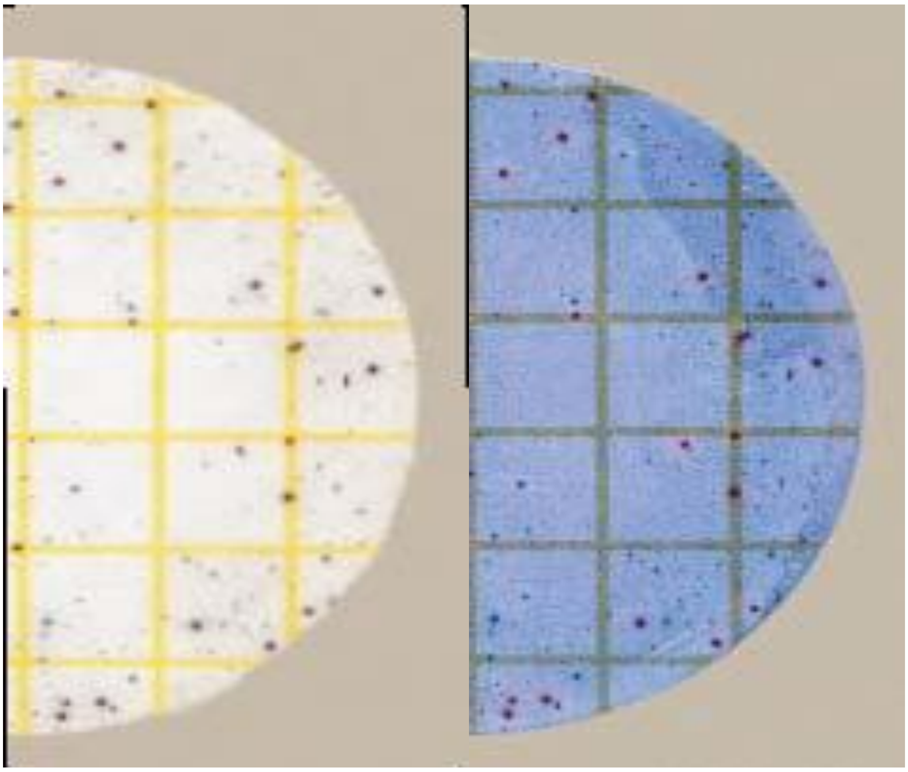


Figure 3.10: 3M™ Staph Express Count Plate & 3M™ Staph Express Disc[5]

The 3M™ Petrifilm™ Staph Express Disc contains a dye and deoxyribonucleic acid (DNA). *Staphylococcus aureus* produces deoxyribonuclease (DNase) and the DNase reacts with the dye to form a pink zone (see left section of Figure 3:9). When the 3M™ Petrifilm™ Staph Express Disc is inserted into the 3M™ Petrifilm™ Staph Express Count Plate, *S. aureus* (and occasionally *S. hyicus* and *S. intermedius*) produce a pink zone. That is to say it is only the coagulase positive *Staphylococcus* (*S. aureus*, *S. intermidius* and *S. hyicus*) that have the ability to produce the pink zone. Other types of bacteria do not produce pink zones. Therefore according to the manufacturer's recommendation, all pink colonies or pink areas even if it did not have a colony were counted as *S. aureus*.

[5] To the right is a 3M™ Petrifilm™ Staph Express Count Plate with background colonies. On the right hand side is a 3M™ Petrifilm™ Staph Express Disc inserted and showing *S. aureus* colonies that had been obscure with pink zones.

c) Testing for *Salmonella* in chicken samples

Two tests were used to screen chicken sourced from the street vendors for the presence of *Salmonella* (3M Food Safety 2015):

i. The conventional screening method involving a 3 step technique (Merck): non-selective pre-enrichment (18-24 h), selective enrichment in (at least) two different selective broth media (24 – 48 h), followed by plating on (at least) two different selective/indicative agars (24 – 48 h). Presumptive *Salmonella* colonies were to be sero-typed by the Bacteriology Laboratory, Department of Tropical Diseases, Faculty of Veterinary Science, University of Pretoria.

ii. The singlepath^R Salmonella rapid test (3M, Saint Paul, Mn, USA) was also used to screen street vended chickens for the presence of *Salmonella*. the steps involved in this rapid test include:

- twenty five grams (25 g) of solid sample was mixed with 225 ml pre-enrichment broth (BPW) and homogenized for approximately 2 minutes in a stomacher;
- the pre-enrichment homogenate was then incubated for 18 ± 2 h at 37 ^{0}C;
- 1-2 mL of the pre-enrichment homogenate was inoculated into 10 ml RVS selective enrichment broth, and incubated for 24 ± 3 h at 41.5 ^{0}C;
- approximately 1 – 2 ml of selective enrichment culture was transferred to polypropylene tubes;
- the tubes were placed in boiling bath for 15 minutes, and there after the tubes were removed and allowed to cool to room temperature (18-26 ^{0}C) prior to use;
- using a micropipette and disposable pipette tip, 160 µl was transferred into the circular sample port on the test device that had been let to warm up to room temperature; and
- As recommended by the manufacturer, the test results were observed 20 minutes after applying the sample to the test device.

The interpretation of the results was done following the manufacturers recommendation (Merck). The test is regarded as working properly if a distinct red line appears in the control zone **(C)** within 20 minutes. A sample is considered to be POSITIVE if at or prior to 20 minutes, red lines appear on both test **(T)** and control **(C)** zones. But if no red line appears in the test **(T)** zone but appears distinctly in the control **(C)** zone 20 minutes after application, then the sample is NEGATIVE.

3.4.6 Microbial risk assessment (MRA)

Microbiological risk assessment was conducted following the definitions and methodology of the Codex Alimentarius systems frame work (CAC (Codex Alimentarius Commission). 2004, FAO/WHO 1995, Rosenquist et al. 2003, CAC (Codex Alimentarius Commission) 2010), based on the model in Figure.3.12 (Lammerding & Fazil 2000). The data used in the model was obtained using participatory research methods, literature review and laboratory analysis.

Given the limited resources and time constraints, a farm-to-fork assessment, which is complex and resource-intensive requiring substantial input of data and expert knowledge from diverse resources could not be undertaken (Lammerding & Fazil 2000).

Therefore, this risk assessment focused only on one segment of the food chain for the RTE chicken (fork/table), a focal point for risk reduction measures and one of the main points under the risk manager's direct control. In the context of the present study, the risk managers are the Environmental Health Officers.

Based on the model in Figure 3.11, the process of risk assessment employed in the present study included conducting (Makita et al. 2012, Lammerding, Fazil 2000, Rosenquist et al. 2003):

- Hazard identification.
- Hazard characterisation.
- Exposure assessment.
- Risk characterization.

Hazard identification and hazard characterization were achieved through conducting literature review. This was described in details in the background and literature review sections of this document.

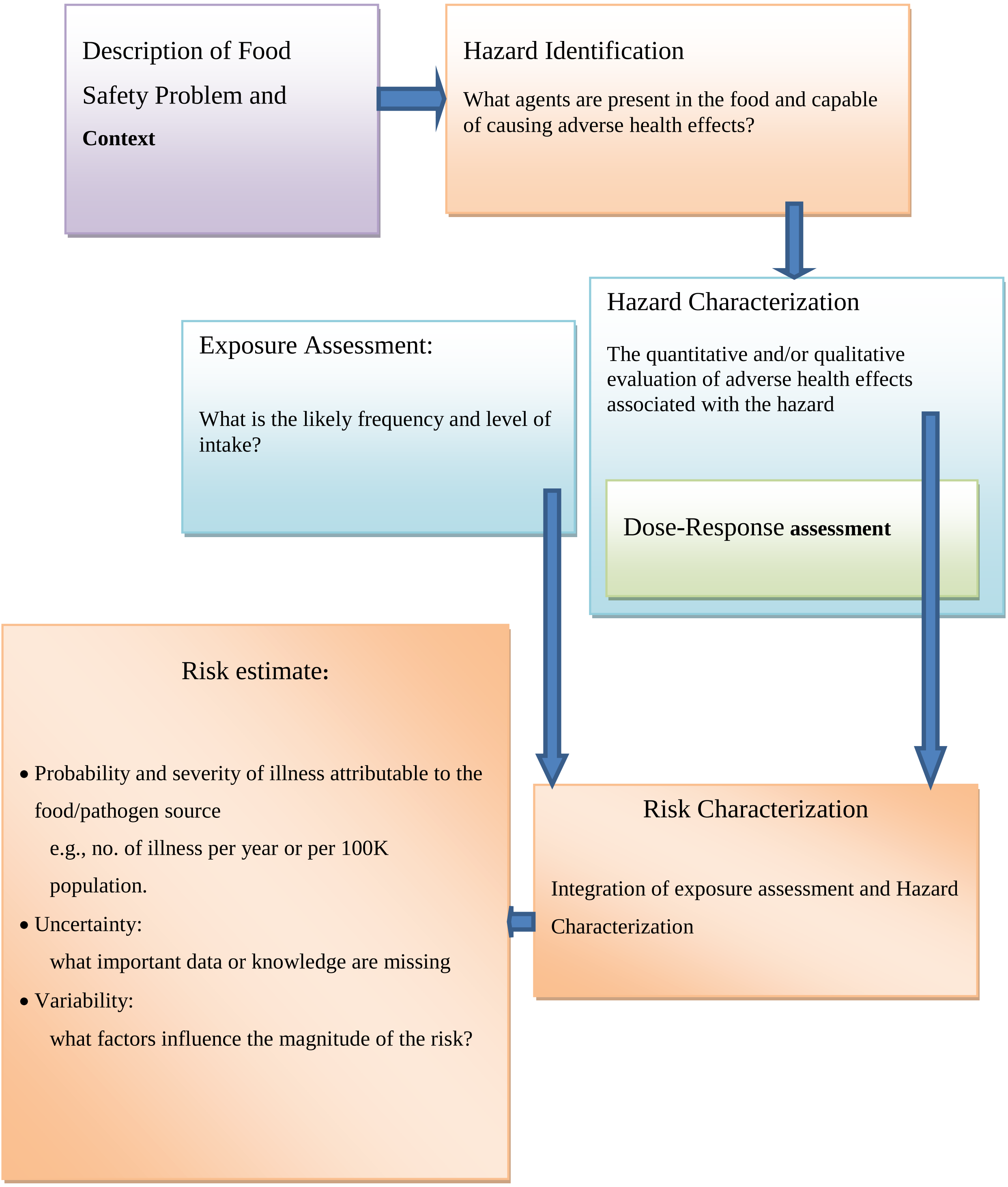


Figure 3.11: Microbial risk assessment model (Lammerding & Fazil 2000)

Exposure assessment was conducted using parameters collected through field work (using participatory research methods) and by reviewing published literature. The data were fed into a model shown as Table 3.2.

Table 3.2: Modelling the risk of staphylococcal food poisoning

Parameter	Model	Source of information
Probability of chicken contaminated with *S. aureus* purchased in a market studied *i*: $Pcont_i$	$Beta(s_i + 1, n_i - s_i + 1)$ Where s_i is the number of samples contaminated with *S. aureus* in a market *i* n_i is the number of samples tested for *S. aureus* in a market *i*	Survey data
Relative quantity of sales in a market *i*: $Sales_i$	$\frac{Q_i}{50}$ Where Q_i is the number of pebbles placed to represent the relative quantity of sales in a market *i*	Proportional piling
Log_{10}Cfu/g of *S. aureus* when the bacteria were too numerous to count: *Logtn*	*Uniform*(4.2, 8.5)	Minimum: the largest Log_{10}Cfu/g observed was 4.19 in a survey Maximum: Fujikawa and Morozumi (2006)
Probability that the bacteria concentration of a sample contaminated with *S. aureus* exceeds $10^{6.5}$cfu/g: *Pexc*	Average of *If* (Non-parametric bootstrap of Log_{10}Cfu/g including *Logtn* >6.5, 1, 0)	*Logtn* Survey data
Probability of *S. aureus* having SE gene: *Pgene*	$Beta(s + 1, n - s + 1)$ $= Beta(110, 183)$	Of 291, 109 *S. aureus* isolates had SE gene (Arcuri et al. 2010)

Since staphylococcal enterotoxins possess a high level of toxicity, in that they are able to cause staphylococcal food poisoning (SFP) at doses as lows as 20-100 ng (Asao et al. 2003), the probability of exposure to the hazard was modelled to be an exposure by the population of *S. aureus* with more than 10^5 CFU/g. At this concentration, *S. aureus* is able to produce staphylococcal enterotoxins (SE) in sufficient concentrations to cause illness following ingestion (Hennekinne, De Buyser & Dragacci 2012). Which means that exposure to *S. aureus* will only result into SFP if the isolates are able to produce SE. But for the later to occur, the isolates should be carrying SE genes. Based on the sources of literature consulted, the proportion of *S. aureus* that carries SE genes varies between different populations. For example, Le Loir et al. (2003) reported that the proportion of *S. aureus* carrying SE genes was about 25%. Meanwhile Acruri (2010) and Normanno (2005) showed that the proportion of *S. aureus* carrying SE genes was 35% and 57% respectively. In view of this, to model exposure to *S. aureus* carrying genes for SE, the proportion of SE positive *S. aureus* reported most recently and the middle (median) value reported by Acruri (2010) was used. The formula below shows the model of exposure to SE, with P(ingest) equal to the probability of ingesting SE.

$$P(ingest) = PexcPgene\sum_{i=1}^{6} Pcont_i Sales_i$$

- Where:*Pexc* = probability that the bacterial concentration of a chicken sample contaminated with *S. aureus* equals to or exceeds 10^5 CFU/g,
- *Pgene* = probability that *S. aureus* has the SE gene,
- *Pconti* = probability of purchasing RTE chicken in a market studied i (in this case 6) and
- *Salesi* = the relative quantity of sales in a market i.

Figure 3.12: Computing the probability of ingesting sufficient SEs to induce SFP

To model the concentration of *S. aureus* in the RTE chicken, the $\log_{10}$ CFU/g values of contaminated samples were bootstrapped. However, for samples that had the number of colonies exceeding the countable limit, a Uniform distribution was used to model the $\log_{10}$ CFU/g of samples by considering a value between the slightly greater value than the maximum countable for the tool used in the survey, and the maximum *S. aureus* population at the static phase of bacterial growth (Fujikawa, Morozumi 2006).

Risk characterisation was performed by combining the exposure assessment and the dose response relationship. The dose response relationship was modelled to be the 100% given ingestion of enterotoxins. This means that for this study, it was assumed that the probability of illness (*P(illness)*) was identical to *P(ingest)*. However, there was uncertainty about this dose-response relationship. This is because there is no data on these parameters in the published literature. As a result, the proportion of SE with emetic ability and the proportion of susceptible population among the consumers could not be modelled. Furthermore, the growth of *S. aureus* between the time of purchase and consumption was not taken into account. The model therefore was developed based on the assumption that consumers do not preserve the RTE chicken, and consume it within a very short time after purchasing.

To model the risk of purchasing RTE chicken of unsatisfactory quality (i.e., unacceptable even though it might not cause disease) the formula below (Equation in Figure 3.13) was employed. According to NSW Food Authority of Australia (2009), food that is contaminated with 10^3 CFU/g or more should be considered unsatisfactory.

$$P(unsatis) = \sum_{i=1}^{6} P(unsatis_i Sales_i)$$

- Where P(unsatis) is the probability that RTE chicken sold in a market i is contaminated with more than 10^3 CFU/g of *S. aureus*, and
- sales is the amount of chicken sold in the market i.
- *P(unsatis)* was modelled using the Beta distribution.

Figure 3.13: Computing the likelihood of purchasing RTE chicken with >10^3CFU/g

The model for the exposure assessment and sensitivity analysis was developed using @Risk version 5.7 (Palisade Corporation, USA). For each of the models, Monte Carlo simulation was run for 10,000 and 1000 iterations respectively.

3.4.7 Food value chain and relative quantities of ready-to-eat chicken

The initial objective was to use trace back techniques to identify the stages that constitute the value chain for RTE chicken. Starting with the informal vendor the stages were to be traced to establish the primary source of the chicken. Information obtained would then to be used to design a flow chart for the value chain for the RTE sold on the informal market. However, due to lack of cooperation on the part of those who supply the chicken to vendors, the trace back technique could not be employed to establish the food chain as initially anticipated. In its place, use was made of structured interviews together with participatory methods like focus group interviews, to gather information on the source of chicken sold in the informal markets by the vendors. This was then used to suggest the possible food value chain (s) for the informally traded RTE chicken sold in Tshwane Metropolitan Council.

Since rigorous random sampling could not be achieved in the informal markets as explained earlier on in this study, proportional piling, a participatory technique commonly used in participatory rural appraisals (PRA) (Mariner, Paskin 2000) to establish the significance of animal and public health problems was adopted. Three key informants with a good understanding of the markets studied who were willing to participate in this section of the study were used to estimate the relative quantities of sales in the different markets using proportional piling. As prescribed by Mariner and Paskin (2000), fifty pebbles were distributed among the six markets by the key informants to reflect on the numbers of customers that patronize the respective markets from where the RTE chicken was obtained. The pebbles were then counted to determine the relative quantities of RTE chicken sales.

3.5 Data analysis

The sections that follow provide a description of how data was handled, and the definition of both the outcome and explanatory variables. They also describe how data were analysed and summarized to achieve the objectives of the present study.

3.5.1 Data cleaning and coding

Raw data were filtered and cross-checked by three persons working independently to check for consistency, errors or missed values. The data were then coded and described, and all generated field data were entered into a Microsoft Excel® worksheet. The agreed values from the questionnaires, checklist and food sample collection were matched on the same spreadsheet using the original identification details of each respondent. The raw data were finally formatted for statistical analyses.

3.5.2 Definition of outcome variable

The observation unit in the present study was the RTE chicken. Samples of RTE chicken were taken from each stall and analysed for *Salmonella*, *Staphylococcus aureus*, *E. coli* and coliforms. A sample of RTE chicken was contaminated if it tested positive for any of these organisms. Therefore, the outcome variable was contaminated vs not contaminated (dichotomous).

3.5.3 Definition of explanatory variables

The explanatory variables were risk factors for contamination of RTE chicken sold by informal vendors. Variables were coded categorically either as dichotomous or with several levels. All the explanatory variables in this study are listed in Appendix Va, Vb, Vc, Vd, and Ve.

3.5.4 Quantitative data analysis

The subsections that follow describe the quantitative data analysis techniques that were adopted to realize the objectives of the present study.

a) Descriptive statistics

Descriptive statistics was performed to assess the prevalence of contamination, and to determine the relative frequency and proportions of age categories, gender, employment status of informal vendors, and hygiene standards. These were then displayed as frequency tables, graphs and charts. Ninety five percent (95%) binomial exact confidence intervals were computed for proportions. Statistical analysis was performed using Stata 9.0 (StataCorp, College Station, Texas, USA).

Relative quantities of RTE chicken sales in the markets studied were computed using proportional piling described by Mariner & Paskin (2000).

b) Inferential statistics

The inferential statistics tests that were performed to attain the objectives of the present study included: Logistic Regression Analysis, Chi Square Test, and Generalized Linear Models.

i) Logistic Regression Analysis

As described by Dohoo et al. (2003), the preliminary step of selection of variables was done so as to lower the chance of obtaining results affected by multicollinearity in the data set. This was done by checking if bilateral relationships between possible explanatory variables existed (X^2). If any two variables exhibited strong structural collinearity, only one that was most related to the outcome was chosen for inclusion in the regression model.

To assess the relationship between explanatory variables and the outcome (contamination of RTE chicken with *E. coli* and coliforms), a two-stage procedure was adopted. Logistic regression as describe by Hosmer and Lemeshow (2000) was adopted for the present study. Two univariable models (for coliform and *E. coli*) were used to screen through a number of potential risk factors. Un-adjusted odds ratios and their 95% confidence intervals resulting from these simple associations were computed. A liberal critical p-value of 0.2 was used to identify variables to be considered for assessment in the multivariable logistic model in second stage. The second stage involved fitting two logistic multivariable logistic regression models (one for coliforms and the other for *E. coli*). All variables that had p-value ≤ 0.2 in the univariable model were assessed for inclusion in the multivariable models. A backward selection procedure was applied using a selection threshold of $p \leq 0.05$ to control for confounding in the multivariable model. To assess the significance of each factor to the model, a likelihood ratio test was used. The fit of the final models was assessed using the Hosmer–Lemeshow goodness-of-fit test and the observation of the area under the ROC curves (see Annexure VII). In the final model, adjusted OR and 95% CI were reported. Statistical analyses were done using Stata 9.0 (StataCorp, College Station, Texas, USA).

ii) Chi Square Test and Generalized Linear Models

The Chi Square test was used to assess for differences between markets using Stata 9.0 (StataCorp, College Station, Texas, USA). The prevalence of *S. aureus* in RTE chicken meat was compared using Generalized Linear Models (GLMs) with binomial errors and logit link in statistic software R version 2.14.2. The level of significance was set at $p \leq 0.05$.

c) Risk assessment model

A quantitative risk assessment model was created in Microsoft Excel®, and Monte Carlo simulation modelling was performed using @Risk 4.5 (Palisade Corp., Ithaca, N.Y.).

3.5.5 Qualitative data analysis

Qualitative data analysis technique described by Lacey and Luff (2001) was adapted for this study and included the following steps:

- Familiarization with the data through reviewing and reading;
- Identification of themes and subthemes;
- Development of provisional categories;
- Exploration of relationships between categories; and
- Refinement of themes and categories.

The output was used to analyse and construct the food value chain for the RTE chicken sold by informal vendors.

3.5.6 Scoring and ranking of informal markets in terms of hygiene practices

The criterion presented in Annexure V was developed to score and rank the various markets and hygiene practices. The scoring was based on descriptive statistics. Due to the small sample sizes, the associations between scores/ranks and possession of a certificate of acceptability were not tested.

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CHAPTER 4

DEMOGRAPHIC PROFILES AND HYGIENE PRACTICES

4.1 Introduction

Results of the qualitative and quantitative investigation into the demographic profiles and hygiene practices among the informal vendors in Tshwane Metropolitan area are presented in this chapter. The methodology used to obtain results for this chapter can be found in Chapter 3 in the following sections:

3.4 Data collection
3.4.1 Market survey
3.4.2 Sample frame and sampling strategy
3.4.3 Administering questionnaires and checklists
3.5 Data analysis.

4.2 Spatial distribution of the informal markets in Tshwane

A map of the study area and sampling frame is shown in Fig 4.1 below. All the markets were in close proximity to the taxi ranks. Out of a total of 13 markets that were surveyed, the majority 7 (53.34%) were located in areas where formally disadvantaged South Africans live. This included Temba City, Hammanskraal, Soshanguve, Mabopane station, Ga-Rankuwa, Atteridgeville and Mamelodi. Only one (7.69%) of the markets was found in Laudium, where the majority of the residents are South Africans of Indian decent. Two (15.38%) markets (Moreleta Park and Centurion) were located in suburbs that were affluent. The three markets in the suburbs (in Lodium, Moreleta Park and Centurion) had few vendors, and were as a result, the smallest markets in the study area. The rest of the markets (n=4; 30.77%) were located within the Central Business District of Pretoria.

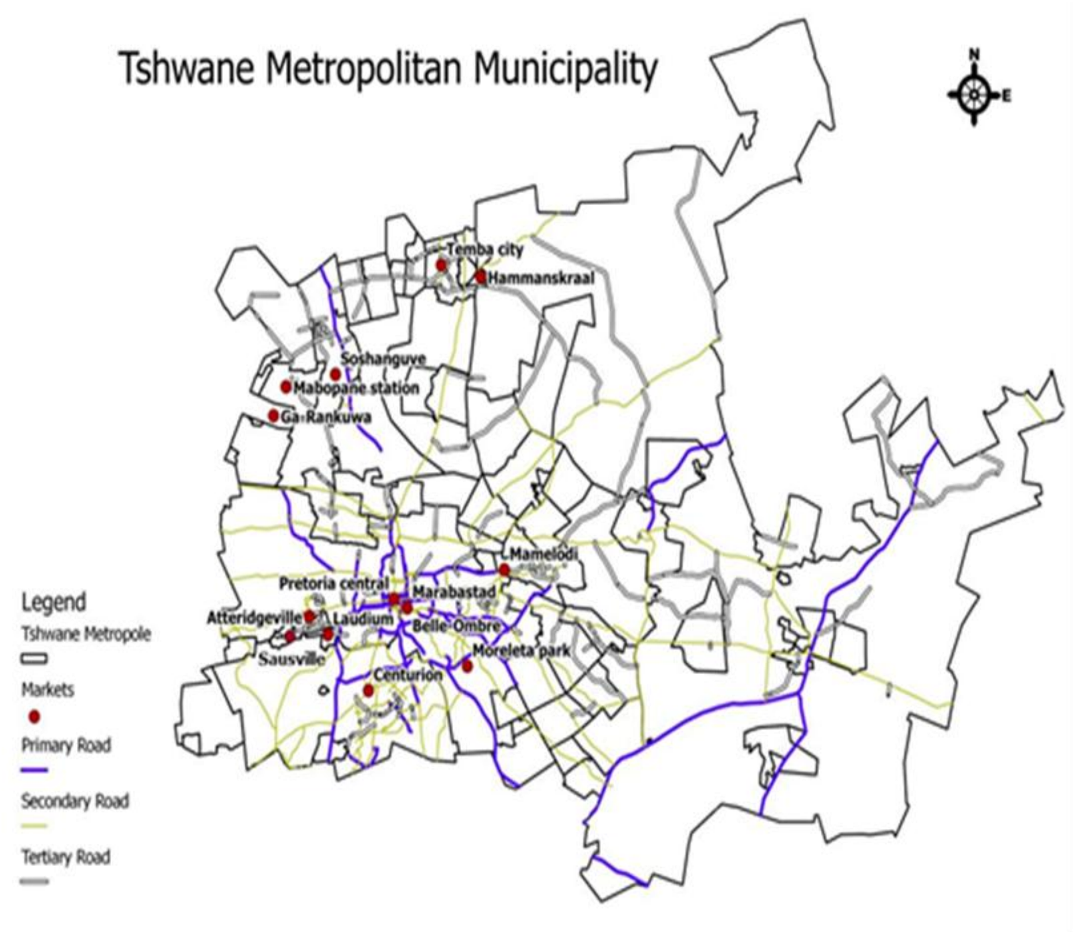

Figure 4.1: The map of Tshwane showing the distribution of markets

To assess whether the distribution of markets was normal and whether there were differences amongst markets with regards to the observations, the Chi square test for counts was used. The distribution of markets was observed to be normal, and significant differences between the observations amongst markets did not occur by chance (P-value < 0.05; DF = 12; Chi square stat = 163.44).

4.3 Socio-demographic profile of the informal vendors

The social demographic profiles of respondents who were interviewed using structured questionnaires (Annexure I) included age, education level, employment status and gender.

4.3.1 Age distribution of the informal vendors

The overall age distribution of respondents in all the markets is summarised in Figure 4.2.

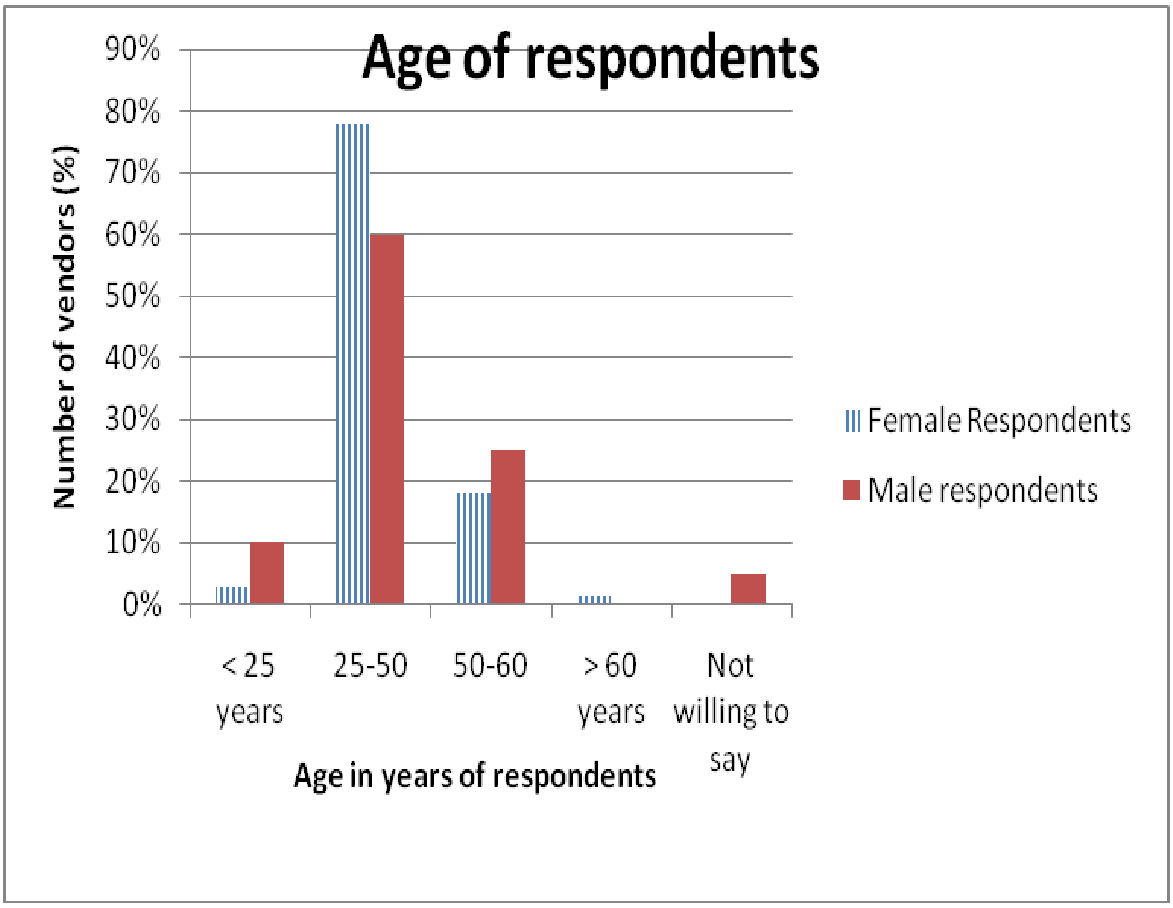

Figure 4.2: Overall age of vendors surveyed (n= 237)

To assess specifically whether age distributions across markets was normal, and if there were differences amongst age groups in markets, the Chi square test for counts was used. The test showed that the distribution of ages was normal and significant differences existed and did not occur by chance (P-value < 0.05; DF = 36; Chi square stat = 54.14).

Without delineating gender and markets, it was observed that the majority of vendors (78.07%) belonged to the 25-50 year old age bracket (Figure 4.2). There were very few young adults (less than 25 years) (3.51%) or pensioners (over 60 years of age) (0.88%) involved. It is worth noting that in the latter two groups the male gender tended to be the most prominent

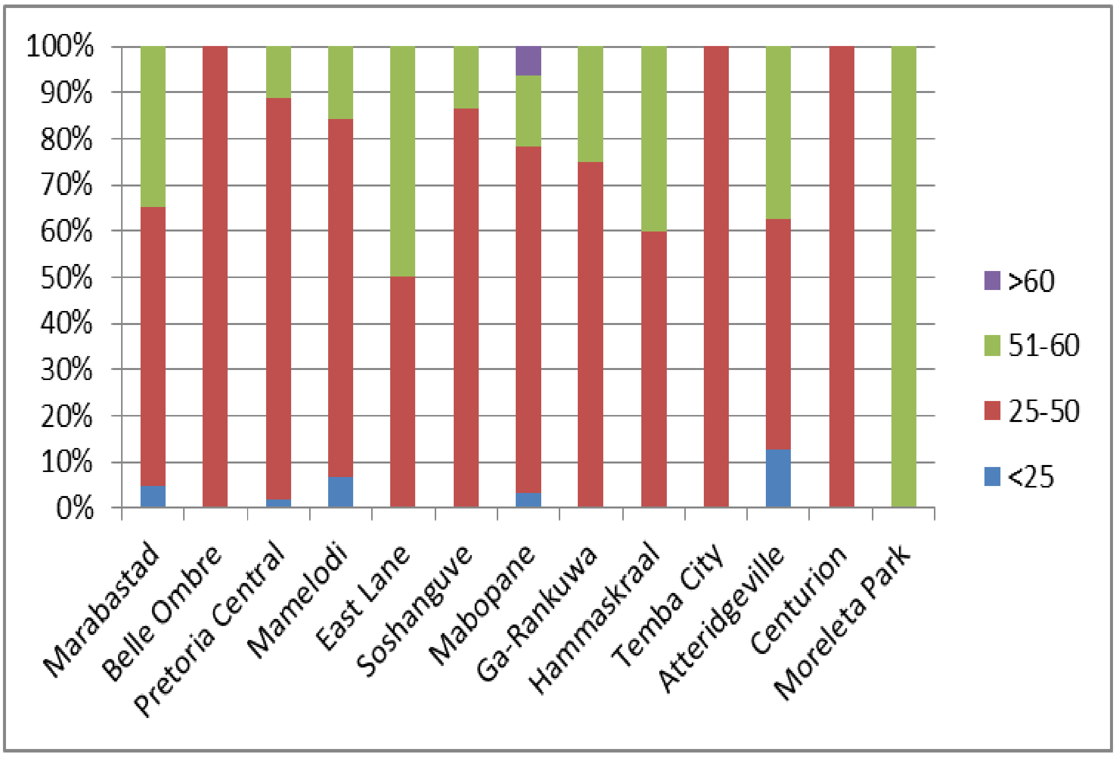

Figure 4.3: Proportions of age categories per market

Analysis of the age of vendors in different markets can be seen in Figure 4.3. In Bella Ombre and Centurion, all (100%) the vendors belonged to the 25-50 year age bracket. The majority of vendors were also in this age group in Pretoria central (86.79%), Mamelodi (77.78%), Soshanguve (86.67%), Mabopane (75%), Ga-Rankuwa (75%), Hammaskraal (60%) and Atteridgeville (50%). Few markets (n=5) had vendors who belonged to the age group <25. These included Marabastad (5%), Pretoria central (1.89%), Mamelodi (6.67%) Mabopane (3.13%) and Temba city (12.5%). Very few vendors in the age group category >60yrs were involved in the informal trade, and these were in Mabopane (6.25%). This area is peri-urban and vendors may include more elderly people who are living in the area on smallholdings as pensioners.

4.3.2 Education status of the informal vendors

Most vendors interviewed had attained at least high school education, or had matriculated (completed Grade 12 at secondary education level) or had at least attained tertiary qualifications. For example, 75% of all the male vendors indicated that they had attained some secondary education or completed matric or had tertiary education. Among the female vendors, 55.5% indicated that they had attained some secondary education or completed matric or had a tertiary qualification.

There was a difference in the educational status of the respondents by gender. More males (35%) indicated that they had completed matric compared to their female counterparts (24%). In addition, more male vendors (20%) indicated that they had attained tertiary education as compared to their female counter parts (5.5%). Furthermore, while 20% of the females interviewed did not have any formal education, all males had at least a primary level of education.

4.3.3 Gender distribution of informal vendors

Results obtained from the survey showed that females constituted the majority (92%) of the informal vendors surveyed.

4.3.4 Employment status of the informal vendors

Four different ways/capacities vendors worked in various markets were observed, and categorised as:

- the owner of the business;
- an employee earning a salary or an allowance;
- part of the family running the business where only family members were involved in the day to day running of the outlet; or
- someone who is hired to help out for one or a few days and thus a temporary employee.

Over all, the majority of vendors (n=157; 69.47%) as shown in Figure 4.4 managed the informal food outlets as personal businesses. In some markets like Atteridgeville and Moreleta Park, all the vendors (100%) indicated that their informal outlets were their personal businesses. Running the business as part of a family enterprise (n=33; 14.6%) or running the business as an employee who earns a salary (n=34; 15.04%) was the next most common form of employment. Pretoria Central (20.4%) and Soshanguve (26.67%) had the highest number of vendors who worked as employees. Hiring of people to assist for a short period of time was the least common among the vendors, and was only observed in 0.88% of the markets. The markets were this form of employment was observed included Belle Ombre (5.88%) and East Lane (25%) (See Fig 4.4)

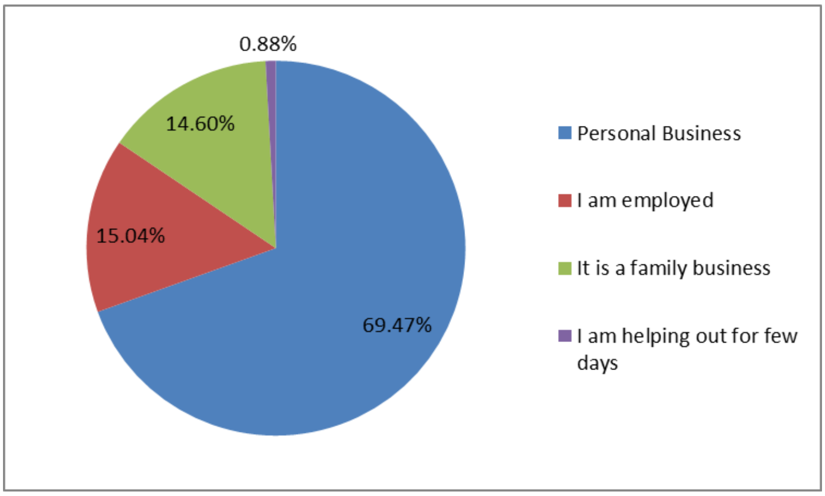

Figure 4.4: Informal vendor employment status

Because employment of people to help out was observed, it shows that informal vendors did not provide employment for themselves only, but also provided employment for other people who help at the vending stalls (Table 4.1). However, in the majority of cases (n= 85; 80.19%), the vendors in the study area tended to employ only one to two people. This trend was also observed in the individual markets (Table 4.1). Actually in some markets (Belle Ombre, East Lane, Hammskraal and Temba City) all the vendors (100%) who employed people said that they employ 1-2 people only.

Table 4.1: Proportions of employees per market

	How many people do you employ?						
Market	1-2 people	95% CI	3-4 People	95% CI	>4 People	95% CI	n
Atteridgeville	75	34.91-96.81	25	3.19-65.09	0	0.0-36.94	8
Belle Ombre	100	29.24-100	0	0.0-70.76	0	0.0-70.76	3
Centurion	0	0	0		0		0
East Lane	100	15.81-100	0	0.0-84.19	0	0.0-84.19	2
Ga-Rankuwa	100	29.24-100	0	0.0-70.76	0	0.0-70.76	3
Hammaskraal	100	15.81-100	0	0.0-84.19	0	0.0-84.19	2
Mabopane	66.67	29.93-92.51	22.22	2.82-60.01	11.11	0.28-48.25	9
Mamelodi	82.76	64.23-94.15	13.79	3.89-31.66	3.45	0.09-17.76	29
Marabastad	84.62	54.55-98.08	15.38	1.92-45.45	0	0.0-24.71	13
Moreleta Park	0	0.0-97.5	100	2.5-100	0	0.0-97.5	1
Pretoria Central	82.14	63.11-93.94	7.14	0.88-23.5	10.71	2.27-28.23	28
Soshanguve	57.14	18.41-90.1	14.29	0.36-57.87	28.57	3.67-70.96	7
Temba City	100	2.5-100	0	0.0-97.5	0	0.0-97.5	1
Total n(%)	85(80.19%)	71.32-87.3	14(13.21)	7.41-21.17	7(6.6)	2.7-13.13	106

With regard to owning other businesses, it was observed that the majority of vendors (93.39%) did not own any other business besides the informal food outlet. For example in Temba City, Soshanguve, Moreleta Park, Marabastad, Hammaskraal, Centurion and Atteridgeville none of the vendors indicated that he or she owned another business besides the informal food outlet. Even Belle Ombre which had the largest number of vendors who indicated that they did own other business, the figure was low (35.29%) (Table 4.2).

Table 4.2: Ownership of other business besides the informal food outlet

	Do you own any other business?				
	%				
Market	Yes	95% CI	No	95% CI	n
Atteridgeville	0	0.0-19.51	100	80.49-100	17
Belle Ombre	35.29	14.21-61-67	64.71	38.33-85.79	17
Centurion	0	0.0-60.24	100	39.76-100	4
Este Lane	20	0.51-71.64	80	28.36-99.49	5
Ga-Rankuwa	12.5	0.32-52.65	87.5	47.35-99.68	8
Hammaskraal	0	0.0-45.93	100	54.07-100	6
Mabopane	3.13	0.08-16.22	96.88	83.78-99.92	32
Mamelodi	4.44	0.54-15.15	95.56	84.85-99.46	45
Marabastad	0	0.0-16.84	100	83.16-100	20
Moreleta Park	0	0.0-97.5	100	2.5-100	1
Pretoria Central	8.16	2.27-19.6	91.84	80.4-97.73	49
Soshanguve	0	0.0-21.8	100	78.2-100	15
Temba City	0	0.0-36.94	100	63.06-100	8
Total (%)	15(6.61%)	3.75-10.66	212(93.39%)	89-34-96.25	227

4.4 Hygiene standards in the different markets

Assessment of hygiene standards was conducted using a structured questionnaire (Annexure I) and a checklist (Annexure II). The later enabled the researcher to assess aspects of hygiene practices that could not be assessed verbally through interviews.

4.4.1 Possession of certificate of acceptance

Persons involved in food production are required by law to apply[6] for a certificate of acceptability (also known as R918 Certificate), that allows them to cook and sell food to the public. The number of vendors with a certificate in the markets surveyed is shown in Figure 4.5.

[6] http://www.restaurant.org.za/pdf/APPLICATION_FOR_CERTIFICATE_OF_ACCEPTABILITY.pdf

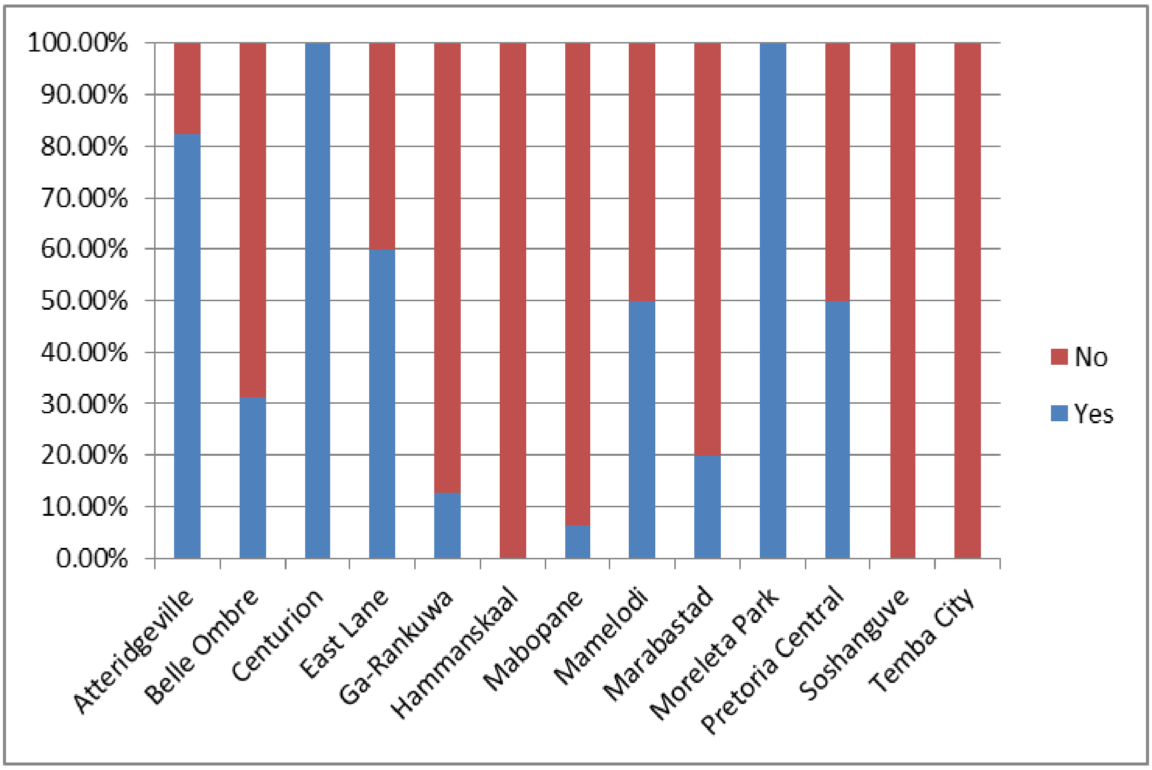

Figure 4.5: Proportion of vendors with certificates of acceptance

Out of a total of 217 respondents who responded to the question regarding possession of a certificate of acceptance, the majority (n=64.95%) did not possess certificates of acceptance.

Analysis per market (Fig 4.5 above) showed that all vendors in Centurion and the sole vendor in Moreleta Park had certificates of acceptance. In Atteridgeville (n=14; 82.35%) and East Lane (n=3; 60%) the majority of vendors indicated that they had the certificates. In Mamelodi and Pretoria Central about half of the vendors indicated that they had certificates, while in Hammaskraal, Soshanguve and Temba City none of vendors (100%) had them. A high percentage lacked certificates in Bell Ombre (n=11; 68.75%), Ga-Rankuwa (n=7; 87.5%), and Mabopane (n=30; 93.75%).

4.4.2 Assessing hygiene practices

Out of a total of 224 vendors for whom checklists were completed to assess hygiene practices at the vending stalls (Table 4.3), the majority (n=160; 71.35%) did not wear jewellery while preparing or cooking food. At the individual market level, there were only two markets; East Lane (80%) and Centurion (60%), where the majority of the vendors wore jewellery during the preparation and sale of food (Table 4.3).

Table 4.3: Proportion of vendors wearing jewellery

	Vendors wearing jewellery				
Markets	Yes (%)	95% CI	No (%)	95% CI	n
Marabastad	40	21.88-61.34	60	38.66-78.12	20
Bell Ombre	22.22	6.41-47.64	77.78	52.36-93.59	18
Pretoria Central	22.22	11.2-37.09	77.78	62.91-88.8	45
Mamelodi	27.08	15.28-41.85	72.92	58.15-84.72	48
East Lane	**80**	28.36-99.49	20	0.51-71-64	5
Soshanguve	35.71	12.76-64.86	64.29	35.14-87.24	14
Mabopane	30.3	15.59-48.71	69.7	51-29-84.41	33
Ga-Rankuwa	25	3.19-65.09	75	34.91-96.81	8
Hammanskraal	0	0.0-45.93	100	54.07-100	6
Temba City	12.5	0.32-52.65	87.5	47.35-99.68	8
Atteridgeville	30.77	9.09-61.43	69.23	38.57-90.91	13
Centurion	**60**	14.66-94.73	40	5.27-85.34	5
Moreleta Park	0	0.0-97.5	100	2.5-100	1
Total n(%)	64(28.57)	22.75-34.97	160(71.43)	65.03-77.25	224

As shown in Table 4.4, it was observed that the practice of washing hands and cutlery in the same container was very prevalent, and the majority of vendors (n=186; 83.04%) surveyed did not comply with the requirement of washing hands and utensils in different containers. Furthermore, in every market the majority of vendors violated this aspect of hygienic handling of food.

With regard to picking up RTE chicken with cutlery and not bear hands, the majority of vendors (n=212; 95.07%) tended to comply with this requirement to use cutlery. Furthermore, at the individual market level, Ga-Rankuwa (12.5%) and Soshanguve (14.29%) exhibited the highest level of none compliance with the requirement to picking up RTE chicken using cutlery (Table 4.4).

Table 4.4: Separation of containers used for washing and the use of cutlery

	Washes hand and utensil in same container					Uses cutlery to pick up RTE chicken				
Market	Yes (%;)	95% CI	No %	95% CI	n	Yes %	95% CI	No %	95 CI	n
Marabastad	95	75.13-99.87	5	0.13-24	20	100	83.16-100	0	0.0-16-84	20
Bell Ombre	77.78	52.36-93.59	22.22	6.41-47.64	18	94.44	72.71-99.86	5.56	0.14-27.29	18
Pretoria Central	86.67	73.21-94.95	13.33	5.05-26.79	45	93.33	81.73-98.6	6.67	1.40-18.27	45
Mamelodi	83.33	69.78-92.52	16.67	7.48-30.22	48	91.49	79.62-97.63	8.51	2.37-20.38	47
East Lane	100	47.82-100	0	0.0-52.18	5	100	47.82-100	0	0.0-52.18	5
Soshanguve	78.57	49.2-95.34	21.43	4.66-50.8	14	85.71	**57.19-98.22**	**14.29**	**1.78-42.81**	14
Mabopane	81.82	64.54-93.02	18.18	6.98-35.46	33	100	89.42-100	0	0.0-10.58	33
Ga-Rankuwa	62.5	24.49-91.48	37.5	8.52-75.51	8	87.5	**47.35-99.68**	**12.5**	**0.32-52.65**	8
Hammanskraal	66.67	22.28-95.67	33.33	4.33-77.72	6	100	54.07-100	0	0.0-45.93	6
Temba City	75	34.91-96.81	25	3.19-65.09	8	100	63.06-100	0	0.0-36-94	8
Atteridgeville	92.31	63.97-99.81	7.69	0.19-36.03	13	100	75.29-100	0	0.0-24.71	13
Centurion	60	14.66-94.73	40	5.27-85.34	5	100	47.82-100	0	0.0-52-18	5
Moreleta Park	100	2.5-100	0	0.0-97.5	1	100	2.5-100	0	0.0-97.5	1
Total (%)	186(83.04)	77.47-87.71	38(16.96)	12.29-22.53	224	212(95.07)		11(4.93)	2.48-8.62	224

Flies were observed at the stalls as shown in Table 4.5. However, out of all the stalls that were inspected, few stalls 14.73% (n=33) had more than 10 flies as compared to 54.46% (n=122) that had < 5 flies around the RTE chicken. Worth noting is that, a large proportion number (69; 30.8%) of stalls did not have any flies around the stall at the time of inspection.

A comparison of the numbers of flies sited at stalls in the various markets showed a variation between markets. Belle Ombre had the lowest number (25.88%) of stalls at which flies were observed, while East Lane (100%) had the highest proportions of stalls at which flies were sighted.

Markets with the highest proportions of stalls where more than ten (>10) flies were observed on cooked RTE chicken, included Soshanguve (28.57%) Mamelodi (20.83%) and Mabopane (18.18%).

Table 4.5: The proportion of stalls where flies were sighted

	Fly population at vending site						
Markets	>10 flies %	95% CI	0>Flies<5 %	95% CI	No flies %	95% CI	n
Marabastad	0	0.0-16.84	45	23.06-68.47	55	31.35-76.94	20
Bell Ombre	5.56	0.14-27.29	22.22	6.41-47.64	72.22	46.52-90.31	18
Pretoria Central	15.56	6.5-29.46	57.78	42.15-72.34	26.67	14.6-41.94	45
Mamelodi	**20.83**	**10.47-34.99**	56.25	41.18-70.52	22.92	12.03-37.31	48
East Lane	40	5.27-85.34	60.00	14.66-94.73	0	0.00-52.18	5
Soshanguve	**28.57**	**8.39-58.1**	42.86	17.66-71.14	28.57	**8.39-58.1**	14
Mabopane	**18.18**	**6.98-35.46**	66.67	48.17-82.04	15.15	5.11-31.9	33
Ga-Rankuwa	12.5	0.32-52.65	62.50	24.49-91.48	25.00	3.19-65.09	8
Hammanskraal	16.67	0.42-64.12	66.67	22.28-95.67	16.67	0.42-64.12	6
Temba City	12.5	0.32-52.65	62.50	24.49-91.48	25.00	3.19-65.09	8
Atteridgeville	0	0.00-24.71	61.54	31.58-86.14	38.46	13.86-68.42	13
Centurion	0	0.00-52.18	40.00	5.27-85.34	60.00	14.66-94.73	5
Moreleta Park	0	0.0-97.5	100.0	2.5-100	0	0.0-97.5	1
Total n(%)	33(14.73)	10.36-20.06	122(54.46)	47.7-61.11	69(30.8)	24.83-37.3	224

Assessment of floors revealed that there were four types of floors in stalls, and these are (Table 4.7):

- Cemented floor
- Concrete floor slab
- PVC carpet
- No flooring (sand or soil)

Only 165 vendors out of the 237 who participated in this study had one of the first three types of flooring in their vending stalls. Of the 165, just over half (n=85; 51.52%) had cemented floors. This was followed by those who had concrete slabs (n=72; 43.64%) and then those that had PVC carpets (n=8; 4.85%) laid out to form the floor. Marabastad (68.42%) and Belle Ombre (61.11%) had the majority of stalls with concrete slabs. Use of PVC carpets as the floor cover in informal vending stalls was the least popular and was used by few vendors in only five markets (Table 4.6). The later was either used in temporary structures or in caravans that had been converted into food vending stalls.

Table 4.6: The floor types observed in the various stalls

Markets	Proportions of stalls with identified floor type						
	Cemented floor		Floor with concrete slab		Floors with PVC carpets		n
	%	95% CI	%	95% CI	%	95% CI	
Marabastad	26.32	9.15-51.2	68.42	43.45-87.42	5.26	0.13-26.03	19
Bell Ombre	38.89	17.3-64.25	61.11	35.75-82.7	0	0.0-18.53	18
Pretoria Central	47.22	30.4-64.51	41.67	25.51-59.24	11.11	3.11-26.06	36
Mamelodi	52.94	35.13-70.22	47.06	29.78-64-87	0	0.0-10.28	34
East Lane	66.67	9.43-99.16	0	0.0-70.76	33.33	0.84-90.57	3
Soshanguve	77.78	39.99-97.19	22.22	2.82-60.01	0	0.0-33.63	9
Mabopane	73.91	51.59-89.77	26.09	10.23-48.41	0	0.0-14.82	23
Ga-Rankuwa	66.67	22.28-95.67	33.33	4.33-77.72	0	0.0-45.93	6
Hammaskraal	60	14.66-94.73	40	5.27-85.34	0	0.0-52.18	5
Temba City	66.67	9.43-99.16	33.33	0.84-90.57	0	0.0-70.76	3
Atteridgeville	42.86	9.90-81.59	42.86	9.90-81.59	14.29	0.36-57.87	7
Centurion	0	0.0-84.19	50	1.26-98.74	50	1.26-98.74	2
Moreleta Park	0		0		0		0
Total (%)	85(51.52)	43.62-59.14	72(43.64)	35.94-51.56	8(4.85)	2.12-9.33	165

With regard to sources of water used at the vending sites, results (Table 4.7) showed that different sources of water were available to the vendors, and these included the following:

- Municipal tap water close by,
- Water from elsewhere,
- Water brought from home for use at the vending site, and
- Water bought from vendors selling water or deliver water to receive food in return.

Generally, the main source of water was the municipal taps closest to the vending site (n=126; 58.88%). This was followed by water obtained from a distance away from the stall (n= 77; 35.98%), water brought from home (n= 7; 3.27%), and lastly water that is bought from other informal vendors who deal in water (n= 4; 1.87%). As shown in Table 4.6, municipal tap water close by was the most popular in the individual markets followed by water obtained from elsewhere. The least common sources of water were water brought from home and lastly water which was bought from vendors who sell water (Table 4.7).

Atteridgeville (69.23%), East Lane (60%) and Mabopane (45.45%) in that order, tended to have the highest number of vendors located far from the municipal taps, and thus had more vendors who depended on water collected from elsewhere.

Table 4.7: Source of water used by informal vendors

Market	Proportions of respondents who used identified sources of water								n
	Municipal tap water	95% CI	water from else where	95% CI	Use water from home	95% CI	Buy water	95% CI	
Marabastad	66.67	40.99-86.66	27.78	9.70-53.48	0	0.0-18.53	5.56	0.14-27.29	18
Bell Ombre	73.33	44.9-92,21	26.67	7.79-55.1	0	0.0-21.8	0	0.0-21.8	15
Pretoria Central	68.18	52.42-81.39	31.82	18.61-47.58	0	0.0-8.04	0	0.0-8.04	44
Mamelodi	68.09	52.88-80.91	23.4	12.3-38.03	8.51	2.37-20.38	0	0.0-7.55	47
East Lane	40	5.27-85.34	60	14.66-94.73	0	0.0-52.18	0	0.0-52.18	5
Soshanguve	50	23.04-76.96	50	23.04-76.96	0	0.0-23.16	0	0.0-23.16	14
Mabopane	54.55	36.35-71.89	45.45	28.11-63.65	0	0.0-10.58	0	0.0-10.58	33
Ga-Rankuwa	12.5	0.32-52.65	75	34.91-96.81	12.5	0.32-52.65	0	0.0-36.94	8
Hammaskraal	50	11.81-88.19	33.33	4.33-77.72	16.67	0.42-64.12	0	0.0-45.93	6
Temba City	16.67	0.42-64.12	16.67	0.42-64.12	16.67	0.42-64.12	50	11.81-88.19	6
Atteridgeville	30.77	9.09-61-43	69.23	38.57-90.91	0	0.0-24.71	0	0.0-24.71	13
Centurion	100	47.82-100	0	0.0-52.18	0	0.0-52.18	0	0.0-52.18	5
Moreleta Park	0		0		0	0	0	0	0
Total (%)	126(58.88)	51.97-65.54	77(35.98)	29.55-42.81	7(3.27)	1.33-6.62	4(1.87)	0.51-4.71	214

As shown in Table 4.8, the most commonly used structures by informal vendors were the temporary structures (n=116; 52.97%) followed by permanent structures (n=40; 18.26%). Generally the number of vendors selling food in the open with no structure was the lowest (n= 63; 28.77%). However at the individual market level, the situation was different with Mamelodi (57.45%), East Lane (60%) and Atteridgeville (46.15%) having large numbers of vendors who operated in places with no structures (Table 4.8).

Table 4.8: Structures used by informal vendors in the various markets

Markets	Relative frequency of respondents %						n
	No structure	95% CI	Temporary structure	95% CI	Permanent structure	95% CI	
Marabastad	26.32	9.15-51.2	68.42	43.45-87.42	5.26	0.13-26.03	19
Bell Ombre	0	0.0-18.53	66.67	40.99-86.66	33.33	13.34-59.01	18
Pretoria Central	22.73	11.47-37.84	47.73	32.46-63.31	29.55	16.76-45.2	44
Mamelodi	57.45	42.18-71.74	21.28	10.7-35.66	21.28	10.7-35.66	47
East Lane	60	14.66-94.73	40	5.27-85.34	0	0.0-52.18	5
Soshanguve	14.29	1.78-42-81	64.29	35.14-87.24	21.43	4.66-50.8	14
Mabopane	18.75	7.21-36.44	71.88	53.25-86.25	9.38	1.98-25.02	32
Ga-Rankuwa	12.5	0.32-52.65	87.5	47.35-99.68	0	0.0-36.94	8
Hammaskraal	0	0.0-45.93	50	11.81-88.19	50	11.81-88.19	6
Temba City	25	3.19-65.09	75	34.91-96.81	0	0.0-36.94	8
Atteridgeville	46.15	19.22-74.87	46.15	19.22-74.87	7.69	0.19-36.03	13
Centurion	25	0.63-80.59	75	19.41-99.37	0	0.0-60.24	4
Moreleta Park	0	0.0-97.5	100	2.5-100	0	0.0-97.5	1
Total (%)	63(28.77)	22.87-35.05	116(52.97)	46.13-59.73	40(18.26)	13.38-24.03	219

Figure 4.6 below is a summary of the results of the assessment of the distance from the stall to the toilets for the different markets.

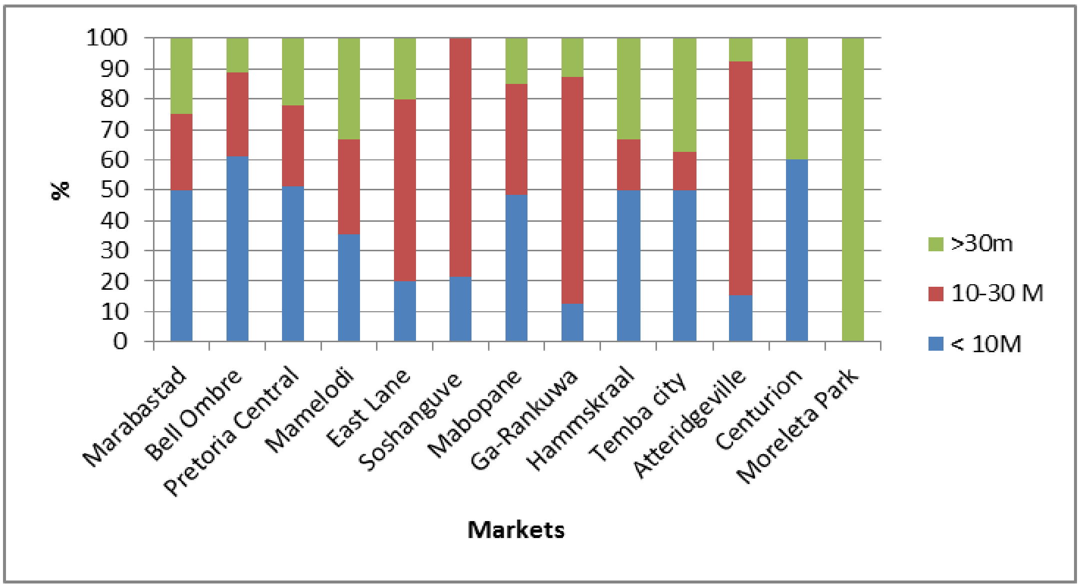

Figure 4.6: The distance from the stall to the toilets

The majority of vendors tended to be located between <10 to 10-30 m distance to the toilets. Very few were located beyond the 30m distance.

Results from the scoring and ranking showed that none of markets met the compliance criterion of 60% and above. Based on the criterion of scoring 60% or more, Mamelodi a peri-urban location, scored 2/9 (22.22%), and was ranked lowest. On the other hand, East Lane, Atteridgeville and Centurion (located in affluent suburbs) each scored 5/9(55.55%), and were ranked highest.

Due to the small numbers involved, a formal test could not developed to test the association between the different factors and possession of a certificate of acceptability.

4.5 Discussion

In the present study (Figure 4.1), informal markets were located predominantly in previously disadvantaged areas also referred to as black townships, and close to taxi ranks where South Africans of African descent lived or congregated in large numbers. This was expected and is consistent with past studies that estimate that approximately 74. 5% of all the vendors in Gauteng were situated near transport areas (i.e., taxi ranks and stations) (Martins & Anelich 2000). This facilitates access to RTE food by this group of people who constitute the majority of the poor in South Africa. Because of this, the informal food trade plays a role in food security among the urban poor in the city of Tshwane.

From the present study, markets with the largest number of vendors such Pretoria Central, Marabastad, Belle Ombre were located in the Central Business District (CBD) of Tshwane either inside the taxi ranks or in close proximity to taxi ranks. This could be associated with the large number of people who pass through CBD on their way to other parts of the city, province or country. Based on what has been reported in previous studies, the location of these markets in the vicinity of taxi ranks enabled commuters to quickly pick up a meal to eat as they waited for their transport or while traveling (Masupye & Von Holy 1999, Masupye & von Holy 2000, Martins 2006). This therefore positions informal markets as a convenient source of nutritious food for the people who patronise these markets.

It was expected that affluent suburbs like Moreleta Park and Centurion, would have few informal markets or that the markets located in such places would be much smaller compared to places like Marabastad, Mamelodi and Mabopane that have large populations of South

Africans of African descent. The findings of the present study confirmed this expectation. The reason for this is that approximately 98.9% of those who patronize street food vendors are black South Africans (Martins 2006). It therefore makes sense that vendors tended to be located where a large number of customers are likely to be found.

A look at the demographic profile of the informal vendors in this study revealed that the majority of informal vendors belonged to the 25-50 years age group. This is the most economically active age group that needs income to maintain their families. These findings are comparable to what was observed by FAO in West Africa where the age range for the majority of vendors was between 33 and 49 years (FAO 2012). In view of this, the informal food trade plays a role in absorbing some of the unemployed adults in the city and its suburbs. This is supported by the fact that 75% and 55% of the males and females respectively indicated that they had completed secondary education (matriculated). These are people who might have failed to secure employment in the formal sectors given the high unemployment rate of over 25% in South Africa (Banerjee et al. 2008, Kingdon & Knight 2007).

South African youth unemployment is one of the highest in the world. Among South African youth of African descent, unemployment stands at 58% (NUMSA 2014). Therefore, the low numbers of people <25 years of age observed to be involved in the informal trade was not expected. In view of this, the findings of the present study point to the fact that young people may not be interested in the informal food vending business or that they are not aware of such opportunities.

The existence of vendors without formal education, confirms that the informal food trade also offers employment opportunities for people with little or no formal education and thus with very limited opportunities for earning livelihoods within the city. Such people are able to use their limited capital assets to earn a living (National Resources International limited (NRIL) 2010, Division of Prevention and Control of Non-communicable Diseases (DNC) 2004, Lues et al. 2006, Martins 2006).

Results of the present study are consistent with those of past studies that reported that women, who often are the first victims of increased poverty, form the majority of informal vendors (Ekanem 1998, Martins, Anelich 2000, Badrie, Joseph & Chen 2011). In the present study, 92% of the vendors were women. This was much higher than what was reported in Trinidad and Tobago, but comparable with reports from studies done in South Africa and

West Africa that reported that women made up 90.5 -98.5% and 89- 98% respectively of the people involved in street food vending (Martins & Anelich 2000, Martins 2006, Badrie, Joseph & Chen 2011, FAO 2012). This high number could be attributed to the fact that traditionally among African cultures, cooking and serving food is reserved for women, while manual labour is done by men. It is therefore possible that men look down upon cooking food to sell.

Like their female counterparts in West Africa, where women also dominated cooking, the street food vendors in Tshwane have managed to turn a daily domestic chore into a profitable business (FAO 2012). The other interesting fact about street food vending is the great flexibility it offers women to be able to combine work and domestic responsibility. For example, it is possible for a street food vendor to go with her child, who is not of school age to work, which might not be the possible when they are employed in the formal sector (FAO 2012).

In the present study, 69.47% (n=157) of the vendors ran the informal food outlets as personal businesses and 93.39% of the vendors did not own another business besides the informal food outlet. This is consistent with the findings by Martins (2006) who reported that 99.5% of the vendors in South Africa had the street food business as the main source of their household income.

It was also observed in the present study that vendors employ other people either on a long term basis or on a temporary basis. In this way, the informal food trade contributes to job creation, and hence, has the potential to make a significant contribution to the urban economy through job creation for both the vendors and the people they employ. Some authors have reported that this would more importantly involve women and entire families in some cases (National Resources Institute 2011, Codjia 2000, Dawson & Canet 1991).

In Trinidad and Tobago, informal vendors are required to display their food handler's badge during the course of cooking and selling food. In South Africa, although the National Hygiene Regulations require all food vendors to possess a certificate of acceptability to run a food outlet (The Directorate: Food Control 1977b, The Directorate: Food Control 1977a, Badrie, Joseph & Chen 2011), the vendors are not expected to display these certificates.

Nearly two thirds (64.95%) of the vendors interviewed in the present study indicated that they did not own a certificate of acceptability. Given that informal vendors in South Africa are not expected to display their certificates, as is the case in Trinidad and Tobago, it is possible that the number of vendors that did not comply with the requirement was higher than what is reported in this study.

Assessment of compliance to possession of a certificate of acceptability as required by the law, varied across markets. This could be due to differences in the level of monitoring and enforcement by municipal environmental health officials in the different districts within the municipality of Tshwane. It could also be related to officials taking bribes in certain markets. This was not directly observed and is thus anecdotal information. However, the author is of the view that in its own way, practices like these could also lead to improvement in the compliance rate in the long run, as it eats into the profitability of vendors who have to keep paying bribes.

Compliance with food hygiene norms like not wearing jewellery and keeping short clean nails when handling RTE varied across all the markets. In some markets, high levels of compliance were observed while in others a low level was observed. For example, while most vendors generally did not wear jewellery while preparing and serving RTE chicken, two markets surveyed displayed a high level of violation as described in 4.3.2 section of the results.

Washing of hands and utensils in the same container was widespread, with as many as 83% of the vendors not adhering to the principle of separating containers for washing hands and utensils. This is consistent with findings of previous studies done in South Africa that also showed that the practice was widespread among informal vendors (Lues et al. 2006, Masupye & von Holy 2000). Hands of food handlers have been shown to be a significant source of contamination for several bacteria including *Escherichia coli* and *Staphylococcus aureus* (Ayçiçek et al. 2004, Mensah et al. 2002). Therefore, washing hands in the container used to wash utensils can lead to recontamination of RTE chicken when served on or using such utensils. This phenomenon is known to be responsible for food borne outbreaks (Reij & Den Aantrekker 2004).

The use of utensils to pick up RTE chicken during serving was one food hygiene handling principle that was widely observed among the vendors. As the results show, up to 95.07% (n=212) were observed picking up RTE chicken using utensils. The compliance rate was higher than what was reported in a study done in Ghana. In the latter, only 36% of the vendors studied did not serve RTE food with bare hands (Mensah et al. 2002). The practice of using forks and spoons to serve food, instead of bare hands, has the potential to limit contamination of RTE chicken with organisms like *E. coli* and *S. aureus*. The risk of foodborne diseases due to handling food with bare hands is discussed in detail by Mensah et al (2002).

Although only 14.73% (n=33) of stalls were observed to have >10 flies around the RTE chicken, flies are still a cause for concern. This is because flies are natural carriers of disease causing organisms such viruses, bacteria, fungi and parasites. The housefly (*Musca domestica*) is an efficient mechanical vector for bacteria like *E. coli* and *Staphylococcus* spp. among others (Förster et al. 2007). Flies transmit pathogens through various ways including via their body surface, mouth parts, vomit and faeces. This makes them significant transmitters of foodborne diseases (Förster et al. 2007). In a study by Barro and colleagues (2006), it was demonstrated that flies tend to carry *E. coli* in higher numbers compared to *S. aureus*.

Failure to dispose of garbage properly is a common problem with informal markets, and it provides food and harbourage for flies and rodents (Barro et al. 2006, Feglo & Sakyi 2012). If there are no facilities for liquid drainage, and waste water and garbage are left in the streets, breeding of both rodents and flies is encouraged (Barro et al. 2006). This could explain the high prevalence of flies observed in the present study.

In environments with a high population of flies, if food is not effectively protected from dust and flies, it could get contaminated easily with food borne pathogens. Therefore, food sold in such environments has a higher likelihood of getting contaminated by flies. Consequently, when such food is eaten, the risk of contracting diarrhoeal diseases is very high (Dawson, Canet 1991, Förster et al. 2007, Barro et al. 2006, Feglo, Sakyi 2012). In this study, a fly was sighted at 69.13% of the markets. Although the present study did not assess rubbish disposal in the markets, the high numbers of vending stalls at which flies were sighted, could be attributed to poor rubbish disposal in the informal markets in Tshwane.

The majority of vendors that were studied had either cemented floors or a concrete slab as the floor for the food stalls. The few who could not afford to cement the floor or construct a concrete slab used polyethylene carpets. The latter were mostly observed in temporary structures or caravans converted into food outlets. The rest of the vendors prepared food in stalls floored with bare ground. The latter were the ones who indicated the option "other" on the questionnaire. Given that the majority of vendors had floors that were amenable to washing such as cemented or concrete floors or in the form of polyethylene carpets, shows that the informal vendors were cognisant of the fact that floors on which food is prepared must be the type that are easy to clean. Unlike floors that are made up of bare ground, cemented floors, concrete slabs and polyethylene carpets can be washed to keep the dust or mud in the stalls at low levels. This can translate into increased food safety. Based on this observation it is evident that vendors who participated in this study make efforts to mitigate for risks associated with RTE chicken bought in these informal markets.

When water of doubtable quality is used anywhere along the food chain, the risk of food getting contaminated is heightened. It is therefore important that potable water is used in production and preparation of food. In Ghana, salads grown in areas where access to potable water was limited resulted not only in contaminated RTE salads but also contaminated RTE food through cross contamination (Feglo & Sakyi 2012). In the present study, the majority of vendors had access to potable water supplied by the Tshwane municipality. This is unlike what has been observed in places like Ghana and Trinidad and Tobago, where the majority of informal vendors did not have access to municipal water (Mensah et al. 2002, Badrie, Joseph & Chen 2011).

Although the majority of vendors in the present study had access to water supplied by the municipality and thus considered potable, in some instances, water had to be delivered to the stall in containers. This is similar to what was observed in a study conducted in Trinidad and Tobago where vendors either brought water from home or collected water from a nearby public stand-pipe (Badrie, Joseph & Chen 2011). The fact that the containers used by vendors to collect water from the municipal taps may not always have been clean means that this practice could negatively influence the microbiological quality of the water used by the vendors.

In a study by Feglo et al (2012) it was observed that when municipal water failed, street vendors resorted to other sources of water. This might also be the case with the informal vendors in Tshwane. However, this was outside the scope of the present study and thus alternative sources of water for the vendor in event of failure of the municipality to supply water were not investigated.

Hygiene aspects of vending operations are a major source of concern for food safety regulators (Mensah et al. 2002). The structure used for food preparation influences the microbiological quality of the food prepared therein. The low score that most markets obtained in the scoring and ranking process is indicative of the poor infrastructure and level of hygiene practices in the markets that were surveyed. This negatively impacts on the ability of the vendors to produce food that is safe from a microbiological risk point of view.

4.6 Conclusions and recommendations

The informal trade in food is linked to South Africans of African descent, and vendors are predominantly located in areas like transit areas or where they congregate in large numbers. Therefore to design a risk communication strategy, the areas to target for disseminating the risk mitigation strategy would be the taxi ranks and commuter taxis and/or buses.

Given that the sale of RTE chicken in Tshwane is predominantly carried out by women and vendors who belong to the economically active age group (25-60 years of age), the informal trade in RTE chicken offers opportunity for urban dwellers who have failed to secure employment in the formal sector. However, very few young (<25 years of age) and pensioners are involved in the trade. Older people tend to be more experienced in cooking and hence more likely to have a better understanding of how to mitigate food associated risk. Therefore, the fact that the majority of vendors were adults probably improves the safety of informally traded RTE chicken.

Women tend to be more experienced in cooking compared to men, and as a result they are likely to have a better understanding of how to mitigate risks associated with the handling of food. This has the potential to positively influence the safety of the RTE chicken. Therefore the fact that the majority of informal vendors were women may help protect consumers.

By informal vendors improvising to ensure that the floors they work on are washable, and where there are no municipal constructed structures, constructed temporary structures suggests that informal vendors do actively mitigate for food associated risks. The fact that the greater majority of vendors used utensils to pick up RTE chicken is further proof that informal vendors do put in place measures to mitigate risks associated with the RTE chicken they sell.

The city of Tshwane needs to put emphasis on monitoring hygiene practices including the following: ensuring that all vendors possess a certificate of acceptance; work on cemented floors that can be cleaned; have direct access to water supplied by the municipality; and not have to depend on water being delivered to the stall; improved refuse removal as part of controlling flies at the vending site; and avoiding washing of hands and utensils in the same container.

Given that the informal food sector is an integral component of the food supply chain for urban centres, further development of taxi ranks in Tshwane should consider the development of suitable facilities for the informal food traders to help improve the hygiene status of the operations. In this way, the sector will be able to grow and continue to play a vital role in providing cheap but nutritious food for the urban poor while serving as a source of income for the hundreds of vendors who otherwise would be unemployed.

Markets that are located in peri-urban areas like Mamelodi scored low based on compliance criteria compared to those located within the vicinity of the Central Business District of Tshwane, like Centurion. The implication of this is that the one size fits all inspection process for monitoring food safety for informally traded RTE chicken cannot work, but should be tailored for each market. More importantly, they should be commensurate to the observed risk in the market. The implication of this is that markets that scored low and thus ranked low need to be monitored more vigorously to improve their score.

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CHAPTER 5

THE FOOD VALUE CHAIN OF READY-TO-EAT CHICKEN

5.1 Introduction

Results of the qualitative and quantitative investigation into the food value chain of RTE chicken sold by informal vendors in Tshwane Metropolitan area are presented in this chapter. The methodology used to obtain results for this chapter can be found in Chapter 3 in the following sections:

3.4 Data collection

3.4.1 Market survey

3.4.2 Sample frame and sampling strategy

3.4.3 Administering questionnaires and checklists

3.4.7 Food value chain and relative quantities of ready-to-eat chicken

3.5 Data analysis.

5.2 Qualitative evaluation of the value chain of RTE

Qualitative results obtained from interviews and focus group interviews showed that there were four types of food value chains for RTE chicken sold on in the informal markets in Tshwane (Figure 5.1):

- One formal chain,
- Two formal-informal hybrid chains, and
- One purely informal chain.

The formal value chain starts from commercial poultry farms which mainly provide broilers. These broilers are slaughtered and processed in formal registered abattoirs, and distributed through the formal markets (butchers, supermarkets and retail shops) where informal vendors and the general public can purchase the raw chicken. This is reflected in the left arm of Figure 5.1.

In the first of the two formal-informal hybrid value chains there is a spill over from the formal to informal chain. The spill-over takes place at the wholesaler/retailor level and involves mainly poultry meat from broilers raised on commercial farms and slaughtered at registered large-scale poultry abattoirs. The informal vendors purchase inspected, packaged and labelled raw chicken from butchers, supermarkets and retail shops. They then cook and sell the chicken meat in informal markets.

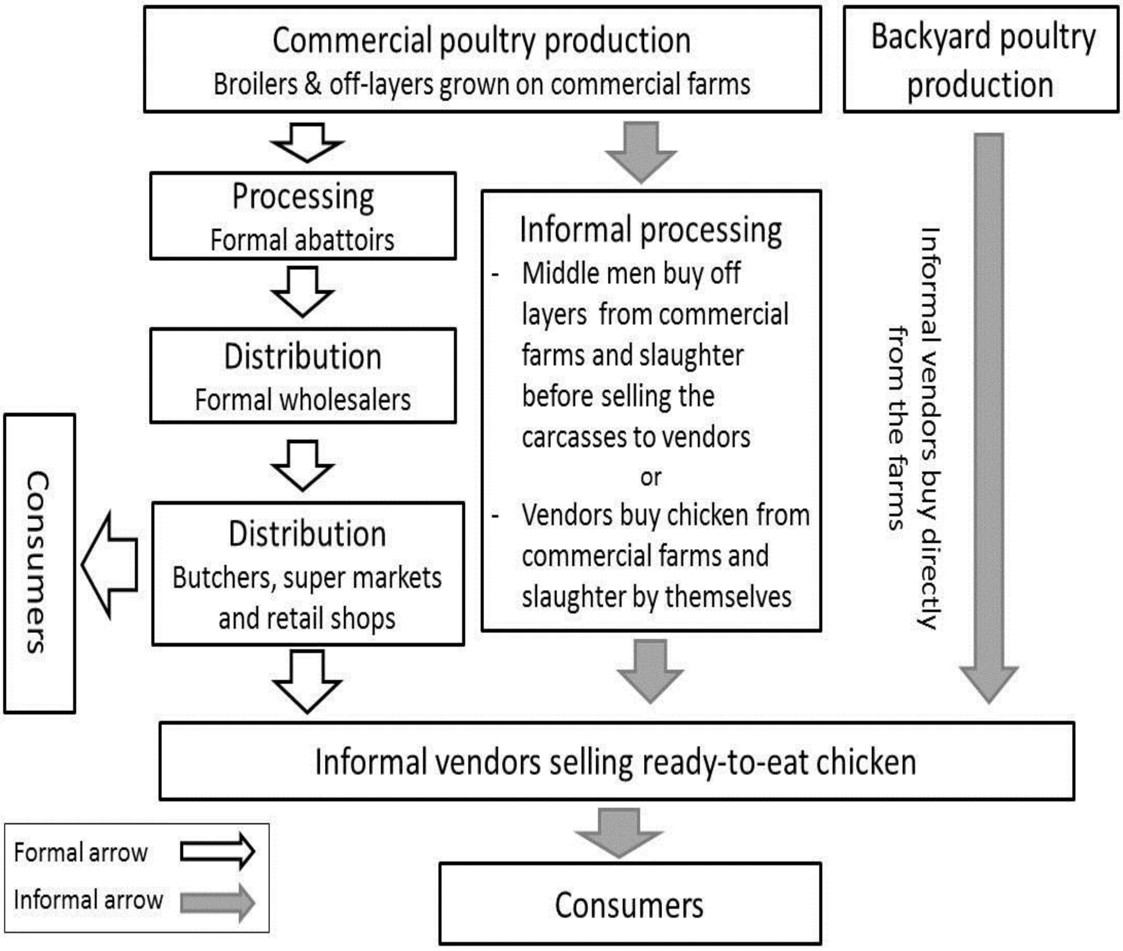

Figure 5.1: The food value chain for RTE chicken sold by informal vendors

The second of the two formal-informal hybrid chains also involves a spill over from the formal to informal chain. However, here it is different in that it starts with commercial producers and eliminates the wholesalers or retailers. Unlike the first formal-informal hybrid chain which is mainly a supply for broiler meat, this second formal-informal hybrid chain is the main source of spent hens (old layers that have reached the end of their laying cycle) as well as old breeder fowls originating from "chick producers". During focus group discussions it was realised that these adult fowls are also called "hard bodies" by informal vendors and their customers. The name "hard bodies" relates to their meat being tougher or harder compared to that of broilers.

In South Africa, the same "hard bodies" are marketed as "Cornish hens" in supermarkets. These "Cornish hens" go through a formal slaughter process and are packed and labelled as is the norm in the formal food sector. The vendors were asked why they buy these adult birds directly from the farms or middle men as live birds instead of buying already processed "Cornish hens" sold by supermarkets. The response was that the ones sold in the supermarkets especially if frozen, do not taste the same as those that are bought as live birds and slaughtered by the vendors or their middle men. It therefore means that if supermarkets sold these "Cornish birds" as fresh products i.e. not frozen they could be acceptable to the informal vendors.

The poultry industry has three main types of producers: layers, broilers and chicks. The breeder birds fall under the classification of "chick producers". All roosters and hens used as breeders also enter the market as poultry meat at some stage (See Chapter 2). When the informal vendors were asked to identify where they source the spent hens, they indicated that they source the birds either through middle men/women or they buy the chicken directly from farms that raise layers or chick producers. Where middle men/women are involved, the chickens are sourced from the farmer by middle men/women who slaughter and process the chicken in informal establishments before selling them to the informal vendors. But where the informal food vendors buy hens directly from the farms, they do the slaughtering at their homes or elsewhere. None of the vendors interviewed or who participated in the focus group discussion indicated that they slaughter birds at the vending site.

The purely informal value chain on the other hand starts from backyard small scale poultry producers. With this value chain, informal vendors buy chicken directly from the farmers. The vendors then slaughter and cook the chicken they sell to the customers who patronise informal food outlets. In some instances, the vendors indicated that farmers slaughter and process the chicken before delivering at the vending site of the informal vendor. This turned out to be the shortest chain of all the four chains identified since it involves the farmer and the vendor only with no intermediary.

5.3 Quantitative evaluation of the value chain of RTE

Given that the informal vendors were not willing to divulge the information on the specific source of chicken they purchase, a complete quantitative value chain could not be established. Therefore, the responses of the informal interviews obtained during the informal interviews were used to compute the various categories of sources and to draw up the qualitative value chain in Figure 5.1. Meanwhile the results of the quantitative assessment of the value chain are presented in Table 5.1.

Informal vendors have access to several categories of sources of chicken for selling as RTE chicken (Table 5.1). Multiple answers were allowed for the question on the sources of chicken during the informal interviews. Out of 234 vendors who answered the question, 24 (10.3%) indicated that they purchased chicken from more than two categories of sources. However, the vendors (217/237, 91.6%) indicated that supermarkets were the most common source (79.3%) of chicken they cook for their customers. This was in clear contrast to what happens in other developing countries, like India, where it is reported that in one of its provinces (Nagaland) most of the meat is sold through the informal sector which lack refrigeration and sanitation, and are not subjected to effective health inspections (Fahrion et al. 2014).

Vendors do buy live and/or processed (slaughtered, de-feathered and eviscerated) chicken. For example, thirty vendors (30/237, 12.7%) indicated that they purchase live birds and slaughter the chicken by themselves. While thirteen vendors (13/237, 5.5%) indicated that they purchase both live birds and chicken carcasses.

With regard to sources of chicken, the respondents indicated that the most common sources of live birds are the middle men/women (25/30, 83.3% (25/237, 10.5%)). Few vendors indicated that they purchase live birds directly from the farms (three vendors said they buy from small scale farmers while two said they buy from commercial farms).

Table 5.1: Source of chicken for informal vendors

Source category	Respondents (n=237)	Relative frequency (%)	Fischer's Exact 95% CI
Source of processed chicken	**217**	**91.6**	**87.27-94.77**
Supermarket	188	79.3	73.6-84.3
Middle men (source not known)	20	8.4	5.23-12.73
Slaughtered at farm	12	5.1	2.64-8.68
Retail shop/ butcher	6	2.5	0.93-5.42
Abattoir	2	0.8	0.10-3.02
Source of live birds	**30**	**12.7**	**8.71-17.58**
Middle men (source not known)	25	10.5	6.94-15.18
Small scale backyard farm	3	1.3	0.26-3.66
Commercial farm	2	0.8	0.10-3.02
Answer not provided	3	1.3	0.26-3.66

5.4 Discussion

The present study provides the first map of the value chain for RTE chicken sold in the informal markets in Tshwane Metropolis of South Africa. This is important for traceability of RTE chicken sold in the informal markets in Tshwane as it increases control over the production, trade and distribution of chicken sold on the informal markets. It has been reported that operations where there is better control over production, trade and distribution of agricultural products traceability of such products is guaranteed (Trienekens, Zuurbier 2008). Furthermore, where traceability is possible, communication linkage for identifying, verifying and isolating sources of noncompliance to agreed standards and customer expectations can be implemented (Opara 2003).

In addition, the end-of-line product inspection has become obsolete and is being replaced by the safety assurance approaches where the suppliers in the chain assume responsibility for safety (Trienekens & Zuurbier 2008). This is enhanced when the role players are known. In view of this, understanding of the food value chain for the supply of chicken for the informal traders means that assuring food safety can now be extended to the other role players in the supply chain. This is consistent with the view held by Trienekens & Zuurbier (2008) who indicate that food standards in a broad sense include social and environmental considerations and their application by the various parties in the food chain.

Tracing the informal part of the value chain proved to be challenging in the present study as mentioned above in the results section. Nonetheless, the study was able to prove the existence of the extensive cross-over or spill-over between the formal and informal sectors. These findings are contrary to what might be happening in other parts of the world especially sub-Saharan Africa, where extensive spill-over from the formal to the informal sector has not been reported in any published studies. The reason for this could be that unlike other parts of Africa, supermarkets in South Africa have gained a sizeable share of the fresh produce market (Louw et al. 2008, Weatherspoon & Reardon 2003). Therefore, as supermarket proliferation takes place in the rest of Africa, which has been predicted by Weatherspoon & Reardon (2003), this model and its associated risks are likely to become more common throughout Sub-Saharan Africa.

The linkage between the formal and informal food sector in the identified food value chain shows that the informal sector in South Africa provides market opportunities for commercial poultry production. It has been reported that such spill over from the formal to the informal sector in business represents millions of US dollars daily (Codjia 2000). Not only that, it has been observed that locally-produced agricultural products represent a large portion of the vendor's raw material purchases. Based on this, the street food sector presents potentially a substantial market for agricultural trade. Therefore, the sale of street foods has the potential to make a sizeable contribution to the economies of developing countries (Rane 2011). Considering that by 2020 the developing world's urban population will have grown to 3.4 billion, the potential for the informal food trade to grow in developing economies is enormous (National Resources Institute 2011). In view of this, if informal food trade is supported and assisted to produce food that is safe sound and wholesome, it has the potential to contribute to the growth of other sectors of the economy in the city and the country.

In the formal food supply chain, it is possible to apply and verify control measures intended to assure the quality and safety of food; food safety assurance systems are applied at each step in the food production chain to ensure safe food and to show compliance with regulatory and customer requirements (Trienekens & Zuurbier 2008). Therefore, the extensive cross-over from the formal to informal sector observed in the present study enables the informal sector in Tshwane to benefit from the application of food safety assurance in the formal sector.

Another noteworthy finding of the present study is that the observed food value chains tended to be short; they entail few steps and in addition the time the chicken takes to move from the producer and consumer is relatively short. This is unlike what happens in the formal food sector where retailers and food industries source products from all over the world, and in the process transform the food industry into an interconnected system with a large variety of complex relationships (Trienekens & Zuurbier 2008). It is known that value chains that are multi-layered with poor visibility tend to be very vulnerable (Roth et al. 2008). In view of this, the short value chains observed in this study is good for food safety in relation to the RTE chicken sold by the informal vendors.

The fact that the majority of informal vendors (217/237, 91.6%) indicated that they purchase processed or slaughtered chicken and that 188 out of 237 (79.3%) source chicken from supermarkets is consistent with reports that suggest that that supermarkets have more than half (55%) of the share of the food retail market in South Africa. As explained above, this is important for food safety because supermarkets are more demanding on quality and safety (Weatherspoon & Reardon 2003).

5.5 Conclusions and recommendations

In this chapter, the food chains of RTE chicken sold in informal markets has been presented as being definite and not multi-layered as is the case in most formal value chains. These two facts enhance safety of the RTE chicken sold by informal vendors.

The observed value chains reflect the importance of informal markets in the economics and marketing of poultry meat in South Africa. Furthermore, reflections on the findings during the study of informal markets, within the context of the annual production of broilers layers and chicks in South Africa, indicate an unexpected magnitude of available poultry meat flowing into the informal market.

The finding that there is a significant cross-over or spill-over from formal markets is important for food safety as well as job creation for vendors. The food safety perspective is related to the fact that the food chain between purchases of inspected, packaged and labelled poultry meat to informally vended RTE chicken is short and the cold chain is maintained.

The job creation is related to the fact that the informal sector is linked to the formal supply that is well developed and able to meet the demand for chi ken. Food security is also positively affected as the low-income taxi commuter is able to access a nutrient dense food source (cooked chicken) conveniently and at an affordable price.

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CHAPTER 6

DRIVERS FOR CONTAMINATION OF RTE CHICKEN

6.1 Introduction

Results of the qualitative and quantitative investigation into the risk factors for contamination of RTE chicken sold by informal vendors in Tshwane Metropolitan area are presented in this chapter. The methodology used to obtain results for this chapter can be found in Chapter 3 in the following sections:

3.4 Data collection
3.4 1 Market survey
3.4.2 Sample frame and sampling strategy
3.4.3 Administering questionnaires and checklists
3.4.4 Collection of food samples and preparation of sample for microbiological analysis,
3.4.5 Culturing and enumeration of bacteria
3.5 Data analysis.

6.2 Results of microbial analysis

A total of 237 samples of cooked RTE chicken from all the markets and individual stands that were visited, were cultured to assess contamination levels with *E. coli* and/or coliforms. Fifteen (15) samples (6.32 %) were positive for *E. coli* (≥ 0.083 CFU/cm^2). Of these, nine (3.79 %) had values of ≥ 100 CFU/g (95% CI presented in Table 6.1).

Another 55 samples (23.21 %) were positive for coliform organisms (≥ 0.083 CFU/cm^2). Out of the 55 positive samples, 45 (18.99 %) had values ≥ 100 CFU/g (95% CI presented in Table 6.1).

Table 6.1: RTE chicken contaminated with *E. coli* and coliforms

	E. coli				**Coliform**			
	Positive samples (%)	Positive with ≥100 cfu/g (%)	Positive with ≤100 cfu/g (%)	Negative samples (%)	Positive samples (%)	Positive with ≥100 cfu/g (%)	Positive with ≤100 cfu/g (%)	Negative samples (%)
Frequency and % of samples contaminated with *E coli* or coliforms (N=237)	15 (6.32)	9 (3.79)	6 (2.53)	222 (93.36)	55 (23.21)	45 (18.99)	10 (4.22)	182 (76.79)
Fischer's Exact at 95% CI	3.91-10.47	1.96-7.18	1.08-5.44	89.53-96.09	19.08-30.25	15.09-25.50	2.27-7.74	69.75-80.92

Comparison between the number of samples with ≥100 CFU/g for *E. coli* and coliform using a two-tailed Chi square test revealed that the difference between the proportions of samples contaminated with *E. coli* and those contaminated with coliforms was significant (X^2= 25.71; two-tailed p = 0.0001) (Figure 6.1).

It can be seen that a very low proportion (1/15; 5.49%) of *E. coli* contaminated samples were also contaminated with coliforms (Figure 6.1).

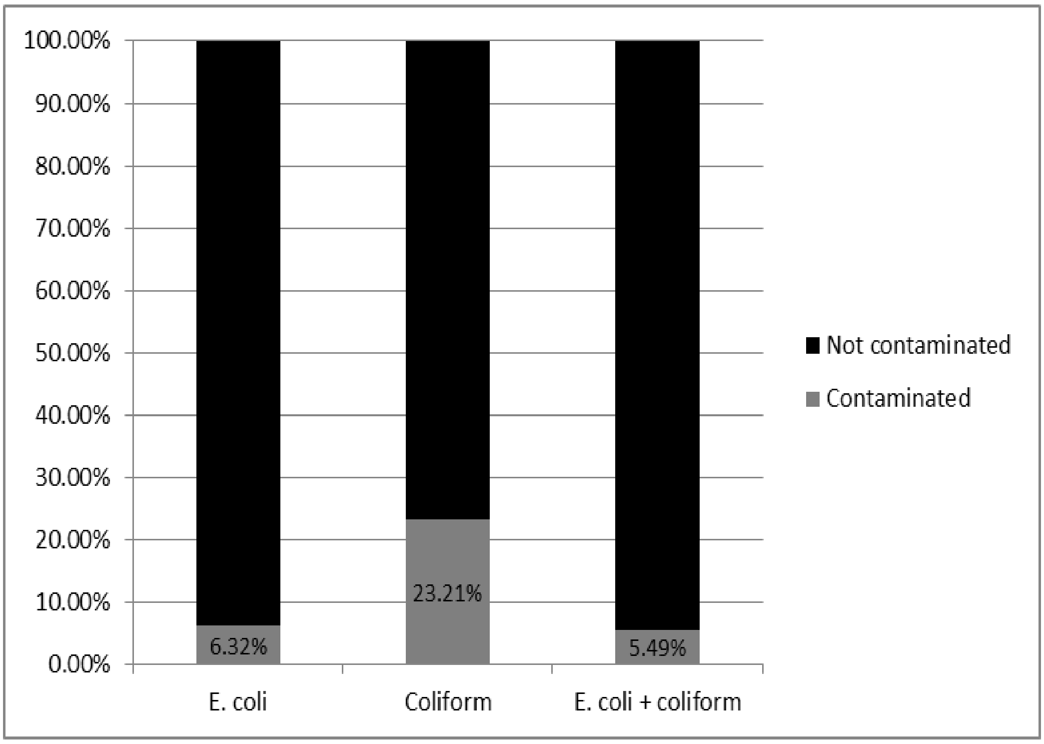

Figure 6.1: RTE chicken contaminated with *E. coli* and coliforms (n=237)

6.3 Establishing drivers of contamination

A total of 237 questionnaires were collected but 19 and 28 had critical missing values needed to do the analysis for *E. coli* and coliforms respectively. Therefore a total of 218 and 209 questionnaires were matched with the results from the food samples. Questionnaires without the required information were dropped from the analysis. A total of thirty nine variables were tested in the univariable model. Details of the analysis are available in Appendix V.

6.3.1 Results of the univariable analysis

Pre-screening to determine the variables to be included in the multivariable model was conducted using a univariable regression model (see details in Chapter 3, Subsection 3.5.4). All variables univariable regression model (see Annexure VI) that were significant at $p \leq 0.2$ were included in the multivariable analysis.

6.3.2 Results of the multivariable analysis

In the multivariable regression model, the holding RTE chicken at a temperature of < 70 °C was a predicator for contamination with *E. coli* (OR=14.43; $CI_{95\%}$ = 1.34-155.32) as compared to when chicken was held at > 70 °C. Likewise, sighting houseflies (≥1 to ≤ 9) at the vending site and/or the vending table also significantly increased the risk of contamination with *E. coli* (OR = 5.47; $CI_{95\%}$ = 1.21 – 24-64) as compared to when no flies where sighted at the vending stall. If the vending site was located >30 meters from the toilet, it was a positive predictor of contamination with *E. coli* (OR = 10.41; $CI_{95\%}$ = 1.44 – 75.40) as compared to when the vending stall was located <30 meters from the toilets. Intermittent washing of hands during the course of handling RTE chicken also positively and significantly predicted *E. coli* contamination (OR = 8.45; $CI_{95\%}$ = 2.12 – 33.63) (Table 2) compared to when vendors washed hands frequently.

For contamination of RTE chicken with coliforms, the multivariable model revealed that the use of potable toilets without hand washing facilities positively predicted contamination (OR = 6.26; $CI_{95\%}$ = 1.87–20.90) than when vendors had access to flushing toilets with hand washing facilities. Also when vendors failed to wash hands regularly throughout the process of preparing and selling food, or did so only at the beginning and end of the day, the odds of contamination of RTE chicken sold by such vendors was 8 times higher (OR = 7.88; $CI_{95\%}$ = 1.44–43.15) than if the vendor frequently washed the hands throughout the preparation and serving of the RTE chicken (Table 6.2).

Table 6.2: Multivariable logistic regression models for *E. coli* and coliform

All variable types	Odds ratio	Standard Error	Fisher's Exact at $CI_{95\%}$	P-value (P>|z|)
[a]***E. coli***				
Ready to eat products held at > 70 °C				
Yes	**1**	-	-	-
No	**14.43**	17.5	1.34-155.32	**0.03**
Houseflies sighted on meat table				
None	**1**	-	-	**-**
≥ 1 to ≤ 9	**5.47**	4.20	1.21-24.64	**0.03**
≥ 10 or above	1.05	1.31	0.09-12.08	0.97
Mean distance from toilet to stall				
≤10m	**1**	-	-	-
31-50 m (>30m)	**10.41**	10.52	1.44-75.40	**0.02**
11-30 (<30m)	3.70	3.16	0.69-19.75	0.12
51-100m	[c]NA	-	-	-
>100m	[c]NA	-	-	-
How often vendor wash hands during operation				
Frequently	**1**	-	-	**-**
Intermittently	**8.45**	5.96	2.12-33.63	**0.002**
At the beginning and end of operations	0.56	0.41	0.14-2.32	0.43
[b]**Coliform**				
Toilet type				
Flushing with hand washing facilities	**1**	-	-	**-**
Potable without hand wash	**6.26**	5.24	1.87-20.90	**0.003**
Flushing without hand washing facilities	1.16	1.15	0.16-8.09	0.88
Potable with nearby tap	0.24	0.22	0.04-1.50	0.13
Long drop or portable with distant tap or none	[c]NA	-	-	**-**
How often vendor wash hands during sale operation				
Frequently	**1**	-	-	**-**
Beginning and end of operation only	**7.88**	0.16	1.44-43.15	**0.02**
Intermittently	1.69	0.99	0.53-5.31	0.37

[a]Hosmer-Lemeshow Goodness of fit Chi Square for *E. coli* model is 2.42 (*P* = 0.79; Degree of freedom = 3).
[b]Hosmer-Lemeshow Goodness of fit Chi Square for coliform model is 0.13 (*P* = 0.94; Degree of freedom = 2).
[c]NA means not applicable as there were '0' response for cases for those distances or toilet type

Subsequent to this analysis, the water used by the informal vendors in selected markets (n=8) for cooking, hand washing and cleaning plates was tested for portability using most probable number (MPN) method. The majority (95%) of the water samples collected (n=100) yielded positive results for Total Coliforms (TC), and were thus considered not to be potable.

6.4 Discussion

The present study demonstrated that RTE chicken sold on informal markets carried both *E. coli* (indicators of faecal contamination) and non-*E. coli* coliforms (indicators of environmental contamination); both are indicators of poor personal and environmental hygiene (Klontz et al. 1995, New South Wales Food Authority (NSWFA) 2009, Taulo et al. 2009). This is consistent with findings of studies that showed that coliforms found on RTE foods may include both *E. coli* and non-*E. coli* coliforms (Koo et al. 2008).

The prevalence of RTE chicken positive for both *E. coli* and coliforms showed that few samples of RTE chicken were contaminated. This is consistent with earlier findings that suggested that despite operating in a less than satisfactory environment, informal vendors were capable of producing food of a reasonable hygiene standard (Martins 2006). This is probably due to two main factors. Firstly, the food value chain for RTE chicken that includes crossover from the formal food chain is short and rapid, which means that chicken meat is not stored for long periods. Secondly, vendors implemented some measures to mitigate for risk of contamination of the RTE chicken.

Very few samples (3.79%) carried >100 CFU/g for *E. coli*. This is good as heavy growth of total coliforms is indicative of poor food handling and processing. Furthermore, food with high counts of *E. coli* is likely to be a source of enteric pathogens (Koo et al. 2008), thus more likely to lead to diarrhoeal diseases following consumption.

A comparison of the level of contamination of RTE chicken meat showed that the prevalence of samples with ≥100 CFU/g for coliforms was higher (23.21%) than that of *E. coli* (6.32%). Statistically, this was also shown to be significantly higher (P= 0.0001), which suggested that environmental sources of contamination played a prominent role in the markets that were studied as compared to personal hygiene. This was expected given that it is not uncommon for informal vendors to operate in the open with food exposed to the elements or in temporary structures which do not offer sufficient protection from the elements.

The higher prevalence of contamination with coliforms (environmental contaminants) as compared with *E. coli* (faecal contaminants) could be related to the less than satisfactory environment wherein the informal vendors in South Africa prepare and sell their products (Martins 2006, Rane 2011, Balkaran, Kok & 2014). Rane (2011) also confirmed that the lack of basic infrastructure and services, difficulty in operational controls and poor knowledge of safety measures could contribute to higher microbial level of contaminants in RTE food.

The WHO recommends that food must be cooked to enable the core of the product to reach a temperature of 70 ^{o}C for it to be rendered safe and free of *E. coli* (CAC (Codex Alimentarius Commission) 2010, WHO 2006, WHO 1996, INFOSAN 2010). Taulo et al.; (2009) demonstrated that food cooked to temperatures ≥ 70 ^{o}C were free of *E. coli*. Borch and Arinder (2002) demonstrated that the number of *E. coli* organisms in carcasses of pigs is greatly reduced as a result of hot water (80^{o}C) decontamination. Bryan et al. (1997) also found that if cooked food is held at high temperatures on glowing charcoal throughout the entire holding period, bacterial growth was inhibited. Therefore, findings of this study were consistent with these reports and confirmed the preventive values of holding RTE chicken at relatively high temperatures between cooking and serving. This explains why holding RTE chicken below temperatures that are known to inhibit bacterial growth (≥ 70 ^{o}C) proved to be a significant predictor for contamination of RTE chicken with *E. coli*. Improper holding temperatures have been identified as a food safety problem in street vended foods (Division of Prevention and Control of Non-communicable Diseases (DNC) 2004, Barro et al. 2007). Given that informal vendors do not usually have access to refrigerators that could be used to keep food at cold holding temperatures, keeping food at temperatures high enough to inhibit bacterial growth should be emphasized, and this stage should be considered a critical control point in the preparation of RTE chicken in informal markets.

When informal vendors intermittently wash their hands when serving RTE chicken, the likelihood of contamination with *E. coli* seemed to be heightened. It then means that failure to wash hands regularly and thoroughly on the part of the food handler increased contamination of the hands of the food handlers. Fawtzi and colleagues (2009) were able to demonstrate that if hands are not washed regularly and properly, the result is an increase in the level of contamination of the hands of the food handlers. This notwithstanding and that failure of maintaining proper hand hygiene could have tragic consequences, food handlers tend to consider washing of hands as being trivial (Fawzi, Gomaa & Bakr 2009, Mensah et al. 2002).

Furthermore, preliminary analysis of the water samples collected from informal vendors who sell RTE chicken in some of the surveyed markets showed that the water was heavily contaminated with coliforms and hence not potable. Based on these findings, it is hypothesized that the hands of the vendors and utensils used to serve or hold RTE chicken get contaminated when they use contaminated water and that this contamination gets transferred to the RTE chicken. This could also explain why intermittent hand washing, was associated with significantly high odds of contamination, and turned out as a positive predicator for contamination with *E. coli*. This is consistent with WHO reports that suggest that water and raw materials that are contaminated with microorganisms can lead to food handlers passing this contamination on to food (INFOSAN. 2010). The importance of using water of acceptable microbial quality cannot be over emphasized. It has been shown that bacterial contamination of hands following washing of hands with water that was contaminated ranged from 1 to 3.6 log10 CFU/g for *E. coli* and from 2.1 to 4.2 log10 CFU/g for *Staphylococcus aureus* (Taulo et al. 2009). Therefore informal food vendors need to be made aware that washing of hands and other food hygiene handling practices/measures will be ineffective if water of questionable microbiological quality is used at their food stalls. The government could help by ensuring that these traders have access to potable water at their stalls where they prepare and serve food.

Several studies have shown that money is usually heavily contaminated with organisms like *E. coli* (Khin et al. 1989, Pope, Ziebland & Mays 2000, Igumbor et al. 2007). Although the present study did not investigate whether vendors wash hands each time they handle money, the author is of the view that this is a risk factor for cross contamination during the course of handling RTE chicken. Studies show that informal vendors tend not to wash their hands in between handling money and serving food (Martins 2006). Based on these findings, adoption of the WHO *Five Keys to Safer Food* (Annexure IV) by informal vendors and relevant authorities charged with monitoring safety of street vended foods should be encouraged (WHO. 2006, INFOSAN. 2010).

Since the present study showed that vendors who did not wash hands regularly had a higher odds of selling RTE chicken that was contaminated as compared to those who washed hands between serving RTE chicken, the use of forks and other suitable cutlery to handle RTE chicken by informal vendors when serving should be strictly enforced as recommended by Mamun et al. (2013) and the WHO, (1996). It has been observed that food handlers play an important role in food safety and in the occurrence of food poisoning by their ability to introduce pathogens into food during production, processing, distribution and/or preparation (Dawson & Canet 1991, Githiri, Okema & Kimiywe 2009, Mensah et al. 2012, Fawzi, Gomaa & Bakr 2009, Shojaei, Shooshtaripoor & Amiri 2006, Taulo et al. 2009). The importance of this is appreciated when one considers that although washing hands by food handlers has the ability to significantly reduce the level of contamination; it does not completely diminish the contamination (Shojaei, Shooshtaripoor & Amiri 2006).

The sighting of houseflies on the table and/or at the vending site turned out to be a significant predictor for *E. coli* contamination of RTE chicken. This is justified by extensive literature that confirmed the potential of houseflies to contaminate food items (Akhtar 2008, Sasaki, Kobayashi & Agui 2000, Kobayashi et al. 1999, Geden 2005, Wasala et al. 2013). Flies have been reported to carry *E. coli* in their mouthparts, crop, intestines and feet and may continue to contaminate meat and other food that is intended for human consumption long after they have become infected with the pathogenic organisms (Akhtar 2008, Wasala et al. 2013, Barro et al. 2006). In view of this, it is desirable for sellers of RTE chicken on the informal market to design a cover for the vending tables to restrict fly access to the RTE chicken. Results from the univariable analysis proved that a covered table has the potential to reduce the risk of contamination by *E. coli* and coliform organisms. Informal vendors can also implement fly traps to help keep the population of flies around their stalls to a minimum. The various types of fly control measures that could be adopted have been described by Geden (2005). Vendors who operate in permanent structures could adopt fly-proof food serving zones used by informal vendors in Trinidad and Tobago, while those who operate in temporary structures or in the open should at all times keep the food covered to limit contamination of food by flies (Badrie, Joseph & Chen 2011). Letting garbage accumulate close to the vending site should also be prohibited because it provides a breeding ground for flies (Akhtar 2008). This is in accordance to the five basic keys of food safety outlined and recommended some WHO publications (INFOSAN 2010, WHO 2006, WHO 1996).

When toilets were located >30 m from the vending site, the risk for contamination of RTE chicken with *E. coli* was greater than when the vending site was located <30 meters from the vending stall. This could be linked to human behavioural patterns. It is possible that vendors whose stalls were closer to the toilet may take time out to make proper use of the ablution and hand washing facilities after using toilets, while those sellers whose stalls were farther from the toilets felt the need to minimize the time they spend away from the stall after using the toilet. As a result the latter are likely not to adhere to the recommended hygiene practices such as washing of hands after using the toilet. A visit to the lavatory can result in hands getting heavily contaminated with enteric pathogens (Githiri, Okema & Kimiywe 2009, Shojaei, Shooshtaripoor & Amiri 2006, Taulo et al. 2009). Moreover, elsewhere, outbreaks of *E. coli* O157:H7 have been linked with distantly located toilets (Bruce et al. 2003). The importance of locating toilets within reasonable distance was also highlighted by Leus et al (2006) who indicated that specific attention to proper personal hygiene particularly with regard to hand washing after visiting the toilet is of utmost importance. This is because it does not visibly influence the hygiene of the stall. The situation is made worse if the informal vendor has a child that accompanies her to the stall, which according to FAO (2012) is common. In this case, it becomes difficult for the vendor to leave the stall to accompany the children to the toilets and observe proper toilet hygiene norms.

With regard to contamination of RTE chicken with coliforms, the present study showed that if vendors make use of potable toilets that did not have hand wash facilities, and if they did not wash hands during the whole operation (i.e., only at the start and end of the day based on Table 6.2), the odds of contamination of RTE chicken with the environmental contaminants were increased. The problem could be exacerbated by the fact that in some instances, water used by the vendors is delivered to the site in containers of questionable hygiene status. As a solution, vendors should be sited as close as possible to places with toilets that have hand washing facilities. Where this is not possible, it should be mandatory for vendors who are located far from the toilets or located in places with only potable toilets without hand washing facilities to make provision for hand washing facilities at their stalls.

6.5 Conclusions and recommendations

Given that the problematic areas associated with high odds of contamination of RT chicken are related to the WHO five keys to safer food (Annexure IV), it is concluded that adoption of the WHO five keys to production of safe food was enforced, would translate into a decrease in the contamination of RTE chicken sold by informal traders.

In line with Key 1 “Keep clean”, there is a need to improve on the environment where the vendors operate so as to control the fly population, dust and dirt in all markets. In addition, the vendors should adopt fly control strategies to deny flies access to the food. This should be a focus for training of vendors. Key 2, “Separate raw and cooked foods”, was not observed as the study was limited to RTE chicken. Therefore, its impact on the level or likelihood of *E. coli* and coliform contamination could not be ascertained. Certainly, the majority of vendors comply with Key 3, “Cook thoroughly”. It was noted that Key 4, “Keeping food at safe temperatures”, was observed by many vendors but there was a definite increase in contamination where vendors failed to keep food at safe temperatures. This should also be a focus for training and made a critical point for control of contamination. For key 5, “Using safe water and raw materials”, although the link between these two and the contamination level was not assessed in the present study, given the high level of contamination of the water samples, it is possible that these two aspects had an influence on the contamination. More care in water safety and easily accessible potable water was probably one of the most important variables where authorities could make a difference by providing infrastructure rather than just training.

The cold chain for raw chicken appeared to be fairly well observed given that the majority of vendors purchased their chicken from the formal sector. This meant that pathogens had been controlled over the majority of the food chain, before retail sale and consumption. In most instances the raw chicken was obtained from a reliable source, prior to cooking, then cooked and kept hot until consumed.

Based on the findings of this study, despite working in less than ideal environments for food production, it is evident that the majority of informal vendors are able to produce food of acceptable microbial quality. It is therefore recommended that attempts to eradicate informal food vendors are not justifiable. What is needed is more support in terms of providing the suitable environment. Secondly, it is recommended that the city authorities should put emphasis on training of informal vendors on the WHO 5 Keys to safe food production.

The present study has highlighted some of the risks associated with food contamination in some of the informal markets in Tshwane, and based on this, possible corrective actions may include the use of municipal sourced water (i.e., directly from the taps and not via vendors who sell water to the food vendors), vendors washing hands frequently during the course of handling RTE chicken as stipulated in the five keys of hygiene food preparation. Other interventions that can be implemented to reduce the risk of contamination include training of employees, frequent knife sterilization and others as stipulated in the WHO documents on hygienic food practices (WHO, 2006; WHO, 2010). The implementation of good farming practices (GFP) by the producers as well as good manufacturing practices (GMP) at the abattoir processing level cannot be overemphasised to enhance the hygiene status of the chicken handled by vendors. This has the potential to reduce the possibilities of cross-contamination at the vending sites.

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CHAPTER 7

RISK OF STAPHYLOCOCCAL FOOD POISONING

7.1 Introduction

The results of the microbial risk assessment of staphylococcal food poisoning associated with consumption of RTE chicken sold in selected informal markets in Tshwane Metropolitan area in Gauteng, South Africa are presented in this chapter. The methods used for this chapter can be found in Chapter 3 in the following sections:

3.4.4 Collection of food samples and preparation of sample for microbiological analysis,

3.4.5 Culturing and enumeration of bacteria,

3.4.6 Microbial risk assessment, and

3.5 Data analysis.

7.2 Microbial test results

The microbiological results (Table 7.1) of the food samples (n=100) that were tested for *Staphylococcus aureus* showed that the proportions of the samples that were positive was 44%. A comparison of the proportion of positive samples between the markets revealed that there was no significant difference in the prevalence among the markets (DF=5, p=0.885).

Ready-to-eat (RTE) chicken contaminated with *S. aureus* at a concentration greater than 10^3cfu/g is considered unfit for consumption (NSW Food Authority 2009, NSW Food Authority 2010). This is RTE chicken that carries the number of microorganism that exceeds the recommended level but not up to that required to induce SFP (NSW Food Authority 2009, NSW Food Authority 2010). In the present study, 29.0% of the samples that were tested had more than 10^3 CFU/g and were thus considered unsatisfactory (Table 7.1). A comparison of the number of samples considered unsatisfactory between the markets, likewise showed no significant difference (DF=5, p=0.097).

The mean CFU/g for the RTE chicken tested in this study was $10^{3.6}$ (90% CI: $10^{3.3}$–$10^{3.9}$). This is below 10^{5} CFU/g, which is the level required for toxin production to occur and consequently lead to staphylococcal food poisoning (SFP).

Table 7.1: Prevalence of *S. aureus* contamination and unsatisfactory RTE chicken

Markets	Sample	*S. aureus* isolates	Prevalence (%)	Unsatisfactory*	Prevalence (%)
Marabastad	21	9	42.9	4	19.0
Mabopane	11	5	45.5	4	36.4
Soshanguve	21	8	38.1	2	9.5
Belle Ombre/ Prinsloo	12	4	33.3	4	33.3
Mamelodi	24	12	50.0	10	41.6
Sausville	11	6	54.5	5	45.5
Total	100	44	44.0	29	29.0

* RTE chicken that had more than 10^{3} CFU/g and were thus considered unsuitable for human consumption even though they did not contain enough bacteria to produce sufficient toxins to induce SFP.

7.3 Evaluation of the quantities of ready-to eat chicken sales

Using the proportional piling technique described by Mariner and Paskin (2000), it was established that Mamelodi contributed most (32%), while Belle-Ombre/Prinsloo contributed the least (6%), to sales of the RTE chicken sold in six of the 13 markets surveyed (Table 7.2).

Table 7.2: Relative quantities of RTE chicken sales per market

Markets	Pebbles	Relative quantities of sales
Marabastad	11	0.22
Mabopane	9	0.18
Shoshanguve	7	0.14
Bell Ombre/Prinsloo	3	0.06
Mamelodi	16	0.32
Saulsville	4	0.08
Total	50	1

7.4 Risk assessment

The study design including the research methods used in this study are described in chapter 3 section 3.3.

a) Hazard identification

Hazard identification (the identification of the agent which can cause adverse health effects to humans) is the first step in risk assessment. The hazard chosen (*S. aureus*) has known adverse health effects on human health as described in Chapter 2.

The next step in risk assessment is hazard characterization, which is the qualitative and/or quantitative evaluation of the adverse health effects associated with the hazard. Both the qualitative and quantitative nature of the adverse health effects of *S. aureus* are well known, and are described in detail in Chapter 2.

b) Exposure assessment

The probability of *S. aureus* occurring in RTE chicken bought from the informal markets surveyed was 44% (90% CI: 36.1% - 52.2%) and the probability of purchasing RTE chicken of quality considered unsatisfactory (*P(unsatis)*) (>10^3 CFU/g) from an informal vendor who sold RTE chicken in the surveyed markets was 32.9% (90% CI: 25.5% - 40.4%).

The likely number of colonies on RTE chicken bought from the markets surveyed was determined by estimating the mean $\log_{10}$ CFU/g of RTE chicken tested. This was estimated to be 3.6 (90% CI: 3.3 -3.9), which was below the threshold (5) required for enterotoxin production needed to induce SFP.

The probability of ingesting (*P(ingest)*) sufficient number of colonies capable of producing toxins when consuming RTE chicken was estimated to be 1.3% (90% CI: 0% - 2.7%).

c) Risk characterization

Risk characterization is the final step of risk assessment, and it is defined as the estimation, including uncertainties of the probability of occurrence and severity of known or potential adverse health effects in a given population based on hazard identification, hazard characterization and exposure assessment. In the present study, risk of SFP was expressed as

P(illness) following consumption of RTE chicken sold in informal markets in Tshwane Municipality. The *P(illness)* was estimated to be identical to the probability of ingesting food with 10^5 CFU/g. This is the level of contamination required to induce acute effect of SFP. Therefore *P(illness)* was computed to be 1.3% (90% CI: 0% - 2.7%) (Figure 7.1).

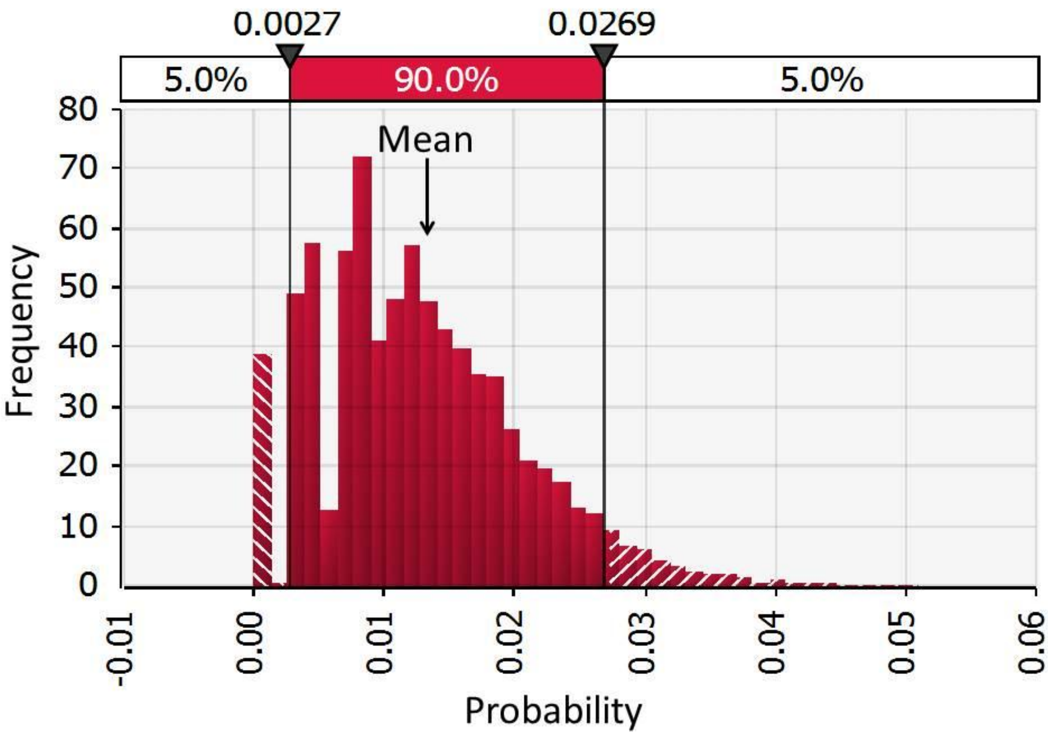

Figure 7.1: The risk of acquiring staphylococcal food poisoning

A sensitivity analysis was conducted to establish the contribution of the various parameters to the risk of SFP, and the results are presented in Table 7.3. Third column presents the value of the parameters that were assessed. While the fourth column shows the contribution of each of the parameters on the risk of SFP and their 96% CI. Using the width of the 95% Confidence Interval of the sensitivity analysis output, the various parameters were ranked to indicate the factors that contributed most to the risk of SFP following consumption of RTE. The most sensitive factor in the risk assessed was when bacteria were TNTC (*Logtn*). The second sensitivity factor was when Log_{10}Cfu/g of *S. aureus*. *Staphylococcus aureus* having SE gene was the third (3^{rd}) most sensitive factor. The prevalence of contamination at the individual market contributed least to the risk.

Table 7.3: Sensitivity analysis showing order of the sensitivity to risk of SFP

Order[7]	Parameters	Parameter values at 50th, 5th & 95th percentiles	Mean probability of staphylococcal poisoning (%) at 50th, 5th & 95th percentiles
1	Log_{10}Cfu/g of *S. aureus* when the bacteria were too numerous to count: *Logtn*	6.4 (4.4 - 8.3)	0.52 (0.52 – 0.92)
2	Log_{10}Cfu/g of *S. aureus* of a sample contaminated	3.5 (2.3 - 7.3)	0.69 (0.69 – 1.08)
3	Probability of *S. aureus* having SE gene: *Pgene*	0.38 (0.33 - 0.42)	0.70 (0.62 – 0.79)
4	Prevalence of *S. aureus* in Mamelodi market	0.50 (0.34 - 0.66)	0.70 (0.63 - 0.78)
5	Prevalence of *S. aureus* in Mabopane market	0.46 (0.25 – 0.68)	0.71 (0.65 – 0.77)
6	Prevalence of *S. aureus* in Marabastard	0.43 (0.27 - 0.60)	0.70 (0.65 – 0.76)
7	Prevalence of *S. aureus* in Soshanguve	0.39 (0.23 - 0.56)	0.71 (0.67 – 0.74)
8	Prevalence of *S. aureus* in Sausville	0.54 (0.32 – 0.75)	0.70 (0.68 – 0.73)
9	Prevalence of *S. aureus* in Belle Ombre/ Prinsloo	0.35 (0.17 - 0.57)	0.70 (0.69 – 0.72)

7.5 Discussion

The high prevalence of *S. aureus* (44%) on the RTE chicken sold in informal markets and the high prevalence of RTE chicken considered to be of unsatisfactory quality (RTE chicken with more than 10^3 CFU/g) was consistent with previous studies that reported that bacterial concentration on informally-sold RTE chicken ranged from 10^2 - 10^3 CFU/g (Lues et al. 2006). The presence of *S. aureus* concentrations of 10^1 to 10^2 on RTE food is not unusual. However, at such levels the food may not pose a danger to the consumer, but can provide sufficient inoculum for growth (Badrie, Joseph & Chen 2011). Such levels of contamination have been attributed to poor hygiene habits like using cleaning cloths heavily contaminated with aerobic bacteria such as *Enterobacteriaceae*, *Escherichia coli*, and *S. aureus* (Little & Sagoo 2009, Badrie, Joseph & Chen 2011). In a study conducted in Botswana, it was demonstrated that dishcloths tended to be contaminated with faecal coliforms (Kaltenthaler,

[7] The parameters were ranked from 1 to 9 (1st column in Table 7.3) based on the sensitivity analysis output (the contribution of each parameter to the risk of SFP) expressed as 95% CI of the mean probability of SFP (%) (4th column in Table 7.3).

Drasar & Potter 1996). The present study did not reveal that vendors used dirty cloths, but showed that other unhygienic practices were observed (See Chapter 6). It is also known that surfaces that are visually dirty and wet, and chopping boards made from plastic or damaged wood also tend to have high levels of these bacteria (Little & Sagoo 2009, Taulo et al. 2009) and could thus contribute to the high levels of contamination observed in the current study.

The high proportions of contamination that was observed, suggests that there is a risk of acquiring SFP following consumption of RTE chicken sold by informal vendors in Tshwane. However, the question which this risk assessment study endeavours to answer is; what is the magnitude of this risk to the consumer? The purpose of risk assessment is to answer questions of interest to decision makers and consumers. It is thus possible through risk assessment to decide if there is a problem and what needs to be done about the problem (Fahrion et al. 2014).

Although the prevalence of *S. aureus* was high in the RTE, the risk of illness was low (1.3% (90% CI: 0%-2.7%). In view of this, the present study demonstrated that high prevalence of *S. aureus* did not translate into a high risk of illness due to ingestion of RTE chicken contaminated with potentially enterotoxigenic *S. aureus*. The significance of these findings is that making decisions on food safety based only on the presence of hazards rather than risks to human health do not necessarily reflect the risk to the consumer. Such decisions could reduce accessibility of food for the urban poor and restrict income generating opportunities for informal food vendors and other actors in the value chain, without any commensurate benefit to human health.

It is important to note that the probability of contracting SFP observed in the present study, is limited to the consumers of the RTE chicken in informal markets that were studied, and is not a reflection of the risk to the whole population in South Africa. Furthermore, although biological hazards like *S. aureus* are usually the most important in terms of human disease burden, other hazards such chemical contaminants and antimicrobial residues cannot be ruled out (Fahrion et al. 2014). This is not of great concern in the present study given that the value chain for RTE chicken sold by the informal vendors as reported in Chapter 5 and by Oguttu et al. (2014) involved sourcing chicken mainly from the formal sector that is regulated in terms of food safety. Only a small proportion came from informal sources where there was a likelihood of using unregistered or substandard feed as well as use of unregistered growth promoters or off label use of antimicrobials.

The other risk that is associated with consumption of RTE foods that the present study did not address is the possibility of contracting drug resistant *S. aureus*. A recently published study that was done in Poland confirmed that RTE food poses as risk of contracting antimicrobial drug resistant *S. aureus* (Chajecka-Wierzchowska et al. 2014). The most important strain in this case is Methicillin Resistant *S. aureus* (MRSA). These have been found in chicken and turkey meat in Germany with humans shown as the source of contamination during food processing (Fessler et al. 2011).

The fact that the risk of illness following consumption of a single meal of RTE chicken sold in informal markets was low (1.3% (90% CI: 0% - 2.7%) could be attributed to the fact that bacterial concentration of *S. aureus* rarely exceeded 10^5 CFU/g (threshold required for *S. aureus* to produce sufficient toxins to cause SFP). The risk reported here is consistent with findings of earlier studies, which, although based on observational studies concerning hazard identification, concluded that RTE street foods in South Africa had a low microbiological risk (Martins 2006). This may be partly due to the fact that some vendors do mitigate for microbial risk by keeping cooked RTE chicken at temperatures that are not conducive for multiplication of the organism, as mentioned previously.

The present study did not take into account the proportion of SEs with emetic properties and the proportion of the susceptible population. Therefore, the present study assumes that all SEs have emetic properties and that the whole population was susceptible to SEs. Furthermore, the microbiological tests used did not show the true bacterial concentration for the samples that were classified as TNTC. Based on these uncertainties, it is therefore possible that risk estimate in the present study is either an over estimate or under estimate of the real risk.

Rajkovi (2014) suggests that although modification of threshold of toxicological concern can be adapted to microbial toxins to allow for the definition of levels of none safety concern, things like multi-exposure, exposure to multi-toxin and multi-sources, and repeated exposure phenomenon among others need to be considered when assessing risk of microbial toxins.

The present study did not take these into consideration, and this too is one of the uncertainties related to the magnitude of risk computed in the present study.

Although, the present study shows that the risk of illness from *S. aureus* was low, the unhygienic practices identified, need to be addressed as they might lead to contamination with other hazards. The hygiene practice of concern is well captured in the following qoute: "*hand and dish washing is usually done in one or more bowls, sometimes without soap; waste water and garbage are discarded in the street, providing food and harborage for flies and rodents; foods are usually not effectively protected from dust and flies that may harbor food borne pathogens, and temperature violation is common"* (Lues et al. 2006).

Water used by informal vendors in the markets studied was in some instances not drawn directly from municipal taps but was delivered to the site via containers that might have not been hygienic and thus led to contamination of water with *S. aureus*. This was attributed to the fact that the municipal taps were located some distance from the vending sites (as mentioned earlier). A study in the UK done with mobile food vendors, demonstrated that 54% of allegedly potable water samples used in food preparation, were of poor microbiological quality (Little & Sagoo 2009).

Since *S. aureus* on chicken carcasses or raw chicken can be eliminated by cooking, the contamination observed in this study is associated with poor post-cooking handling of RTE chicken meat. This was expected given that *S. aureus* is found on hands and finger tips of more than 50% of healthy individuals (Lues et al. 2006, IFT. 2004, Le Loir, Baron & Gautier 2003, Taulo et al. 2009). According to Taulo et al. (2009), 60% of a given human population carry this organism in their nose and fingers. However, focus group discussions conducted in the present study revealed that times between cooking and selling, and between purchase and consumption, were usually short. Focus group discussions also revealed that serving of RTE chicken normally starts immediately it is ready. The general consensus among informal vendors was that most RTE chicken gets sold within 1 to 3 hours after cooking, and that all of it is consumed the same day. It was also revealed during interviews and focus group discussions that vendors tended to cook amounts of food they are certain will get finished instead of cooking large amounts at one single go that could result in leftovers. This means that some vendors do cook more than once in the course of the day in cases where there are more people who need to eat after when the first cooked batch is finished. The fact that RTE is not held for a long time has also been confirmed by previous studies (Campbell 2011, Martins, Anelich 2000). The implication of this is that *S. aureus* might not be able to multiply to levels that would pose a risk to the consumer, which also explains the overall low risk of SFP observed in this study.

According to the sensitivity analysis, three parameters in the model (Table 7.3) that were the most sensitive (i.e., contributed most to the risk of SFP) were; when bacteria were TNTC (*Logtn*), when Log_{10}Cfu/g of *S. aureus* (concentration of *S. aureus*), and the proportion of *S. aureus* with enterotoxigenic genes). All the three parameters are related to bacterial concentration on the RTE chicken. Of these, the proportion of *S. aureus* with enterotoxigenic genes cannot be controlled. In view of this, control measures aimed at decreasing bacterial concentration rather than prevalence of contamination would be the most effective to improve food safety.

According to the guidelines for safe street foods, cleaner environment, separation of raw and cooked foods, thorough cooking, refrigeration, use of safe water and raw materials, and raised awareness are recommended to assure safety of RTE food (INFOSAN 2010, Donkor 2009). This is important because staphylococci are ubiquitous in the environment and can be found in the air, dust, sewage, water, environmental surfaces, humans and animals (Hennekinne, De Buyser & Dragacci 2012, 2009). Therefore, provision of hygiene training, improvement of infrastructure and improved direct access to municipal tap water (minimizing or eradicating the practice of delivering of water in containers at the vending site), has the potential to improve on the safety of RTE chicken sold by informal vendors. Control of temperature is another effective measure to prevent SFP (IFT 2004, Donkor 2009). This was proved in a study that was conducted by (Dablool & Fouad 2014), which showed that temperatures > 58 ºC were prohibitive to *S. aureus* growth in RET rice as opposed to lower temperatures (≤ 58 ºC). The same authors recommended that hot food must be kept at temperatures > 63.8 ºC to minimise the risk of *S. aureus* contamination. However, achievement of temperature control in informal markets is challenging.

7.6 Conclusions and recommendations

In conclusion, the present study showed that by using participatory risk analysis methods and rapid diagnostic methods, it was possible to perform risk assessment in a sector that is characterised by a lack of data. The study also clearly demonstrates that prevalence of contamination does not necessarily translate into risk. However, although the risk of SFP was low, there are many other microbiological and chemical hazards to consider and the importance of hygiene improvement should not be neglected. The low risk estimated is good news for both the vendors and customers as RTE chicken sold in informal markets is an affordable source of nutrition for a large poor urban population, and is a good source of income as well for the informal vendors. To further diminish the risk of SPF it is recommended that vendors keep the RTE chicken at temperatures that fall outside what is considered "the microbiological temperature danger zone[8]". Moreover, the present study was able to show that the informal RTE chicken business offered opportunities for employment in South Africa, a country characterised by high unemployment rates. In view of this, consideration should be given to how benefits from informal food businesses can be maximized instead of viewing them with suspicion as a source of food that is not safe. This requires decision-makers to be involved and convinced of the benefits of improving food safety in the informal food sector. A holistic understanding of the risk, economics and sociological role played by informal vendors of RTE chicken is key to improve food safety, job creation and poverty alleviation associated with poultry value chains in South Africa.

[8]The "microbiological temperature danger zone" is temperatures that do not inhibit microbial growth in a food (Dablool & Fouad 2014).

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CHAPTER 8

CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

8.1 Overview of the conclusions of the present study

This section presents a general overview of the conclusions and the recommendations plus the limitations of the present study.

8.1.1 Conclusions about hygiene assessment

The present study considered the spatial distribution of informal vendors in and around Tshwane. Results showed that the informal trade in RTE chicken was associated with townships and parts of the city of Tshwane like taxi ranks where formally disadvantaged South Africans, who form the bulk of the urban poor, are likely to be found. This agrees with past studies that have reported that in South Africa, 98.9% of the people who patronize street food vendors are black South Africans (Martins 2006). It is also in line with previous studies that have reported that street foods tended to be found in places where there are a high number of potential customers (FAO 2012) and confirms the role of informal food markets as sources of cheap, convenient and easily accessible RTE food.

Chapter 4 considered the demographic profile of vendors located within the different markets. It was observed that the majority of informal vendors for RTE chicken were women and people who belonged to the economically active age group (25-50 years). A similar observation was made by the FAO in West African cities, where 89 to 98% of the vendors who were interviewed were women aged between 33 to 49 years (FAO 2012). Results of the present study also agree with previous studies from South Africa and other countries (Martins, Anelich 2000, Mensah et al. 2002, Martins 2006, FAO 2012). From a food safety point of view, women dominating the food trade suggest improved food safety given that in the African setting, cooking is the responsibility of women who might therefore be more experienced in mitigating food safety risks as compared to their male counter-parts.

It appears, therefore that the success of informal trade in RTE chicken in Tshwane is largely dependent on women. The informal food trade sector offers women the opportunity to make a living. This is important given the slow pace at which the South African economy is growing and creating jobs (Lues et al. 2006). However, as the FAO reported for West Africa (FAO 2012), the figures presented here did not give a whole picture of the involvement of women in the informal food trade, in that it did not capture the army of mothers, sisters, daughters who work along the entire food chain hidden away from official figures.

The majority of informal traders selling RTE chicken had the food outlet as their only source of income. This confirms that informal food vending is not just a temporary and convenient source of income while vendors search for something else or a means to cope with economic contraction. It is the main and long standing employment option for the most vulnerable groups in low income urban and peri-urban areas (FAO 2012). The author is of the view that such people would most likely welcome training geared towards improving their trade.

Furthermore, informal food traders included people with formal education which could be a reflection of the difficulty, as also mentioned by the FAO, of finding employment in the formal sector due to high unemployment in the city (FAO 2012). This indicates that the informal food markets are an important contributor to job creation in the city of Tshwane.

The food vendors also included people who do not have formal education and thus lack the skills to be absorbed into the formal sector. Street food vending is a large source of employment that offers abundant informal labour opportunities as compared to the scarce labour demand in the formal sector, especially for unskilled workers. This is confirmed by the fact that on average, the informal food sector employs more than 37% of the labor force, and contributes about 38% to total GDP in Africa (FAO 2012). In Tshwane, therefore, it can be seen that the informal food vending sector is an economic absorber, given that it offers job opportunities for many who otherwise would not qualify to get employment in the formal sector.

Only a small number of vendors indicated that they hired other people to assist at their stalls, and the tendency was for each vendor to hire only 1-2 people. Based on the results of the present study, informal trade in RTE chicken offered jobs mainly to entrepreneurs and to lesser extent, members of the general public. This was anticipated given the small size of these enterprises. According to a report by FAO (2012), women entrepreneurs start up informal food vending as a survival strategy and use the revenue they get to finance household expenditures such as clothing, health and child education. They are not able to divert the resources to business investment. Furthermore given the financial burden carried by these vendors at household level and the limited startup capital, very few vendors can afford to expand their ventures.

A study of street vended foods in Ghana showed that children (> 10 years) and women were the main participants in the informal food trade (Mensah et al. 2002). In Tshwane, very few young people (<25yrs), who make up the bulk of the unemployed in South Africa (NUMSA 2014) were involved in the informal sale of RTE chicken. The results of this study show that there could be employment opportunities associated with selling RTE chicken, and highlighted a need to investigate why the youth are not involved at the levels observed in Ghana.

The law requires vendors to own a certificate of acceptability to cook and sell food to the public (The Directorate: Food Control 1977a). Despite existing regulations, the present study revealed a poor to low level of compliance to regulatory requirements of owning a certificate of acceptability. Furthermore, compliance to this regulatory requirement was not uniform across markets. This could be linked to the different level of monitoring and/or enforcement of the legislation across districts in the Tshwane municipality. A low level of enforcement has also been reported among street food vendors in West Africa (FAO 2012). Based on anecdotal evidence and confessions from the vendors, the element of corruption was highlighted as a factor in the low compliance levels observed. Vendors who do not own a certificate of acceptability pay a bribe to be allowed to continue operating. Taking bribes by city authority personnel has also been reported in West Africa as one of the constraints to the development of partnerships between the informal food vendors and the local government in the area of urban planning (FAO 2012).

A positive finding, probably linked to the lower than expected levels of coliforms and *E. coli* in RTE chicken, as well as the low risk of Staphylococcal food poisoning (SFP), was that many vendors exhibited a reasonable degree of compliance. Investigation showed that a majority did not wear jewelry during cooking and serving of food, picked up RTE chicken with spoons and forks when serving, had washable floors in their food stalls, and used potable water supplied by the municipality for cooking and washing. All these have the potential to limit contamination of RTE chicken with coliforms (*E. coli* and environmental coliforms). Mensah et. al. (2002) in their study of street vended foods identified picking up food with bare hands as a risk factor for contamination.

On the other hand, a low level of compliance was observed to the following hygiene practices: keeping flies away from the vending site, washing utensils and hands in the same containers. Even though violation of these hygiene practices poses a significant public health problem, it is common to observe these violations among informal food vendors (Mensah et al. 2002). Flies have the ability to transport foodborne pathogens and hands can be a serious source of contamination. The failure to control flies could be linked to poor environmental hygiene in which the vendors operated.

Washing hands and utensils in the same containers is another hygiene practice that was observed to be commonly violated. This could be related to ignorance on the part of the vendors (Mensah et al. 2002). Several authors have suggested that the biggest problems facing the street vending industry is not being adequately informed about the importance of even trivial matters such as sanitary hygiene (Lues et al. 2006, Balkaran, Kok 2014).

The majority of informal traders in the study area used either crude structures or had no structures dedicated to the production of food for consumption by the general public. The effect of the environment has been highlighted by a study done in Ghana which showed that if food is prepared in an enclosed area the risk of contamination is greatly reduced (Mensah et al. 2002).

While the majority of vendors operated on types of floors such as cemented floors, floors made out of concrete slabs or polyethylene carpets that could be cleaned, there were vendors who operated in stalls where the floors were sand or bare ground. However, these less than satisfactory conditions prevailing among informal vendors do not stop people who patronize these food outlets from buying and eating food produced in such places (Balkaran, Kok 2014). This is because people usually do not select where to eat based on the establishment, but how they psychologically interpret the properties of the product produced by the establishment (Badrie, Joseph & Chen 2011, Balkaran, Kok 2014).

With regard to access to water, the majority of informal vendors in this study had access to municipal tap water. This was contrary to what was reported for informal vendors in Ghana who struggle to get access to potable water (Mensah et al. 2002). However, in this study, water had to be collected either from close by or from a distance using containers. In other instances, water was brought from home or bought from people who collected it from somewhere else. The problem with this is that the containers used could lead to contamination of the water. This is because using containers of questionable microbiological status undermines the microbial quality of the water which otherwise was supposed to be potable.

The other problem that was highlighted was, in some instances, the location of toilets far (>30m) from the vending stalls. A long distance between the stalls and toilets has been associated with failure to adhere to thoroughly washing hands after using the toilet.

All the problems highlighted in the preceding paragraphs are related to physical structures and planning. This highlights the fact that the city authorities either do not plan for the informal food sector or have plans but are not able to implement them. According to Morgan (2009), it is the norm for authorities in most cities to plan for essential requirements of life like air, water, shelter but not food. This is usually a problem in cities that do not have food planners. Two definitions of a food planner have been suggested and these include: a person or institution working in food, or engaged with the food system with the aim of rendering it more sustainable with respect to its social, economic and ecological effects, or any one striving to integrate food policy in the mainstream planning agenda (Morgan 2009).

The provincial and national governments in South Africa recognize the significance of food to the health and wellbeing of the city dwellers, as evidenced by the laws and bylaws governing the way food should be handled (Department of Health 2007, South Africa Department of National Health: Directorate of Environmental Health 1996, The Directorate: Food Control 1977b, The Directorate: Food Control 1977a). However, there seems to be no political will to integrate informal food trade in the planning of the city as has been observed in other cities like Toronto, Amsterdam and Kampala that have woven food policy dimension into existing urban plans (Morgan 2009). This explains the failure of the city of Tshwane to build informal food markets as is the case in some cities close to every new taxi rank. Alternatively, this could also point to the fact that there is no food policy for the city.

With burgeoning of African cities, poverty and hunger are being urbanized at an alarming rate. In view of this, food planning is going to be a big challenge for cities in Africa, South Africa included. In the past planners in African cities systematically tried to get rid of urban agriculture and street food vendors for reasons ranging from genuine public health concerns to frivolous ones like modernization of the city (Morgan 2009). This needs to change and informal food vendors should be recognized as an integral component of the food supply system of the cities.

8.1.2 Conclusions about the food value chain

Chapter 5 considered the food value chain for RTE chicken sold by informal vendors in Tshwane. This is the first time the value chain for RTE chicken has been modeled. Results showed that there were four value chains: one formal chain, two informal-formal hybrid chains and one purely formal chain.

The significance of mapping the value chain is appreciated when one considers the need to establish a basis for traceability of RTE chicken sold by informal traders. Where traceability in a food value chain is established, monitoring of none compliance with agreed standards along the value chain is possible. This fits in well with the modern trend in food safety assurance that advocates replacing end product testing with the suppliers along the chain assuming responsibility for safety. For this to be successful, the role players in the value chain have to be known. The present study could not identify the individual role players due to lack of cooperation on the part of the participants.

The present study is also the first to suggest the existence of the extensive cross-over or spill-over between the formal and informal value chains for RTE chicken sold by informal traders. In addition, the present study observed that the four value chains were very short and rapid. By the value chains being short; few role players were involved or that the RTE chicken goes through very few steps as it moves from the farm to the fork. This means that it takes a short time for the chicken to move from farm to fork. Furthermore, there are usually no leftovers as all the RTE chicken is usually eaten the same day and within a few hours of cooking. These two factors can be considered as risk mitigation strategies for risk associated with the long and tortious food value chains.

The strong linkage observed between the informal and formal value chains of the RTE chicken sold on the informal market is related to the strong culture of super markets and commercial poultry growers in South Africa. As a result what was observed here may not be similar to what is happening in other parts of the African continent where the food value chain for food sold on the informal marker is predominantly informal. In such places, chickens are grown mainly by back yard chicken farmers and traded by middle men or women who are themselves informal traders. However, as super market proliferation takes place on the continent, it can be anticipated that the value chain observed here with the associated risks is bound to be replicated.

Furthermore, the strong linkage between the formal and informal value chain is good news for the informal traders. It implies that the informal market for RTE chicken has a reliable source of chicken in the form of commercial growers. Commercial production is known to be associated with stringent disease control programmes. The implication of these two facts is food security for people who depend on such markets for their nutritional requirements, and the informal trade in RTE chicken is well established with a reliable supply of chicken of high standard from a food safety perspective.

By providing a market for produce from the formal sector, the informal market contributes to the economies of cities and nations. This is consistent with the view that street food vending not only improves urban diets, but also promotes local food production (FAO 2012). Therefore, supporting the informal trade to produce food that is safe, sound, and wholesome for the urban poor who are dependent on such markets for their source of nutrition is a worthwhile venture for the city authorities.

8.1.3 Conclusions about the risk of coliforms and *Escherichia coli*

In Chapter 6 the drivers for contamination of RTE chicken with *Escherichia coli* and coliforms were assessed, and the findings demonstrated that RTE chicken can be contaminated with both. This was anticipated given that informal vendors are known not to be conversant with the importance of personal hygiene and that they usually work in environments that are not ideal for preparation of food (Rane 2011).

In terms of foodborne pathogens, the rule of thumb is that, processed foods should be free from pathogens (KZN-DOH 2001). However, both *E. coli* and coliforms tested in the present study are indicator organisms. Unavoidable contamination introduces coliforms at a level of 10^1 to 10^2 per gram of food (Badrie, Joseph & Chen 2011). At this level the food is considered acceptable and can be consumed. However, when contamination with either of these organisms exceeds 100 CFU/g, the food is considered unacceptable for human consumption (New South Wales Food Authority (NSWFA) 2009). The presence of coliforms in RTE chicken as observed in the present study suggested the environment contributing to post cooking contamination of samples collected for laboratory analysis, while the presence of *E. coli* suggest poor personal and sanitary hygiene (Badrie, Joseph & Chen 2011).

Comparison of the number of samples with >100 CFU/g for *E. coli* and coliforms showed that the number of samples that were contaminated with coliforms was significantly higher than those with *E. coli* (X^2 = 25.71; two tailed p=0.0001). Therefore, the environmental contaminants were more likely to be the cause of contamination of the RTE chicken as compared to *E. coli*.

Since the number of RTE chicken with >100 CFU/g was very low among the samples studied, the implication is that the RTE chicken sold by informal vendors presents a low risk to the consumer. This is because, the risk of the presence of food borne pathogens of enteric origin decreases greatly when the food carries <100 CFU/g. According to the results of the present study it can be concluded that informal vendors were able to produce RTE chicken with low microbial risk to the consumers. Previous studies that assessed the microbiological profile of various foods sold (not only RTE chicken as was the case with the present study) by informal vendors in South Africa were also able to conclude that such food presented a low microbial risk (Masupye, von Holy 2000, Masupye, Von Holy 1999).

Assessment of dual contamination with faecal (*E. coli*) and environmental contaminates (coliforms), showed that fewer samples were simultaneously contaminated with both organisms as compared to those contaminated with *E. coli* and coliforms individually. This further proves that the risk associated with eating RTE chicken sold on the informal market due to simultaneous contamination with coliforms and *E. coli* is low.

It is known that in South Africa the informal food vendors operate in less than ideal conditions for preparation of RTE food. However to date, no studies have been done to describe the operational conditions that influence most the safety of RTE food sold by vendors on informal markets. The present study is the first to identify the food handling hygiene practices that are significant for contamination of RTE chicken sold by informal vendors. Using multivariable analysis, it was shown that drivers of contamination of *E. coli* and coliforms were different.

The following factors were identified as drivers of contamination of RTE chicken with *E. coli*:

- sighting of house flies at the vending site;
- vendors intermittently washing hands as opposed to washing them regularly while handling RTE chicken;
- vendors located >30 m from the toilet; and
- maintaining cooked chicken at <70 °C.

As for coliforms, the drivers for contamination of RTE chicken included:

- the use of potable toilets without hand washing facilities;
- vendors failing to wash hands during the process of preparing and selling of RTE chicken, or only wash hands at the beginning and end of the day.

According to Mensah et al (2002) informal vendors do not easily associate failure to wash hands with transmission of foodborne pathogens. This could explain why "not washing hands regularly" featured as a driver for contamination with both *E. coli* and coliforms in the present study.

The four factors identified for *E. coli* and the three for coliforms should constitute the main areas of monitoring for the law enforcement agents to ensure that their role in microbial contamination is kept to the minimum.

Analysis of the water using the most probable number method revealed a high prevalence of contamination with coliforms. This means that most of the water used by the informal vendors was not potable. This is because water is not drawn directly from the tap but is collected in large containers whose microbiological status could be poor. This has potential to contribute to contamination of RTE chicken with both *E. coli* and coliforms.

8.1.4 Conclusions about staphylococcal food poisoning

Chapter 7 dealt with the risk of contracting staphylococcal food poisoning (SFP) following consumption of RTE chicken. The present study presented the first quantitative microbial risk assessment for *S. aureus* on RTE chicken bought form informal vendors in Tshwane. This entailed performing a quantitative microbial risk analysis following the Codex Alimentarius Commission methodology in conjunction with participatory research methods.

Left on their own, consumers cannot determine the risk of contracting a foodborne illness at the time of purchasing and consuming a food. This is because the level of microbial contamination and chemical residues cannot be determined by mere observation. Furthermore, consumers use their senses to assess if the food is safe based on how it smells or looks. If consumers think that a certain type of food is associated with a foodborne disease the response is avoiding purchasing such a food (Badrie, Joseph & Chen 2011). These are not reliable methods of quantifying risk. Therefore, this study seeks to assist consumers of street vended foods to make informed choices.

The present study observed that a relatively high percentage (44%) of RTE chicken was positive for *S. aureus*. This was true in all the markets that were tested as statistically no significant difference was observed between the markets. Although the source for the *S. aureus* was not investigated in this study, past studies have shown that sources of contamination with *S. aureus* include the hand of food handlers given that *S. aureus* is a normal inhabitant of the skin of food handlers, and contaminated water and/or the environment (Badrie, Joseph & Chen 2011). Therefore, in RTE food in which *S. aureus* has been destroyed by processing, the presence of organisms is an indication of contamination from the skin, mouth and nose of food handlers (Badrie, Joseph & Chen 2011).

Out of the 44% samples of RTE chicken that were positive for *S. aureus*, only 29% had 10^3 CFU/g. According to the North South Wales Food Authority of Australia, contamination of food with 10^3 CFU/g renders such food unacceptable (New South Wales Food Authority (NSWFA) 2009). Based on this, it was thus, judged that the majority of RTE chicken tested were acceptable for consumption.

The mean CFU/g of *S. aureus* on RTE chicken was $10^{3.6}$ CFU/g, which is below the 10^5 CFU/g threshold required for production of sufficient toxins to induce SFP (New South

Wales Food Authority (NSWFA) 2009). The implication here is that on average the number of *S. aureus* on RTE chicken was below the threshold level required to induce SFP.

The markets in the Tshwane metropolitan area that were studied varied in size. Mamelodi contributed most to the sales of RTE chicken, while Belle/Prinsloo contributed the least. This suggests that the different markets present different risks in relation to hazards associated with eating RTE chicken.

The first two steps of hazard assessment (Hazard identification and Hazard characterization) were based on published data and were reported in Chapter 2. Therefore Chapter 7 considered only exposure assessment and risk characterization.

Results of the exposure assessment showed that both the probability of the occurrence of *S. aureus* on RTE chicken and purchasing RTE chicken that was unsatisfactory were 44% (90% CI: 36.1% - 52.2%) and 32.9% (90% CI: 25.5 - 40.4%), respectively. The high prevalence of *Staphylococcus* detected here has been reported in other studies (Normanno et al. 2005), and confirms that *S. aureus* commonly contaminates RTE food.

In the present study, the RTE chicken must have been contaminated post cooking or during handling given that these were RTE products. The vegetative forms of *S. aureus* are heat labile and so could not have survived the cooking. In view of this, there is a need to instruct the vendors on how to implement good manufacturing practices.

The results of risk characterization for *S. aureus* due to consumption of RTE chicken was estimated to be the risk of going down with SFP (*P(illness)*) following consumption of RTE chicken sold on informal markets included in the present study. This was based on the assumption that the probability of contracting SFP was equivalent to ingesting RTE chicken with 10^5 CFU/g. At this level, the *S. aureus* is able to produce sufficient toxins to induce SFP. Thus the risk was observed to be 1.3% (90% CI: 0% - 2.7%), which is low. Based on this, a high prevalence of contamination with *S. aureus* did not translate into a high risk of illness following ingestion of RTE chicken. In view of this, it is erroneous to judge the safety of RTE chicken based on the presence of the hazard. Doing so would only serve to harm the informal trade without any commensurate benefit for human health.

Results of the sensitivity analysis showed that two factors were significant for the risk of SFP. These were the probability of *S. aureus* having SE genes and the concentration of *S. aureus* on the RTE chicken. What these results show is that between prevalence and concentration, the latter was more significant for SFP. This serves to confirm that the prevalence of contamination of RTE chicken with *S. aureus* cannot be used as an accurate measure of the magnitude of the risk of SFP following consumption of RTE chicken bought of the informal markets.

The bacterial concentration of *S. aureus* on RTE chicken rarely exceeded 10^5 CFU/g. This could be attributed to keeping the RTE chicken at a temperature exceeding simmering heat before it was served, as well as the fact that the majority of vendors served RTE chicken using spoons and forks (see Chapter 4) and the fact that the food value chain is short and rapid (Chapter 5).

Since the presence of SE genes is dependent on biological variability, nothing can be done to regulate the occurrence of those isolates with SE genes. Therefore, the most effective measure that would help bring down the risk of SFP would be further control of the level of contamination on RTE chicken. This would include raising the level of awareness through hygiene training for informal vendors. Although temperature control after cooking is effective for controlling SFP, maintaining the cold chain may not be achievable in informal markets, thus rapid sale of cooked chicken is important.

As the RTE chicken carried *S. aureus*, the possibilities of contamination were present and high. In view of this, all the poor hygiene practices identified in Chapter 4 need to be addressed, to limit contamination of RTE chicken.

8.2 Recommendations

Areas where black South Africans congregate in large numbers (i.e., taxi ranks) should be targeted for development so as to facilitate access to this source of cheap, convenient and nutritious food by this group of people who form the bulk of the urban poor.

The success of the informal trade in RTE chicken in Tshwane is predominantly dependent on women, who belong to an economically active age group, but have failed to secure jobs in the formal sector. Therefore, as has been suggested elsewhere, efforts to improve the informal food trade in Tshwane should target mainly women (Mensah et al. 2002).

Youth form a very small component of informal food vendors. There is a need to determine why this is the case and find ways to encourage them to take up opportunities in the informal food. This has potential to lower unemployment which is high in this section of the population.

The study also revealed that among the vendors, there were people who were educated. This presents a situation of trained and educated vendors, receptive to initiatives aimed at improving their lives and the service they offer to their customers (FAO 2012). It is suggested that food safety messages could be transferred both to vendors and consumers, using electronic forms of communication such as "Google" adverts on smart phones, or healthy food messages on video screens at taxi stations. This needs further study in line with modern mass communication strategies.

To be able to assist informal vendors to move from the second economy (informal sector) to the 'first economy' (formal sector), there is a need to provide for proper infrastructure, potable water and easy access to toilets in some markets. This will pave a way for the eventual implementation Hazard Analysis and Critical Control Point (HACCP) system.

Tshwane needs to pay more attention to enforcement of ownership of the certificate of acceptability in markets like Marabastad, Belle Ombre, Pretoria Central, Mamelodi, Soshanguve, Mabopane, Ga-Rankuwa, Hammaskraal, and Temba City that had a low compliance score.

Based on ranking and scoring of hygiene practices, the city of Tshwane needs to put emphasis on monitoring the following hygiene practices: appropriate structures for preparation of RTE chicken with floors that can be cleaned; providing direct access to water supplied by the municipality so vendors do not have to depend on water being delivered to the stall; controlling flies at the vending site; and hand washing facilities for use after visiting the toilets to prevent washing of hands and utensils in the same container.

The informal food sector is an integral component of the food supply chain for urban centers as it is critical in meeting the daily food needs of millions of inhabitants in the world's cities.

It is especially true, in the absence of formal food marketing and distribution companies offering affordable nutritious food for the urban poor (FAO 2012). Based on the present study, the available infrastructure to informal vendors in Tshwane does not fully meet the criteria suggested by the WHO for food safety in street markets. This should also be prioritized to help improve the environment where informal vendors operate.

While the Johannesburg metropolitan council has taken the initiative to register street food vendors in its area of jurisdiction and allocated space for them with facilities such as shelter, running water, toilets and, in some instances electricity at which to operate (International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa 2005), Tshwane metropolitan council seems to be lagging behind. However, as the metropolitan council tries to integrate the informal vendors into the food supply system of the city, it is important that the views of the informal vendors are considered.

The food value chains for RTE chicken sold in informal markets presented in this study indicates an unexpected magnitude of available poultry meat flowing into the informal market from the well-established formal sector. The significant cross-over or spill-over from formal markets is important for food safety given that the formal sector is regulated to ensure that it adheres to good production and manufacturing practices. The strong link between formal and informal sectors is important for job creation for vendors because of the reliable source of chicken for use as raw material.

The food value chain for the inspected, packaged, labeled poultry meat, that ends up as the informally vended RTE chicken is short and as a result, the likelihood of maintaining the cold chain is high. This is good for food safety because the raw material that vendors use is of good quality from a microbiological perspective. Food security for urban dwellers is also positively affected as the low-income taxi commuter is able to access a nutrient dense food source (cooked chicken) conveniently and at an affordable price.

Given that the problematic areas associated with high odds of contamination of RT chicken were related to the WHO five keys to safer food (WHO 2006), there is a need to apply the WHO five keys among informal vendors to decrease the contamination of RTE chicken sold by informal traders.

The important keys that need to be emphasized among the vendors include the following:

a) Key 1, "Keep clean": there is a need to improve on the environment where the vendors operate so as to control the fly population, dust and dirt in all markets. Based in the results of the multivariable regression analysis, there is a need to wash hands frequently and often before handling food.

b) Key 5, "Using safe water and raw materials": while the cold chain for raw chicken appeared to be fairly well observed, more care in water safety and ensuring that potable water was not contaminated should be enforced. This would limit the possibility of cross-contamination.

With respect to *E. coli* and coliforms, despite working in less than an ideal environment for production of food, it is evident that the majority of informal vendors are able to produce food of acceptable microbial quality. Therefore, attempts to eradicate informal food vendors are not justifiable from a public health point of view. More support in terms of providing the suitable environment and emphasis on training of informal vendors on the WHO Five Keys to safe food production (Annexure IV) is strongly advised. Furthermore, self-regulation supported by legislation should be implemented for informal vendors. Legislation alone without encouraging self-regulation is not likely to yield positive results.

Using participatory risk analysis and rapid diagnostic methods, it was possible to perform risk assessment in a sector that is characterised by lack of data. The prevalence of contamination of RTE chicken with *S. aureus* does not necessarily translate into risk. Furthermore, the prevalence of contamination of RTE with *S. aureus* is not a good indicator of the magnitude of the risk.

The risk of SFP from eating RTE chicken sold by the informal vendors was low. This is good for both the vendors and customers as RTE chicken sold in informal markets is an affordable source of nutrition for a large poor urban population, and is a good source of income as well for the informal vendors (Mensah et al. 2002). However, this does not represent the whole risk posed by RTE chicken sold by informal vendors. There are many other microbiological and chemical hazards to consider.

Although the risk of SFP was low, the fact that samples positive for *S. aureus*, *E. coli* and coliforms were encountered in the study, suggests that hygiene improvement should not be neglected. This is important considering that people who patronize informal food outlets, rate tastiness of the food above the other considerations like the hygiene status of the food (Martins 2006, Mensah et al. 2002). In other words, they are less concerned about the hygiene of the food or the premises where the food is prepared (Mensah et al. 2002, FAO 2012).

For purposes of informal traders where the HACCP system in its entirety cannot be implemented because the prerequisites are not in place, a step where control for a hazard is critical for safety, should be considered a Critical Point (CP) for control of hazards. According to Doménech et al. (2008), if a hazard has been identified at a step where control is necessary for safety (as was the case in this study with *S. aureus* being observed in RTE chicken) and yet no control measure exists at the step, or any other, then the process should be modified at that step, or at any earlier step or later step, to include a control measure. In view of this, since contamination of samples of RTE chicken with the three organisms was observed at the final stage before consumption and there were no further steps that RTE chicken would undergo before consumption, serving of RTE chicken is a CP during the preparation and selling of RTE chicken by informal vendors.

Based on the low level of risk with regard to *S. aureus* observed in this study, in a developing country like South Africa where unemployment is above 26%, a section of the population still lives under third world conditions, many people are unschooled without formal qualifications and relatively poor, there is no justifiable reason to prevent the people involved in the trade from continuing to earn a living from the trade. Rather consideration should be given to maximizing benefits from the informal food businesses, and the informal vendors should not be viewed as a public health nuisance. A holistic understanding of the risk, economics and sociological role played by informal vendors of RTE chicken is key to improve food safety, job creation and poverty alleviation associated with poultry value chains in South Africa.

8.3 Limitations of the present study

The present study was limited in scope in that it only considered a small section of the food value chain when assessing the associated risk. Therefore, a risk assessment model that incorporates the influence of various factors before the food reaches the consumer, also called the farm-to-fork approach or process risk model or product/pathogen pathway analysis would have been more appropriate. This would allow consideration of a broad range of risk management options along the food chain and provide the most information for food safety risk management (Lammerding, Fazil 2000).

Furthermore, the present study does not take into account the proportion of SEs with emetic properties and the proportion of the susceptible population. Therefore, the study assumes that all SEs have emetic properties and that the whole population was susceptible to SEs. In addition, the microbiological tests used did not show the true bacterial concentration for the samples that were classified as TNTC.

Things like multi-exposure, exposure to multi-toxin and multi-sources, and repeated exposure phenomenon need to be considered to be able to arrive at a more accurate risk of SFP to consumers. Therefore given that the present study did not take these into consideration, this is a weakness of the study and the resultant assessment may not be an accurate estimate of the associated risk.

The probability of contracting staphylococcal food poisoning is limited to the consumers of the RTE chicken in informal markets and is not a reflection of the risk to the whole population of the country. Furthermore, although biological hazards like staphylococcal food poisoning are usually the most important in terms of human disease burden, other hazards such chemical contaminants and antimicrobial residues cannot be ruled out.

Ranking of the hygiene practices did not consider all the hygiene practices that could have affected the microbiological quality of the RTE chicken. It is therefore possible that if all hygiene practices had been considered, the results of the ranking could have been different.

Other *Staphylococcus* species other than *S. aureus* that are also capable of SE production but are not looked for in routine tests were not considered in this study. It is therefore possible that the risk estimate in the present study is an under-estimate of the actual risk associated with *S. aureus* on the RTE chicken.

To better understand the risk associated with SFP, more research is still required for better understanding of the interactions between *S. aureus* and the food matrix, and of the mechanisms of SE production in foodstuffs. Research is also needed to identify the new SEs and new enterotoxigenic staphylococci. The new and more sensitive techniques for SE detection in food stuff being developed currently should lead to better control and subsequent reduction of staphylococcal food poisoning outbreaks (Le Loir, Baron & Gautier 2003).

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ANNEXURES

a) ANNEXURE I: QUESTIONNNAIRE

b) ANNEXURE II: CHECKLIST FOR ASSESSMENT O HYGIENE

c) ANNEXURE III: CONSENT FORM

d) ANNEXURE IV: FIVE KEYS TO SAFER FOOD

e) ANNEXURE V: SCORING AND RANKING OF MARKETS

f) ANNEXURE VI: THE UNIVARIABLE ANALYSIS OUTPUT

g) ANNEXURE VII: THE GOODNESS OF FIT TEST OUTPUT

h) ANNEXURE VIII: PUBLICATION FOOD CONTROL

i) ANNEXURE IX: APPROVAL FOR RESEARCH PROJECT

ANNEXURE I: QUESTIONNAIRE

Participatory risk analysis of street vended chicken meat sold on the informal markets in Tshwane, Gauteng

Questionnaire formatted for research in fulfilment of a Doctoral degree in Paraclinical Sciences at the University of Pretoria.

Questionnaire Reference number

A General information

1.1 Enumerator's name

Initials Surname

1.2 Respondent's Residence

Suburb Province

1.3 Date of interview

DD MM YY

1.4 Description/Name of Stall

1.5 Market where business is located

GPS reading Code

1.6 Comments by Enumerator

				Ref No
B	**Biographic information**			
2.1	Respondent's gender			
	Male			
	female		V1	0 to 1
2.2	Which category describes your age in yrs:			
	Less than 25			
	25-50			
	50-60			
	more than 60		V2	2 to 5
2.3	What is your home language?			
			V3	Language
2.4	Which one of these best describes the highest level of education attained by you?			
	No formal education			
	Primary education			
	completed metric			
	University			
	none of the above		V4	6 to 10
2.5	Are you employed or working for someone else?			
	This is my personal business			
	I am employed by somebody			
	else and work on a daily basis			
	I am helping out for			
	only a few days			
	None of the above		V5	11 to 14
	Explain if you chose none of the above.			
2.6	Do you possess a certificate of acceptance?			
	Yes			
	No		V6	15 to 16

				Ref No
2.7	Do you employ other people to help sell chicken at your stall?			
	Yes			
	No			
	N/A		V7	17 to 19
2.8	If your answer to question 2.7 was yes, how many people do you employ?			
	1-2 people			
	3-4 people			
	more than 4 people		V8	20 to 21
2.9	Do you have any other business or work besides selling food?			
	No			
	Yes		V9	22 to 23
2.10	At what time are you at the stall to start preparing food?			
	Before the morning rash hrs.			
	(between 6 & 7 am)			
	After the morning rash hrs.			
	(between 8 & 10 am)			
	later in the day (between 10 & 12 am)			
	Other		V10	24 to 27
	explain			
2.11	Which of the following best describes the time when you close the stall?			
	After the morning rush hours			
	After the afternoon rush hours			
	When the food is has all been sold			
	other		V11	28 to 31
	explain			
2.12				
	South African			
	From the SADC region			
	From another part of Africa			
	From outside Africa			
	Decline to answer this question		V12	32 to 36

Ref No

C.	**HYGIENE HANDLING PRACTICES**		
3.1	From where do you prepare the chicken and/or chicken by products you sell at this stall?		
	At the vending site		
	At home and brought to vending side		
	other (explain below)		V13 37 to 39
3.2	If no source of potable chlorinated water is available what do you use?		
	River water		
	Bore hole water		
	Water from a tank		
	Water brought from home		
	Others		V14 40 to 44
	Specify if your answer was others:		
3.3	Do you have soap/washing liquid for washing hands and utensils at the stall?		
	Yes but I bring soap/washing up		
	liquid from home		
	Yes, soap is available for washing at		
	ablution/toilets for washing hands		
	No I do not have soap here at the stall		
	Other		V15 45 to 48
	specify if you chose other		
3.4	After taking chicken off the fire, how long do you store cooked		
	Chicken before it is all sold off?		
	>6hrs		
	>12hrs		
	>24hrs		
	>36hrs		
	>72hrs		
	Not sure		V16 49 to 54
3.5	Which of the following statements best describes what happens to left over chicken?		
	Taken home to and eaten by family		
	members		
	Sold the following day		
	Given to the homeless		
	Other		V17 55 to 58
	Please explain if your answer was other		

				Ref No
3.6	Have you ever received training on food hygiene handling practices?			
	Yes			
	No		V18	59 to 60
3.7	If your answer was yes to the question in 3.6, who offered you the training?			
	City of Pretoria health officials			
	As part of formal training			
	(specify By choosing one of options below)			
	NGO			
	University or Technikon outreach course			
	Other (explain)		V19	61 to 65
3.8	When do you buy chicken for selling?			
	On the morning of the day the is cooked			
	before selling			
	The day before			
	Other (explain below)		V20	66 to 68
3.9	How is the raw chicken stored at site before it is cooked?			
	In refrigerator			
	In a deep freezer			
	In a container containing warm water to defrost			
	Kept in the cool boxes from time it is bought			
	None of the above		V21	69 to 72
	Please explain if your answer was none of the above			
D	**INFORMATION IMPORTANT FOR RISK MITIGATION**			
4.1	Give an estimate of the amount of chicken (Kg) bought for sale for a day's sale			
	1-2kg			
	3-5 kg			
	6-8kg			
	9-11kg			
	12-14kg			
	>14 kgs		V22	73 to 78

				Ref No	
4.2	Which of these best describes the amount chicken bought each time:				
	Enough to last about a week				
	Enough to last more than a week				
	Enough to last for a day's sale only				
	Other		V23	79 to 82	
	Explain if your answer was other				
4.3	If you buy in bulk to last more than one day, how is the chicken stored?				
	Freezer at home				
	Cool box with ice packs				
	Ordinary container without ice				
	Not willing to say				
	Other		V24	83 to 87	
	Explain if your answer was other				
4.4	Which of the following best describes the condition of the chicken when you buy it?				
	I buy already cut up chicken				
	I buy whole chickens and cut them up my self		V25	88 to 89	
4.5	If your answer in 4.6 was you buy cut up pieces, select ones you usually buy.				
	Thighs/drum sticks				
	Wings				
	Intestines/feet				
	Gizzards/Livers/hearts		V26	90 to 93	
4.6	Tick off the things you consider when buying chicken				
	size of pieces				
	Smell/freshness				
	whether plastic is sealed or not				
	Temperature				
	Origin of the meat				
	Price				
	none of the above		V27	94 to 100	
4.7	What do you sell (tick more than one where applicable)?				
	Cooked chicken				
	Raw chicken				
	Both				
	Chicken plus other meats				
	chicken and other foods e.g. papa or rice				
	Other explain:		V28	101 to 106	

				Ref No
E	**CUSTOMER PROFILE**			
5.1	Who is your main customer?			
	Taxi drivers			
	Taxi commuters			
	School children			
	Office workers			
	Other (Specify)		V29	107 to 111
5.2	Which of the following best describes the age group of people who eat the food you sale?			
	Children less than 6 years			
	Children ages between 7 and 15 years			
	Young adults between 16 and 18 years			
	Mature people between 18 and 70 yrs			
	Old people over 70 yrs		V30	112 to 116
F	**FOOD CHAIN AND MARKET SUSTAINABILITY**			
6.1	Where do you purchase the chicken you sell?			
	(tick off more than one if applicable)			
	Chicken is supplied to me by a whole seller			
	From a super market			
	Small spazer shops			
	From vendors selling chicken by the roadside			
	I personally buy the chicken from the abattoir			
	From someone who buys live chickens from			
	commercial farms			
	I buy live chickens directly from the farms			
	I buy live chickens from individuals that			
	raise them from their homes			
	chickens is supplied to me by a farmer			
	who processes them before delivering to me			
	I am a small scale poultry farmer			
	I am part of a small scale poultry project			
	Other (explain)		V31	117 to 128
6.2	How many pieces on average do you sell on a daily basis?			
	>10 pieces			
	10 -20 pieces			
	20 -30 pieces			
	30 -40 pieces			
	40-50 pieces			
	>50 pieces		V32	129 to 134

			Ref No
6.3	On the average, how many pieces does each customer eat?		
		V33	No of pieces

6.4	How much do you charge for each serving of chicken?		
		V34	Rands/serving

6.5	How do you benefit from selling chicken meat?			
	My employer pays me a daily rate &			
	I pay the money from the chicken sales to him			
	My employer gives me commission			
	My employer gives me chicken and			
	I pay back after I have sold the chicken			
	I by the chicken myself and sell it to make			
	a profit on which I leave			
	Other		V35	135to 139

6.6	How many days do you work per week?			
	one day a week			
	Two days a week			
	Three days a week			
	Four days a week			
	Five days a week			
	Six days a week			
	Seven days a week			
	Other (explain)		V36	140 to 147

6.7	Do you keep records of amounts of money spent, chicken bought and sales made?				
	Yes				
	No			V37	148 to 149

6.8	How is waste generated during the course of doing business disposed of?			
	In the municipal waste disposal bins			
	Dumping site close to the stall and or			
	close to the street			
	On a nearby municipal dumping site			
	Other (explain)		V38	150 to 153

			Ref No
6.9	Which of these best describes the materials used to serve food by the vendor?		
	Washable plates as those used at home		
	Paper plates		
	Plates made from polystyrene take away		
	recyclable material		
	Paper bags		
	Other-specify		V39 154 to 158
6.10.	If you are unable to work due to say not feeling well or other commitments names of who assists with selling at the stall?		
	My children or spouse		
	I hire somebody to assist for that day		
	The owner of the business hires somebody		
	to stand in for me		
	Nobody		
	Other		V40 159 to 163
6.11	Does getting involved in this business in anyway pose a danger to your life or health?		
	Yes		
	No		V41 164 to 165
6.12	If your answer was yes to the above question (6.11), explain the way in		
	which your life or health is endangered		
			V42 Dangers to life & Health
6.13	If you would improve the working conditions here, what would you do?		
			V43 Suggestions

			Ref No
6.14	What is the best thing about being involved in this kind of business?		
	I am my own boss		
	Flexible working conditions		
	Close to my place of residence		
	Good income		
	Very little paperwork (vat, registration of a shop etc.)		
	Low capital input		
	Other - explain		V44 166 to 172

6.15	Would prefer to be doing something else than selling chicken here?		
	No		
	Yes		V45 173 to 174
	If your answer was yes explain what you would prefer to be doing for a living.		

ANNEXURE II: CHECKLIST FOR ASSESSMENT OF HYGIENE

Check list for street vendors selling chicken in Tshwane

Ref No:

A Hygiene: facilities

1.1 Structure of the stall used for preparing and selling of food.

Permanent structure built by municipality	
No structure	
Temporary structure	
Other	
(explain)	

1.2 Nature of the floor where the vendor works from.

Cemented	
Concrete slab	
PVC/plastic carpet	
Other:	

1.3 Water source for use by vendor and customers

Municipal tap available at vending site	
Vendors collects water in containers from municipal taps from somewhere else	
Vendor brings water from home	
Vendor buys water from someone who delivers it at the stall	
Other:	

1.4 Nature of toilet and washing facilities available at the vending site

Potable toilets only	
Potable toilets with a tap close by (±20m)	
Potable toilets with a tap ± 100M away	
Long drop toilets only	
Long drop toilets with tap close by (±20m)	
Long drop toilets with tap ±100M away	
Flushing toilets with no hand washing basin	
Flushing toilets with hand basins	

Ref No:

1.5 How far from the vendor's stall are the toilets located?

<10m	
10-30m	
30-50m	
50-100m	
>100m	

1.6 Which of these best describes the toilets used at the vending site?

Exclusively used by the informal traders	
Constructed for use by the taxi rank	
Use is made of toilets at petro station	
Use is made of toilets at the mall/shopping centre	
Use made of toilets at someone's house	
Other:	

B Hygiene: Food handling practices and personal hygiene

2.1 Washing of hands and utensils is carried out in different containers at the shop

Yes	
No	

2.2 What measures are employed by the vendor to avoid cross contamination of ready to eat chicken?

Utensils used for handling raw meat and ready to eat meat are separate	
Knives are washed and disinfected between using	
containers used for serving ready to eat food is not used to handle raw meat	
Vendors wash hands between handling of raw meat and serving ready to eat chicken	
Others:	

2.3 Protective clothes worn while cooking

Cap	
Apron	
gloves	
other clothing worn, please specify below	

Ref No:

2.4 Does vendor wash hands before serving each and every customer?

Yes	
No	

2.5 Which of these bests describes the way chicken is cooked (observe)

Not cooked thoroughly	
Cooked thoroughly	

2.6 Ready to eat cooked chicken is reheated before serving

Yes	
No	

2.7 At what temperature is cooked chicken meat stored?

$> 65^0$ C	
$< 65^0$ C	

2.8 Is ready to eat cooked chicken covered to protect it from dust and flies?

Yes	
No	

2.9 Rate the fly population at the site

>10 flies	
±5 flies	
Not even one observed	

2.10. Is raw chicken covered to protect it from dust and flies?

Yes	
No	

2.11 Do customers get to touch the cooked meat in the process of showing the vendor the Pieces they would like to be served?

Yes	
No	

2.12 Which of this best describes the preparation of the meat?

All the day's meat for sale is prepared at one go	
Not all the meat is cooked at one go	

2.13 Which of this best describes the way meat is displayed at the vending site?

Raw and cooked meat are displayed on the same table	
Raw and cooked meat are displayed on different tables	

2.14 Length of vendor's finger nail length

Short	
Long	

2.15 Are the vendor's nails clean?

Yes (no grime visible)	
No (grime visible)	

Ref No

2.16 Is the vendor wearing jewellery/bangles?

Yes	
No	

2.17 Do vendor use utensils e.g. fork when handling ready to eat meat?

Yes	
No	

2.18 How often does the vendor wash his/her hands

Frequently after every serving	
Once in a while throughout the day	
Not at all during time of observation	

2.19. If vendor washes hands, does he/she use detergent/soap?

Yes	
No	

2.20. Vendor ware gloves do they change gloves when handling different products?

Yes	
No	

C Product range and preparation

3.1 Type of product traded by street vendors

Chicken meat	
Head and feet	
Intestines	
Gizzards, livers and necks	

3.2 Is the product traded by the vendor raw or ready to eat?

Raw products	
Ready to eat products	
Both	

3.3 Proportion of raw products to ready to eat products

More than 50:50	
About 50:50	
Less than 50:50	

Ref No

3.4 Method used to prepare ready to eat products

Frying in oil	
boiling in water	
Roasting/braaing	
Other	

3.5 In case of frying describe the nature of the cooking oil used

Fresh from retailer	
Old oil that is has been used by other retailers	
Old oil that has been used in in the restaurant	

3.6 Temperature at which ready to eat products are stored or held

Hot	
warm	
Ambient temperature	

3.7 How many pieces are served on average to each customer?

One piece per customer
Two pieces per customer
Three pieces per customer
Four pieces per customer
more than five pieces per customer

D Environmental evaluation

4.1 Scavenging animals and birds seen in the vicinity of the market

Species	Number
No	

4.2 Animal dung present in the spot where the vendor has sited his/her stall

Yes	
No	

4.3 How is the waste/affluent water used for washing disposed of?

Thrown onto the ground	
Disposed of into the drainage	
Disposed of into the toilet	
Not applicable	

Ref No

4.4 How is rubbish disposal handled?

Left behind unwrapped	
Left behind wrapped	
Thrown into the communal bin	
Rubbish is taken home	

4.5 Does the activity of the vendor interfere with traffic and movement of people?

Yes	
No	

4.6 Which of these best describes the level of dust at the vending site?

Very dusty	
Not so dusty	
Almost none	

4.7 Does the location of the business interfere with human or traffic flow?

Yes	
No	

ANNEXURE III: CONSENT FORM

PROJECT TITLE

Participatory risk analysis of ready-to-eat chicken sold by informal vendors in Tshwane, South Africa

PROJECT MEMBERS:

Dr J.W. Oguttu (main researcher)

PROJECT LEADER:

Professor Cheryl ME McCrindle

SPONSORING OR COLLABORATING ORGANIZATION(S):

- Safe Food, Fair Food project funded by BMZ and CRP A4NH led by IFPRI,
- University of South Africa and
- University of Pretoria

INTRODUCTION

Dear Research participant,

You are kindly invited to participate in a research study entitled “Participatory risk analysis of ready-to-eat chicken sold by informal vendors in Tshwane, South Africa”. This leaflet will help you decide whether you are willing to participate in the study or not. You have the right to understand the aspects of the study before you agree to participate. If you agree to participate you have the right to withdraw at any time without giving any reason.You are being asked to participate in this study because you own or work at an informal food outlet that sells ready-to-eat (RTE) chicken to the public.

We are doing research on the risks associated with eating RTE chicken sold by informal vendors. We are interested in determining where you source the chicken you cook and sell, if the chicken you cook is contaminated with certain bacteria or not and the hygiene practices and habits observed at your stall. The intension is to determine the food value chain of the RTE chicken sold by informal vendors, factors that influence the microbial food safety of RTE chicken and the risk of acquiring food borne diseases. Participatory methods of research that include a questionnaire, observational checklist and focus group discussions will be used us to get the information requested.

The results of the study will be used by the main researcher to write a report called a thesis for which he will be awarded a doctorate degree from the University of South Africa. The findings of this study will be presented to various meetings of scientists locally and internationally. This report will elicit a depiction of the situation of the informal food market in South Africa. The report will help the Provincial Department of Health to improve extension and advisory services to informal food vendors.

EXPECTATIONS FROM PARTICIPANTS

If you decide to participate in the study, you will be required to do the following:

- To sign this informed consent form;
- To complete a survey questionnaire. The survey should not take more than 30 minutes to complete it.
- To provide a sample of the RTE chicken for microbiological analysis in the laboratory.
- To allow the researcher or his assistants to complete a checklist in relation to your stall and how you do things.

POTENTIAL HARMS

Physical harm: There is no physical harm associated with your participation in this research.
Questionnaires: The study and procedures involve no foreseeable physical discomfort or inconvenience to you.

POTENTIAL BENEFITS

- The benefits of participating in this study are:
- You will make a contribution that will help better understand the informal food markets;
- Government will know about the challenges you experience as an informal vendors and hence be able to assist you to improve on your ability to produce food that is microbiologically safe; and
- Through the answers you provide the food value chain for the informally traded chicken will be modeled for the first time in this country.

FINANCIAL COMPENSATION OR INCENTIVES FOR PARTICIPATING IN THE STUDY

Please note that you will not be paid to participate in the study. You are therefore requested to note that before participating in the study.

YOUR RIGHTS AS A PARTICIPANT, CONFIDENTIALITY AND ANONYMITY IN THE STUDY

Your decision to participate in this study is voluntary. You have the right to decide not to participate, or to stop taking part at any time without providing a reason for doing so. You will not be penalized if you decide to stop participating at any time. Your withdrawal will in no way affect your business operations. You have the right not to disclose the information requested from you without giving any reason.

All documents and information obtained during the course of this study will be kept confidential. Information about your food outlet and the hygiene practices and/or habits will also be kept confidential. The study data will be coded so that it will not be linked to your name. Your identity will not be revealed while the study is being conducted. The results of this study may be published in scientific journals, but your name will not be revealed. Access to your data will be strictly limited to the researcher team. Your data and personal information will be kept and stored in a confidential format which will only be accessible to the research team.

QUALIFICATIONS OF RESEARCHERS WHO WILL CARRY OUT THE STUDY

The main researcher is a veterinarian who has had extensive training in the field of veterinary public health and is also a lecturer at UNISA. The research leader is a Professor at the University of South African has extensive experience in research and the field of veterinary public health. Both the main researcher and the research leader have been involved in research in the past and produced good results.

STUDY APPROVAL

The College Research Committee and the College Research Ethics Committee of College of Agriculture and Environmental Sciences have approved the project proposal. The

Mpumalanga Provincial Department of Agriculture has granted us a written approval to conduct research in the province.

WHO TO CONTACT ABOUT ANY FURTHER CONCERNS OR QUESTIONS

The field researcher Dr J.W. Oguttu can be contacted during office hours at Tel (011) 741-3353, or on his cellular phone at 084 745 6768. Should you have any questions regarding the ethical aspects of the study, you can contact the project leader Professor Cheryl ME McCrindle during office hours at Tel (012) 529-8181 or by email: cheryl.mccrindle@gmail.com

CLOSURE

Your co-operation and participation in the study will be greatly appreciated. Please sign the underneath informed consent if you agree to participate in the study. In such a case, you will receive a copy of the signed informed consent from the researcher.

WRITTEN CONSENT

I have read and understood the information given in this informed consent and all my questions have been answered to my satisfaction. I have had sufficient time to consider whether to participate in this study. I am aware that the results of the study will be anonymously processed into a research report. I understand that my participation in this study is entirely voluntary and that I may withdraw from the study at any time without penalty. I voluntarily consent to participate in this study.

Research participant's name: ________________________(Please print)

Research participant's signature: _____________________

Date: _____________

Researcher's name: ______________________ (Please print)

Researcher's signature: ___________

Date: _______

VERBAL CONSENT

(Applicable when participants cannot read or write)

I hereby declare I have read, or have been read, and understand the information given in this informed consent form, and all my questions have been answered to my satisfaction. I have had sufficient time to consider whether to participate in this study. I am aware that the results of the study will be anonymously processed into a research report. I understand that my participation in this study is entirely voluntary and that I may withdraw from the study at any time without penalty. I voluntarily consent to participate in this study.

I hereby certify that the research participant has verbally agreed to participate in this study.

Research participant's name: ______________________________(Please print)

Researcher's name: _____________________________________(Please print)

Researcher's signature: __________________________________

Date: _____________

ANNEXURE IV: FIVE KEYS TO SAFER FOOD

Adopted from: http://www.who.int/foodsafety/publications/consumer/en/5keys_en.pdf?ua=1

ANNEXURE V: SCORING AND RANKING OF MARKETS

Hygiene practice assessed	Markets surveyed												
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total (%)
Possess certificate 1					X						X	X	X	4/13(30.77)
Toilets <30m from vendor	X	X	X	X	X	X	X	X	X	X	X	X		**12/13(92.31)**
Cemented floor 3					X	X	X	X	X	X				6/13(46.15)
Direct access to municipal water 4	X	X	X									X		4/13(30.77)
Vendor not wearing jewellery 5	X	X	X		X	X	X	X	X	X	X		X	**11/13(84.62)**
>10 flies not observed 6											X	X	X	3/13(23.08)
Permanent structure 7														0/13(0%)
Not washing hands & utensils in same container														0/13(0%)
Vendors use cutlery to pick up RTE		X	X	X	X	X	X	X	X	X	X	X	X	**12/13(92.31)**
Compliance (%)	3/9 (33.33)	4/9(44.44)	4/9(44.44)	2/9(22.22)	**5/9(55.55)**	4/9(44.44)	4/9(44.44)	4/9(44.44)	4/9(44.44)	4/9(44.44)	**5/9(55.55)**	**5/9(55.55)**	4/9(55.55)	

1= Marabastad; 2= Belle Ombre; 3=Pretoria Central; 4=Mamelodi; 5= East Lane; 6=Soshanguve; 7=Mabopane; 8 =Ga-Rankuwa; 9= Hammaskraal; 10=Temba City; 11= Atteridgeville; 12=Centurion; 13=Moreleta Park

ANNEXURE VI: THE UNIVARIABLE ANALYSIS OUTPUT

Annexure VIa: Univariable analysis of environmental, waste-related, sanitary measures, personal hygiene, food safety and preventative measures for association with risk of *E. coli* and coliform contamination

E. coli							Coliform				
Environment-related variables	Class	Case	Control	Odd ratio	Fisher's Exact CI95%	P-value	Case	Control	Odd ratio	Fisher's Exact CI95%	P-value
Dust level in the environment	Almost non-detectable	3	82	1.00	Reference	NA	18	72	1.00	Reference	NA
	Moderately dusty	8	87	2.51	0.58-15.13	0.17	26	70	1.49	0.71-3.15	0.26
	Very dusty	2	20	2.73	0.21-25.27	0.27	3	19	0.63	0.11-2.52	0.49
Houseflies sighted on meat table	None obvious	2	61	1.00	Reference	NA	14	51	1.00	Reference	NA
	≥ 1 to ≤ 9	11	99	3.39	0.70-32.30	0.10	30	85	1.29	0.59-2.88	0.50
	≥ 10 or above	1	29	1.05	.017-20.96	0.97	4	25	0.58	0.13-2.13	0.38
Business location interference	No	2	23	1.00	Reference	NA	8	25	1.00	Reference	NA
	Yes	8	176	0.52	0.10-5.37	0.4221	39	136	0.90	0.36-2.49	0.81
Interference in vendor activities	No	2	20	1.00	Reference	NA	6	25	1.00	Reference	NA
	Yes	8	179	0.45	0.08-4.63	0.3171	41	136	1.26	0.46-4.00	0.64
Animal dungs sighted around business premises	No	0	2	1.00	Reference	NA	1	2	1.00	Reference	NA
	Yes	10	197	-	-	-	46	159	0.58	0.03-34.87	0.65

Annexure VIb: Univariable analysis of food safety-related measures for association with risk of *E. coli* and coliform contamination

E. coli							Coliform				
Food safety-related variables	Variable	Case	Control	Odd ratio	Range (Fisher's Exact) at $CI_{95\%}$	P-value	Case	Control	Odd ratio	Range (Fisher's Exact) at $CI_{95\%}$	P-value
Temperature for cooking of ready to eat products	Hot (≥ 100 °C)	2	63	1.00	Reference	NA	17	37	1.00	Reference	NA
	Warm (≥ 40 to ≤ 70 °C)	6	76	2.486842	0.4231617; 25.87924	0.26	19	64	0.6461	0.2795; 1.5064	0.26
	Ambient (≥ 25 to ≤37 °C)	5	49	3.214286	0.4955335; 34.7745	0.15	11	59	0.4058	0.1544; 1.0424	0.037
Food product sold	Cooked	10	181	1.00	Reference	NA	42	155	1.00	Reference	NA
	Both uncooked and cooked	2	7	5.171429	0.4597843; 32.04951	0.0360	4	5	2.9524	0.5566; 14.2995	0.10
	Uncooked only	2	1	36.2	1.650414; 2145.663	< 0.00001	2	1	7.3810	0.3709; 438.1155	0.06
Cooking method for product	Boiled	5	110	1.00	Reference	NA	26	90	1.00	Reference	NA
	Fried in oil	6	95	1.389474	0.3407476; 5.94081	0.5952	21	86	0.8453	0.4185; 1.6941	0.61
	Roast/braai	2	12	3.666667	.3120265; 25.32375	0.1212	6	11	1.8881	0.5187; 6.2008	0.25
	Other method	0	1	-	-	-	0	1	-	-	-
Type of products traded	Whole chicken	7	168	1.00	Reference	NA	37	139	1.00	Reference	NA
	Chicken intestine	1	41	0.5854	0.01268; 4.7756	0.6170	7	33	0.7969	0.2755; 2.0310	0.62
	All parts of chicken	1	6	4.0000	0.0762; 40.7291	0.1930	3	7	1.6100	0.2556; 7.4646	0.50
	Chicken head and neck	1	36	0.666667	0.0144; 5.4646	0.7067	6	26	0.8669	0.8669; 2.3727	0.77
	Chicken gizzard	3	22	3.2727	0.5052; 15.5854	0.0860	5	16	1.1740	0.3152; 3.6427	0.77
Cooked chicken reheated before sale	Yes	4	113	1.00	Reference	NA	27	81	1.00	Reference	NA
	No	6	85	1.9941	0.4551; 9.8842	0.2884	20	79	1.3166	0.6506; 2.6920	0.41
Covering of cooked chickens on display	No	3	19	4.0376	0.6165; 19.3999	0.0407	8	19	1.5223	0.5334; 3.9794	0.36
	Yes	7	179	1.00	Reference	NA	39	141	1.00	Reference	NA
Customer touch cooked chicken when negotiating purchase	No	0	5	-	-	-	3	4	2.6000	0.3654; 15.8974	0.21
	Yes	11	193	1.00	Reference	NA	45	156	1.00	Reference	NA
Preparation style for cooked chicken	Bulk preparation	6	173	1.00	Reference	NA	36	131	1.00	Reference	NA
	Piecemeal preparation based on demand	5	25	5.7667	1.2747; 24.2904	0.0025	12	29	0.6641	0.2932; 1.5801	0.29

Annexure VIc: Univariable analysis of waste and disposal measures for association with risk of *E. coli* and coliform contamination

		E. coli					Coliform				
Waste-related variables	Variable	Case	Control	Odd ratio	Fisher's Exact at $CI_{95\%}$	P-value	Case	Control	Odd ratio	Fisher's Exact at $CI_{95\%}$	P-value
Disposal of waste	Left behind unwrapped	0	6	-	-	-	1	6	0.50	0.01-4.81	0.53
	Left behind wrapped	2	48	1.00	Reference	NA	13	39	1.00	Reference	NA
	Thrown into communal bin	11	132	2.00	0.41-19.16	0.37	32	114	0.84	0.38-1.93	0.65
	Taken home for disposal	0	3	-	-	-	1	2	1.50	0.02-30.84	0.75
Throw waste product on the processing floor	No	3	74	1.00	Reference	NA	18	69	1.00	Reference	NA
	Yes	8	125	1.58	0.36-9.50	0.51	30	92	1.25	0.61-2.59	0.51
Dispose waste into toilet drainage	No	9	186	1.00	Reference	NA	48	161	1.00	Reference	NA
	Yes	2	13	3.18	0.30-17.73	0.14	0	0	-	-	-
Dispose waste into processing drainage	No	11	155	1.00	Reference	NA	37	120	1.00	Reference	NA
	Yes	0	44	-	-	-	11	41	0.87	0.62-2.59	0.51
Other disposal methods	No	11	182	1.00	Reference	NA	44	144	1.00	Reference	NA
	Yes	0	17	-	-	-	4	17	0.77	0.18-2.54	0.65

Annexure VId: Univariable analysis of preventative measures for association with risk of contamination with *E. coli* and coliforms

		E. coli					Coliform				
Preventative measures	Variable	Case	Control	Odd ratio	Fisher's Exact at $CI_{95\%}$	P-value	Case	Control	Odd ratio	Fisher's Exact at $CI_{95\%}$	P-value
How often do vendor wash hand during sale operation	Frequently	4	107	1.00	Reference	NA	18	48	1.00	Reference	NA
	Intermittently	5	22	6.09	1.18-32.62	0.01	4	24	0.44	0.10-1.57	0.17
	Beginning and end of sale	4	60	1.78	0.319-9.91	0.42	25	89	0.75	0.35-1.62	0.42
Vendors use forks	No	3	22	1.00	Reference	NA	18	45	1.00	Reference	NA
	Yes	8	177	0.33	0.073-2.10	0.11	30	116	0.65	0.31-1.36	0.21
Knives are washed and disinfected before use	No	0	36	1.00	Reference	NA	14	30	1.00	Reference	NA
	Yes	11	163	-	-	-	34	141	0.56	0.25-1.27	0.12
Containers used to serve food also used to carry uncooked products	No	5	56	1.00	Reference	NA	7	42	1.00	Reference	NA
	Yes	6	143	0.47	0.11-2.04	0.22	41	119	2.07	0.83-5.87	0.10
Vendors wash hands when switching operations	No	0	6	1.00	Reference	NA	2	6	1.00	Reference	NA
	Yes	11	193	-	-	-	46	155	0.89	0.15-9.31	0.89
Other preventative measures applied	No	8	105	1.00	Reference	NA	35	104	1.00	Reference	NA
	Yes	3	94	0.42	0.07-1.80	0.20	13	57	0.68	0.30-1.44	0.28
Wear cap during processing	No	2	43	1.00	Reference	NA	14	41	1.00	Reference	NA
	Yes	9	156	1.24	0.24-12.21	0.79	34	120	0.83	0.39-1.85	0.61
Wear apron during processing	No	1	11	1.00	Reference	NA	2	11	1.00	Reference	NA
	Yes	10	188	0.59	0.07-27.67	0.62	46	150	1.69	0.35-16.17	0.50
Wear gloves during processing	No	0	11	1.00	Reference	NA	48	160	1.00	Reference	NA
	Yes	0	199	-	-	-	0	1	-	-	-
Use other protective clothing	No	1	7	2.74	0.06-24.98	0.35	47	153	2.46	0.31-111.31	0.39
	Yes	10	192	1.00	Reference	NA	1	8	1.00	Reference	NA
Wash hands before prepared food is served	No	7	74	3.94	0.86-24.17	0.04	26	71	1.57	0.78-3.19	0.17
	Yes	3	125	1.00	Reference	NA	21	90	1.00	Reference	NA

Annexure VIe: Univariable analysis of sanitary measures and personal hygiene for association with risk contamination with *E. coli* and coliforms

E. coli							Coliform				
Sanitary measures and personal hygiene	Variable	Case	Control	Odd ratio	Range (Fisher's Exact) at $CI_{95\%}$	P-value	Case	Control	Odd ratio	Range (Fisher's Exact) at $CI_{95\%}$	P-value
Mean distance from toilet to stall	31 to 50 m	3	20	1.00	Reference	NA	5	19	1.00	Reference	NA
	≤ 10 m	8	79	.6751055	.1449658; 4.321462	0.5843	25	64	1.4844	0.4652; 5.6258	0.48
	11 to 30 m	3	74	.2702703	.0341148; 2.20902	0.1050	14	65	0.8185	0.2380; 3.2878	0.73
	51 to 100 m	0	14	-	-	-	3	12	0.9500	0.1246; 5.9936	0.95
	> 100m	0	2	-	-	-	1	1	3.8000	0.0404; 313.5722	0.35
Toilet type	Flushing with hand wash basin	9	141	1.00	Reference	NA	32	124	1.00	Reference	NA
	Potable without hand wash	2	11	2.848485	.2654728; 16.3524	0.1957	7	6	4.5208	1.1947; 17.3237	0.006
	Flushing without hand wash basin	0	6	-	-	-	3	3	3.8750	0.4902; 29.9961	0.085
	Potable with nearby tap	3	28	1.678571	.2743462; 7.275851	0.4538	6	25	0.9300	0.2876; 2.5892	0.88
	Long drop or potable with distant tap or none	0	3	-	-	-	0	3	-	-	-
Toilet used by informal traders only	No	9	185	1.00	Reference	NA	42	145	1.00	Reference	NA
	Yes	2	14	2.9365	0.2805; 16.2132	0.1749	6	16	1.2946	0.3893; 3.7585	0.61
Toilet shared with the taxi rank	No	2	93	1.00	Reference	NA	20	61	1.00	Reference	NA
	Yes	9	106	3.9481	0.7844656; 38.2447	0.0640	28	100	0.8540	0.4226; 1.7494	0.64
Toilet shared in the petrol station	No	11	181	1.00	Reference	NA	42	145	1.00	Reference	NA
	Yes	0	18	-	-	-	6	16	1.2946	0.3893; 3.7585	0.61
Toilet shared in the shopping mall	No	11	162	1.00	Reference	NA	41	157	1.00	Reference	NA
	Yes	0	37	-	-	-	7	4	0.9746	0.3304; 2.5505	0.96
Toilet shared in a residential building	No	11	192	1.00	Reference	NA	47	150	1.00	Reference	NA
	Yes	0	7	-	-	-	1	11	0.8351	0.0166; 8.7154	0.87
Toilet has wash facility	Present	4	114	1.00	Reference	NA	35	116	1.00	Reference	NA
	Absent	7	85	2.3471	0.5727; 11.2468	0.1734	13	45	1.0444	0.4846; 2.3554	0.90
Vendors wear jewelleries	No	5	110	1.00	Reference	NA	37	135	1.00	Reference	NA
	Yes	6	89	1.4831	0.3631; 6.3444	0.5241	11	26	1.5437	0.6265; 3.5968	0.28

ANNEXURE VII: GOODNESS OF FIT TEST OUTPUT

***E coli* model**

```
Logistic regression                        Number of obs   =       201

                                   LR chi2(5)      =       18.44

                                   Prob > chi2     =      0.0024

Log likelihood = -38.950888                Pseudo R2       =     0.1914

------------------------------------------------------------------------------

       ecoli | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]

-------------+----------------------------------------------------------------

Flypopn >1 to <9 |      5.47   4.200583     2.21   0.027     1.21     24.64

Howofthdwa (intertmitent) |   8.45   5.955083     3.03   0.002     2.12     33.63

temprdytoeat <70 |   14.43   17.49619     2.20   0.028     1.34    155.32

diststalto 31-50 |   10.41   10.51673     2.32   0.020     1.44     75.40

------------------------------------------------------------------------------

estat gof, group(10)

Logistic model for ecoli, goodness-of-fit test

  (Table collapsed on quantiles of estimated probabilities)

  (There are only 7 distinct quantiles because of ties)

       number of observations =       201

             number of groups =         7

      Hosmer-Lemeshow chi2(5) =         2.42

                  Prob > chi2 =         0.7890
```

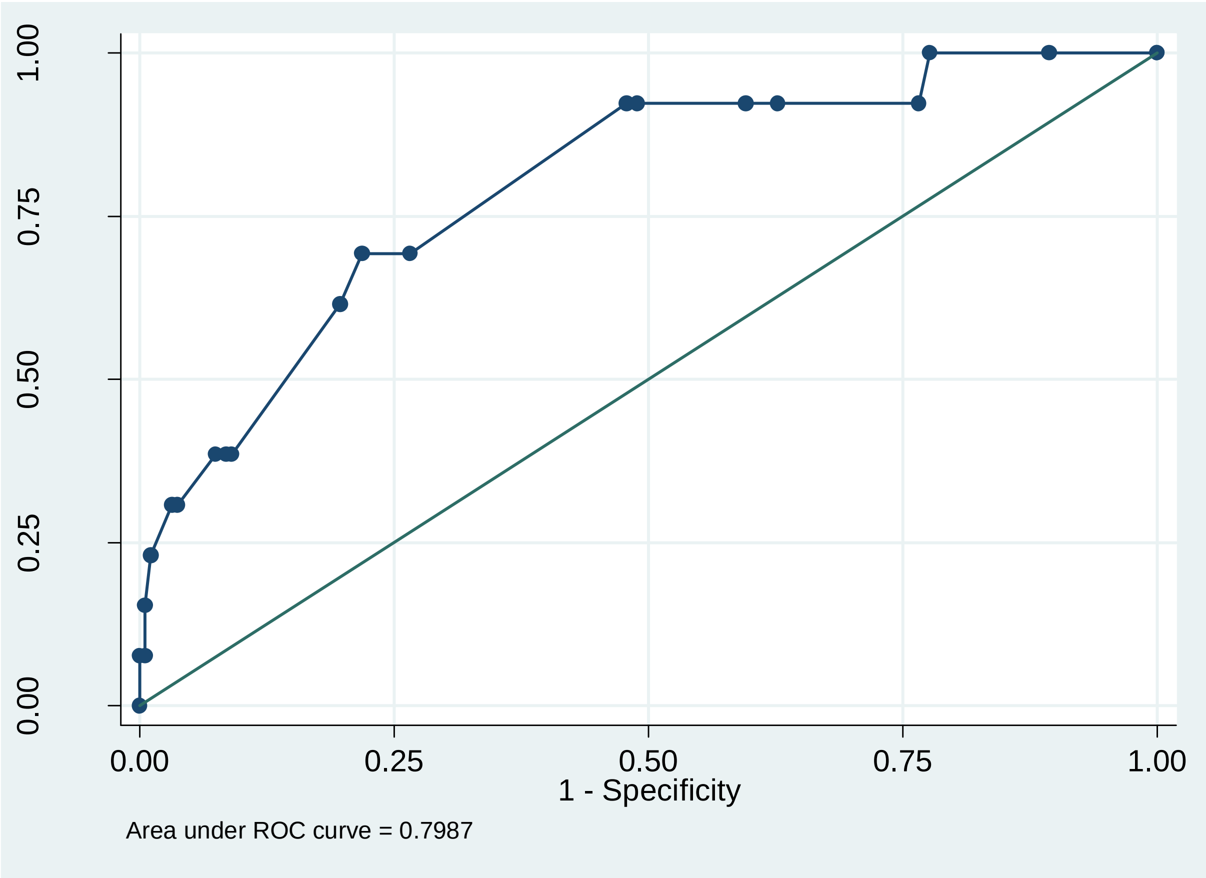
lroc

Logistic model for ecoli

number of observations =   201

area under ROC curve   =   0.7987

. estat gof, group(10)



***Coliform* model**

Logistic regression Number of obs = 208

LR chi2(4) = 19.40

Prob > chi2 = 0.0007

Log likelihood = -101.44488 Pseudo R2 = 0.0873

----

coliforms | Odds Ratio Std. Err. z P>|z| [95% Conf. Interval]

-------------+--

washdb4serv | 1.57 .0762824 -2.76 0.17 0.78 3.19

toil type port without | 6.26 5.237626 3.28 0.003 1.87 20.90

howofthdwa_Begin/end | 7.88 .155141 -1.96 <0.020 1.44 43.15

----

estat gof, group(10)

Logistic model for coliforms, goodness-of-fit test

(Table collapsed on quantiles of estimated probabilities)

(There are only 4 distinct quantiles because of ties)

number of observations = 208

number of groups = 4

Hosmer-Lemeshow chi2(2) = 0.13

Prob > chi2 = 0.9376

estat ic

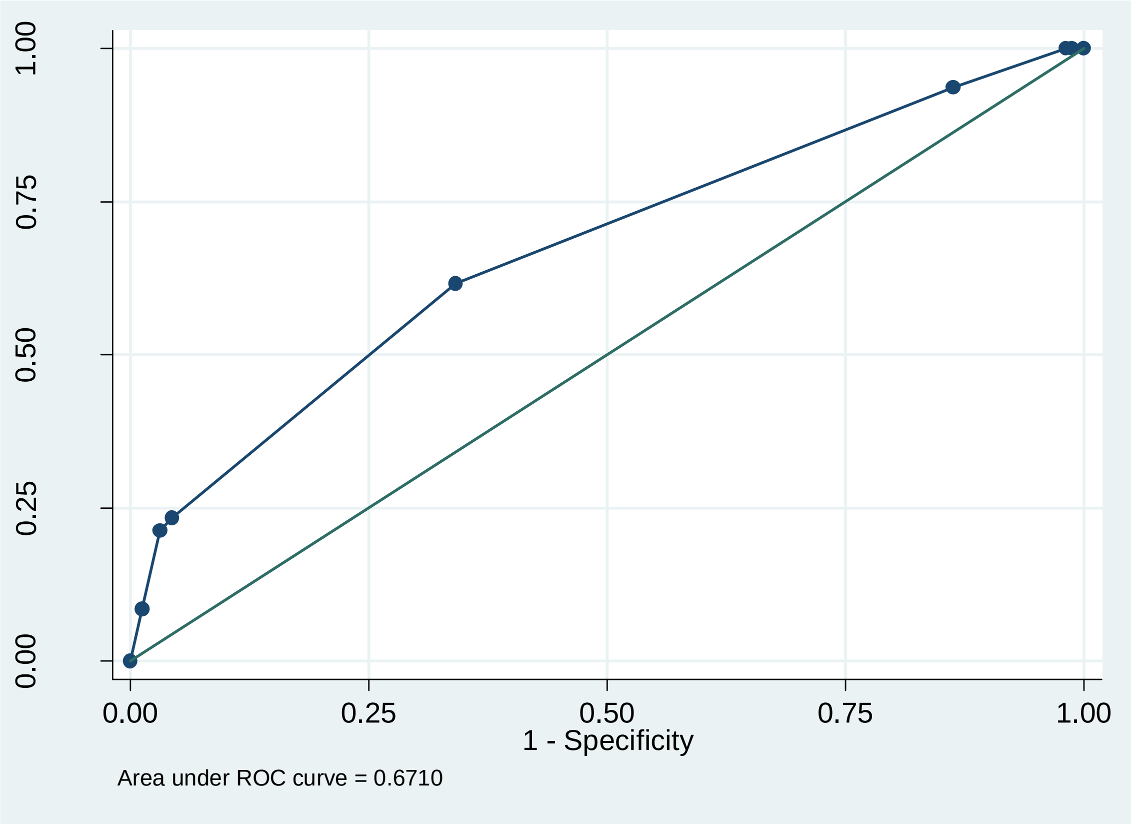
Model	Obs	ll(null)	ll(model)	df	AIC	BIC
.	208	-111.1449	-101.4449	5	212.8898	229.5775

lroc

Logistic model for coliforms

number of observations = 208

area under ROC curve = 0.6710



ANNEXURE VIII: PUBLICATION FOOD CONTROL

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Investigation of the food value chain of ready-to-eat chicken and the associated risk for staphylococcal food poisoning in Tshwane Metropole, South Africa

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ABSTRACT

The objective of the study was to better understand the informal markets for ready-to-eat (RTE) chicken in Tshwane Metropole, Gauteng Province, South Africa, and in particular the links between the formal and informal sector. As part of this, we assessed the risk of a common food poisoning (staphylococcal) through consumption of RTE chicken sold by informal vendors. We used participatory risk assessment, a novel approach to understanding food safety in data scarce environments to collect information. Structured interviews and focus group discussions with informal vendors ($n = 237$) were conducted to understand poultry value chains for informal RTE chicken, business operation and hygiene practices. Samples ($n = 100$) of RTE were collected from informal vendors in six major taxi ranks. *Staphylococcus aureus* counts were determined using 3M™ Petrifilm™ plates. Data collected in this present study plus information obtained from reviewing of literature, were used to develop a stochastic risk model. The number of colonies which were too numerous to count (TNTC) was artificially modeled.

A mapping of the informal food value chain revealed that there are four possible value chains and that chicken spilled over from formal to informal markets. The prevalence of *S. aureus* in RTE chicken samples (44%; 90% CI: 36.1%–52.2%) was high. The mean *S. aureus* counts in the ready to eat chicken was $10^{3.6}$ (90%CI: $10^{3.3}$–$10^{3.9}$), and the risk of purchasing chicken of unsatisfactory quality (>10^3 cfu/g) was 32.9% (90%CI: 25.5%–40.4%). The probability of food poisoning due to consumption of RTE chicken contaminated with staphylococcal enterotoxin was estimated to be 1.3% (90% CI: 0%–2.7%). Sensitivity analysis showed that the probability of *S. aureus* having the enterotoxin gene was the most sensitive parameter for food poisoning. This was followed by *S. aureus* concentration in RTE chicken and lastly the prevalence of *S. aureus* in ready-to-eat chicken.

This study demonstrates the existence of a strong link between formal and the informal market. In view of the low risk observed, the relevant authorities in Tshwane should continue to support the informal sale of RTE chicken. However, there is still a need for provision of hygiene training to reduce the concentration levels of *S. aureus* on the RTE chicken, and to promote the sale of safer affordable source of protein for the large urban poor population in South Africa. This will also help secure the opportunities for employment associated with the trade.

1. Introduction

The great majority of poor people in developing countries obtain food from informal or "wet markets" but these are often neglected by food safety authorities and little is known about their impacts on public health (Grace et al., 2008; Grace, Makita, Kang'ethe, & Bonfoh, 2010). In South Africa, the first comprehensive study into the safety of street vended foods was conducted at a major taxi rank

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in Johannesburg central business district (Masupye & von Holy, 1999). This has been followed by a few other studies, with the most recent study conducted in Bloemfontein, Free State Province (International Union of Microbiological Societies, International Committee on Food Microbiology and Hygiene (IUM-ICFMH) and South Africa, 2005; Lues, Rasephei, Venter, & Theron, 2006). Some of these studies have suggested opportunities for improving safety of street vended foods (von Holy & Makhoane, 2006), and other studies indicate the importance and the benefits associated with the informal sector (Steyn, Labadaries, & Nel, 2011).

Food that is contaminated, irrespective of whether it has unacceptable levels of pathogens or chemical contaminants or other hazards, poses health risks to consumers and economic burdens on individual communities and nations (KZN-DOH, 2001; Mensah, Mwamakamba, Mohamed, & Nsue-Milang, 2012); but quantifying these burdens is essential for rational resource allocation. Previous studies done in South Africa which focused on detecting the presence of hazards could not predict the risk to human health. However, quantitative risk assessment (QRA) can predict health risk along with margins of uncertainty. This information is important to decision makers in developing countries who have to allocate scarce resources across competing health priorities. The application of QRA has been limited in Africa because of the high requirements of data and skilled personnel. In the past decade, participatory risk assessment has been developed as a method that integrates participatory techniques, long used in rural and urban development, with conventional risk assessment (Grace et al., 2008, 2010). Although participatory risk assessment has been applied to several food safety problems in Africa (Appiah, 2010; Grace et al., 2008, 2010), this is the first study on its use in South Africa to address a key hazard of informally marketed food.

Staphylococcal food poisoning (SFP) is one of the most common food-borne diseases that affects hundreds of thousands of people each year worldwide (Asao et al., 2003; Hazariwala et al., 2002; Hennekinne, De Buyser, & Dragacci, 2012; Ji-Yeon et al., 2013). According to the Centers of Disease Control and Prevention (CDC), USA, 240, 000 illnesses with 1000 hospitalizations and 6 deaths associated with staphylococcal food poisoning occur annually (Tallent, DeGrasse, Wang, Mattis, & Kranz, 2013). The role of poultry in SFP has been recognized, and in one study 6.8% of the 236 outbreaks were associated with poultry (Hennekinne et al., 2012; Ji-Yeon et al., 2013).

The cause of SFP is staphylococcal enterotoxins produced by enterotoxigenic strains of coagulase-positive staphylococci (CPS), among which *Staphylococcus aureus* is the main cause with other species such *Staphylococcus intermedius* very occasionally implicated (Hennekinne et al., 2012). While there is evidence for coagulase negative strains being enterotoxigenic, only CPS have been evidenced in food poisoning incidence. In view of this, the present study considers CPS *S. aureus* the main causative agent described in SFPOs (Hennekinne et al., 2012).

In milk *S. aureus* starts producing SE when the population density reaches about $10^{6.5}$ cfu/ml (Fujikawa & Morozumi, 2006). However in low a_w conditions, such as in salted RTE chicken, *S. aureus* accumulate low molecular weight compounds called compatible solutes, which stimulate not only growth but also toxin synthesis (Qi & Miller, 2000). In food, a slightly lower population density of 10^6 CFU/g of *S. aureus* is able to produce sufficient amounts of SEs to cause SFP (Min et al., 2013), but SFP is in many cases confirmed by recovery of at least 10^5 *S. aureus* from food remnants (Hennekinne et al., 2012). Therefore, the present study considers that SFP from consumption of RTE chicken occurs when the chicken is contaminated with *S. aureus* with its concentration higher than 10^5 cfu/g.

The motivation for this study is based on following facts: there is a paucity of data on street foods in South Africa, and to our knowledge, there is no study that has looked at the links between the formal and informal food sectors. Furthermore, quantitative microbial risk assessment (QMRA) of the risk of SFP through consumption of RTE sold by informal traders in Tshwane, South Africa has not been conducted.

2. Material and methods

2.1. Study sites

The study was conducted in Tshwane Metropole with a population of 2,345,908. The Metropole includes Pretoria, the capital city of South Africa.

2.2. Study design

Participatory risk assessment (Grace et al., 2008) was applied in the present study following the procedure of the Codex Alimentarius Commission system framework (CAC (Codex Alimentarius Commission), 2010). Participatory methods are well suited where there is a need to improve understanding of issues and yet data is scarce. Methods that can be employed in such situations include interviews and focus group discussions, visualizations, matrix scoring and proportional piling (Catley & Berhanu, 2003).

2.3. Sampling strategy

Past studies on informal markets in South Africa show that informal food vendors tend to concentrate in and around taxi ranks and railway stations (Lues et al., 2006). In view of this, taxi ranks and railway stations with higher vendor concentration were targeted. Given that the location and population of vendors is continually fluctuating in these informal markets, it was difficult to design a formal sampling frame. Therefore six larger clusters were purposively selected out of a possible 13 markets identified in the Tshwane Metropolitan. The markets that were sampled in this study include; Marabastad, Mabopane, Soshanguve, Belle Ombre/Prinsloo, Mamelodi and Sausville (Fig. 1). With the exception of Belle Ombre that serves a nearby railway and a bus station as well as a taxi rank, the rest are located at taxi ranks. Where the railway stations and taxi ranks are in close proximity to each other, the market is more closely related with the taxi rank. In that case one informal market serves both the railway station and the taxi rank.

While the markets/taxi ranks formed clusters, the units of concern were the vendors selling RTE chicken. All vendors encountered in each of the selected clusters/markets were invited to participate in the study. Verbal and written consent was obtained from each vendor prior to purchase of RTE chicken samples for microbial analysis. Sampling was conducted in April and May 2011 and in total, 100 samples were collected from six markets. The sample size was determined basing on the expected prevalence and the available budget.

2.4. Enumeration of bacteria

Enumeration of *S. aureus* was performed on 3M™ Petrifilm™ Staph Express Count Plate (3M, st. Paul. Mn, USA), which uses a selective and differential medium for *S. aureus* (Merck, 2007), chromogenic modified Baird–Parker medium, following instructions by the manufacturer. When the numbers of colonies on a plate was greater than 150, the count was recorded as too numerous to count (TNTC). In cases where background flora (colonies with non-red-violet color i.e. black colonies or blue-green colonies) were encountered on the plates, as recommended by the manufacturer, 3M Petrifilm Staph Express Discs (3M, st. Paul.

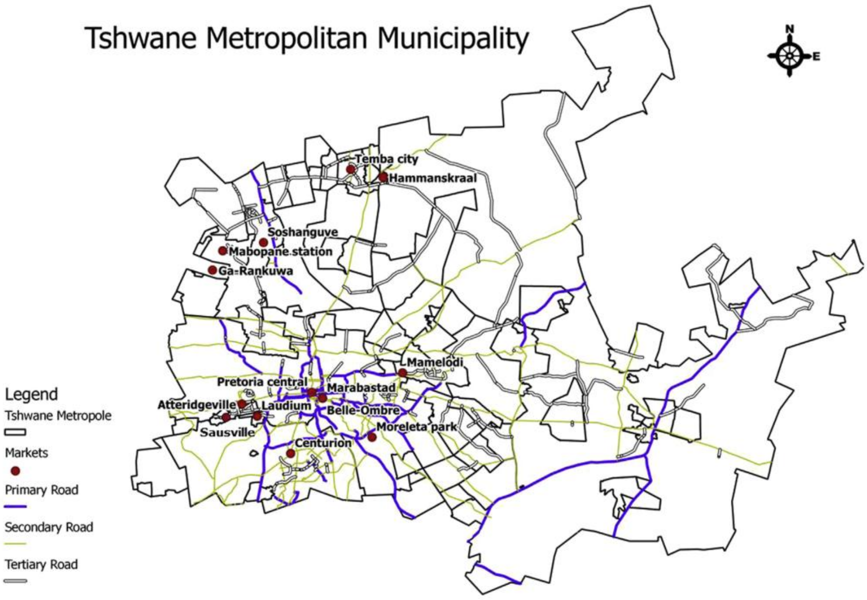

Fig. 1. A map showing the informal markets studied in Tshwane Metropolitan City, South Africa.

Mn, USA) were used to confirm the colony as *S. aureus*. In the present study, only the colonies of coagulase positive *Staphylococcus* (*S. aureus*, *S. intermedius* and *Staphylococcus hyicus*), which produces deoxyribonuclease (DNase) were counted as *S. aureus*.

The prevalence of *S. aureus* in ready-to-eat chicken meat was compared among the six markets studied using Generalized Linear Models (GLMs) with binomial errors in statistic software R version 2.14.2.

2.5. The value chain and sales survey

The value chains of informal RTE chicken from producer to sales were studied in the focus group discussions and informal interviews. Using structured questionnaires, operation of business and hygienic practice were studied among 237 informal vendors in the 13 taxi ranks. Verbal and written consent was obtained from each vendor who participated in the survey prior to collection of information. The information gathered from interviews was triangulated by focus group interviews.

2.6. Relative quantities of ready-to-eat (RTE) chicken sales

In order to estimate the overall risks of SFP from consumption of RTE chicken in entire Tshwane Metropole, the prevalence at the markets studied, should be weighted by the quantity of sales at the respective six taxi ranks. As rigorous random sampling could not be

Table 1
Parameters used to model the risk of staphylococcal poisoning due to consumption of ready-to-eat chicken sold in informal markets in Tshwane Metropolitan area, South Africa.

Parameter	Model	Source of information
Probability of chicken contaminated with *S. aureus* purchased in a market studied *i*: $Pcont_i$	$Beta(s_i + 1, n_i - s_i + 1)$ where s_i is the number of samples contaminated with *S. aureus* in a market *i* n_i is the number of samples tested for *S. aureus* in a market *i*	Survey data
Relative quantity of sales in a market *i*: $Sales_i$	$\frac{Q_i}{50}$ Where Q_i is the number of pebbles placed to represent the relative quantity of sales in a market *i*	Proportional piling
Log_{10}Cfu/g of *S. aureus* when the bacteria were too numerous to count: *Logtn*	*Uniform*(4.2, 8.5)	Minimum: the largest Log_{10} Cfu/g observed was 4.19 in a survey Maximum: Fujikawa and Morozumi (2006)
Probability that the bacteria concentration of a sample contaminated with *S. aureus* exceeds $10^{6.5}$ cfu/g: *Pexc*	Average of *If* (Non-parametric bootstrap of Log_{10}Cfu/g including *Logtn* >6.5, 1, 0)	*Logtn* Survey data
Probability of *S. aureus* having SE gene: *Pgene*	$Beta(s + 1, n - s + 1) = Beta\ (110, 183)$	Of 291, 109 *S. aureus* had SE gene (Arcuri et al., 2010)

achieved in informal markets, proportional piling, a participatory technique commonly used in participatory rural appraisals (PRA) (Mariner & Paskin, 2000) to establish the significance of animal and public health problems was adopted for the present study. Three key informants who know the markets studied well and were willing to participate in this section of the study. As prescribed (Mariner & Paskin, 2000), fifty pebbles were distributed among the six markets studied by the key informants to reflect the numbers of customers that patronize the respective markets. These pebbles were then counted to determine the relative quantities of ready-to-eat chicken sales.

2.7. Risk assessment

Microbiological food safety risk assessment involves hazard identification, hazard characterization, exposure assessment and risk characterization (CAC, 2010). Hazard identification (the identification of the agent which can cause adverse health effects to humans) and hazard characterization (the qualitative and/or quantitative evaluation of the adverse health effects associated with the hazard), were described in the introduction section.

Exposure assessment was conducted using parameters collected through the field work and literature review (Table 1). In the present study, given the high toxicity of SE, which causes SFP with very little amount, such as 20–100 ng for SEA (Asao et al., 2003), probability of exposure to the hazard was modeled to be an exposure to the population of *S. aureus* with more than10^5 CFU/g as a proxy, because *S. aureus* may produce SE under such concentration (Hennekinne et al., 2012), as explained in the introduction. For *S. aureus* to produce SEs, they must be carrying the enterotoxigenic genes. However, the proportion of *S. aureus* isolates with enterotoxigenic genes varies considerably between different populations. For example, the proportions of *S. aureus* having enterotoxigenic genes have been reported to be 25% by Le Loir, Baron, and Gautier (2003), 37.5% by Arcuri et al. (2010), and 57% by Normanno et al. (2005). In the present paper, the proportion reported most recently, and the middle value among them, 37.5% by Arcuri et al. (2010) was used. Below formula shows the model of exposure to SE, *Pingest* as the probability of ingesting SE:

$$Pingest = PexcPgene\sum_{i-1}^{6} Pcont_i Sales_i$$

Where *Pexc* is the probability that the bacterial concentration of a sample contaminated with *S. aureus* equals to or exceeds 10^5 cfu/g, *Pgene* is the probability of *S. aureus* having the SE gene, $Pcont_i$ is the probability of purchasing RTE chicken in a market studied i (six markets were studied) and $Sales_i$ is the relative quantity of sales in a market i.

The additive set of the multiplication of $Pcont_i$ and $Sales_i$ is calculating the overall prevalence of *S. aureus* in ready-to-eat chicken in Tshwane, weighing the difference of prevalence among the markets, although it was statistically not significant (see Results section).

In order to model the bacterial concentration in RTE chicken contaminated with *S. aureus*, the Log_{10} cfu/g values of contaminated samples were bootstrapped. However, there were samples that exceeded the countable limit i.e. colonies were TNTC. Therefore, a Uniform distribution was used to model the Log_{10} cfu/g of such samples by considering a value between the slightly greater value than the maximum countable value for the tool used in the survey, and the maximum *S. aureus* population at the static phase of the bacterial growth (Fujikawa & Morozumi, 2006).

Risk characterization was carried out by combining the exposure assessment and dose–response relationship. The dose–response relationship was modeled to be 100% given ingestion of enterotoxin; the probability of illness (*Pillness*) was modeled to be identical to *Pingest*. There is a limitation in this dose–response relationship in that the proportion of SE with emetic ability and proportion of susceptible population were not modeled due to lack of information in literature.

In the present study, the growth of *S. aureus* between the times of purchase and consumption was not taken into account in modeling, because according to participatory assessment in the markets, consumers do not preserve the product and consume it within a short period of time. The model was constructed using @Risk version 5.7 (Palisade Corporation, USA) and Monte Carlo simulation was run for 10,000 iterations.

According to the NSW Food authority of Australia (2009), food that is contaminated with 10^3 cfu/g or more should be considered unsatisfactory. Based on this, the risk of purchasing an unsatisfactory quality of chicken (*Punsatis*), was assessed using the formula below.

$$Punsatis = \sum_{i-1}^{6} Punsatis_i Sales_i$$

Where $Punsatis_i$ is the probability that RTE chicken sold in a market i is contaminated with more than 10^3 cfu/g of *S. aureus*. $Punsatis_i$ was modeled using the Beta distribution.

Sensitivity analysis was performed using the uncertainty parameters listed in Table 1. Monte Carlo simulation was run for 1000 iterations.

3. Results

3.1. Semi-quantitative value chain of ready-to-eat chicken (RTE)

From focus group discussions and structured interviews using questionnaires, four types of food value chains – one formal chain, two formal-informal hybrid chains and one purely informal chain – were identified for RTE chicken sold in the informal markets in Tshwane (Fig. 2). The formal value chain starts from commercial poultry farms and mainly provides broilers. The broilers are slaughtered and processed in formal abattoirs and distributed to butchers, supermarkets and retail shops where consumers purchase (to the left side of Fig. 2). In the first formal-informal hybrid value chain, spill over from formal to informal chain occurs at the retailer level. Here the informal vendors purchase raw chicken meat from butchers, supermarkets and retail shops. They then cook and sell the chicken in informal markets. The second hybrid chain enters into the informal chain from commercial producers of off-layers (spent hens). These are either bought by the middle men who slaughter them informally before selling carcasses to vendors. Alternatively, the informal food vendors buy these spent hens and do the slaughtering. The purely informal value chain on the other hand starts from backyard small scale poultry producers. The chicken is directly sold to informal vendors who slaughter and cook them before selling them to their customers in informal markets (Fig. 2).

Because of lack of cooperation from the informal vendors for the information of the specific source of chicken which they purchase, complete quantitative value chain was not established; however, the categories of the sources were provided in the informal interviews. Table 2 shows the sources of chicken from where informal vendors purchase. Multiple answers were allowed in this question and 24 of 234 vendors (10.3%) who provided answers purchased from more than two source categories. Majority of informal

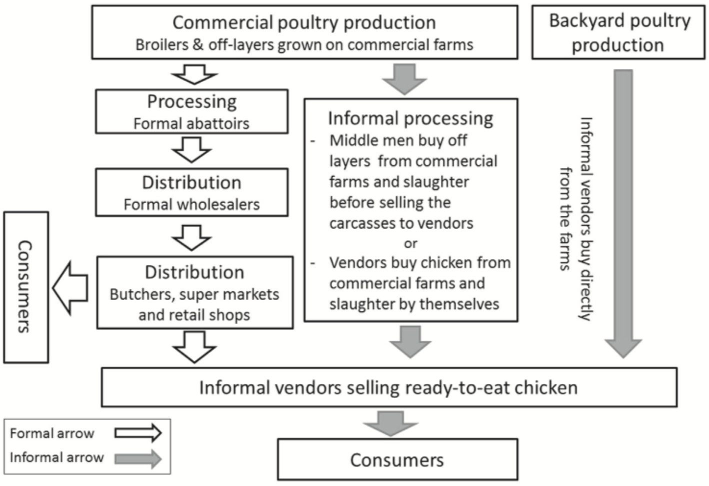

Fig. 2. Informal value chains of ready-to-eat chicken sold in informal markets in Tshwane Metropole, South Africa.

vendors (217/237, 91.6%) purchased processed or slaughtered chicken and supermarkets were the most common source (79.3%) overall. Thirty vendors (12.7% of 237) purchased live birds and slaughter by themselves. Thirteen vendors (5.5% of total respondents, 237) purchased both live and non-live birds. The most common sources of live birds were middle men (25/30, 83.3% (10.5% of 237)) and only a few vendors purchased live birds at farms (3 vendors from small scale and 2 from commercial farms).

In addition, proportional piling technique (Mariner & Paskin, 2000) was adopted to the quantify structure of markets surveyed (Table 3). Consequently it was determined that Mamelodi contributed most (32%) while Belle-Ombre/Prinsloo contributed the least (6%) of the RTE chicken sold in the six markets surveyed.

3.2. Hygiene of informal chicken sales

Interviews were conducted with 237 vendors in total. The majority of vendors started business in the morning, with 87.3% (207) saying that they started before the morning rush hour, 9.7% (23) started a bit later, while 7 did not provide clear answers to the question as to when they start. The time when they close the business was diverse; 12 vendors (5.1%) indicated that they close after the morning rush hour, 102 vendors (42.6%) closed after the evening rush hour and 100 (42.2%) closed only when all the RTE chicken had been bought.

The majority of vendors (227/234, 97%) prepare chicken at the vending site. Only seven vendors (3%) indicated that they prepared the chicken from home and bring it to the market as RTE chicken. The rest of the vendors (three vendors) did not answer this question.

In terms of access to water, of the 76 vendors who responded, 42 (55.2%) said they used water from a tank, while 24 (31.6%) said that they brought water from home, and 10 vendors (13.2%) obtained water from sources such as bore hole, toilets nearby and from garages close by. Only one respondent indicated that water used at the vending site was sourced from a river.

Hygiene assessment of the operations revealed that out of 112 vendors who responded, 95 (84.8%) brought soap from home, while three of the vendors said that their customers used soap that is available at a toilet facility close by. Only 14 vendors (12.5%) indicated that soap was not available at the vending site for use by their customers to wash their hands.

Out of 237 vendors who replied to the question on plates used to serve their customers, 209 (88.2%) said that they served RTE chicken on a washable plates, while 10 (4.2%) served using disposable plates, and 7 (3%) used a plastic paper bag to serve RTE chicken. The remaining 11 vendors preferred not to answer the question.

Exposure to training was very low. Only seventy five (31.6%) of the vendors interviewed indicated that they had received some training on food hygiene.

Table 2
Source of chicken from where informal vendors purchase ($n = 237$).

Source category	Respondents	Percentages out of 237 vendors
Source of processed chicken	217	91.6
Supermarket	188	79.3
Middle men (source not known)	20	8.4
Slaughtered at farm	12	5.1
Retail shop/butcher	6	2.5
Abattoir	2	0.8
Source of live birds	30	12.7
Middle men (source not known)	25	10.5
Small scale backyard farm	3	1.3
Commercial farm	2	0.8
Answer not provided	3	1.3

Table 3
Proportional piling results showing the relative quantities of ready-to-eat chicken sales in the informal markets studied.

Markets	Pebbles	Relative quantity of sales
Marabastad	11	0.22
Mabopane	9	0.18
Shoshanguve	7	0.14
Bell Ombre/Prinsloo	3	0.06
Mamelodi	16	0.32
Sausville	4	0.08
Total	50	1

Table 4
The prevalence of *S. aureus* on ready-to-eat chicken and unsatisfactory quality chicken samples (*S. aureus* greater than 10^3 cfu/g) according to the markets.

Markets	Sample	*S.aureus* isolated	Prevalence (%)	Unsatisfactory	Prevalence (%)
Marabastad	21	9	42.9	4	19.0
Mabopane	11	5	45.5	4	36.4
Soshanguve	21	8	38.1	2	9.5
Belle Ombre/ Prinsloo	12	4	33.3	4	33.3
Mamelodi	24	12	50.0	10	41.6
Sausville	11	6	54.5	5	45.5
Total	100	44	44.0	29	29.0

3.3. Microbial test results

Table 4 shows the microbiological test results. The overall prevalence of *S. aureus* was 44%. There was no significant difference in the prevalence among the markets (DF = 5, $p = 0.885$). The overall prevalence of unsatisfactory quality chicken was 29.0%. These are RTE chicken contaminated with *S. aureus* at a concentration greater than 10^3 cfu/g (Table 3). Likewise, there was no significant difference observed between the markets (DF = 5, $p = 0.097$). The mean cfu/g observed on RTE chicken was $10^{3.6}$ (90% CI: $10^{3.3}$–$10^{3.9}$).

3.4. Risk assessment

3.4.1. Exposure assessment

The prevalence of *S. aureus* in ready-to-eat (RTE) chicken samples was 44% (90% CI: 36.1%–52.2%) and the probability of purchasing unsatisfactory quality of chicken (>10^3 cfu/g, *Punsatis*) from an informal RTE vendor who sales RTE chicken was 32.9% (90% CI: 25.5%–40.4%). Mean $\log_{10}$ cfu/g of *S. aureus* on the ready-to-eat contaminated chicken was 3.6 (90% CI: 3.3–3.9). The probability of ingesting enterotoxin from consumption of RTE chicken (*Pingest*) was estimated to be 1.3% (90% CI: 0%–2.7%).

3.4.2. Risk characterization

The risk of SFP due to the consumption of ready-to-eat chicken sold in informal markets in Tshwane Municipality (*Pillness*) was estimated to be identical to *Pingest*, 1.3% (90% CI: 0%–2.7%). This probability is limited to the consumers of the RTE chicken in informal markets and is not a reflection of the risk to the whole population in the country.

Table 5 shows the results of the sensitivity analysis. The most sensitive factor in the risk assessed was probability of *S. aureus* having SE gene. The second sensitivity factor was Log_{10}Cfu/g of *S. aureus*, when the bacteria were TNTC (*Logtn*), and the third was Log_{10}Cfu/g of *S. aureus* of a contaminated sample. The latter includes, *Logtn*. These parameters represented the concentration of *S. aureus*, and they were more sensitive than the prevalence of *S. aureus* in ready-to-eat chicken.

4. Discussion

The present study provides the first map of the value chain for RTE chicken sold in the informal markets in Tshwane Metropol of South Africa. This can help establishing traceability of RTE chicken sold in the informal markets in Tshwane, although tracing informal part of this value chain was found to be challenging in the present study. Where traceability is possible, communication linkage for identifying, verifying and isolating sources of noncompliance to agreed standards and customer expectations can be implemented (Opara, 2003).

An important finding of the study of the food chain was the cross-over between formal and informal sectors. We did not observe extensive spillover from the formal to the informal sector in any published studies in sub Saharan Africa. This is probably related to the fact that unlike other parts of Africa, in South Africa supermarkets have gained a sizeable share of the fresh produce market (Louw, Jordaan, Ndanga, & Kirsten, 2008). It can therefore be postulated that if supermarket proliferation takes place in the rest of Africa, as is predicted, this model and its associated risks are likely to become more common. Furthermore, the linkage between the formal and informal food sector in the value chain shows that this informal sector provides a market opportunity for commercial poultry production. It is reported that such formal-informal spill over business represents millions of US dollars daily (Codjia, 2000).

Value chains were also found to be short: that is with few steps and a relatively short time between producer and consumer. This is good for food safety in relation to the RTE chicken. It is known that value chains that are multi-layered with poor visibility tend to be very vulnerable (Roth, Tsay, Pullman, & Gray, 2008).

The high prevalence of *S. aureus* (44%) on the RTE chicken sold in informal markets and the high unsatisfactory quality (RTE chicken with more than 10^3 cfu/g) is consistent with previous studies that reported that bacterial concentration on informally-sold RTE chicken ranged from 10^2 to 10^3 cfu/g (Lues et al., 2006).

Very importantly, this study also highlighted the fact that high prevalence of *S. aureus* does not translate into a high risk of illness due to ingestion of chicken with potentially enterotoxigenic *S. aureus* on RTE chicken bought from informal markets in Tshwane Metropole. The risk of illness due to consumption of ready-to-eat chicken sold in informal markets was found to be low (1.3% (90% CI: 0%–2.7%). This finding can be attributed to the fact that bacteria concentration of *S. aureus* on the chicken rarely exceeds 10^5 cfu/g (threshold for *S. aureus* required to produce sufficient toxins to cause SFP). The risk reported here is consistent with findings of earlier studies, which although purely hazard identification studies

Table 5
Sensitivity analysis results shown in the order of the sensitivity to the risk assessed.

Order	Parameters	Values at 50th, 5th & 95th percentiles	Mean probability of staphylococcal poisoning (%) at 50th, 5th & 95th percentiles
1	Log_{10}Cfu/g of *S. aureus* when the bacteria were too numerous to count: *Logtn*	6.4 (4.4–8.3)	0.52 (0.52–0.92)
2	Log_{10}Cfu/g of *S. aureus* of a sample contaminated	3.5 (2.3–7.3)	0.69 (0.69–1.08)
3	Probability of *S. aureus* having SE gene: *Pgene*	0.38 (0.33–0.42)	0.70 (0.62–0.79)
4	Prevalence of *S. aureus* in Mamelodi market	0.50 (0.34–0.66)	0.70 (0.63–0.78)
5	Prevalence of *S. aureus* in Mabopane market	0.46 (0.25–0.68)	0.71 (0.65–0.77)
6	Prevalence of *S. aureus* in Marabastard	0.43 (0.27–0.60)	0.70 (0.65–0.76)
7	Prevalence of *S. aureus* in Soshanguve	0.39 (0.23–0.56)	0.71 (0.67–0.74)
8	Prevalence of *S. aureus* in Sausville	0.54 (0.32–0.75)	0.70 (0.68–0.73)
9	Prevalence of *S. aureus* in Belle Ombre/Prinsloo	0.35 (0.17–0.57)	0.70 (0.69–0.72)

concluded that informal foods in South Africa have a low microbiological risk (Martins, 2006). However, as the present study does not take into account the proportion of SEs with emetic property and the proportion of susceptible population. Moreover, the microbiological tests could not show the true bacteria concentrates for the samples with TNTC. These are clear limitations and our assessment may be over estimating the risk. Too often, decisions on food safety are based on the presence of hazards rather than risks to human health. This can reduce accessibility of food to poor people and restrict income generating opportunities for poor producers and value chain actors without any commensurate benefit to human health.

Although, the risk of illness from *S. aureus* was not found to be high, there were several poor practices, which should be addressed as they might lead to contamination with other hazards. Unhygienic behaviors observed in the present study are consistent with previous studies as reflected in the following quote (Lues et al., 2006): "*hand and dish washing is usually done in one or more bowls, sometimes without soap; waste water and garbage are discarded in the street, providing food and harborage for flies and rodents; foods are usually not effectively protected from dust and flies that may harbor food borne pathogens, and temperature violation is common*".

The low direct access to tap water (water is not drawn directly from municipal taps but is delivered to the site via containers that might be of doubtable hygiene) can be attributed to the fact that the municipal taps are located a distance away from the vending sites. As a result vendors in most cases rely on water delivered to their site in containers. This is a concern as it has the potential of increasing the likelihood of contamination of water with hazards including *S. aureus* if the containers used to deliver and hold the water at the vending site are not cleaned regularly. This can in turn lead to contamination of the RTE chicken with hazards.

Since *S. aureus* on chicken carcasses or raw chicken can be eliminated by cooking, the contamination observed occurs because of poor post-cooking food handling. Previous studies reported that *S. aureus* is found on hands and finger tips of more than 50% of healthy individuals (IFT, 2004; Le Loir et al., 2003; Lues et al., 2006). However, focus group discussions conducted in the present study revealed that times between cooking and selling and between purchase and consumption were usually short. This has also been confirmed by previous studies (Campbell, 2011; Martins & Anelich, 2000).

Sensitivity analysis suggested that a control measure to decrease bacterial concentration would be most effective to improve food safety, as the biological variability, proportion of *S. aureus* with enterotoxigenic genes cannot be controlled. According to the guidelines for safe street foods, cleaner environment, separation of raw and cooked foods, thorough cooking, refrigeration, use of safe water and raw materials and raised awareness are recommended (INFOSAN, 2010). This is important because staphylococci are ubiquitous in the environment and can be found in the air, dust, sewage, water, environmental surfaces, humans and animals (Hennekinne et al., 2012). Provision of hygiene training, improvement of infrastructure and improved direct access to municipal tap water (minimizing or eradicating the practice of delivering of water in containers at the vending site), has the potential to improve on the safety or RTE chicken sold by informal vendors. Control of temperature is another effective measure to prevent SFP (IFT, 2004). However, achievement of this in informal markets is questionable.

Although the risk of SFP was low, there are many other microbiological and chemical hazards to consider and the importance of hygiene improvement should not be neglected. The low risk estimated is good news for both the vendors and customers as RTE chicken sold in informal markets is an affordable source of nutrition for a large population and is a good source of income as well for the informal vendors. Moreover the present study was able to show that the informal RTE chicken business offers opportunities for employment for those who cannot get employed in the formal sector. In view of this, consideration should be given to how to benefit from informal food businesses can be maximized instead of viewing them with suspicion as a source of food that is not safe. A holistic understanding of the risk, economics and sociological role played by informal vendors of RTE chicken is the key to improve food safety, job creation and poverty alleviation associated with poultry value chains in South Africa.

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ANNEXURE IX: APPROVAL FOR RESEARCH PROJECT

Ref: V010/10

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15 March 2010

Prof CME McCrindle
Department Paraclinical Sciences
(cheryl.mccrindle@up.ac.za)

Dear Prof McCrindle

PROTOCOL V010/10: PARTICIPATORY RISK ANALYSIS OF CHICKEN MEAT SOLD IN THE INFORMAL MARKETS IN PRETORIA GAUTENG SOUTH AFRICA- *JW Oguttu*

I am pleased to inform you that the abovementioned protocol was approved by the Research Committee. Kindly note that, if there are animal ethical issues involved in the project, the protocol needs to be approved by the Animal Use and Care Committee as well before you may commence with the project.

Please take note of the attached document.

Kind regards

NIESJE TROMP
SECRETARY: RESEARCH COMMITIEE

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