Quantitative Exposure Assessment to Listeria species through Consumption of Polony Imported from South Africa in Lusaka, Zambia

BY

SIAMATE SAKALA JAMES

Masters of One Health Food Safety

A research report submitted in partial fulfilment of the requirements for the degree of Master of One Health Food Safety Science

The University Of Zambia
School of veterinary medicine
Department of disease control
Lusaka

January 2019

DECLARATION

I, **Siamate Sakala James** do hereby declare that the contents of the research report being submitted herein are my original work and they have not been previously submitted to any University for the award of a degree or any other qualification.

Signature……………………………………. Date…………………………………

……………………….	………………….	/……/……/……
………………………..	…..………………..	/……/……/…..…
…………………………	……………………	/……/……/…….
Supervisor(s)	Signature	Date

Examiner ------------------------------ Signature --------------------- Date ---------------------

Examiner ------------------------------ Signature --------------------- Date ---------------------

ABSTRACT

This study aimed to quantitatively assess the Risk of Exposure to Listeria through consumption of ready to eat meat and meat products (RTE) imported from South Africa in Lusaka Province of Zambia. A swift quantitative microbiological risk assessment (sQMRA) simulation model was used to analyse data, which was collected through a literature review. A literature review was guided by the eleven questions, which make up the Microsoft Excel-based sQMRA model.

Results showed that the average serving portion for Polony in Lusaka District was 30g per day. The probability of exposure to Listeria species through consumption of Polony was relatively low. At a serving portion of 30g, the concentration of 1000 cfu/g, infectious dose 50 (ID50) of 10^5, two people in a population of 1,765,488 would get ill, representing a probability of 0.00011 percent. Similarly, at a serving portion of 30g, the concentration of 100 cfu/g, infectious dose 50 (ID50) of 10^5 and 10^7, no person in a population of 1,765,488 would get exposed, representing a probability of zero.

This study concludes that the risk of exposure to *Listeria spp* through consumption of RTE meat and meat products imported from South Africa in Lusaka district, was extremely low, mainly due to the nature of the product (Polony), which it is well done at factory prior to supply in supermarket and the serving size portion was very minimal. Since cross-contamination accounted for 100% high risk of exposure to *Listeria spp.*, it is important to sanitise the slicing equipment every time they are used to slice Polony. A proper hygienic system can prevent the cross-contamination with *L. monocytogenes*, which is a fundamental risk factor in Polony facilities.

DEDICATION

This work is especially dedicated to my dearest wife Petronella Chilobe Hibajene Siamate and my children Chimwemwe, Tatiana, Tician, Luyando, and Lumuno who shared with me the challenges and hardships during my studies at the University of Zambia. I thank them all immeasurably for their moral support and understanding when I could not avail myself as much as I should have done during the period of my studies. To you all, this is the reward of your endurance.

Acknowledgements

My humble gratitude goes to God Almighty, for the protection throughout my studies and granting me life in abundance, strength to push forward when my spirit was low and lacked motivation. I owe a deep and sincere debt of gratitude to the Ministry of Fisheries and Livestock-Veterinary Department at the National Livestock Epidemiology Information Centre (NALEIC), and Central Statistical Office (CSO). I Further wish to thank the Africa Centre of Excellence for Infectious Diseases for Human and Animals (ACEIDHA), for financial and logistical support towards this study and my supervisor, Dr. Chisoni Mumba for the knowledge imparted in me during my study at the University of Zambia under School of Veterinary Medicine. His valuable suggestions and professional guidance enriched this study at every stage. Sincere debt of gratitude to my employer Ministry of Fisheries and Livestock through the District Fisheries and Veterinary Coordinator and Executive officer of Kafue Veterinary office for permitting me to undertake this study.

Furthermore, I would like to express my heartfelt appreciation to all the lecturers in the Department of Disease Control and indeed academic members of staff of the School of Veterinary Medicine for their input. Finally, a big thank you to my late mum and dad Aliness and Lawrence Siamate (MYSRIP) for guiding me to be a hard-working person. Last but not the least; I would like to thank all data clerks in the organisations I collected my secondary data.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

COMESA: Common Market for Eastern and Southern Africa

CFSANFDA: Center for Food Safety and Applied Nutrition Food and Drugs Association

CFU: Colony Forming Unity

CDC: Centre for Disease Control

CAC: Codex Alimentarius Commission

DONs: Disease Outbreak News

DRGS: Directorate of Research and Post-Graduate

FAO: Food and Agriculture Organization

FDA: Food and drug administration

FSANZ: Australia New Zealand Food Standards

HIV: Human Immunodeficiency Virus

JANE: Journal Author, Name Estimator

MoH: Ministry of Health

NALEIC: National Livestock Epidemiological Information Centre

NZ: New Zealand

NHD: National Health Department

RTE: Ready to Eat

SQMRA: Swift Quantitative Microbiological Risk Assessment

SSA: Sub-Saharan Africa

SADC: Southern Africa Development Countries

UN: United Nations

WHO: World Health Organization

DEFINITION OF TERMS

- **Listeriosis:** The disease caused by infection with Listeria monocytogenes (CFSANFDA, 2003).
- **Risk:** The likelihood of the occurrence and the magnitude of the consequences of exposure to a hazard to human health (CFSANFDA, 2003).
- **Risk Assessment:** The scientific evaluation of known or potential adverse health effects resulting from human exposure to hazards (CFSANFDA, 2003).
- **Processed meat:** is defined as any meat preserved by smoking, curing or salting, or with the addition of chemical preservatives; examples include bacon, salami, sausages, hot dogs or processed deli or luncheon meats (Pepperoni et al., 2018).

CHAPTER ONE

1.0 BRIEF BACKGROUND

1.1 Introduction

The consumption of meat in developing countries has continuously gone up Increasing to 26kg in 2000 unlike earlier in the 1960's which was at 10kg average annual per capita consumption, its estimated to reach 37kg around 2030 (Heinz and Hautzinger, 2007).

Meat and meat products provide or rather contribute significantly to the intake of energy and Protein that are important micronutrients to the body when consumed. However, "the consumption of animal-derived foods is highly variable among and within populations, hence the impact thereof on human health is also diverse''(Evans and Leighton, 2014).

Zambia is a member of Southern Africa Development Community (SADC) countries thus it is bound to promote trade in the region where most of the South African products, such as ready to eat meat and meat products are imported. However, recently in South Africa, there was an outbreak of Listeriosis through consumption of ready to eat meat and meat products contaminated with *Listeria monocytogenes* bacteria. The outbreak affected 674 people and claimed 183 lives in South Africa (Anonymous, 2017). This development prompted Zambia, Mozambique, Namibia, Malawi, and Botswana to have all South African processed ready to eat meat and meat products recalled after a deadly listeria outbreak. The responsible business entities issued a recall on their ready-to-eat meats following listeria being found in their colonies (Rayser, E.T., 1999; Anonymous, 2017)

Listeria monocytogenes is widespread, but the human illness is almost always food-borne. "Listeriosis is a rare but serious illness, mainly affecting elderly people, pregnant women, and their unborn fetuses or newborn babies, and people with serious underlying disease''. Listeria monocytogenes is a food-borne pathogen that can contaminate processed meats products and has caused outbreaks in several nations in which processed meats were the vehicle. Due to its ecology, the control of this organism in ready-to-eat meats is difficult''(Friesema et al., 2015).

1.2 Problem Statement and Justification

Lusaka and Copperbelt are essential towns that consumed many processed meat and meat products due to the fast-growing population (Hichaambwa, 2012).

Recently there was an outbreak of Listeriosis in South Africa, with ready to eat meat and meat products being the source of the disease. This suspected outbreak prompted the Government of the Republic of Zambia (GRZ) to impose a ban on imported processed ready to eat meat and meat products from South Africa. The ban was put in place in order to prevent the spread of listeriosis, and most South African ready to eat meat and meat products were recalled from all the chain stores around the country that had in stock South African ready to eat meat and meat products (MOH-Zambia, 2018). Furthermore, an unpublished research study by Kasaro,(2018) isolated Listeria species from ready to eat meat products from both open and closed markets in Lusaka, Zambia. This indicates that listeria species are present and pose a risk to consumers in Lusaka.

Identification of food products associated with Listeriosis is difficult, because of the ubiquitous and psychotropic (cold-tolerant) nature of *L. monocytogenes*, the long and varying incubation period and severe illness are mainly restricted to vulnerable populations (Friesema et al., 2015). Outbreak investigations can provide information about risk products, in the case of Listeriosis, outbreaks are often associated, with errors during food production, such as contaminated slicing machines followed by opportunities for growth of the pathogen (Friesema et al., 2015).

The following were the research questions for the study; was there a risk of exposure to listeriosis from consumption of South African ready to eat meat and meat products? What was the probability of exposure? To answer these questions the study aimed to quantitatively assess the risk of exposure to Listeria species through consumption of ready to eat meat and meat products imported from South Africa.

In this case, the research was more bias to Lusaka province where mostly ready to eat meat and meat products in shopping malls where imported into Zambia from South Africa and sold in supermarkets; Polony was chosen due to its convenience and demand by consumers. Hence, the risk of exposure to Listeria was likely to occur. However, there was no known risk of exposure to Listeria through consumption of ready to eat meat and meat products imported from South Africa in Lusaka Province of Zambia. In March 2018 the ministry of health, Zambia, through the permanent secretary-technical services issued an alert notification on outbreak of Listeriosis in South Africa, this prompted the government to instruct the provincial health office to conduct and investigate the availability of the products and withdraw them from retail chain stores with immediate effect (MOH-Zambia, 2018).

The suspected outbreak of listeriosis despite the availability of ready to eat meat and meat products from South Africa did not affect any single person in Lusaka. However, the importation bans and shelf recall of South Africa ready to eat meat and meat products were not based on scientific risk assessment. Was there a risk (among people of Lusaka) of exposure to listeria through consumption of South African ready-to-eat meat and meat products? This study also seeks to answer this question. Both South Africa and Zambia did not conduct a risk assessment on the outbreak of listeriosis after imposing a ban, so as to conduct a risk assessment if there was a risk of exposure to listeria through consumption of South African ready to eat meat and meat products within South Africa and other countries like Namibia (WHO-DONs, 2018) which reported a confirmed case. Therefore, the findings of this study are very cardinal for decision-making in food safety and improving trade policy formulation and implementation.

1.3 AIM OF STUDY

1.3.1 Main Objective

To quantitatively assess the Risk of Exposure to Listeria through consumption of ready to eat meat and meat products imported from South Africa in Lusaka Province of Zambia.

1.3.2 Specific Objective

- To assess the risk of exposure to *Listeria spp* through consumption of South Africa imported ready to eat meat and meat products.
- To quantify the number of people that would get exposed to listeria through the consumption of ready to eat meat and meat products.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The general overview of meat and meat products

Processed meat is defined as any meat preserved by smoking, curing or salting, or with the addition of chemical preservatives; examples include bacon, salami, sausages, hot dogs or processed deli, Polony or luncheon meats (Pepperoni et al., 2018).

2.2 The general overview of Listeriosis

Six different species comprise the genus Listeria; these are; *L. grayi* and *L. innocua* are considered non-pathogenic, while *L. seeligeri, L. ivanovii,* and *L. welshimeri* are rarely causing human infection. *L. monocytogenes* is the most important species with respect to human health (Gilbert et al., 2009).

"Listeriosis is caused by the Gram-positive ubiquitous bacterium *Listeria monocytogenes,* which was first recognised as a foodborne pathogen in the early 1980s. Since its discovery, it has been identified as a cause of major foodborne outbreaks (Maertens de Noordhout et al., 2014). Unlike most other foodborne pathogens, *L monocytogenes* can grow in food with fairly low moisture content and high salt concentration. Most importantly, *L monocytogenes* grows at refrigeration temperatures, by contrast with many other foodborne pathogens. This ability to persist and multiply in the food environment makes *L monocytogenes* especially difficult to control" (Maertens de Noordhout et al., 2014).

Some studies conducted have alluded that, Listeria monocytogenes remains a significant cause of foodborne illness. Even though the illness is in most cases expressed as a mild, febrile illness, it can also present as systemic (invasive) listeriosis with more severe symptoms and high hospitalisation and case fatality rates. Although the incidence of listeriosis is low in the general population despite the wide distribution of the microorganism in the environment, other researchers have confirmed that they are relative of a high frequency of isolation in foods (Buchanan et al., 2017).

The study by Buchanan et al., (2017) further attributed the incidence of systemic listeriosis to be much higher in susceptible populations, including pregnant women, the elderly and individuals with compromised immune systems. In some studies, conducted in New Zealand, researchers confirmed that only improved control measures put in place starting in the 1990s greatly reduced the prevalence of *L. monocytogenes* in many food categories, particularly in meats and meat products. However, the rate of illness has remained constant during the last decade. Furthermore, recent outbreaks have challenged the conclusions of existing risk assessments and the understanding of the influence of virulence.

2.3 Sources of Listeria Monocytogenes

2.3.1 Human

Gilbert *et al.*, (2009) stated that *L. monocytogenes* is carried asymptomatically in the faeces of 2-6% of the population. Person-to-person spread (other than mother to fetus) is infrequently reported but has been recognised. *L. monocytogenes* is shed in high numbers (≥ 104/g) in the faeces of infected people.

2.3.2 Animal

In the study conducted in Australia and New Zealand by Gilbert *et al.*, (2009) objected that it may cause disease in animals, however, Veterinarians were originally considered to be an "at risk" group, but the World Health Organization has stated that animals are not considered to be important as direct sources of human infection. Occasional incidents of cutaneous infection in livestock handlers have been reported. *Listeria spp*. Present in animal faeces can contaminate milk or red meat.

2.3.3 Food

Meat and meat products were considered as potential contaminants. Listeria may be present in cooked foods as a result of post-cooking contamination. The study identified that the risk posed was likely to be greatest in ready-to-eat cooked foods with long shelf lives on which L. monocytogenes can grow and has been isolated from a wide variety of ready-to-eat and raw foods in NZ studies (Gilbert et al., 2009), however, little information is available regarding numbers of cells, it is considered to be present in low numbers (<10/g) on most foods, although it has been detected at numbers far in excess of this (Gilbert et al., 2009).

2.3.4 Environment

The study was done by Beumer et al., (1996)on the environment found that *Listeria species(spp.)* was widespread in the environment including soil, vegetation, water, and sewage. Beumer further expressed that, in domestic environments, 101/213 (47.4%) houses in the Netherlands had Listeria spp. Present (37%) and bathroom drains (27.2%) were most frequently contaminated, and enumeration of dishcloths and washing-up brushes found 104 cfu/object. From kitchen sinks, refrigerator vegetable compartments and toothbrushes, 103 cfu/object was obtained. Domestic refrigerators have been shown to harbour *L. monocytogenes.*

2.3.5 Processed Ready-to-Eat Meats and meat products

Ready-to-eat meats are products whose processing includes one or more pathogen control steps to render the products safe for consumption without further processing or cooking by the consumer. The processed meats considered in this category principally include the red meats pork, beef, and lamb, or mixed species products. Poultry products are also included in this risk profile, as ready-to-eat poultry products will usually be processed, sold and consumed in the same way as red meat products (Gilbert et al., 2009). The study further explained the vulnerability of the processed meats and products he stated "Ready-to-eat foods are vulnerable to recontamination with *L. monocytogenes* during handling following listeriocidal treatment. This may occur during further processing or packaging at the manufacturing facility, during processing (e.g., slicing) and packaging at the retail level, or in the domestic environment. The organism's ability to grow at low temperatures during any subsequent period of storage before consumption increases the risk. *L. monocytogenes* may be present in the environment of many food-processing and retail food facilities, and its complete"(Gilbert et al., 2009).

2.4 Bacteria (*Listeria Monocytes)*

The Gram-positive bacterium *Listeria monocytogenes* is capable of habiting the soil as well as the cytosol of mammalian cells, and as a result is an environmental pathogen which poses a continuous threat to food safety. This saprophyte is a facultative intracellular pathogen that is capable of causing severe invasive disease in susceptible human populations. *L. monocytogenes* infections are most commonly associated with foodborne outbreaks involving soft cheeses, deli meats, and produce, but sporadic cases of the disease can also occur (McMullen and Freitag, 2014).

2.5 Bacterial Contamination of processed meat and meat products

Various investigators have reported that listeria in meat and meat products is influenced by many factors, including animal rearing, geographical differences, handling and slaughtering methods as well as storage conditions such as temperature control. Studies have shown that listeria was long known as an animal pathogen, but recently it has been recognised as an important foodborne agent in human disease (Johnson et al., 1990).

RTE are considered the important food-borne source of human *L. monocytogenes* infections in the EU. The risk for human health arises from exposure to *L. monocytogenes* in such foods and particular foods containing *L. monocytogenes* exceeding the level of 100 cfu/g, the investigators have further assumed that "widespread distribution of L. monocytogenes and other Listeria spp. in nature and an association with domestic livestock makes the occasional presence of these bacteria on raw meats almost unavoidable. Contamination of ready-to-eat meat products with L. monocytogenes poses a special threat to public health because of the organism's ability to grow at refrigeration temperatures and its pathogenicity within certain segments of the population"(Johnson et al., 1990).

2.6 Routes of Contamination in RTE Meat Products

Further processing after heat treatment is vulnerable and exposes products to cross contamination. Food and Drug Administration (FDA) Food Code (FDA, 2007) defined cross contamination as the unintentional transfer of microorganisms, chemical contaminants (including allergens) or any foreign matter from food, person or object to another food product. It usually occurs from raw foods to RTE or between products that contain allergens and those that do not. Cross-contamination can cause food spoilage or foodborne illnesses when viable microorganisms and toxins are transferred to products. There are three major routes through which cross-contamination can occur: food to food, equipment, and food contact surfaces to food and people to food (FDA, 2007).

2.6.1 Listeria on equipment and food contact surfaces to food

In the study conducted by Lin et al., (2006) stated that residues on equipment and other contact surfaces might provide cross-contamination opportunities. He further emphasised that RTE products may become contaminated with bacteria and or allergens due to improper washing and sanitation of equipment and utensils, use of dirty clothes to clean surfaces and equipment as well as the use of contaminated packaging material. To prove their findings, they conducted research that showed that Listeria can survive on processing equipment such as meat slicers and can be transferred from a contaminated slicer onto meats where it will grow and survive.

Mustapha, (2007) supported their findings through similar research which indicated that E. coli and Listeria remained viable on air-dried stainless-steel surfaces for considerable periods of time. Lin et al., (2006) pointed out that in order to prevent this type of contamination, suggested the use of separate equipment for different product categories, clean and sanitise all surfaces and equipment after each task/batch.

2.7 Listeria in humans

Listeriosis is commonly presenting as food poisoning is caused by a bacterium known as *Listeria monocytogenes*. In humans it generally presents, symptoms that include fever, muscle aches and sometimes nausea or diarrhoea. In severe cases, the bacteria may spread to the bloodstream and nervous system with symptoms such as headaches, stiff neck, confusion, loss of balance and convulsions. It may be fatal (MOH-Zambia, 2018).

2.8 Risk of exposure

In conducting the exposure assessments, the researchers acknowledged and advised the importance to include a distribution of *L. monocytogenes* in the food at the point of consumption (frequency of contamination) and also the amount consumed (number of servings per year and size of servings) (WHO/FAO/UN, 2004).

Another study was done in the united states of America by (CFSANFDA, 2003) to assess the contamination levels of listeria they first highlighted that exposure is a function of the quantity of food consumed and the level of contamination in that food. CFSANFDA,(2003) further alluded to the contamination level in food at consumption as an important parameter in evaluating public health, most of the available contamination data pertain to foods sampled at retail stores. CFSANDA,(2003) commended necessity to develop estimates of the frequency and amount of each serving of the contaminated foods likely to be consumed in the United States, as well as the Listeria monocytogenes levels in those foods. Limitations inherent in food consumption data and the paucity of contamination data for certain foods made certain assumptions necessary to develop the estimates. Scholars in Australia Predicted average risk of Listeriosis for serving of Australian processed meats was 1.00×10^{-8} (Ross et al., 2009).

According to the information accessed from the website,www.thebump.com,(2018) it was reported by the Centers for Disease Control and Prevention (CDC) that, there are approximately 1,600 cases of listeriosis in the United States each year. However, only about one in seven cases or about 200 cases per year occurs in pregnant women, out of nearly 4 million pregnancies every year.

An expert consultation by the codex committee on food hygiene (CCFH) was in favour of a full farm-to-fork risk assessment models which was objected by WHO/FAO/UN,(2004), instead suggested that, the focus of the exposure assessment models was to account for changes in the frequency and extent of contamination in the food between retail marketing and the point of consumption, which simplified the modelling and reduced the model uncertainties, thereby decreasing the ranges around the final risk estimates (WHO/FAO/UN, 2004)(WHO/FAO/UN, 2004).

Research experts of (WHO/FAO/UN, 2004) in the USA developed models to describe the growth or decline of L. monocytogenes in RTE meat and meat products between the time of purchase and consumption. Calculating the numbers of *L. monocytogenes* consumed also required consideration of how much of and how often the food is eaten (i.e., the size and the number of servings) (WHO/FAO/UN, 2004). RTE foods are a broad and diverse food category, prepared and stored in different ways and under different conditions, some of which support the growth of L. monocytogenes and others that do not support growth at specific storage and shelf-life conditions (WHO/FAO/UN, 2004)

2.9 Thresholds and models designs for Listeriosis

Fsanz,(2001) devised Guidelines for the Microbiological Examination of Ready-to-eat Foods they advise that detection of *L. monocytogenes* in foods prepared specifically for ‘at risk' populations should be considered "potentially hazardous." These guidelines apply only at the end of production or at the wholesale stage of distribution (Table 1).

Table 1: FSANZ Guidelines for *L. monocytogenes* in ready-to-eat foods. Foods with a long shelf life stored under refrigeration should have no *L. monocytogenes* detected in 25g. Source: *Guidelines for the microbiological examination of ready-to-eat foods* (FSANZ, 2001).

Microbiological quality (cfu per gram unless other stated)				
Test	Satisfactory	Marginal	Unsatisfactory	Potentially hazardous
L. monocytogenes	Not detected in 25g	Detected but<10^2		>10^2

Microbial risk assessments based on dose-response modelling provide additional insight into the public health implication of *L. monocytogenes* concentration. According to food consumption information from the national nutrition surveys in New Zealand (Ministry of Health, 2003), it was found that ham was the most commonly consumed processed ready-to-eat meat product in New Zealand, accounting for more than 50% of all servings consumed. In a survey of pre-packaged ham samples, 104 samples from sixteen brands were tested (Wong et al, 2005). All samples were held at 4°C and tested at the end of their shelf-life. Less than 7% of samples contained Listeria, and the single sample that contained *L. monocytogenes* was at a count of 50 CFU/g.

Analysis of animal trial and outbreak data for the dose-response relationship of invasive listeriosis has produced models for both "at risk" and "not at risk" populations. As a means of demonstrating how the model would be used, the estimate was based on the literature by Farber and Ross,(1996), that the ID10 and ID90 for *L. monocytogenes* are 10^7 and 10^9 CFU for healthy adults and 10^5 and 10^7 CFU for high-risk individuals, respectively, Farber and Ross, (1996) used this dose-response relationship to estimate the probability of illnesses based on data for both the consumption of RTE and their contamination by *L. monocytogenes.*

The study done by Chen et al., (2003) described very low probability of disease at low doses and prompted analysis that showed that foods containing more than 100 CFU/g were responsible for more than 99% of listeriosis cases and confirmed that ingestion of large numbers of cells (107 or more) is necessary for *L. monocytogenes* to cause the febrile gastroenteritis version of listeriosis.

A study conducted in Poland the researcher Kołakowska et al, (2011) pointed at the main route of acquisition of Listeria as through the ingestion of contaminated food products. He further said that an important element of the *L. monocytogenes* pathogenesis infection is an affiliation with the high-risk group of immune-compromised patients; infants or pregnant women, when infected by this microorganism can lead to miscarriage. He further said listeriosis could appear in the form of sepsis, infection of the nervous system or local abscesses and another form of listeriosis affect gastrointestinal tract infection-noticed in case of food poisoning outbreak (Kołakowska et al, 2011).

A study conducted in Europe by (Ricci et al., 2018) used the general quantitative microbiological risk assessment (gQMRA) model to assess the risk of listeria in RTE meat and meat products, used a conceptual model. The gQMRA model was developed to reflect a generic RTE food consumed in the EU/EEA. Contamination of the RTE food at the moment of consumption was based on consumption data, growth properties, packaging, and empirical data on initial *L. monocytogenes* concentrations of the considered foods. The gQMRA model can be updated with additional food categories when data become available. Based on this gQMRA model, 92% of invasive listeriosis cases for all age-gender groups are attributable to doses above 105 CFU per serving. Assuming an average serving size of 50 g, this would correspond to an average *L. monocytogenes* concentration in RTE foods above 2,000 CFU/g at the time of consumption. Still, a smaller proportion of cases are associated with the more frequently occurring RTE foods having a *higher L. monocytogenes* prevalence and lower *L. monocytogenes* levels. The frequency of exposure (i.e., the prevalence of *L. monocytogenes* in RTE food) over 25 years old appears to increase with age for both genders, due to differences in consumption patterns (Ricci et al., 2018).

2.10 Global

Listeria monocytogenes is a food-borne pathogen that can contaminate processed meats and has caused outbreaks in several nations in which processed meats were the vehicle. Due to its ecology, the control of this organism in ready-to-eat meats is difficult (Ricci et al., 2018).

Similar study conducted in France by Pouillot *et al.*,(2009) on salmon said since 1999, surveillance of human listeriosis in France was made mandatory to notify health authorities, it was estimated the period between 1999 to 2000 recorded the annual incidence of diagnosis of listeriosis declined from approximately 4.5 cases/million persons, which relates to 265 cases/year to approximately to 3.5 cases/million persons during 2001 to 2005 which relates to 220 cases/year. In Europe, the tendency of annual incidence of listeriosis increased to 4.6 cases/million persons that are 290 cases /year.

Pouillot *et al.*,(2009) in his research objected to Europe's rare case of listeriosis he said "Although rare, listeriosis is very severe and has a high case-fatality rate, it accounts to 14%-34% of foodborne disease-related deaths in France is second to salmonellosis. He further observed that England was at 11% and united states was at 28% of the case fatality rate, with this observation he concluded that the foods that were associated with Listeriosis transmission mostly were ready to eat foods that support *L. monocytogenes* growth.
In the study conducted in New Zealand, they disclosed that *L. monocytogenes* was detected in a range of New Zealand ready-to-eat meats, commonly consumed ready-to-eat meat was ham, with a prevalence of approximately 3.5% (Gilbert et al., 2009).

An in-depth study conducted in Australia where they compared the prevalence of listeria with New Zealand they found contamination and consumption prevalence to be similar and made a conclusion that ready-to-eat meats were responsible for up to 40% of cases of listeriosis, based on a prevalence of contamination similar to that found in New Zealand. This attribution is in good agreement with the results of an expert elicitation for New Zealand, which estimated that 85% of listeriosis was foodborne and of this foodborne component 54% was due to transmission via processed ready-to-eat meats (Gilbert et al., 2009).

The earlier study conducted in France by Pouillot et al.,(2009) presented in the first model of Risk Analysis for the assessment of exposure to *Listeria monocytogenes* from cold-smoked salmon. In the present study done by the same researchers Pouillot et al.,(2009)expressed that the exposure model output was combined with an internationally accepted hazard characterisation model, adapted to the French situation, to assess the risk of invasive listeriosis from cold-smoked salmon consumption in France in a second-order Monte-Carlo simulation framework. In another study by Ross et al., (2009) done in Australia used a Stochastic model using @Risk simulation method, the risk assessment was undertaken in accordance with Codex Alimentarius Commission (CAC) (Bemrah et al.,1998).

The risk analysis and assessment of listeriosis has triggered a number of debates amongst the debates going on globally indicate that most outbreaks of *L.monocytogenes* have been reported in the United States of America (USA), Europe, Canada and less extent in Australia and New

Zealand study by Mataragaset al.,(2010) alluded that, *L.monocytogenes*/RTE combination constitute high risk for specific groups of population (elderly, infants, immunosuppression adults, and children) whereas, the rest of the population, healthy adults the Incidence is 0.3-10 cases per million persons in Europe, USA, and Australia. Children are low-risk population hence the risk is medium(mild or asymptomatic). Therefore, Mataragas et al., (2010) study concentrated on the high-risk population since they are very susceptible to listeriosis.

2.11 Regional

Listeriosis outbreak did not spare the region on the southern part of Africa, World Health Organisation Disease Outbreak News (WHO-DONs, 2018) reported in their findings through the disease outbreak news that, In South Africa, an outbreak of listeriosis, a serious foodborne disease, has been ongoing since the start of 2017. Between 1 January 2017 through 14 March 2018, a total of 978 laboratory-confirmed listeriosis cases were reported to the National Institute for Communicable Diseases (NICD) from all provinces. It was reported that majority of cases came from three provinces: namely Gauteng, with581 (59%) cases, Western Cape, recorded 118 (12%) cases, and KwaZulu-Natal provinces had 70 (7%) cases, with the remaining cases coming from the other provinces in South Africa. The outcome of illness recorded 674 patients, of whom 183 (27%) of them died (who-dons,2018).

This case fatality rate was comparable to other recorded listeriosis outbreaks worldwide. Most of the cases were persons who have higher risks of a severe disease outcome, such as neonates, pregnant women, the elderly and immunocompromised persons. In this outbreak, 42% of the cases were neonates who were infected during pregnancy or delivery (WHO-DONs, 2018).

WHO-Health Emergency Programme,(2017) in its findings further reported that the first documented reports of outbreaks in South Africa were in 1977 (14 cases) where reported and in 2015 (seven cases) were equally reported, since then sporadic cases have occurred throughout the country. However, since October 2017, the Department of Health has seen a marked increase in the number of cases. This increase and the associated deaths are worrying, particularly in the face of South Africa’s high prevalence of HIV infection.

WHO-Health Emergency Programme,(2017) in other independent findings they pointed at some factors such as flooding in Gauteng Province and KwaZulu-Natal, and the severe drought in the Western Cape, which might have as well exacerbated the situation, with associated problems with safe food storage and general hygiene. Street food vendors are common across South Africa and poorly regulated, and many people lack access to electricity and thus refrigeration. World Health Organisation (WHO) advised authorities to act swiftly and efficiently to prevent the outbreak from spreading further. WHO reported Namibia to have a confirmed case of listeriosis? They advised on the case and other possible cases around be adequately investigated, and the implicated food sources identified. WHO reported that currently, “12 out of 15 countries have recalled the implicated processed meat products, and banned imports of the same, while three out of these countries have additionally banned imports of other food products? WHO continues to monitor the travel and trade measures taken by countries in relation to this outbreak and their compliance with requirements under the International Health Regulations”(WHO-DONs, 2018).

2.12 Local

Apart from recent unpublished work by Kasaro (2018), there is currently, there is no information about listeriosis in Zambia, but information prevailing in New Zealand says it is present due to similar settings as the temperature is favourable for the bacteria to proliferate and cause disease (Buchanan et al., 2017). Zambia being a landlocked country has no direct links to ports instead it is at the receiving end of most products that are imported into the country including ready-to-eat meat and meat products from South Africa. South Africa is one of Zambia’s top five trade partners in the southern African development community (SADC) (BoZ, 2017) following a number of South African business entities operating in Zambia this entails that the possible risk of experiencing a disease outbreak is high.

This prompted the minister of health to issue a ministerial statement in parliament to inform the nation about the outbreak in South Africa, he pointed at some of the key issues on the measures put in place to prevent the outbreak reaching Zambia, he informed the nation through parliament, he said, "a team of experts led and coordinated by the Zambia National Public Health Institute has been constituted to urgently address the concerns of the country because Zambia imports many food products listed as risky from South Africa"(MOH-Zambia, 2018).

He further aligned his speech to the legislation that was guiding the activities undertaken which were, Using the provisions of the Public Health Act Cap 295 and the Food and Drugs Act Cap

303, an immediate ban on imports of hazardous foods including processed meats, dairy products, vegetables and fruits from South Africa was instituted. Furthermore, in order to ensure compliance with the regulatory health requirements, the following activities were undertaken:

(a) Existing stocks of the named risk foods were removed from the shelves and stored for disposal; (b) health inspectors conducted inspections to ensure compliance with the ban; (c) the points of entry where instructed to seize all suspected risky products."(MOH-Zambia, 2018).

2.13 Exposure assessment studies

In another study conducted by Schlundt et al.,(2003) for fao/who risk assessment research stated that "exposure assessment is the estimation of how likely it is that an individual or a population will be exposed to a pathogen via food and what numbers of the pathogen are likely to be ingested." The study further emphasised that three types of information are usually necessary to do this assessment: information on the prevalence and concentration of the pathogen in raw ingredients, information on the effects that food processing, distribution, handling and preparation steps have on the pathogen and information on consumption patterns. This involves collecting sufficient, relevant and accurate data, generating estimates, creating models and making assumptions to describe the prevalence and the concentration of the pathogen at each step of the farm-to-fork continuum. Since the most important food-related to *L. monocytogenes* are RTE foods, stored a long time at refrigeration temperatures. Reflecting the fact that *Listeria* is a ubiquitous organism, none of these studies fully encompasses a farm-to-fork approach. The most extensive study assessed exposure with *L. monocytogenes* growth modelled only from retail to consumption (Schlundt et al., 2003).

Schlundt et al.,(2003) in the study stressed that, in order to determine whether the risk of these foods serving as a vehicle for human food-borne listeriosis can be estimated. It was also decided to limit the study to foods at retail and their subsequent public health impact at the time of consumption.

2.14 Listeria Prevention and control

Listeriosis is a serious, but preventable and treatable disease caused by the bacterium, Listeria monocytogenes. The bacteria are widely distributed in nature and can be found in soil, water, vegetation and the faeces of some animals. Animal products (including meat, meat products, dairy products), seafood and fresh produce such as fruits and vegetables can be contaminated from these sources (MOH-Zambia, 2018).

The minister assured the nation that, Ministry of Health, through the Zambia National Public Health Institute, have instituted measures in place in order to prevent the disease from spreading into Zambia which is; surveillance and disease intelligence, emergency preparedness and response and communication of findings for timely action and policy interventions. Through this approach, any disease of significance is noted and mitigated in a timely manner (Anonymous, 2018). However, the minister of health further reiterated that although listeriosis is a serious disease, it is treatable and preventable, Zambia has not recorded any case of listeriosis, and the Government through the Ministry of Health is working with local and international stakeholders to ensure that people are protected from this outbreak (MOH-Zambia, 2018).

The studies in Australia and New Zealand done by (Buchanan et al.,(2017) have devised measures on the control they concluded that, since *L. monocytogenes* is widespread in the environment, and control of Listeria in food production facilities requires constant focus by risk managers. Therefore, a better understanding of the characteristics of the microorganism, environmental impact, and interactions of virulence factors with host susceptibilities is necessary to devise better control measures to reduce the incidence of listeriosis."(Buchanan et al., 2017). Control measures that prevent the occurrences of high levels of contamination at consumption would be expected to have the greatest impact on reducing rates of listeriosis.

WHO-DONs,(2018) further advised that, for travellers, it is advisable to practice good food hygiene, such as avoiding uncooked food, avoiding food that has been kept at room temperature for several hours and always washing hands thoroughly with soap and water before preparing or consuming food. To implement control measures such as better temperature control or limiting the length of storage periods that will mitigate increased risk due to increases in *L. monocytogenes.*

2.15 The general overview of the Codex Alimentarius Commission Risk Assessment Framework

The Codex Alimentarius Commission (CAC) is the Joint FAO/WHO Food Standards setting organisation with the mandate of protecting the health of the consumers from being exposed to food hazards and ensuring fair practices in international food trade. In promoting fair trade, CAC encourages member states to adopt the Codex standards. However, in the absence of standards or where a member state seeks higher standards than those provided by the CAC, member states are allowed to adopt higher levels of protection as long as they are justified by a risk assessment (FAO/WHO, 2013).

2.15.1 Risk assessment of Listeria in RTE meat and meat products

Studies concerning risk assessment in relation to listeriosis in the report by (WHO-DONs, 2018) in its findings described globally South African to have the largest outbreak of listeriosis that has been detected. Due to the potentially long incubation period of listeriosis (one to three weeks and up to 70 days). Following the identification of the source of this outbreak, the World Health Organisation (WHO) is now concerned that the export of implicated products may have resulted in listeriosis cases in other countries.

Codex Alimentarius Commission (CAC) has identified risk assessment as a science-based investigation which has four steps under its framework, which is the international standard-setting body for foods in international trade (FAO/WHO, 2013). The steps include Hazard identification, exposure assessment, hazard characterisation, and risk characterisation. Risk analysis has been incorporated by the CAC, and other international organisations, for the management of public health risks for hazards in food though there are few studies on Salmonella risk assessment in beef (FAO/WHO, 2013).

Another study done by (WHO/FAO/UN, 2004) showed that the most important key findings of the risk assessment as a whole are: the probability of illness from consuming a specified number of *L. monocytogenes* is appropriately conceptualized by the disease triangle, where the food matrix, virulence of the strain and susceptibility of the consumer are all important factors. The models developed predict that nearly all cases of listeriosis result from the consumption of high numbers of the pathogen. They further based on the available data, that there is no apparent evidence that the risk from consuming a specific number of *L. monocytogenes* varies for the equivalent population from one country to another.

WHO/FAO/UN, (2004) alluded differences in manufacturing and handling practices in various countries that may affect the contamination pattern and therefore the risk per serving for food. The public health impact of food can be evaluated by both the risk per serving and the number of cases per population per year. Control measures that reduce the frequencies of contamination will have a proportional reduction in the rates of illness, provided the proportions of high contaminations are reduced similarly. Control measures that prevent the occurrences of high levels of contamination at consumption would be expected to have the greatest impact on reducing rates of listeriosis.

2.16 Knowledge Gap

Presently, studies on listeriosis have been on the biology, epidemiology, a number of illnesses and the global burden of the disease (Charline et al., 2014). There is a paucity of information on the risk of exposure to Listeria through consumption of Polony. No study has been conducted to ascertain the risk of exposure to listeria through consumption of Polony in both Zambia & South Africa. The government instituted a ban, which was supposed to be informed by results of a risk analysis Ideally an import ban is supposed to be informed by results of the risk analysis. However, this was not done. This study, therefore, attempted to provide information on which the ban was supposed to be based on.

CHAPTER THREE

3.1 Methodology

3.2 Study design and data sources

This was a simulation study and depended on secondary sources (literature review), and the volume/quantity of the ready-to-eat meat and meat products imported into Lusaka, Zambia from South Africa was used.

3.2.1 Secondary data

This constituted a risk analysis of desktop study, which depended on a review of scientific peer-reviewed papers and grey literature (secondary data). The literature review was guided by research questions (Table 2) based on the swift quantitative microbiological risk analysis (sQMRA) model. The literature search was conducted on major electronic databases including Web of Science such as; Research Gate, Science Direct and PubMed using the University of Zambia (UNZA) library database. Further, secondary literature from Parliament proceedings, Conference proceedings and reports from Government institutions such as Department of Veterinary Services at National Livestock Epidemiology and Information Centre (NALEIC) and Public Health Institute of Zambia (PHI) under Ministry of Health. The major research data was obtained online and was imputed in Mendeley for data citation and referencing process; the data was obtained using "Google search engine" and "Journal Author Name Estimator" (JANE). A search for key terms such as Quantitative risk assessment, listeriosis," was used. SQMRA model questions were incorporated to guide the literature, which contained relevant data for the study and excluded that which was not relevant. Secondary data and the volume or quantity of polony imported into Lusaka, Zambia from South Africa was the main source of data for this research.

3.3 Study setting

This study was conducted in the Lusaka district of Zambia, an area where most imported South African processed meat and meat products are traded in both deli shops and supermarkets. Lusaka is one of the fastest developing cities in southern Africa, and in the southern part of the central plateau at an elevation of about 1,279 meters with an area coverage of 418 km^2 with the population of 3002,530 by 2017 (Central Statistical Office, 2018).

3.4 Sampling technique

Table 2: Research questions based on the swift quantitative microbiological risk assessment (sQMRA) model.

Case definition Consumption data	**Consumption data**
1. What is the pathogen of interest? 2. What is the food product of interest? 3. What is the population size? 4. What are the population characteristics? 5. What is the consumption period?	1. How many portions are consumed in the Population per consumption period? 2. What is the average size of one portion? 3. What percentage of the Portion is Contaminated at retail? 4. What is the average concentration of colony forming units (cfu) per gram in contaminated Portion?
Kitchen cross contamination 1. Given the contaminated portion, what percentage of the portion will contaminate the environment? E.g., hands and kitchen equipment? 2. Given the contaminated portion, what percentage of the cfu's on a portion will contaminate the environment? E.g., hands and kitchen equipment? 3. Given cross contamination, what percentage of cfu's in the environment ends up being ingested?	**Kitchen preparation** 1. What percentage of the portion is prepared; Done, Half done, Raw. 2. What percentage of cfu's on Portion will survive during preparation? Done, Half done and Raw. **Infection and illness** 1. At which dose (number of cfu's) per Portion will half of the exposed population get infected? 2. What percentage of infected people will get ill?

3.5 Data collection tools and techniques

3.5.1 Swift Quantitative Microbiological Risk Assessment (sQMRA) model was used

The sQMRA-model developed by Eric et al., (2010) was implemented in a Microsoft Excel spreadsheet. Deviating from a full-scale Quantitative Microbiological Risk Assessment (QMRA), where pathogen numbers were followed through the whole food chain, this model was starting at retail and ended with the number of human cases of illness. The model was deterministic and included cross-contamination. The general setup of the sQMRA tool consisted of consecutive eleven (11) questions for values, always followed by intermediate model output broken down into categories of contamination and cross-contamination.

The model allowed the results of the research to be quickly interpreted in terms of public health risk, given that pathogen concentration was determined from the model. It was also more accessible and understandable for scientists that were new to the QMRA research area or were not mathematically inclined (Eric et al., 2010).

3.6 Data management and analysis

Data from the literature review was entered in the excel version of the sQMRA model developed by Eric et al., (2010). The model was run to come up with results for the exposure assessment following the consumption of RTE meat and meat products, risk exposure pathways was developed and deterministic exposure assessment, the deterministic method used a random estimate for each model variable (for example, an average) to determine the results of the model (Gilbert et al., 2009).

3.7 Ethical consideration and clearance

Ethical clearance was obtained from the University of Zambia; School of Veterinary Medicine board of graduate studies and the University of Zambia Directorate of Research and Graduate Studies (DRGS) and final clearance was obtained from ERES Converge Lusaka. Permission to collect secondary data was requested and obtained from the Management of the Government Institutions like Ministry of Health (Public Health Institute) and Ministry of Fisheries and Livestock (Veterinary Department) where the data was collected. The researcher took into consideration the fundamental principles of ethical research, which included justice, beneficence, and respect for human dignity.

CHAPTER FOUR

4.1 RESULTS

Results presentations of an exposure assessment will be presented in this section through the following stages of risk assessment; hazard identification, hazard characterisation, exposure assessment, and risk characterisation.

4.2 Hazard Identification

The literature reviewed so far in this study found that listeria is a febrile disease. Listeriosis is commonly presenting as food poisoning is caused by a bacterium known as *Listeria monocytogenes*.

4.2.1 What is its source and how is it transmitted?

Listeria monocytogenes is a food-borne pathogen that can contaminate processed meats and has caused outbreaks in several nations in which processed meats were the vehicle. Due to its ecology, the control of this organism in ready-to-eat meats is difficult. In the study conducted by (Lin et al, 2006) stated that residues on equipment and other contact surfaces provided cross-contamination opportunities. RTE meat and meat products may become contaminated with bacteria due to improper washing and sanitation of equipment and utensils to the presence of *L. monocytogenes* (Beumer et al., 1996; Chaitiemwong et al., 2014).

Once introduced into the plants*, L. monocytogenes* can persist over time in the processing environment. L. monocytogenes is among the most frequently detected pathogens in meat products, and several studies have documented the incidence of the pathogen reaching prevalence levels of up to 40%–45% (Gómez et al., 2015).

4.2.2 What are the symptoms?

In humans it generally presents, symptoms that include fever, muscle aches and sometimes nausea or diarrhoea. In severe cases, the bacteria may spread to the bloodstream and nervous system with symptoms such as headaches, stiff neck, confusion, loss of balance and convulsions. Infected pregnant women may experience a mild flu-like illness, and in more serious cases it may cause miscarriages, stillbirths, premature delivery or a life-threatening infection to the newborn (MOH-Zambia, 2018).

4.2.3 How many cases or outbreaks have been reported?

Several numbers of cases have been reported globally, the study conducted in Australia by Ross et al., (2009) reviewed that ready to eat meats accounted for 44 cases which equated to approximately one-third of Australia's listeriosis cases. However, (Ross et al., 2009) further said the cases in the United States of America were different in which the study estimated approximately 2500 annual cases of listeriosis including unreported cases.

Similar study conducted in France by Pouillot *et al.*,(2009) on salmon said since 1999, surveillance of human listeriosis in France was made mandatory to notify health authorities, it was estimated the period between 1999 to 2000 recorded the annual incidence of diagnosis of listeriosis declined from approximately 4.5 cases/million persons, which relates to 265 cases/year to approximately to 3.5 cases/million persons during 2001 to 2005 which relates to 220 cases/year. In Europe, the tendency of annual incidence of listeriosis increased to 4.6 cases/million persons that are 290 cases /year. South Africa outcome of illness recorded 674 patients, of whom 183 (27%) of them died (WHO-DONs, 2018).

4.2.4 What foods are affected?

The common sources of infection include dairy products, meats from infected animals, including poultry, and vegetables, Polony, Russian Sausages, Vienna’s, Cold Meats, Ham, Meat Spreads, Corned Meat, Salami and most refrigerated uncooked foods (MOH-Zambia, 2018).

4.2.5 What factors impact the growth and survival of the micro-organism?

Several post-retail factors that could influence the consumer risk of acquiring foodborne listeriosis such as temperature and duration of refrigerated storage. In the food processing industries, many factors influence the survival of microorganisms. Among these, processing machines are very important, especially those with complex designs which are difficult to clean (Gómez et al., 2015)**.**

4.3 Hazard Characterization

4.3.1 Characteristics of the organism (pathogenicity)

L.monocytogenes pathogenesis infection is an affiliation with the high-risk group of immune-compromised patients, infants or pregnant women and the aged. It may be fatal, the groups that are at highest risk include pregnant women, newborns, the elderly especially those over sixty-five years of age and the immune compromised adults (MOH-Zambia,2018). The growth characteristics of L. monocytogenes enable it to survive on equipment, in drains and on floors in cool and high humidity conditions, which makes it a highly persistent microorganism with repeated isolation in the food industry environment. Additionally, RTE meat and meat products have a recognised potential for contamination with L. monocytogenes, either primary (by contaminated raw meat) or by cross-contamination from contaminated surfaces. In the food processing industries, many factors influence the survival of microorganisms. Among these, processing machines are very important, especially those with complex designs which are difficult to clean (Gómez et al, 2015).

The adverse effect in this study was quantitatively evaluated due to its nature of adverse effect caused after consumption of RTE meat and meat products contaminated with listeria the data obtained were inputted in swift Quantitative Microbial risk assessment (sQMRA) model. In this regard, the Model was used to determine the level of risk in terms of the number of people who will become ill following consumption of contaminated RTE meat and meat products after twelve simulations.

4.3.2 Characteristic of the host

"Human populations are highly diverse in their response to infectious agents, reflecting the population's diversity in genetic background, general health and nutrition status, age, immune status, stress level and prior exposure to infectious agents. For certain foodborne diseases, it appears that prior exposure to the agent renders the individual resistant to subsequent exposures to the pathogen"(WHO/FAO/UN, 2004). However, for many infectious foodborne pathogens, immunity is of limited importance, due to either the presence of the pathogen being restricted to the intestinal tract (e.g. enterohaemorrhagic Escherichia coli), great diversity of serotypes (e.g. Salmonella), or mechanisms for avoiding or overcoming the host's defense's (e.g. L. monocytogenes). Severe listeriosis most often affects those with severe underlying illness, the elderly, pregnant women and both unborn or newly delivered infant Infection in healthy adults is typically asymptomatic (WHO/FAO/UN, 2004).

4.3.3 Dose-response relation

‘’The severity of a hazard can be evaluated by qualitative, semi-quantitative and quantitative approaches (WHO/FAO/UN, 2004). Summarised approaches used to rank or prioritise different foodborne illnesses in terms of their severity or consequences. Different criteria used to evaluate severity included’’:

- The number of acute illness cases.
- The number of deaths.
- The number of chronic illness cases.
- The quality-adjusted life-years lost due to the illness.
- The damage to society in terms of medical costs and loss of productivity.
- The willingness of the society to pay for reducing the risk of illness (WHO/FAO/UN, 2004). Other works to assess or describe the severity of microbial hazards have tried to relate the dose to the severity of the disease (WHO/FAO/UN, 2004). Due to the difficulty of obtaining the relevant information during outbreaks, case fatality rate and hospitalisation rate have been used for assessing severity, while attack rate, incubation period, amount of contaminated food and the vehicle involved have been used as proxy measures of infecting dose.

4.4 Exposure Assessment

4.4.1 Case definition

The pathogen of interest was Listeria species in which the product of interest was ready-to-eat meat and meat products. The population size of the study area (Lusaka) stood at 3,002,530 by 2017 according to the report (Central Statistical Office, 2018). To assess the number of people who would get ill, the study defined a consumption period of one year (that is, the number of people who would get ill per year).

4.4.2 Consumption data

In this study, portion size was defined as a slice of Polony an individual consumes at breakfast. However, there was no available consumption data on RTE meat and meat products in Lusaka district. The assumption was that the population in labour force with the purchasing power of RTE meat and meat products stood at 58.8% of 3,002,530 population of Lusaka, this encompasses both the formal and the informal in employment according to 2015 Living Conditions Monitoring Survey of Zambia (Central Statistical Office, 2016). The study, therefore, assumed that 58.8% of the residents in Lusaka who were in the labour force consumed Polony at breakfast because of their purchasing power (Central Statistical Office, 2016). Hence the number of portions consumed by a population was calculated to be 1,765,488 per consumption period multiplied by one (1) serving at breakfast meal (1,765,488 portions).

4.4.3 Serving portions and consumption patterns

The maximum weight of 300g/pack of Polony we divided by 10 and we found the minimum was 30g per day serving. This was the average serving portion for Polony in Lusaka district. Most RTE meat and meat products (Polony) at household level was consumed as cold meat (did not require further preparation by heat treatment before consumption) (Ross et al., 2009). It was served at breakfast once a day. Since a survey was not carried out in this study, it was based on literature review and secondary data since preparation method of Polony was supplied as RTE meat and meat products was consumed 100% done, half done 0%, and prepared raw was 0%.

4.4.4 Contamination of RTE meat and meat products at retail shops.

Many works evaluated demonstrated that Polony sliced in retail shops often have a higher level of bacterial contamination than products prepared in deli meat factories (Kurpas et al., 2018; Mataragas et al., 2010). As tested in the United States of America (USA) approximately 83% of listeriosis cases caused by deli meats were associated with products sliced at retail. This study well-thought-out only a minimum and high concentrations of listeria and hence the average concentration of colony forming units (cfu) per gram in a contaminated portion of Polony which was taken to have a minimum value of 100cfu/g and a maximum value of 1000cfu/g (Gómez, 2015;Mataragas et al., 2010;Ministry of Health, 2003; FSANZ, 2001).

INPUT PARAMETERS			
Pathogen:			Listeria
Food product:			Polony
Population size:			3002530
Population characteristics:			Total Lusaka Population
Consumption period:			One Year
Number	Para-meter	Question	Value
1	N	Portions consumed	1.8E+06
2	M	Portion size in grams	30
3	Sr/+	Prevalence in retail	2.3%
4	Cr/+	cfu per gram contaminated product	1.0E+03
5	Scc/r	Portions causing cross. Cont.	83%
6	Fcc	cfu's from portions to environment	2.0%
7	Fei	cfu's from the environment to ingestion	4.7%
8	Sprd/cc	Portions prepared done	100%
8	Sprh/cc	Portions prepared half-done	0.000%
8	Sprr/cc	Portions prepared raw	0.000%
9	Fprd	cfu's surviving when prep. Done	0%
9	Fprh	cfu's surv. when prep. half-done	0.000%
9	Fprr	cfu's surviving when prep. Raw	100%
10	ID50	ID50 (Number of cfu's)	1.0E+05
11	Pill/inf	% People infected who get ill	25%
Time stamp:		1/12/2019 11:45	
sQMRA-tool			

Figure 1: sQMRA input parameters for the 30g portion of Polony risk exposure pathway.

4.5 Kitchen cross-contamination

Due to lack of literature on listeria in kitchen cross-contamination, listeria in retail and deli shops cross contamination was used as a proxy (Chaitiemwong et al., 2014;Kurpas et al., 2018; Ricci et al., 2018). This is because cross contamination does not differ regardless of the environment and equipment for food product preparation methods are similar (Eric.G. et al., 2010). The percentage of portions that would cause cross-contamination is 83% (Kurpas et al., 2018; Mataragas et al., 2010). The percentage of cfu on a Portion that would contaminate the environment such as hands and equipment was 2% (Gómez et al., 2015). In the risk pathways, it was assumed that 4.7% of cfu from the environment such as slicing machine would end up being ingested (Lin., et al 2006;www.researchgate.net, 2018).

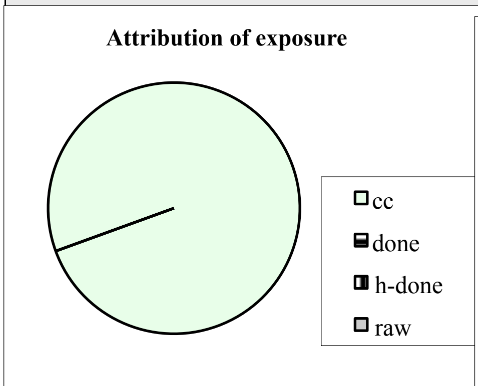
4.6 Kitchen preparation

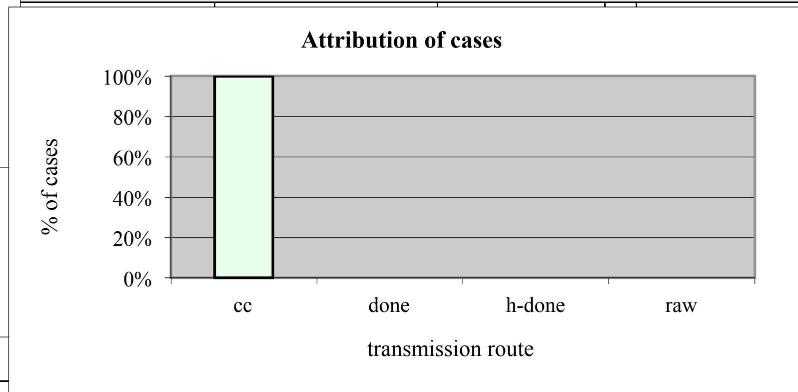
The survey was not done in this study to come up with data on how Polony was consumed at various households. However, the percentage of doneness was 100% (Ross et al., 2009) half done 0% and raw was 0%. The percentages of microorganisms surviving on a contaminated portion during preparation on the plate (at kitchen), since it was ready to eat meat and meat products were 0%, and 100% when raw due to poor hygiene practices along the food chain due to poor manufacturing practice (Mataragas et al., 2010).

4.7 Infection and illness

In this study, the dose (number of cfu's) per gram of portion that would cause half of the exposed population to get listeria infection (ID50) was taken to be a minimum of 100,000 cfu/g and a maximum of 10,000,000 cfu/g (Gómez et al., 2015;Mataragas et al., 2010;Ministry of Health, 2003;FSANZ, 2001). The assumption in this study was that 25% of the exposed population would get ill when they ingested such doses of Listeria (Buchanan et al.,2017). The average concentration of cfu's per gram in a contaminated portion of Polony was a minimum of 100 cfu/g and maximum 1,000 cfu/g (Gómez., 2015; Mataragas et al., 2010).

EXPOSURE	EFFECT





Transmission route	Exposure	Transmission route	Calculation	Attribution of cases
Cross-contamination	100%	Cross-contamination	Scc/r=0%	100%
Prepared done	0%	Prepared done	Fprd=0%	0%
Prepared half-done	0%	Prepared half-done	Fprh=0%	0%
pared raw	0%	Prepared raw	Fprr=0%	0%

RELATIVE RISK	Compared with QMRA *campylobacter* in chicken fillet		
Point of comparison	Model output	Reference data	Relative value
Portions consumed	1.8E+06	8.5E+07	2.08%
Contaminated portions (at retail) consumed	4.1E+04	3.3E+07	0.12%
Total number of cfu's before Kitchen	1.2E+09	7.0E+10	1.74%
Total number of cfu's after kitchen	9.5E+05	6.1E+06	16%
Number of people ill	1.6	1.2E+04	0.01%

Figure 2: Model output at 1000cfu/g and ID50 at 10^5cfu (high probability of a portion of 30g of Polony risk exposure pathway.

4.8 Risk Characterization

The study focused on the imported South African ready to eat meat and meat products risk exposure pathway, a total of 4 simulations were run. The runs contained a summary of input parameters and output model results (figure 1 and 2). Table 2 (Risk characterisation) summarises the results of all the outputs of the four simulations of the 4 case scenarios, for the consumers of minimum portion of RTE meat products.

Scenario 3 recorded the highest risk with two (2) people out of a population of 1,765,488 people to be exposed to *listeria spp* through the consumption of listeria-contaminated Polony, representing a probability of 0.00011%.

Scenario 1 recorded no risk of people out of the population of 1,765,488 people to be exposed to *listeria spp* through consumption of listeria-contaminated Polony representing no probability of exposure to *Listeria spp.* Whereas, scenario 2 and 4 recorded no risk of people out of the population of 1,765,488 people to be exposed to *listeria spp* through consumption of listeria-contaminated Polony.

Table 2: Summary of the outputs of 4 simulations in the ready to eat meat and meat products imported from South Africa risk exposure pathways.

Consumers of Ready-to-eat meat and meat products minimum serving portion					
Scenario	**Portion (g)**	**Cfu/g**	**ID50**	**Model output (Number of people who get ill)**	**Qualitative risk**
1	30	100	10^5	0.2	Low
2	30	100	10^7	0.0	Low
3	30	1000	10^5	1.6	High
4	30	1000	10^7	0.0	Low

Quantitative Risk characterisation using sQMRA for consumers of the 30g minimum portion of RTE meat and meat product risk pathway (Table 2).

Scenario 1: No person per year in a general population of 3 million people of Lusaka Province would be exposed to listeriosis through consumption of infected RTE meat and meat products in average portion consumers.

Scenario 2: No person per year in a general population of 3 million people of Lusaka Province would be exposed to listeriosis through consumption of infected RTE meat and meat products in average portion consumers.

Scenario 3: 2 people per year in a general population of 3 million people of Lusaka Province would be exposed to listeriosis through consumption of infected RTE meat and meat products in average portion consumers.

Scenario 4: No person per year in a general population of 3 million people of Lusaka Province would be exposed to listeriosis through consumption of infected RTE meat and meat products in average portion consumers. In general, the combination of higher cfu levels and lower ID50 would result in a higher number of people getting ill.

4.9 Uncertainty

The last step in this assessment for *L. monocytogenes* in Polony examines the simulated results to consider how much the various inputs affect the outputs. As they are based on a simulation model, the risk characterisation results are subject to uncertainty associated with a modelled representation of reality, involving assumed simple relationships among prevalence, concentration, consumption characteristics and adverse response to consumption of some number of *L. monocytogenes* organisms (Foerster, 2014).

Like many risk analysis studies, there were substantial missing data as input parameters in the model. To cover up for these information gaps, assumptions were employed from the literature to obtain some information on the consumption patterns and serving portions of Polony in the population, to circumvent dependence on logical assumptions and use of global data. The pathogen numbers were followed through the food chain, which in this case starts at retail and ends with the number of human cases of illness. It would be more robust to follow the pathogen numbers along the entire value chain (farm to the folk at a national level), but this would require more resources. The relative risk was compared to the reference point in the model to avoid overestimation of the results. However, the reference point in the model was for *Campylobacter* in chicken fillet in the Netherlands where the model was developed. This, however, does not have much effect on the model because the epidemiology of these pathogens is less the same and only serving portions would differ with regard to each household (Eric.G. et al., 2010).

CHAPTER FIVE

5.1 Discussion

The aim of conducting this study was to assess the risk of exposure to *Listeria spp* through consumption of Polony imported from South Africa in Lusaka. The following were the research questions for the study, was there a risk of exposure to *Listeria spp* from consumption of South African ready-to-eat meat products? How many Zambians in Lusaka accessed these products? What was the probability of exposure? To answer these questions, the study conducted a swift quantitative exposure assessment to *listeria spp* through consumption of Polony imported from South Africa. The study was conducted in Lusaka. The cfu/g of contaminated product portions causing cross contamination (Chaitiemwong et al.,2014; Kurpas et al., 2018; Ricci et al., 2018).The cfu's from portion to environment (Gómez et al., 2015),CFUs from environment to ingestion (Lin. et al, 2006), portions prepared well done, half done and raw (Eric et al., 2010;Ross et al., 2009), cfu's surviving when prepared well done, half done and raw (Chaitiemwong et al., 2014;Eric et al., 2010), ID50 and % of people infected who get ill (Buchanan et al., 2017;Mataragas et al., 2010),we estimated a relatively low risk of exposure to *Listeria spp* through consumption of Polony imported from South Africa at household level. Attributable factors included in this current study would be due to low serving portions per meal, low consumption patterns and it was ready to eat meat and meat product (Polony) mostly prepared well done, at household level they are consumed as cold meat (did not require further preparation by heat treatment before consumption) (Ross et al., 2009). It was served at breakfast once a day for the consumers of serving portion of 30g of Polony, scenario 1,2 and 4 recorded no risk there were no people to be exposed to *Listeria spp.* Scenario 3 recorded the high risk with two (2) people to be exposed to *Listeria spp*.

In this study, the serving portion of Polony was 30g, the frequency of consumption was mostly once a day according to this study findings. The study assumed that most households only consumed 30g per day serving of Polony. This contributed to low risks found in this study. The serving portion of Polony has the potential to contribute to the risk of exposure to *Listeria spp* if it exceeds the threshold of 100cfu/g. This is in agreement with the previous findings by Mataragas et al.,(2010) on the risk of exposure to *Listeria spp*, which stated that, the number of *L. monocytogenes* must not exceed the limit of 100 cfu/g during the shelf life

(Mataragas et al., 2010; Ross et al., 2009). They also reported risk per serving of Polony of the smallest serving ranging between $10^{-13.4}$ to $10^{-14.2}$, this was based on the ready to eat meat and meat products from Australia, it is in line with the current study on Polony.

The amount of Polony consumed varies according to the size of portions. The overall serving size was 30g. These findings were similar to the studies conducted in Australia by Ross et al., (2009) who outlined that, the serving size in Australia was in the range of 20g - 120g of the serving size. The data in this study assumed that 58.8% (Central Statistical Office, 2016) of 3,002,530 population of Lusaka (Central Statistical Office, 2018) consumed Polony once per day at a breakfast meal in the morning.

From the scenarios in the output of simulations conducted in this study, scenario 3 of 30g Polony was the highest with an average of 0.00011 cases of listeriosis per 1000 in a year. Scenario 1, 2 and 4 recorded no cases of listeriosis per 1000 in a population in a year. Similarly (Ross et al., 2009) in their study reported the incidence of listeriosis in Australia as 0.2-0.4 per 100,000 population per annum. In the study conducted by (Lin et al, 2006) stated that residues on equipment and other contact surfaces provided cross-contamination opportunities. He further emphasised that Polony may become contaminated with bacteria due to improper washing and sanitation of equipment and utensils to the presence of *L. monocytogenes* (Beumer et al., 1996; Chaitiemwong et al., 2014). In this study cross-contamination of Polony was 100% according to simulation output the results further indicated that at scenario 3, the cross-contamination levels were high, following the concentration of *listeria* at 1000cfu/g and infectious dose fifty (ID50) 1×10^5.

Other studies conducted in Ireland the prevalence of *L. monocytogenes* on slicing machines used for RTE meat and meat products at the retail level was a source of cross-contamination (Gómez et al.,2015) the literature review showed a high incidence (100%) of *Listeria* which was cited in swab samples from tabletops in a butchers shop in Nigeria (Gómez et al., 2015). Although consumption of Polony does not pose a risk of exposure to listeriosis, there are other processes of exposing an individual to infection of *Listeria spp* through cross-contamination at retail, which could occur during slicing. Given the fact that cross-contamination of Polony during their retail is unlikely, prevention or at least reduction of cross-listeriosis contamination during their manufacturing is vital. The literature review showed many studies which demonstrated that

Polony sliced in retail shops often have a higher level of bacterial contamination (Kurpas et al., 2018; Mataragas et al., 2010). In the current study, cross-contamination in the kitchen or retail during slicing was one of the contributing factors for risk of exposure to *Listeria spp*. Results showed that much of the risk was contributed by cross contamination at retail or kitchen during slicing which was 1 x 10^3 cfu/g of Polony and infectious dose fifty (ID50) 1 x10^5 cfu/g. This study was in agreement with the findings of Kurpas et al.,(2018) who confirmed that 83% of listeriosis cases caused by deli meats were associated with products sliced at retail. Chaitiemwong et al.,(2014) observed that the risk of higher concentration of bacteria increased when deli products were sliced separately for individual customers. Furthermore, Chaitiemwong et al., (2014) documented that the last slice often had a higher number of *L. monocytogenes* than the previous ones. Hence, these were risk factors for infection with listeria pathogen from the environment such as tabletops and slicing machines. In the current study, there were low numbers of predicted cases of listeriosis at a high contamination level of (1x 10^3 cfu/g) and high ID50 of (1 x 10^5cfu/g). Therefore, this finding clearly shows that Polony is not only safe and free of pathogenic bacteria contamination, but other factors like cross-contamination could also lead to exposure to listeriosis infection (Kurpas et al., 2018). In general, the low risk of exposure to Listeriosis in the current study is in agreement with the observation by Scholars in Australia (Mataragas et al.,2010;Ross et al.,2009) who predicted the average risk of Listeriosis per serving of Australian processed ready to eat meat and meat products (Polony) as 1.00 x 10^{-8}.

The study had some limitations due to lack of information. There was no survey done on the consumption patterns and serving portions of Polony, hence, focusing only on scientific assumptions. This study seeks to answer this question. Both South Africa and Zambia did not conduct a risk assessment on the outbreak of listeriosis after imposing a ban, so as to conduct a risk assessment if there was a risk of exposure to *Listeria spp* through consumption of South African ready-to-eat meat and meat products within South Africa and other neighbouring countries like Namibia (WHO-DONs,2018) which reported a confirmed case. Therefore, the findings of this study were very cardinal for decision making in food safety and improving trade policy formulation, and implementation and the results would help decision-makers to prioritise their actions in the area of foodborne diseases.

CHAPTER SIX

6.1 Conclusions

This study in its findings concludes that the risk of exposure to *Listeria spp* among consumers of Polony in Lusaka was relatively low. This was attributed to portion serving size, supplied as ready to eat processed well done (Polony). Cross-contamination in the kitchen during slicing would be one of the contributing factors for risk of exposure to *Listeria spp*.

6.2 Recommendations

More robust studies must be carried out at a national level to come up with data on consumption patterns, general risk and number of people that would get infected to listeriosis.

Policy makers and stakeholders such as the Public Health Institute (PHI) under Ministry of Health and National Livestock Epidemiology Information Center (NALEIC) in the Ministry of Fisheries and Livestock under the Department of Veterinary Services should come up with the traceability system of tracking through data on the imported ready to eat meat and meat products through collaborating with other stakeholders and other line Ministry.

Food and Nutrition Council of Zambia and meat processors should also come up with the mechanism of data collection on serving portion and consumption patterns of various food items, including ready to eat meat and meat products imported.

Generally, consumers and food handlers have to be educated on the dangers of not observing good housekeeping of RTE meat and meat products in retail and home to prevent contamination. Contaminations of Polony may also be connected with slicing machines. Therefore, it is important to sanities' the equipment every time they are used to slice Polony.

Several foods producing plants have difficult to overcome cross-contamination of the processing environment. One of the important preventing procedures is to properly separate places like cutting rooms and cooling zones or raw meat delivery corridors from other spaces, such as delivery areas of heat-treated products, packing rooms, or places with boiling equipment.

A proper hygienic system can prevent the cross-contamination with L. monocytogenes, which is a fundamental risk factor in RTE meat and meat products facilities.

REFERENCES

Anonymous, 2017. National Department of Health South Africa-Media Report. Pretoria.

Bemrah, N., Sanaa, M., Cassin, M.H., Griffiths, M.W., Cerf, O., 1998. Quantitative risk assessment of human listeriosis from consumption of soft cheese made from raw milk. Prev. Vet. Med. https://doi.org/10.1016/S0167-5877(98)00112-3

Beumer, R.R., Te Giffel, M.C., Spoorenberg, E., Rombouts, F.M., 1996. Listeria Species in Domestic Environments. Epidemiol. Infect. 117, 437–442. https://doi.org/10.1017/S0950268800059094

BoZ, 2017. Zambia Direction of Trade-Second quarter Report. Lusaka.

Buchanan, R.L., Gorris, L.G.M., Hayman, M.M., Jackson, T.C., Whiting, R.C., 2017. A review of Listeria monocytogenes an update on outbreaks, virulence, dose-response, ecology, and risk assessments. Food Control 75, 1–13. https://doi.org/10.1016/j.foodcont.2016.12.016

Central Statistical Office, 2018. Zambia in figures 2018, Demographic Indicators. Lusaka.

Central Statistical Office, 2016. 2015 Living Conditions Monitoring Survey report 2016 living Conditions Monitoring Survey. Lusaka.

CFSANFDA, 2003. Quantitative Assessment of Relative Risk to Public Health From Foodborne Listeria monocytogenes Among Selected Categories of Ready-to-Eat Foods.

Chaitiemwong N., Hazeleger W.C., Beumer R.R., Z.M.H.., 2014. Quantification of transfer of Listeria monocytogenes between cooked ham and slicing machine surface. Food Control 44, 177–184.

Chen Y, Ross WH, Scott VN, G.D., 2003. Listeria monocytogenes, low levels equal low risk. J. Food Prot. 570–577.

Diego Gómez, 1 Laura Pilar Iguácel, 2 M[a] Carmen Rota, 1 Juan José Carramiñana, 1 Agustín Ariño, 1, andJavier Y., 2015. The occurrence of Listeria monocytogenes in Ready-to-Eat Meat Products and Meat Processing Plants in Spain. Foods. https://doi.org/10.3390/foods4030271

Eric.G., Evers, Jurgen, Chardon, 2010. A swift Quantitative Microbiological Risk Assessment (sQMRA) tool BA Bilthoven, The Netherlands. J. Food Control 21, 319–330.

Evans, B.R., Leighton, F.A., 2014. A history of One Health. Rev. Sci. Tech. 33, 413–420.

FAO/WHO, 2013. Food Standards Programme, Codex Alimentarius Commission procedural manual. Joint Communique of Food Agriculture Organisation and World Health Organisation, Geneva. https://doi.org/10.1007/BF02582346

Farber JM, Ross WH, H.J., 1996. Health risk assessment of Listeria monocytogenes. Int. J. Food

Microbiol. 145–156.

FDA, 2007. Food safety code [WWW Document]. http://www.foodsafety.gov/~dms/foodcode/htmlsupplement.

Foerster, C., 2014. Risk assessment of Listeria monocytogenes in ready-to-eat foods. Risk Assess. List. Monocytogenes Poult. Beef. 117, 779–792.

Friesema, I.H., Kuiling, S., Van Der Ende, A., Heck, M.E.H., Spanjaard, L., Van Pelt, W., 2015. Risk factors for sporadic listeriosis in the Netherlands, 2008 to 2013. Euro surveillance 20. https://doi.org/10.2807/1560-7917.ES2015.20.31.21199

FSANZ, 2001. Guidelines for the microbiological examination of ready-to-eat foods [WWW Document]. http://www.foodstandards.gov.au/_srcfiles/Guidelines%20for%20Micro%20exam.pdf.

Gilbert, S., Rob, S., Hudson, A., Cressey, P., 2009. Listeria Monocytogenes in Processed Ready-to-Eat Meats. Inst. Environ. Sci. Res. Ltd. 1–82.

Heinz, G., and Hautzinger, P., 2007. Meat Processing Technology For Small To Medium Scale Producers, Food and Agriculture Organization of the United Nations Regional Office For Asia And The Pacific. Bangkok, Thailand.

Hichaambwa, M., 2012. Urban Consumption Patterns of Livestock Products in Zambia and Implications for Policy by Urban Consumption Patterns of Livestock Products in Zambia and Implications for Policy (No. 65). Lusaka.

Johnson, J.L., Doyle, M.P., Cassens, R.G., 1990. Listeria-monocytogenes and other Listeria spp in meat and meat products. J. Food Prot. 53, 81–91.

Kasaro, N., 2018. Detection of Listeria spp in Pork and Pork Products in Lusaka, Zambia. Lusaka.

Kołakowska A, M.G., 2011. Listeria monocytogenes in human infections. PubMed 65, 57–62.

Kurpas, M., Wieczorek, K., Osek, J., 2018. Listeria monocytogenes. Gruyter -J Vet Res 2018, 49–55. https://doi.org/10.2478/jvetres-2018-0007.

Lin C, Takeuchi K, Zhang L, Dohm CB, Meyer JD, Hall PA, and D.M., 2006. Cross-contamination between processing equipment and deli meats by Listeria monocytogenes. J. Food Prot. 69, 71–79.

Maertens de Noordhout, C., Devleesschauwer, B., Angulo, F.J., Haagsma, J.A., Havelaar, A.H., Speybroeck, N., 2014. Global burden of listeriosis. 6th Eur. Public Heal. Conf. (EUPHA 2013) Heal. Eur. are we there yet? https://doi.org/10.1016/S1473-3099(14)70870-9.

Mataragas, M., Zwietering, M.H., Skandamis, P.N., Drosinos, E.H., 2010. International Journal of Food Microbiology Quantitative microbiological risk assessment as a tool to obtain useful information for risk managers — Specific application to Listeria monocytogenes and ready-to-eat meat products. Int. J. Food Microbiol. 141, S170–S179. https://doi.org/10.1016/j.ijfoodmicro.2010.01.005.

Mataragas, M., Zwietering, M.H., Skandamis, P.N., Drosinos, E.H., 2010. Quantitative microbiological risk assessment as a tool to obtain useful information for risk managers - Specific application to Listeria monocytogenes and ready-to-eat meat products. Int. J. Food Microbiol. 141, S170–S179. https://doi.org/10.1016/j.ijfoodmicro.2010.01.005.

McMullen, P.D., Freitag, N.E., 2014. Listeria monocytogenes, Molecular Medical Microbiology: Second Edition. Elsevier Ltd. https://doi.org/10.1016/B978-0-12-397169-2.00074-3.

Ministry of Health, 2003. New Zealand Food, National Children's Nutrition Survey. New Zealand, Wellington.

MOH-Zambia, 2018. Ministerial statement to update parliament on listeriosis findings of the Investigations on imported ready-to-eat meat and meat products, http://www.parliament.gov.zm/sites/default/files/images/publication_docs/MIinisterial %20%Statement. Lusaka.

Mustapha, A., 2007. Real-time monitoring of cross-contamination of Listeria monocytogenes between equipment and ready-to-eat meat products via a GFP reporter Principal Investigator. J. Public Heal. Epid, 3(2), 49–53.

Pepperoni, B., Bacon, S., Canned, S.T., Luncheon, L., 2018. Guide to Processed Meats / Meat Products / Cheeses. Spain.

Pouillot, R., Goulet, V., Delignette-Muller, M.L., Mahe, A., Cornu, M., 2009. Quantitative risk assessment of Listeria monocytogenes in French cold-salmon : II. Risk Characterization. Risk Anal. 29, 806–819.

Rayser, E.T., M.E.., 1999. Listeria, listeriosis and food safety, 2nd edition. Ed. Marcel Dekker, New York.

Ricci, A., Allende, A., Bolton, D., Chemaly, M., Davies, R., Girones, R., Herman, L., Salvador, P., Koutsoumanis, K., Nørrung, B., Robertson, L., Ru, G., Sanaa, M., Simmons, M., Skandamis, P., Snary, E., Speybroeck, N., Kuile, B. Ter, Takkinen, J., Wagner, M., Arcella, D., Threlfall, J., Wahlstr, H., Teresa, M., Silva, D., Georgiadis, M., Messens, W., Lindqvist, R., 2018. Listeria monocytogenes contamination of ready-to-eat foods and the risk for human health in Europe. Efsa 16. https://doi.org/10.2903/j.efsa.2018.5134

Ross, T., Rasmussen, S., Fazil, A., Paoli, G., Sumner, J., 2009. Quantitative risk assessment of Listeria monocytogenes in ready-to-eat meats in Australia. Int. J. Food Microbiol. 131, 128–137. https://doi.org/10.1016/j.ijfoodmicro.2009.02.007

Schlundt, J.R.P.B.H.T.J., 2003. Quantitative risk assessment of Listeria monocytogene in ready-to-eat foods-the FAO/WHO approach. Fems Immunol. Med. Microbiol. Volume 35, Pages 263–267. https://doi.org/https://doi.org/10.1016/S0928-8244(02)00468-6

WHO-DONs, 2018. South-Africa Listeriosis Outbreak [WWW Document]. http://www.who.int/csr/don/.

WHO-Health Emergency Programme, 2017. Weekly bulletin on selected acute public health emergencies occurring in the who African Region.

WHO/FAO/UN, 2004. Risk assessment of Listeria monocytogenes in ready-to-eat foods joint fao/who Expert Consultation [WWW Document]. http//www.fao.org/food Microbiol. hazard. URL http://www.fao.org/3/a-y5394e.pdf%0Ahttp://www.fao.org/docrep/010/y5394e/y5394e00.htm

Wong TL, Carey-Smith GV, Hollis L, H.J., 2005. Microbiological survey of prepackaged pâté and ham in New Zealand. New Zealand.

www.researchgate.net, 2018. An overview of L. monocytogenes [WWW Document]. Website.

www.thebump.com, 2018. Risk of Exposure to Listeria during pregnancy [WWW Document]. www.thebump.com/a/listeriosis.