Food hygiene in the National Schools Nutrition Programme among primary schools in Vryheid, KwaZulu-Natal, South Africa.

Submitted in fulfilment of the requirements of the degree of Master of Health Science in Environmental Health in the Faculty of Health Sciences at the Durban University of Technology

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ABSTRACT

Background: The National School Nutrition Programme is implemented by the Department of Basic Education in schools located in low-socio-economic communities. Municipal Health Services is legally mandated to monitor compliance of all food premises, including school kitchens to Regulation 638 of the Foodstuffs, Cosmetics and Disinfectants Act, (No. 54 of 1972). Food can become contaminated at any stage during processing, handling, and preparations, leading to foodborne outbreaks. Contamination of food is commonly facilitated through food contact surfaces and the hands of food handlers.

Aim: The study aimed to assess the compliance of the food preparation and storage areas of schools to R638 of the Act and to identify the presence of food pathogens on food contact surfaces and hands of food handlers.

Methods: Thirty-three primary schools offering NSNP meals were randomly selected in Bhekuzulu CMC, in Vryheid, KwaZulu-Natal, South Africa. A cross-sectional survey study was conducted in which a checklist was used to assess the compliance of 33 school food preparation and storage areas to the standard requirements of R638 of the Act. IBM SPSS Statistics 28.0 was used to analyse the checklist. Thirty swabs were aseptically collected from various food contact surfaces and metagenomic analysis was used to assess the prevalent bacteria genera on food contact surfaces.

Results: The checklist revealed poor pest and vector control, inadequate provision of sanitary and hand washing facilities for food handlers, lack of training of food safety principles of the food handlers, and poor waste management. *Pseudomonas* (25-84%), *Stenotrophomonas* (0.9-15%), *Acinetobacter* (0.9-16%), *Rahnella* (2-3%) and *Pantoea* (1-12%) were the most dominant genera on food contact surfaces.

Discussion/***Conclusion***: The school food preparation and storage areas had structural shortfalls that required prioritisation to ensure school meals are prepared and stored in a safe and hygienic manner. School C had the most diverse bacterial community and abundance of bacterial species. Metagenomic analysis revealed a truer account of the bacteria genera prevalent in NSNP food contact surfaces, therefore introducing other potential sources of food contamination.

Keywords: National Schools Nutrition Programme, food safety, R638, food contact surfaces, food handlers, amplified metagenomics, *Pseudomonas*, *Stenotrophomonas*, *Acinetobacter*, *Rahnella*, *Pantoea*.

DECLARATION

I, Sithembile Sidisiwe Madlala, declare that this is representative of my own work. All sources that I have used or quoted have been indicated and acknowledged by means of complete references. To the best of my knowledge, this work has not been submitted before for any other degree at any other university.

12 April 2023

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Sithembile Sindisiwe Madlala Date

DEDICATION

To my late
grandmother, Regina “Ntombi” MaBlose Madlala;
sister, Charity Nthabiseng Gabisile Madlala;
dad, Sipho Lewis Chili and mamkhulu, Thulisile Clarice Chili.

As long as I live, you will live.
As long as I live, you will be remembered.
As long as I live, you will be loved.

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I wish to express my deepest gratitude to:

- My friends and family for your enduring love and support and understanding my unavailability and holding me accountable to my goals.
- Ma, Gcina and my daughter, Zukhanye. I am so grateful to have you as a safe and warm space that I can turn to when life starts to overwhelm me. Thank you for the pure joy you bring to my life. I love you.
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LIST OF ABBREVIATIONS

FBD	Foodborne disease
NSNP	National School Nutrition Programme
WHO	World Health Organisation
HACCP	Hazard Analysis Critical Control Point
WFP	World Food Programme
EHP	Environmental Health Practitioner
PSNP	Primary School Nutrition Programme
RDA	Recommended Daily Allowance
PED	Provincial Education Programme
SLA	Service Level Agreement
VFH	Volunteer Food Handler
CGF	Conditional Grant Fund
EC	European Commision
EU	European Union
DBE	Department Basic Education
UKM	University Kebangsaan Malaysia
GEMS	Global Enteric Multi-center Study
CMC	Circuit Management Centre
GVCR	Global Vector Control Response
WASH	Water, Sanitation and Hygiene

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

School nutrition programs are intended to provide free lunches to students from communities who lack regular access to meals and frequently live in low-socioeconomic zones (World Food Programme, 2013). Most South African schools with school food programs are situated in or near rural communities and informal settlements and usually these schools lack basic resources such as a constant electricity supply and potable water (Sibanyoni & Tabit, 2016). Food can become contaminated at any point during preparation and distribution, and it is the responsibility of the food handler to ensure it is safe for human consumption (WHO, 2015). However, a significant fraction of foodborne illness (FBD) outbreaks are brought on by foods that are prepared food safety practices are neglected (WHO, 2015). It is essential that food safety practices are implemented during preparation and serving of meals to ensure that the food being served is also free of food pathogens (Owusu, 2010).

Previous studies on school nutrition programmes from different countries have established that foodborne disease outbreaks in schools pose a food safety hazard and, in several nations, including the United Kingdom (Bayliss *et al.*, 2016) and Ghana (Kunadu *et al.*, 2016). In South Africa, FBD outbreaks in schools have been reported in various provinces showing a gap and a need to monitor food safety in the National School Nutrition Programme (NSNP) (Dlova, 2018). Learners in Sekhukhune, Limpopo Province suffered nausea and abdominal pain and subsequent investigation attributed the outbreak to the supplier of NSNP food, who allegedly contravened food safety standards (Devereux *et al.*, 2018). Despite being harmless to most healthy adults, opportunistic bacteria can cause mortality and morbidity in children, especially those with compromised immune systems (Mellou *et al.*, 2013). In addition to disrupting learning in schools, outbreaks in school feeding programs can cause students to contract life-threatening diseases and even death (Abushelaibi *et al.*, 2016). This makes the implementation of food safety measures in school feeding programs crucial (Nyenje & Ndip, 2013).

1.2 Background to the problem

The World Health Organisation (WHO) defines foodborne disease (FBD) as an infectious disease produced after the ingestion of food containing pathogenic microorganisms or their

toxins (WHO, 2008). Foodborne diseases are common anywhere unsafe water is used for the cleaning and preparation of food, poorly enforced regulations and a lack of adequate food storage infrastructure (WHO, 2015). Although preventable, FBDs still remain a neglected disease that directly impedes global communities in achieving sustainable development goals (SDGs) by 2030 such as, zero hunger, and good health and well-being (WHO, 2002).

South Africa, through the Department of Health, gazetted R638 of the Foodstuffs, Cosmetics and Disinfectants Act, 1972 with provisions for general hygiene requirements for food premises. The Department of Basic Education administers the National School Nutrition Programme (NSNP) in schools servicing low socio-economic communities. The provision of healthy meals is dependent on schools having adequate infrastructure and equipment for storing and preparing meals in accordance with R638 of the Act. Nonetheless, many establishments, especially schools, continue to prepare meals in non-compliant premises. Previous evaluations of the NSNP found the adequacy of infrastructure in schools to be a challenge (Graham *et al*., 2015), including an analytical cohort study conducted in Bojanala District, North West, South Africa, following 164 learners presented with diarrhoea (97.9%) at the local district hospital. Environmental health investigation revealed some infringements of food safety, including lack of staff training and an absence of records of food safety concepts according to the hazard analysis and critical control points (HACCP) principles (Motladile *et al*., 2019). Assessment of NSNP food preparation areas is therefore necessary especially in Vryheid, KwaZulu-Natal, where 109 of the 204 schools provide NSNP meals. The findings of this study will highlight risk factors that could lead to the incidence of FBDs and assist the relevant department with prevention strategies (Venuto *et al.*, 2015).

1.3 **Rationale of the study**

The implementation of proper food hygiene is recommended R638 of the Act and covers various provisions. Precautions in food handling are necessary and must be adopted by all food service facilities, including school kitchens, to minimize the risk of foodborne disease occurrence. Scallen and Weissenberger (2013) mentioned that most learners may be susceptible to the effects of foodborne diseases during the first few years of life because their immune systems are either not fully developed or other conditions may have been compromised. Therefore, this research was motivated to investigate food safety compliance in primary schools in Vryheid in an effort to contribute towards the safety of meals produced by NSNP. It is also

important to determine the presence of foodborne pathogens on food contact surfaces as there were also few community-based studies available on school compliance to food safety regulations in KwaZulu-Natal, South Africa.

1.4 Significance of the study

This is the first cross-sectional survey of food hygiene conducted in Vryheid, KwaZulu-Natal primary schools. The need for the study was justified by the prevalence of foodborne diseases, particularly involving learners (Motladile *et al*., 2019; Ramwala *et al*., 2020). This is of particular concern as foodborne diseases are largely preventable and food safety is a shared responsibility between governments, the food industry and the public (WHO, 2015). Considering that one of the main objectives of the NSNP is the provision of safe meals, the findings of the study will contribute to food safety literature and efforts, in the school environment, and provide recommendations to improve food safety practices in order prevent the occurrence of NSNP-linked foodborne diseases.

1.5 Purpose of the study

The purpose of the study is to highlight what gaps there may be in NSNP preparation and storage areas in Vryheid primary schools, and where food pathogens on food contact surfaces are detected, discuss how food hygiene may be compromised.

1.6 Objectives of the study

The study's objectives include:

- Assess the compliance of food preparation and storage areas in schools offering NSNP meals to R638 of the Act.
- Detect the prevalent bacteria genera on food contact surfaces.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Foodborne illnesses (FBDs) and consumer death can result from poor food hygiene (WHO, 2019). Food can become contaminated at any point during slaughtering or harvesting, processing, storage, distribution, transportation, and preparation. As a result, food safety and hygiene continue to be a top priority for both consumers and governments worldwide (Lee, 2013). Health authorities and organizations, such as the Codex Alimentarius Commission of the World Health Organization/Food and Agriculture Organization, are working to reduce the risks of foodborne illness (WHO/FAO, 2009) and designed food safety intervention systems and best practice guidelines. Internationally, food laws are fundamentally similar, legally binding, and mandate that food prepared for sale be healthy and safe, prepared under hygienic conditions by people with the necessary training (Ababio *et al.*, 2016).

Governments and other stakeholders are providing children and adolescents who are of school age with wholesome food because it promotes learning in developing nations and improves learners' health, growth, and development (WHO, 2002). Every day, countless children across the globe attend school hungry, making it difficult for them to concentrate. For these children, school nutrition programmes not only provide nutritious meals and increase productivity in the classroom, but it also gives parents an incentive to send their children to school (Kazianga, de Walque et al. 2009). In 2017, the World Food Programme (WFP) reached 18.3 million children in 71 countries with school meals and provided technical assistance to 65 governments in establishing improved national school feeding programmes for another 39 million children (World Food Programme, 2018). It is estimated that 2,700,000 children in Italy receive free meals at public schools (Marzano and Balzaretti 2013), while 77,627 out of 495,000 learners in Wales are eligible for the school meal programme which provides the safe drinking water and nutritious meals in a safe environment (Meldrum, Mannion & Garside, 2009).

The Ghana School Feeding Programme (GSFP) provides one warm meal (lunch) daily in schools to an estimated 1 million learners in basic education in the poorest areas of Ghana (Ababio *et al.*, 2016). In South Africa, the National School Nutrition Programme (NSNP) provided one meal a day to 9.6 million learners during the year 2019/2020 (Treasury, 2020). In order to prevent FBDs in the farm to fork food chains in schools, it is crucial that appropriate

food safety and hygiene measures are put in place given the rise in the number of public schools serving NSNP meals to learners in South Africa (Asiegbu *et al*., 2016). The quality of the food provided to learners can be affected by an inadequate supply of supplies and equipment. All schools must have adequate kitchen infrastructure and facilities with storage, kitchenware, and utensils for food preparation in order to ensure food safety in South Africa's NSNP (Sibanyoni *et al.*, 2017). Every school nutrition program prioritises food safety during transportation, storage, preparation, handling, and serving (DBE, 2013). School feeding programs, according to the World Food Program (WFP), need important institutional capacity to operate, but they frequently begin without enough capacity to handle daily operations (WFP, 2013).

Foodborne disease outbreaks have been connected to negligent food handling practices in food service establishments such as, poor food preparation techniques, including improper cooking materials, environmental contamination, improper holding temperatures, and the use of materials from questionable sources (Da Cunha et al, 2012). Food handlers play an important role in reducing food safety risks as their personal hygiene practices can greatly influence food hygiene (WHO, 2014). The hand has been the primary mode of pathogen transmission in the majority of foodborne outbreaks. The contaminated hands of food handlers could easily transmit foodborne diseases through cross-contamination of food products (Sharma, Gangopadhyay et al. 2021). According to Wright *et al*., (2012), food handlers must receive ongoing or regular training in food hygiene practices throughout the food production chain, particularly important in the school nutrition programme.

In 2011, South Africa reported 2560 foodborne disease outbreaks, with the majority (1700) affecting students in primary and secondary schools (Stats SA, 2014). In 2014, three learners in Limpopo and Gauteng died after consuming contaminated NSNP meals (Nzimande, 2014). A foodborne outbreak occurred in a high school in Gauteng in 2016 where approximately 90 learners and educators complained of abdominal cramps and diarrhoea after eating contaminated food from the feeding scheme. The Bhekisisa Center for Health Journalism, in South Africa reported that there were rats in the school's storerooms and that it was inadequately equipped for food preparation and service, and food preparation areas lacked health certification from the local authority (Devereux *et al*., 2018); the presence of foodborne pathogens such as, *Salmonella enterica (*Motladiile, Tumbo *et al.* 2019*)* and *Escherichia coli* (*E. Coli*) was detected on NSNP meals, and faecal coliforms in water (Mafani, Kwatsha *et al*. 2022).

Non-compliant food preparation areas in schools are a major obstacle facing local authorities in South Africa and EHPs have the duty to ensure that regulatory requirements for food hygiene compliance are met (Department of Health 2018). There are numerous studies in the literature that attempt to investigate the nutritional and developmental effects of school meals (Wall, Tolar-Peterson et al. 2022), (Mafugu 2021), but there are fewer that explain what is essential to the implementation of food safety, specifically in developing countries. Currently, there are limited studies evaluating the compliance of school nutrition programmes nor, has there been any microbiological assessment to determine the presence of *E.coli* and *coagulase-positive Staphylococcus*, *Listeria monocytogenes*, *Shigella* and *Salmonella typhi* on food contact surfaces and on the hands of food handlers-particularly in Vryheid.

2.2 National School Nutrition Programme (NSNP) origin and challenges

State-sponsored mass school nutrition programmes in South Africa date back to the 1940s, when one million white, colored, and African children received free milk (DBE & DPME, 2014). In an effort to ensure that hunger did not interfere with learning, the Primary School Nutrition Programme (PSNP) was started in 1994. A wider incorporation of nutrition and school wellbeing was advised in a 1997 review of the PNSP (Health Systems Trust, 1997). The original PNSP's goals were to enhance educational outcomes by giving students a morning snack that satisfied 25% of their recommended daily allowance (RDA) of calories and to enhance their health by giving them information, micronutrient supplements, and parasite control (DBE & DPME, 2014).

In 2004, the programme was transferred to the Department of Education (DoE) given that its beneficiaries were school children, and the name was changed to the National School Nutrition Programme (NSNP) (Department of Basic Education and Unicef, 2013). The NSNP has standardized nutrient-dense menus based on the Department of Health's food-based dietary recommendations and added fruit and vegetables (Nhlapho 2013). The funding of the programme was allocated according to the National Norms and Standards for School Funding which ranked schools using a series of school and community-based indicators. The school indicators included criteria such as the learner to classroom ratio, and availability of power and water. Community based criteria included functional literacy, per capita income and other poverty indicators. The objective of the ranking was to place schools into groups (Quintiles)

from most to least poor for the purposes of allocating pro-poor per-learner funding. Schools classified as quintiles 1, 2 and 3 comprise 60% of the schools in the country, largely in rural areas and townships (NKosi 2018). According to funding criteria, quintile one represents the "poorest" schools, while quintile five represents the "least poor". Schools in quintile 1 in each province received the most funding since they served the poorest communities and were most disadvantaged in terms of school infrastructure, and over-crowding. All schools in quintiles 1-3 are the focus of NSNP (Department of Basic Education and Unicef, 2013) and most of these schools are no-fee paying and receive R1316 from the state for each learner in 2018 and was set to increase to R1390 in 2019 and R1468 in 2020 (Rendal-Mkosi, 2018).

Provinces use both the centralised and decentralized NSNP implementation models to accomplish the same objective. In the centralized model, Provincial Education Departments (PEDs) select service providers and sign service level agreements (SLAs) to obtain and deliver food to schools and also transfer money to schools to pay for fuel and Volunteer Food Handlers (VFHs) stipends. (Morris 2022). In the Eastern Cape, Free State, North-West, and Northern Cape, the decentralized model is in use where the PEDs transfer money to schools and schools appoint service providers and enter into SLAs with them. This model is used in Gauteng, Limpopo, Mpumalanga, and the Western Cape (DBE, 2015). In KwaZulu-Natal, the centralised model is followed, where the Provincial Education Department (PED) assigns service providers and enters into service level agreements with them (DPME/DBE, 2016). The funding is allocated according to the following values: minimum 96% towards the procurement of food and cooking utensils; a maximum 3,5% towards administration and minimum 0,5% for deworming (National Treasury, 2015). Effective from July 2019 to 31 March 2020 Volunteer Food Handlers (VFHs) receive a monthly stipend of R1217 (DBE, 2019). There are additional programme expenses that are not covered by the Conditional Grant Fund (CGF), such as food processing (preparation and cooking) and food quality (Poswell and Leibbrandt, 2006). The KZN NSNP circular no. 48 of 2019 effectively adjusted the wood/gas allocation between R700 to R2400 per month, depending on the schools' enrolment (**Table 1**). The Conditional Grant has a backlog of existing schools without the infrastructure needed for food preparation, despite the norms and standards on school infrastructure requiring a food preparation area in every newly built school (DPME/DBE, 2016). The program's primary target schools lack kitchens and often improvise by preparing meals in classrooms instead (DPME/DBE, 2016). Rendall-Mkosi *et al* (2013), also discovered that it was difficult to store and prepare food as only a

handful schools in Mpumalanga had adequate kitchens and storage spaces, which caused rat infestations in some of them.

Table 1: NSNP wood/gas allocation per learner enrolment for 2022/2023 (DBE, 2022)

NSNP Approved Enrolment 2019/20	**New adjusted rate per month**
1-200 learners	R700
201-500 learners	R900
501-1500 learners	R1300
1501-above learners	R1900

Cleanliness is of paramount importance in food preparation. Food handlers have an important role in preventing food contamination that can develop into foodborne disease outbreaks and must handle food properly (Putri and Susanna 2021). According to 6% of NSNP coordinators who participated in an evaluation of the NSNP conducted in 2016, some schools lacked access to water, which is necessary for washing dishes, floors, and other surfaces, while 78.4% of the schools stated that they had enough water for cooking, 87.2% said they had enough for drinking, and 92% said they had enough for washing hands, despite reports of water shortages and irregular supplies at some schools (DPME/DBE, 2016). All VFHs interviewed by Dlova (2018) expressed that they continued working even when they had cold/illness. Respondents interviewed by Nyawo, Kesa et al. (2012) in an assessment of knowledge levels of food safety and hygiene practices among NSNP food handlers in Gauteng maintained that the schools had no storage facilities, the kitchen was used for cooking and as a storeroom; in addition, they reported that they have basic knowledge on how to store the food properly to avoid food being exposed to bacteria.

Along with having access to water, people also need enough room to store food and prepare meals, as well as the right tools and fuel (DPME/DBE, 2016). According to Rendall-Mkosi et al. (2013), parents were required to gather firewood in the Eastern Cape as a commitment to the NSNP. The ability to store food and prepare meals in accordance with health regulations depends on schools having the necessary equipment and infrastructure. According to Nhlapo et al. (2015), meals for the NSNP had a wide range of nutrients, possibly as a result of prolonged storage times or exposure to light and oxygen that caused deterioration. This finding emphasizes the significance of properly storing food items, rotating stock, and making sure it is used when necessary.

Infrastructure at the school level was found to be inadequate in prior NSNP assessments (Graham *et al*. 2015; Rendall-Mkosi *et al*., 2013). Principals have detailed several equipment and infrastructure-related issues, such as the lack of kitchens that forces VFHs to prepare food outside. The infrastructure for the NSNP, including storage spaces, kitchens, and fridges, was found to be insufficient in KwaZulu-Natal, Mpumalanga, Gauteng, and Limpopo, where it was most common. This made the NSNP challenging to implement (DPME/DBE, 2016). This led to inspectors from the Department of Planning: Monitoring and Evaluation rating several KZN schools as "very poor," where food is prepared in the open air. Graham et al., (2015), also reported that several NSNP kitchens in the Eastern Cape lacked the necessary appliances to prepare meals. Lack of kitchenware for preparing food was most common in Mpumalanga, Gauteng, Mpumalanga, KwaZulu-Natal and Western Cape. Overall, schools that were reported to have the most challenges and infrastructure-related issues more frequently used the centralised model reported these.

Concerns about health and safety when preparing food are equally important. Nationally, 66.4% of schools use gas for cooking. Wood is the other primary fuel source used by 36.7% of schools nationally, 96.1% of which were in Limpopo. In order to ensure fire safety, a fire extinguisher must be kept in the kitchen. Only 23.7% of the schools, however, were equipped with kitchen fire extinguishers and were accordingly prepared. Only 43.9% among those fire extinguishers had received maintenance in the previous 12 months, in addition. Therefore, most schools weren't equipped to handle a fire. For instance, only 37.5% of VFHs in Gauteng had received training in gas safety, but they maintained their gas cylinders outside or locked in a safer manner than 50.4% of VFHs in Mpumalanga (DPME/DBE, 2016).

Up to 84.5% of schools assessed by Rendall-Nkosi et al., (2013) in Mpumalanga prepared NSNP meals cooked in designated areas, of which 52% used a permanent kitchen and 32.7 % used a temporary food preparation area. Handful schools had adequate kitchens and storage areas, making it difficult to prepare food and prevent rodent infestations (Rendall-Nkosi et al., 2013). A food safety risk arises from the fact that many schools do not have a designated kitchen where meals are prepared because this lack of infrastructure can lead to the spread of foodborne illnesses (Kibret & Abera, 2012). The provision of appropriate management support, knowledgeable and skilled food handlers and designated and adequate equipped infrastructure, are necessary for ensuring food safety in food service establishments (Rendall-Mkosi et al.,

2013). It is crucial that appropriate quality assurance and food safety measures are implemented in order to prevent or lessen the incidence of foodborne diseases in schools given the rise in the number of public schools providing NSNP meals to students (Asiegbu, Lebelo and Tabit 2016). Inadequate prior training regarding foodborne pathogens may be the main cause of NSNP food handlers' inadequate knowledge of certain food safety hazards (Quinlan, 2013).

The regulation governing general hygiene requirements for food premises, the transport of food and related matters states that persons in charge of food premises and all food handlers must be trained on health and hygiene standards after employment (Department of Health 2018). The Department of Basic Education (2009) reported that 82.7% of schools assessed nationally showed that their various food preparation facilities lacked a dedicated team to ensure food safety. This is because the Department of Basic Education regularly nominates educators to supervise the NSNP in schools despite their lack of training or expertise in food safety management (Department of Basic Education, 2009). Inadequate oversight of proper food safety practices could result from the NSNP's lack of trained food safety staff (Rendall-Mkosi *et al*., 2013) given that a barrier to the successful implementation of HACCP is a lack of knowledge about it (Ova, 2012). Alqurashi *et al*., (2019b) additionally discovered that some VFHs did not receive enough regular training. Although most food handlers the case study by Sibanyoni et al., (2017) had training on good personal hygiene (71.7%), the majority had not received training on a pest control (63.3%), chemical storage (77.5%), equipment cleaning procedures (64.8%), kitchen operation procedures (65.5%), an equipment care and maintenance programme (68.7%), purchasing and receiving procedures (73%), and food allergy safety precautions (82.4%). Lack of previous training regarding foodborne pathogens may be the main cause of NSNP food handlers' inadequate knowledge of a number of these food hazards (Quinlan, 2013). To prevent the spread of foodborne pathogens from one food to another, NSNP food handlers should receive training on the proper technique for cleaning and sanitizing chopping boards (Farahat et al., 2015) and adequate knowledge on temperature regimes during storage (Smigic et al., 2016).

Due to the fact that many learners eat NSNP meals, the school nutrition programme is an initiative that shows will not slowing down. As a result, food safety needs to be a top public health priority. Currently, the requirements of school food preparation areas are given less consideration. Despite the regulations being clearly explained, there are several instances where

they should not be applied (Banati & Lakner, 2012). Ensuring that learners are provided with meals prepared in premises that comply with food hygiene regulations should be a requirement of this programme, thus ensuring the prerequisites for the maintenance and promotion of learners' health, including compliance to food hygiene regulations.

2.3 National School Nutrition Programme Guidelines

Prerequisite programs must be in place in all food handling premises. These are food safety practices that cover the standard requirements for operating a hygienic environment for handling food (FSAI, 2016). Prerequisite programs include areas such as premises and structure, facilities and equipment, zoning e,g. separation of activities to prevent cross-contamination with biological hazards, protocols for limiting and preventing chemical and physical contamination from the preparation area, supplier management, the availability of basic services such as, water, gas and ventilation, waste management, temperature monitoring, employee training records, standards for personal hygiene, pest control, written requirements, and documented cleaning and sanitation guidelines (Youn & Sneed, 2003).Most hazards can be controlled by prerequisite programmes, as they are a fundamental base upon which to construct a strong self-control system and are essential to the creation and execution of successful Hazard Analysis and Control Control Point (HACCP) plans (Henroid & Sneed, 2004). HACCP is a food safety management system that enables the identification and management of any risks to the safe preparation of food (FSAI, 2016).

In addition to the quality of the raw materials, the proper atmosphere, technology, and methods of food preparation and consumption also have an impact on the health effects of catering services. In addition to the quality of the raw materials, the proper atmosphere, technology, and methods of food preparation and consumption also have an impact on the health effects of catering services (USDA Food and Nutrition Service, 2000). Accordingly, the National Department of Basic Education has guidelines that specify the bare minimum of necessary tools and utensils for implementing a long-term National School Nutrition Program. In order to guarantee that students are provided high-quality, nourishing, and safe meals in a dignified manner, the document guides Provincial Education Departments, districts, and schools in the selection of quality and durable equipment and utensils, it specifies that any kitchenware purchased for the program must meet South Africa Bureau of Standards requirements (SABS) (DBE, 2011).

The guidelines recommend materials such as stainless steel, aluminium and polypropylene plastic (strong plastic) for use as they comply with HACCP principles which ensure food safety requirements. The guideline indicates that wooden equipment, such as wooden spoons and chopping boards; were to be avoided as they increase the chance of cross-contamination. The NSNP also provides a catalogue of must-have cooking equipment that is required for 350 learners and more, such as food storage equipment, 3 plate gas burners, cylinder, polypropylene plastic or stainless-steel long cooking spoons, 60 litre stainless steel or aluminium heavy duty cooking pots, stainless steel worktable, tablespoons, serving spoons, plates, serving containers, cleaning equipment, protective clothing and safety equipment. The cooking fuel used by the NSNP is mostly gas therefore, safe installation and use is of utmost importance. The NSNP has additional guidelines on gas safety in schools and measures to be taken ensure compliance with the requirements of specifications and mandatory aspects detailed within the Occupational Health and Safety Act of 1993 and SANS 1539 – "Appliances operating on liquefied petroleum gas-safety aspects", which schools were encouraged to be familiar with. Gas cylinders used in the NSNP range from 19-48kg and by law, only one 19kg cylinder is allowed indoors. The guidelines state that bigger cylinders should be stored outdoors in a lockable steel cage with appropriate signage indicating that gas can be hazardous. There are measures of safety and precaution to be taken when using gas to cook, i.e., ensuring that windows are open to allow cross-ventilation; with the provision of a fire extinguisher (DBE, 2011).

2.4 Food safety handling and practices in the NSNP

Food hygiene is defined as "the means and circumstances essential to prevent hazards and to assure fitness for human consumption of a food item, taking into consideration its intended use" in European Commission (EC) Regulation No. 852/2004. Poor hand hygiene is a significant risk factor in the occurrence of food contamination, according to the Codex Alimentarius Commission (2003), and inappropriate food handling is a primary source of foodborne illnesses. Food can become contaminated at any point during harvesting, processing, storage, distribution, transportation and preparation. Without the above-mentioned conditions and measures in place, food safety will be compromised, and the life of the consumer placed at risk. For the European community and the global food industry, respectively, health authorities such as the European Food Safety Authority, created food safety management systems and best

practice guidelines. (Ababio *et al.* 2016). In food handling, the barrier between implementing proper sanitary standards and not implementing them may be the food handlers' awareness of the risk involved. Food handlers' improper handling and disregard for hygienic precautions may allow harmful germs to contaminate food and grow in significant numbers to make consumers ill. Angelillo *et al*. (2000) suggested that food handlers that are knowledgeable about safe food handling procedures may be able to reduce the number of cases of food poisoning since they frequently come into touch with food, especially ready-to-eat items. A "weak link" can result in significant morbidity and mortality from foodborne illness even in cultures with highly developed food safety systems, such as the European "farm-to-fork" and American "farm-to-table" methods. A "weak link" can result in significant morbidity and mortality from foodborne illness even in cultures with highly developed food safety systems, such as the European "farm-to-fork" and American "farm-to-table" methods (Lazou *et al,* 2012).

WHO (2001) developed the Five Keys to Safer Food in an effort to promote safe food handling behaviours and educate both the food handler and the consumer. The Five Keys to Safer Food explain the basic principles that everyone should know globally to prevent foodborne diseases. The core messages of the Five Keys to Safer Food are: (1) keep clean; (2) separate raw and cooked; (3) cook thoroughly; (4) keep at safe temperatures; and (5) use safe water and raw materials.

The first key: Keep Clean, emphasises the importance of a clean food handler, clean equipment and a clean food preparation area. Despite the fact that the majority of microorganisms do not spread disease, it is common to find harmful bacteria in soil, water, animals, and humans. The slightest contact can result in the transmission of these bacteria from hands, wiping cloths, and utensils, particularly cutting boards, to food causing foodborne illnesses. Therefore, it is important to distinguish between “cleaning” and “sanitising”, because "sanitizing" is the process of disinfection, whereas "cleaning" is the act of physically removing dirt and food crumbs. To stop the spread of microbes, towels, cloths, and other cleaning supplies should be kept spotless and replaced every day. Separate cloths should be used for washing surfaces and dishes. The food preparation area can be kept clean by having measures to prevent pests and pets from accessing the area. Pests such as rats, cockroaches and flies can transfer harmful microorganisms on food and food contact surfaces. Food should be kept safe from pests by: covering or storing in closed containers; keeping rubbish bins covered and ensuring that waste

is disposed regularly; ensuring the structure of the food preparation area is maintained in good condition.

The second key: Separate raw and cooked, highlights the danger presented by raw foods, especially meat, poultry, and shellfish, as well as their juices, should not be consumed since they may contain bacteria that can be spread during food preparation and storage to other foods. Cross-contamination can be avoided by using separate knives and cutting boards, putting raw meat below cooked or ready-to-eat meals, storing food in containers with lids, and using clean plates for prepared foods. Good practices were discovered in every school foodservice assessed in Portugal, including food storage in suitable containers and documentation of freezing and refrigeration temperatures. Only 74.2% of establishments kept uncooked foods from cooked foods in separate refrigerated units or placed raw goods beneath cooked items in the same refrigerator to minimize the danger of cross-contamination, despite the fact that 93.5% of foods were stored in suitable containers (Martins and Rocha, 2014).

The third key: Cook thoroughly; stresses how correct cooking can destroy all food pathogens, thus ensuring that meals are indeed safe for consumption. For food to be considered safe to consume, it must reach a temperature of 70°C, where even significant concentrations of germs are instantly eliminated.

The fourth key: Keep food at safe temperatures, underlines how food should be kept at temperatures below 5°C or above 60°C to ensure that the growth of germs is slowed down or stopped as they can multiply quickly when stored at ambient temperature.

The fifth key: Use safe water and raw materials, puts emphasis on how harmful chemicals and pathogens can contaminate raw supplies, especially water. Damaged cans or mouldy fruit, vegetables, and dry goods may produce toxic compounds, therefore care should be taken in selection. Boiling, chlorination, and filtration of water makes it safe for washing hands; fruits and vegetables; cooking with and drinking (WHO, 2001).

In 2006, the EU passed legislation requiring food enterprises to follow HACCP guidelines. (European Union, 2004). Within nine years of the law's passage, all of the schools in Lincolnshire, England, that were visited had some sort of food safety management system in

place and functioning (Ababio *et al.* 2016), while annual HACCP training is compulsory for food handlers in Hungary (Toth *et al.* 2017). According to the NSNP policy, food establishments must adhere to local authority rules regarding hygiene standards and must be kept in a sufficiently hygienic state (DBE, 2012). Up to 91.4% of food handlers who participated in a study assessing their knowledge and awareness of food safety in the NSNP in the South African province of Mpumalanga said that the HACCP system was not in place at their individual NSNP food preparation facilities (Sibanyoni, Tshabalala and Tabit 2017). The policy also stipulates that following employment, food handlers must get training in health and hygienic requirements (DBE, 2012). Schools in South Africa did not have HACCP in place, despite the fact that doing so in South Africa is required of all businesses that handle food (Department of Health, 2003). Food handlers' capacity to execute food safety procedures at food service establishments may be hampered by their lack of HACCP knowledge (Webb & Morancie, 2015). Sani and Siow (2014) also discovered that most food service establishments in Malaysia employed food handlers were not knowledgeable about the HACCP system. A statistically significant difference ($p=0.01$) between the number of trained and untrained food handlers was found when the knowledge and behaviours of food handlers were evaluated, as well as the hygienic conditions of food premises in Bahir Dar, Ethiopia. These behaviours included hand washing, touching with food without washing, wearing jewellery, and touching their bodies while handling food (Mulugeta and Abera 2012).

Food handlers are warned against engaging in actions that could affect food quality, such as sneezing, coughing, eating, chewing, or smoking while near exposed food (WHO/ FAO, 2009). Although there are provisions in international and local food safety regulations governing proper hygiene required in food premises, school nutrition staff in developed and developing countries significantly differ in their compliance. Food workers who don't cover their mouths or their hair could become potential causes of food contamination (Samapundo, *et al*, 2015). This behaviour could have severe effects on learners since their food may be contaminated by hair strands or microorganisms from food handlers' mouths, especially those who are ill with airborne infections. (McLinden, *et al,* 2014; Parra, *et al,* 2014). However, training in personal hygiene standards can help to alleviate this concern about food safety (Jianu & Golet, 2014).

Sibanyoni, Tshabalala and Tabit (2017) reported that 99.1% of food handlers in Mpumalanga, South Africa, said they always check the use-by date of food goods before utilizing them. This

is a smart food safety practice that enables food handlers to decide how long food products should be stored without jeopardizing quality and safety (O'Connell *et al*, 2016). Food goods that are held longer than they were intended to be can spoil and develop germs that can lead to foodborne illnesses (Evans & Redmond, 2014). In Mpumalanga, South Africa, most food handlers indicated they had never done the following: cleaned by washing in hot soapy water and then sanitised meat cutting surfaces after usage (95.5%), cleaned by washing in hot soapy water and then sanitised cooking utensils after each use (80.7) (Sibanyoni *et al.,* 2017). Despite the fact that the majority of food handlers in the case study (71.7%) had been trained on good personal hygiene, the majority had not received training in purchasing and receiving procedures (73%), chemical storage (77.5%), equipment cleaning procedures (64.8%), a pest control program (63.3%), an equipment care and maintenance programme (68.7%) , kitchen operation procedures (65.5%), and food allergy safety precautions (82.4 percent) (Sibanyoni, 2017).

A review on prevalence of foodborne illness, food handling and food access by consumers found that lack of prior training regarding microbiological food safety hazards before they were recruited may be the main cause of NSNP food handlers' inadequate knowledge of food safety hazards (Quinlan, 2013). Food handlers with little knowledge of microbiological hazards are likely to be unaware of the need for or lack of usage of sanitizers (Crandall *et al*., 2016). Hand washing must always precede the washing of food stuffs and utensils to avoid cross-contamination (Hassan, 2012). Regarding temperature regulation and storage techniques, Sibanyoni, Tshabalala and Tabit (2017) discovered that few food handlers working in feeding programs in Mpumalanga, South Africa, performed the following actions: leftovers that have been heated up a lot or always (26%) and when monitoring food temperatures, always or almost always used a calibrated food thermometer (3%). Many people who handle food had never warmed up leftovers (food that remained after lunch had been served). This could be explained by the use of energy sources including wood, coal, gas, and even paraffin, which are unsuitable for maintaining food at a high temperature for several hours after lunch because they can be quickly depleted (Sugru & Lebelo, 2009). Food that has been prepared a second time should be kept extremely hot (above 60 °C) or quickly cooled and refrigerated (below 5 °C) (WHO, 2006).

Given that most school nutrition programs are frequently viewed as measures to reduce poverty and hunger, ensuring the proper handling of food in these programs remains a significant concern in many nations (Jomaa et al., 2011). Additionally, many schools that participate in

school feeding programs lack the resources necessary to properly implement food safety measures (WFP, 2013). Due to the increased population and increased personal contact, foodborne outbreaks are common in semi-enclosed settings like school settings (Mellou et al., 2013).

2.5 Legislation related to formal and informal food preparation

Due to the increased number of foodborne outbreaks in restaurants, hospitals, schools and day-care centres, publications like Codex Alimentarius (2003) and food safety laws have been created to help professionals and owners of food services globally. Basic Hygiene Text for Codex Alimentarius (WHO/FAO, 2009) Section 7.2 further suggests that those with diarrhoea, jaundice, fever, vomiting, obvious infected skin lesions, sore throat with fever, and discharges from the ear, eye, and nose be potentially excluded from food handling. Through R638 of the Foodstuffs, Cosmetics and Disinfectants Act 54 of 1972, South Africa addresses all matters relating to the hygiene requirements of food premises, transport of food and related matters. School nutrition programmes must comply to the standards established by the South African Department of Health (DoH) in order to guarantee that students are receiving meals of the highest quality. These include the implementation of the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act 54 of 1972) and the sections of the Health Act, 1977 (Act 63 of 1977) that relate to food hygiene and safety (DoH, 2012b).

South African legislation states that food may only be handled in premises that adhere to the norms and standards for food facilities and premises contained therein, premises issued with a valid Certificate of Acceptability, that persons in charge of food premises are suitably trained and it is their duty to ensure that all persons handling food are also suitably trained in the principles and practices of food safety and hygiene, and to routinely assess the effects of training. R638 also provides the necessary internal temperature of stored food, whether frozen, chilled or heated. The statutes governing the microbiological standards (**Table 2**) for foodstuffs and related matters (Department of Health 2001) and its amendments also make provision for permissible limits of pathogenic bacteria in foodstuffs.

Table 2: Permissible limits of pathogenic bacteria in foodstuffs (Department of Health, 2001)

Pathogenic bacteria	**Permissible limit**

Staphylococcus aureus	Counts of 10^5/g are highly suggestive of food poisoning
Salmonella	Counts of 10^5/g are highly suggestive of food poisoning
Listeria monocytogenes	The minimal infectious dose is estimated to be >10^2/g
Escherichia coli O157:H7	The infectious dose is as low as 10^1/g-10^2/g
Shigella	The infectious dose is as low as 10^1/g-10^2/g

2.6 **Food handler personal hygiene**

Good personal hygiene and proper food handling practices can diminish the transfer of pathogens from food handlers to consumers. Therefore, it should be taken into consideration to train and monitor food handlers to ensure thorough hand washing, adequate cleaning, and effective sanitation processes in order to limit the danger of cross-contamination. In Ghanaian schools, staff hygiene procedures such as reporting infectious disease and monitoring, hand washing, and not wearing jewellery wear during food preparation, and eating while preparing food preparation were poor (Ababio *et al*., 2016). Martins & Rocha (2014) identified lack of facilities and resources for proper hand washing techniques as the main cause of poor personal hygiene habits. Structures and amenities adequacy has a favorable relationship with the observed practice. A wash hand basin is one example of adequate equipment, tools, and structure that may encourage the food handler to perform properly (da Cuhna, Stedefeldt and de Rosso, 2014). Food handlers play a major role in food production and serving. They are responsible for preparing the food and this means they have more direct contact with food systems and can invariably be agents of contamination (Ehuwa, Jaiswal *et al*. 2021). The chance for contamination largely depends on how healthy the food handlers are, their personal hygiene, knowledge and application of food hygiene rules (Mama and Alemu 2016). The hands have the ability to cross-contaminate food and the surfaces they come in contact with (Todd *et al.*, 2009). Cross contamination and subsequent outbreaks may be caused by the person handling the food and by contact with contaminated surfaces. At every stage of food production, food handlers should wash their hands, but especially before handling food, after eating, after contacting contaminated objects, after visiting the restroom, etc. Hand sanitizers can be used as a proper step in hand washing and use waterproof gloves that have been cleansed and disinfected while handling food. Food handlers who directly handle RTE foods should wash their hands properly using soap under hot running water and dry with a disposable paper towel (CDC, 2010). Gloves reduce the likelihood of food contamination by preventing bare hands from coming into direct touch with food and food contact surfaces when worn properly (Sibanyoni *et al*., 2017). In a lot

of food premises, the wearing gloves is not required. (Tan *et al*., 2013) however, this is a crucial safeguard for food safety, particularly in the NSNP. Given that it has been noted that food handlers do not wear gloves, it is essential for them to wash their hands often because doing so is a crucial step in preventing cross-contamination in food premises (Scallan *et al.*, 2013). One of the main contributors to cross-contamination is improper hand washing procedures when handling food, which can expose NSNP consumers to a variety of food safety risks. (Choi *et al.*, 2016). Therefore, to prevent cross-contamination, hand washing must always be practiced before washing foodstuffs and utensils. (Hassan, 2012).

Food contamination that results in food poisoning has been linked to poor personal hygiene, particularly inefficient hand washing (Curtis and Cairncross, 2003). The most fundamental yet important requirement for maintaining hygienic practices by food handlers is hand cleanliness and has traditionally been recognized as a crucial preventative strategy in healthcare environments, (WHO, 2009) including in the kitchen, to stop the transmission of infectious diseases from person to person or from person to food (Chinakwe *et al.*, 2013). Therefore, it is thought that maintaining good hand hygiene could be a sign that food handlers follow safe food preparation procedures. Poor personal hygiene has been linked to the microbial contamination of food handlers' hands and the potential for contaminated hands to spread contamination, according to several studies (Lues & Van Tonder, 2007). A systematic review of 25 research articles evaluating the adequacy of Good Manufacturing Practices and microbiological quality in school food services revealed the most frequent non-conformities were hand washing practices, use of uniform, exclusive sanitary installations for the food handlers and the presence of *Staphylococcus* on the hands of food handlers (da Cunha, Stedefeldt and de Rosso, 2012). Choi *et al*., (2016) observed that only around half of the employees demonstrated adequate hand washing behaviors during the observation, despite the fact that all observed locations in Houston, Texas, and Columbus, Ohio, were adequately equipped with hand hygiene facilities with disposable paper towels and soap (96.8%). Due to handlers' low risk attitude of hand hygiene, poor physical structure, or work overload, the practices are frequently not carried out adequately, leading them to give higher priority to other tasks they believe to be more important (da Cunha *et al*., 2014).

In Ghana's schools in the Ashanti Region, there was poor hand washing practice (Asiegbu, Lebelo and Tabit 2016). This contrasted with Sibanyoni *et al.*, (2017) who reported 86% of

food handlers in Mpumalanga, South Africa claimed to always wash their hands with running water before and after handling uncooked foods, as well as before using fruits and vegetables. In developing countries, since most school restrooms lack conveniently accessible wash basins and water, worker hygiene standards may be impacted by management neglect or poor economic situations. In industrialized nations, all school nutrition employees receive training, and hand washing is a protocol that staff members are instructed to follow. Staff had access to hand washing stations with easily available detergents and dryers, which aided in the practice. (Ababio *et al.* 2016). In impoverished nations like Ghana, it is not commonly practiced removing jewellery during food preparation and delivery in order to reduce the risk of physical and microbiological contamination, as stated in Codex Alimentarius Section 7.3 on Personal cleanliness (WHO/FAO, 2009). All those who handle food have a duty to keep themselves very clean and follow hygienic and safe food handling procedures (Adimasu et al, 2016).

2.7 **Training in food hygiene and safety**

Studies confirm the effectiveness of food safety practices at various places when there is adequate and ongoing training: such as a survey, where workers who were required to receive annual training in food hygiene had more practical knowledge than those who weren't (Pichler *et al*, 2014). Newly hired food handlers shouldn't start working in restaurants right away if they haven't had any training or experience handling food safely (Ababio and Lovatt 2015). Along with meaningful learning, the primary objective food hygiene training is to change employees' conditioned behaviours (Gomes *et al*, 2014). Most NSNP food handlers lack basic training in food safety, an observation seconded by Sani and Siow (2014) in Brazil, when questions involving temperature, time management, and cross-contamination had just a 50% correct response rate.

According to multiple studies, trained food service personnel used safer food handling techniques and had higher hygiene ratings than untrained personnel (Ababio and Lovatt, 2015). In a study of the environment of fast-food establishments, better hygienic conditions and greater sanitary knowledge awareness have been highly linked with the educational level and age of workers (Olumakaiye and Bakare, 2013). The majority of NSNP personnel, according to a 2012 assessment from the South African Department of Basic Education (DBE), did not undergo official food safety training (Rendall-Mkosi, Wenhold et al. 2013). In the study by Ali and Immanuel (2017), The risk of food contamination was unknown to all food handlers

(n=25), who all engaged in eating, drinking, smoking, or chewing tobacco leaves while handling food. Food handlers were ignorant of temperature and timing limits. This conclusion is reinforced by Webb and Morancie's (2015) report, which demonstrates that full-time and part-time staff who actively participated in the preparation of food at 14 restaurants on a university campus in Trinidad and Tobago lacked appropriate awareness of critical temperatures. Unsafe food handling techniques and cross-contamination in restaurants can stem from food handlers' lack of knowledge and expertise in food safety (McGill *et al.*, 2015). Previous research has shown that many food handlers in food service organizations frequently lack the fundamental knowledge of food safety regarding temperature control, personal cleanliness, and the control of cross-contamination (Afolaranmi *et al*., 2015). The World Health Organization's (WHO) findings indicate human actions are the primary source of food contamination in food preparation because of non-adherence to appropriate hygiene measures emphasize the importance of the situation. (WHO, 2013). To increase food safety in food establishments, it is required to train and educate a workforce on food safety and hygiene (Baluka 2015).

2.8 **Food contact surfaces**

The processing environment is perhaps more crucial for the risk assessment of food safety, although it has gotten less attention to date. Environmental bacteria are significant indications of the processing facility's environmental hygiene even though they are typically not thought to pose a threat to food safety (Ferreira et al., 2014; Moretro and Langsrud, 2017; Pérez-Rodríguez *et al*., 2018). When food contact surfaces are not effectively cleaned and disinfected, microbial cross-contamination issues can arise in the foodservice facilities of schools that offer school nutrition programmes (Nhlapo *et al*., 2014). In order to eliminate plant debris, soil, and microbiological pollutants that collect on surfaces during processing, cleaning and disinfection are often carried out at the end of the manufacturing shift (Moretro and Langsrud, 2017) and is a component of the majority of food processing facilities' overall food safety procedures. These residential bacteria could spread to foods and compromise its quality (Moretro and Langsrud, 2017). However, the types of bacteria found in areas where produce is processed and how they affect food safety and quality remain mostly unknown (Moretro and Langsrud, 2017).

Regardless of the material, cutting boards can spread cross-contamination. Wooden surfaces that have been previously used must be cleaned properly. Kitchen countertops, for instance, are frequently seen as a critical control point in the preparation of meals. Even if it is less often now, using wood in touch with food has historically proven hygienic and secure. In fact, because of the way it is built, there are surface crevices that can trap germs and prevent them from surviving, which severely restricts bacterial development (Aviat et al, 2016). However, it is still widely employed in various established industries around the world, including the production of wine, the production of cheese, the preservation of fruits and vegetables, and the shipping of seafood and meat (Aviat *et al*., 2016). Due to the material's porosity, hardwood cutting boards were thought to be more difficult to maintain in the 1990s. During this time, the USDA's Food News for People advised consumers to use plastic cutting boards rather than wooden ones, although now this organization advises both types (USDA 2013). To prevent cross-contamination between various raw foods and to replace cutting boards that are overly worn, French consumer organizations and public authorities advised using two cutting boards, one for meat and one for fruit and vegetables. After each usage, they suggested giving a wooden chopping board a thorough scrub with dish soap before washing it with warm water. The cutting board should then be dried outside or cleaned with a dry, clean cloth (Association Leo Lagrange, 2014). Working surfaces need to be continually maintained and watched for cleaning and disinfecting, despite of the surface material. This is also promoted by the NSNP food preparation rules poster with principles such as, separating raw food from cooked, keeping a clean food preparation area, washing fruit and vegetables, and using clean cooking and eating utensils (Department of Basic Education 2012).

Schools should adhere to food hygiene standards as tightly as other food facilities given the high danger of cross-contamination causing outbreaks. Given that these bacteria can contaminate foodstuffs produced in these facilities, their presence on surfaces in contact with food must be taken into consideration as a source of concern. Every surface that comes into contact with food might enable the growth of other microbes in addition to *S. aureus* (Gutierrez *et al*., 2012). Food contact surfaces have also been recognized as a substantial risk factor for foodborne disease, in addition to insufficient cooking, insufficient temperature control, the use of contaminated raw components, and cross-contamination between uncooked and cooked meals (Boro *et al*., 2015; Nhlapo *et al*., 2014). The food business uses a variety of materials for food contact surfaces, including plastic, stainless steel, glass, and wood. These surfaces are

susceptible to microbial contamination, some of which can create biofilms (Sibanyoni, 2017). Abdul-Mutalib *et al.,* (2015) identified bacteria on 26 kitchen worktops (wood or plastic) that were gathered from various food establishments in Malaysia. Each sample included a microbial community that was extremely diverse, and 40 different kinds of bacteria were found. Additionally, they showed how similar the microbial population was on chopping boards from various food establishment grades.

Foodborne illness outbreaks in schools have been brought on by improperly cleaned utensils and equipment or modifications to processed foods. In ensuring microbiological safety of foods, sanitation (cleaning and disinfection) is the most effective control. Therefore, it is important to ensure that cleaning is done to a point that significantly decreases cross-contamination with the assurance of food integrity (Nhlapo *et al*., 2014). There are numerous ways to evaluate the cleanliness and hygiene of school facilities, which help to pinpoint key areas for microbe survival, growth, and contamination. One of the main ways used to evaluate the cleanliness of facilities that make food is the detection of pathogens using environmental monitoring after disinfecting surfaces that come into contact with food. In Porto Alegre, Brazil, 90.3 % of establishments had the necessary washing facilities, however only 12.9 % and 16.1 % had records of the chemical sanitizing concentrations (in parts per million) or sanitizing temperatures for manual and mechanical washing, respectively. Results showed that counters and cutting boards' surfaces were rarely properly cleaned in most schools, indicating that these areas need more care because they had the largest concentrations of mesophilic heterotrophic bacteria. Cutting boards and countertops both most surpassed the set criterion (50 CFU/cm²), whether alone or in combination. In 98 % of the schools, it was found that cleaning processes were not standardized, which showed that tools and equipment were not properly cleaned. The lack of a cleaning schedule and equipment maintenance was another aspect that illustrated the lack of consistency (de Oliveira, 2014).

2.9 **Common food pathogens associated with improper food safety practices**

A risk to food safety is any substance that, when present over a certain tolerable level, is likely to cause harm, injury, or sickness. Hazards to food safety might be biological, chemical, or physical. Food contamination at any stage of manufacturing, processing, storage, and

distribution can pose a threat to public health (Singh, 2015). Microbial contamination is widespread in areas with inadequate sanitation and limited access to clean water, and both are significant causes of foodborne infections, particularly among children (WHO, 2014). Any step of the farm-to-table process might experience microbial contamination, which can come from the environment, animals, people, and technology applications. In addition to physical contact, microorganisms can also spread through water and the air (FDA, 2001). Over 250 foodborne diseases are caused by consuming water and food contaminated with possible foodborne pathogens such bacteria, viruses, parasites, and toxins (WHO, 2014; Woh *et al*., 2016). The severity of the symptoms, the wide range of foods and bacteria that can be affected, and other factors make microbiological sources a higher threat to public health (Melngaile & Karklina, 2013). In the kitchen, using the same knife, cutting board, or other instrument without rinsing it with warm soapy water in between uses might lead to the transmission of microorganisms from one food to another (Nyamari, 2013). According to reports, the following are the main causes of foodborne illnesses: Lack of basic sanitation, abuse of time and temperature, improper hand washing techniques, poor personal hygiene, lack of knowledge of food safety precautions, lack of cooking fuel, inappropriate food storage facilities, absence of food handler education programs, and errors during food processing (Baluka *et al*., 2015). If food handlers adhered to food safety procedures when handling and preparing food, one of the most efficient ways to stop the transmission of bacteria, most cases of foodborne disease might be eliminated (Scallan *et al*., 2015). Food handlers may be the source of food contamination either as carriers of pathogens or through poor hygienic practices (Adimasu *et al.*, 2016).

Foodborne outbreaks have historically been linked to consuming goods with an animal origin. However, epidemic cases in recent times have become more and more associated with unprocessed, raw fruits and vegetables. Consumer health is seriously at risk when food products are contaminated with microorganisms in food processing facilities due to poor hygiene standards. Furthermore, it is challenging to completely eradicate pathogens from areas where food is processed, partly because bacteria can adhere to food contact surfaces and create biofilms where they can persist long after cleaning and disinfection (Yang *et al*., 2012). As part of the Food Standards Programme, regulatory organizations like the Codex Alimentarius have set permissible levels of several dangers. The prevention, eradication, or reduction of hazards to tolerable levels are some of the tactics used to handle food hazards. The HACCP system also makes use of these techniques (Martins, & Rocha, 2014).

The bacteria commonly involved in foodborne diseases are *Salmonella spp, Staphylococcus aureus, Escherichia coli* and, *Shigella spp.* (WHO, 2008). *E. coli, Shigella* and *Salmonell*a the most prevalent gastrointestinal disease-causing factors in sub-Saharan Africa (Fletcher *et al*., 2011), and they are all linked to foodborne illnesses (FDA, 2012). Enterohemorrhagic *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella spp*., are the main pathogens that must be controlled in the meat sector. Adequate hygiene and the use of antimicrobial intervention technologies at the harvest, processing, storage, distribution, and consumption stages are the best methods for enhancing the safety of meat products. Fish products can occasionally include pathogenic microorganisms such *Listeria monocytogenes*, *Staphylococcus aureus* and *Escherichia coli* (Herrera *et al*., 2006). While some of these bacteria may be present in the environment naturally, many more are introduced into the food chain through unsanitary conditions during food processing and storage. (Gutierrez *et al.*, 2012). *L. monocytogenes* and *S. aureus* are two bacteria that are frequently found on food contact surfaces in dairy environments. They contaminate milk machinery via water used in milking machines and direct contact with pollutants in the dairy farm environment (Bremer, 2006). Consumers can find quick, wholesome meals from a source of ready-to-eat food products. However, concerns have been made over these foods' safety and microbiological quality (Mashak *et al.*, 2015).

According to reports in the literature, people are aware that pathogens, particularly bacteria, are to blame for foodborne illnesses, but they know relatively little about their pathogenesis (Alimi, 2016). Asiegbu *et al.,* (2016) found that while knowing little about specific pathogens, consumers of street food in Johannesburg, South Africa were aware that some microbes might cause illnesses and even death. Their awareness was attributed to previous bacterially-caused foodborne illness outbreaks that received substantial media coverage. The effects of foodborne outbreaks in school nutrition programmes could cause students to get life-threatening illnesses, incur high medical costs as a result, and disrupt instruction in schools (Toth *et al*., 2014).

2.9.1 ***Staphylococcus aureus***

S. aureus is one of the major bacterial agents causing foodborne diseases in humans (Le Loir *et al.*, 2003). In the nose, throat, and skin of people, enterotoxigenic *S. aureus* is frequently present

without causing any symptoms. Food handlers may therefore be a significant cause of food contamination (Gotz, 2002). The potential of some strains of foodborne *S. aureus* to create enterotoxins is related to the pathogenicity of the organism (Le Loir, 2003). *S. aureus*, which is common in contaminated food, including beef, chicken, and dairy products, and which can stick to surfaces where food comes into touch with it before multiplying to create biofilms (Azelmad *et al.,* 2017). *S. aureus* can attach to biofilms on food contact surfaces and withstand most cleaning techniques, it can contaminate food contact surfaces and other foods (Silva *et al.,* 2017).

The prevalence of enterotoxigenic *S. aureus* strains is substantially higher in the seafood business, and as a result, the risk of food poisoning is also much higher. In various dairy products and seafood, coagulase-positive staphylococci (CAS; primarily *S. aureus*) are utilized as a process hygiene criterion. Additionally, it appeared that some spoilage bacteria microorganisms and other food microbial pathogens coexisted with *S. aureus* on surfaces used in the food business. The level of coagulase-positive *S. aureus* is considered potentially hazardous at $\geq 10^4$ cfu/g and may even lead to foodborne illness (Kharel *et al.,* 2016). Approximately 71.4 percent of food handlers in a Malaysian study that examined the level of food safety knowledge, attitudes, and practices among those working in eleven cafeterias on the main campus of the Universiti Kebangsaan Malaysia (UKM) were unaware that S. aureus was a cause of foodborne illness (Sani and Siow, 2014), this was worrying since it was linked to outbreaks that happened all across the world (Afifi & Abushelaibi, 2012). During the preparation and presentation of food, food handlers have the potential to spread *S. aureus* to food and food contact surfaces by sneezing, talking, laughing, or donning filthy clothing (Sinclair and Gerba, 2011). Sibanyoni and Tabit (2019) Evaluation of the hygienic situation and the prevalence of pathogenic organisms on food contact surfaces in school kitchens in Mpumalanga, South Africa surface samples showed the highest incidence of *S. aureus* infection on cutting boards (31.3%) and dry storage shelf (37.5%) followed by benchtop (25%) and refrigerator handle (25%). The surfaces of serving spoons (12.5%) and sink taps (21.9%) had the lowest percentage of samples in which S. aureus was found.

2.9.2 ***Salmonella***

With approximately 83000 confirmed cases documented, salmonellosis is the second most common infection in Europe. Foodborne Salmonellosis is usually as a result of the ingestion of

contaminated animal products like poultry, raw meat, and eggs. Other sources include eating fresh fruits and vegetables without washing them, inadequate cleaning of contact surfaces at the kitchen use in the preparation of foods such as raw meat (Mama and Alemu, 2016) as well as by direct contact (Owusu, 2010). Abdul-Mutalib *et al.,* (2015) indicated that all poultry populations had shown a drop in the prevalence of the target *Salmonella*. However, *Salmonella* has continued to be the most often identified causal agent in foodborne illnesses in European nations (22.5% of total outbreaks). Raw foods with an animal origin are frequently sources of *Salmonella* isolation. Salmonella can also be found in a wide range of foods due to environmental contamination, albeit often in smaller amounts. Outbreaks associated with *Salmonella* have been traced back to worker handling and contaminated food contact surfaces.

The most typical symptoms of a Salmonella infection are severe nausea, vomiting, and diarrhoea, which can progress to an enteric fever resembling typhoid. Individuals vary in their resistance to this infection, but morbidity is significant in an outbreak. Diarrhoea may last for many days (Owusu, 2010). Salmonellosis is still a serious public health issue. Most recent outbreaks in the United States and Europe have involved both well-known and unknown dietary sources. In the United Kingdom and Ireland an outbreak occurred which was caused by the serotype. Salmonellosis was reported to have impacted 119 patients between February and July 2008 in Ireland and the United Kingdom, as well as one instance in Finland. A sandwich shop in Ireland was connected to the epidemic strain's origin (Owusu, 2010).

2.9.3 ***Listeria monocytogenes***

Listeria monocytogenes, the foodborne organism that causes listeriosis, a serious illness with significant hospitalization and fatality rates that range from 20 to 30% (Choi, Park *et al.* 2018). *L. monocytogenes* can multiply in tainted food while it is being stored in a refrigerator, it is very common in uncooked and processed ready-to-eat foods that need to be stored at low temperatures (Du *et al.,* 2017). Studies on the potential spread of *L. monocytogenes* in retail and food service operations have shown that the environment (utensils and equipment), food handlers, and incoming uncooked or cooked products that have been contaminated following treatment at the manufacturing facility are all potential sources of the organism (Lianou & Sofos, 2007). From January 2017 to March 2018, the South African National Institute for

Communicable Diseases reported 978 laboratory-confirmed listeriosis cases from all provinces of South Africa (National Institute of Communicable Disease 2018), the majority of cases coming from three provinces: 581 (59%) from Gauteng, 118 (12%) from Western Cape and 70 (7%) from KwaZulu-Natal. Whole genome sequencing was performed on isolates from a large subset of patients and 91% of the strains identified belonged to *Listeria monocytogenes* Sequence Type 6 (ST6). The same ST6 sequence type was identified in a widely consumed ready-to-eat processed meat product called "Polony". The same strain was also found in the processing environment of the manufacturer of the implicated product. (WHO, 2018). This indicates that the cleaning and disinfection practices used in this food service business were ineffective at removing *L. monocytogenes* biofilms and preventing the build-up of a significant amount of *L. monocytogenes* in the area where food is produced (Hoelzer *et al.*, 2011).

2.9.4 ***Escherichia coli***

Escherichia coli, was mostly found in the meat of ruminants (cattle, goats and sheep). Bovine meat and products thereof were the primary source of the 73 *E. coli* outbreaks that were reported in the EU in 2013, followed by "vegetables and juices" and cheese. High counts of *E. coli* usually indicate inadequate storage, poor handling and production hygiene, and post-process contamination (De Sousa *et al*., 2002). *E. coli* is a faecal indicator bacterium, thus its enumeration is utilized as a food-quality metric. Its presence in food generally indicates direct or indirect faecal contamination. Its presence in cooked food indicates inadequate cooking or post-processing contamination.

2.9.5 ***Shigella***

Shigella is extremely contagious and sickens people all around the world. It frequently breaks out in economically underdeveloped nations, regions of sub-Saharan Africa, Asia, and South America, and is mostly linked to filthy and unsanitary living circumstances (Bhunia, 2018). *Shigella* is primarily passed from person to person by the faeco-oral route. From infected people, *Shigella* can be transmitted by several means including food, fingers, faeces and flies. Examples of foods incriminated in past outbreaks are salads (potato, egg, tuna), cheese, stewed apples, chicken shrimp, clams and milk. The main cause of food contamination is poor personal hygiene on the part of food handlers, with improper storage of contaminated foods the second most common factor. Inadequate preparation, food from questionable sources and tainted tools

are other means of spreading shigellae. Houseflies are passive vectors. *Shigella* can spread to foods by either passing through the gut of flies or being transported directly from contaminated faeces via the surfaces of the flies (Cliver and Riemann 2002). *Shigella* is still one of the main causes of morbidity and mortality in children (Anderson, Sansonetti and Marteyn, 2016). Shigella appeared among the top-ranking pathogens discovered in the sites investigated (Sub-Saharan Africa, and Asia), it was strongly demonstrated in a case-controlled investigation by the Global Enteric Multi-center Study (GEMS), an update on the occurrence of Shigella among severe forms of diarrhoea (Kotloff *et al.*, 2013).

2.10 **Metagenomics sequencing**

Metagenomics is the study of genetic material recovered directly from environmental samples. This next-generation sequencing is used to analyze a sample by creating sequences for several (if not all) of the sample's microorganisms (Grützke et al., 2019). Metagenomics sequencing identifies the microflora from the processing environment by applying a culture independent and quick method that relies on genetic content for both non-culturable and culturable microbial populations (Alkema *et al*, 2016; Herpertz Dahlmann *et al*, 2017) without isolation or any unusual growth supplements and temperatures (Dass and Anandappa, 2018). In order to create a profile of variety in a natural sample, environmental gene sequencing clones particular genes (typically the 16S rRNA gene) using primers. In this method, DNA is used as a template for amplification and sequencing (Dass and Anandappa, 2018). Such work has revealed that most microbial biodiversity had been missed by cultivation-based methods (Hugenholtz et al, 1998). The outcomes are presented as relative abundance, which shows the abundance of organisms in the sample in comparison to other organisms (Mayo *et al*, 2014).

The traditional methods for identifying pathogenic bacteria mostly rely on cultivating techniques that involve enrichment broths, colonies isolated on selective media, biochemical identification, and pathogenicity confirmation. With this culture approach, a single type of pathogen can be found at a time (Gugliandolo *et al*, 2010) through sample preparation, enrichment, dilution, plating, enumeration, and isolation of single species colonies for further characterization. By morphology inspection, gram-staining, or biochemical testing, the microbe is identified based on its biochemical, physiological, genetic, and/or other properties (Ferone *et al*, 2020). Due to their dependability, effectiveness, sensitivity, and variety of applications, conventional culturing techniques are still regarded as the gold standard. They are still required for detection and enumeration, viability determination, and the validation of phenotype

predictions based on genomic analysis (Ferone *et al,* 2020). Traditional methodologies, such as selective media, are laborious and time-consuming despite being relatively cheap and straightforward. This is because the identification process typically takes between 5 and 7 days due to the time needed for the pre-enrichment step, the incubation time to allow bacterial growth, and the execution of the biochemical tests (Zhao *et al*, 2014).

Culture-based techniques are commonly used to analyse microbiota associated with food; however, microorganisms don't exist as single colonies; instead, they exist as complex communities (Dass *et al.*, 2018). Work that is dependent on culture includes selective isolation, and procedures are oriented toward the culturable microbial community, leaving the non-culturable microbial population behind. Genomic sequencing enables detection of the variety of complex microbial communities based on their genomic composition, avoiding these problems (Kergourlay *et al*, 2015). Metagenomics offers a lens for seeing the microbial world that has transformed our overview of the complete living universe due to its capacity to show the previously unseen diversity of microscopic life (Marco, 2011). Since it enables the detection, characterisation, and identification of a variety of pathogens in a single experiment without pre-cultivation, it is a potent tool in the field of contemporary food safety (Alkema *et al.*, 2016; Herpertz Dahlmann *et al.*, 2017). The identification of unique bacterial communities, including pathogens, can aid in improving food safety (Hussain et al, 2021). Nevertheless, sample handling, sequencing, and data processing are difficult and may result in biases and errors (den Besten *et al*., 2018; Leonard et al, 2015). Metagenomics now enables microbial ecology to be examined at a far greater scale and detail than before as the cost of DNA sequencing continues to decrease (Eisen, 2007).

Investigating how hygiene and environmental factors affect microbial diversity in food handling environments can open up exciting new opportunities for understanding the dynamics of the microorganisms that make up food ecosystems, which will ultimately result in safer, more effective, and sustainable methods of food production (Bokulich *et al*., 2016). The effectiveness of sanitation procedures has frequently been assessed by industry using total bacterial counts, such as APC (aerobic plate count). However, the identification of the entire bacterial community in places where produce is processed and its effects on the quality and safety of food are mostly unexplored (Moretro and Langsrud, 2017). Compared to the studies on the microbiological quality of NSNP meals, food preparation areas not been investigated with

metagenomic approaches and not much is known about the microbiological communities on food-contacting surfaces and on the food handlers' hands.

3 CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter will outline the research methodology used in this study, which was used to assess the compliance of school food preparation areas and storage areas to R638 of the Act and to determine the content of the microbial community on Food handlers' hands and surfaces that come into contact with food.

3.2 Study area

Vryheid comprises rural and urban settlements that cover an estimate of 4185 square kilometres (27° 45' 55" South, 30° 47' 37" East) and is inhabited by a population of 243 795, according to the 2016 Community Survey. Zululand Education District is the link between the Provincial Department of Basic Education and the 537 schools it provides administrative and management support to in the area, of which 109 are primary schools that provide NSNP meals. Subject to provincial plans, the district office collaborates with school principals and teachers to increase educational access and retention, provide managerial and professional support, and support schools in accomplishing goals in learning and teaching. Circuit offices play a crucial role in this effort.

The study was based in Zululand District in the northern part of KwaZulu-Natal, in Bhekuzulu Circuit Management Centre (CMC). The research site included 109 primary schools in Filidi, eMondlo, eMvunyane, Khambi, Ngotshe and uMfolozi circuits providing NSNP meals. The schools included in the study were either ranked in quintile 1, 2 or 3. The socioeconomic status (inequality and poverty) of students is considered when ranking and funding schools using quintiles (DBE, 2009). 20% of all students are distributed across each national quintile, with quintile one representing the "poorest" schools and quintile five being the "least poor" for funding purposes (Dlova, 2018). The quintile system aims to address the unequal distribution of poverty across provinces, with learners in the poorest provinces, such as the Eastern Cape, who make up 34.8% of the student population, falling into quintile 1, as opposed to learners in the relatively wealthy Western Cape, who make up 6.5% of the student population (Branson et al, 2012). The study is based in Abaqulusi Local Municipality (**Fig.1**), Bhekuzulu CMC, an area that is predominantly rural and the socio-economic status of inhabitants is very low.

Figure 1:Map of Zululand District Municipality (www.muicipalities.co.za)

3.3 Study design

A quantitative, cross-sectional design was used for this study. Bryman and Bell (2016) describe cross-sectional design as a collection of data on a series of variables at a single point in time.

3.4 Study sample

The study population consisted of 109 primary schools in quintile 1 and 2 in Vryheid. The total number of primary schools that participated in the NSNP was 109. The sample size was calculated by statistician. At a 95% level of confidence of a medium to large effect (0.45), a sample of 33 schools was required to observe a power of 80%.

The sample was selected using the random sampling function on MS Excel from 109 primary schools. This form of sampling eliminates bias because all members of a population have an equal and independent chance of being selected. The selected schools were approached and informed of the study and asked to participate. All schools that responded positively were accepted until the minimum sample size of 33 was reached.

3.4.1 Inclusion criteria

Thirty-three primary schools in quintile 1 and 2 who participated in the NSNP were eligible for the study.

3.4.2 **Exclusion criteria**

All primary schools in quintile 3 to 5 and those who did not participate in the NSNP were excluded. All schools outside of the Bhekuzulu CMC were not eligible for the study.

3.5 **Data collection**

3.5.1 **Direct observation**

Quantitative data was collected with the use of two data collection methods were used, viz. a checklist and microbiological sampling. A checklist (Appendix A) comprising of 39 questions with "Yes" or "No" as the only possible answers to assess the condition of the food preparation and storage areas. Environmental sampling of food contact surfaces was also conducted to detect the presence of pathogenic bacteria.

The checklist was adapted from the provisions of R638 of the Act, which EHPs use for the inspection sheet for food premises and the Red Meat Abattoirs Hygiene Assessment System Checklist (Agriculture and Rural Development, 2018). The checklist consisted of 39 questions that were divided into six sections: Certificate of Acceptability, Standards and requirements for food premises, facilities on food premises, storage of food, protective clothing and food handlers. Responses were dichotomised into 0 and 1, with No=0 and Yes=1. The mean duration of the observational survey was 40 minutes.

3.5.2 **Validity and reliability**

The checklist was already validated as it was used by EHPs in their routine inspection of school in South Africa. In order to address bias, the researcher used other methods such as microbiological analysis. The reliability of microbiological analysis was confirmed by the usage of approved analytical methods.

3.5.3 **Data analysis**

3.5.3.1 **Assessment of compliance**

A Microsoft® Excel® for Microsoft 365 MSO (Version 2302 Build 16.0.16130.20298) 64-bit spreadsheet was used to record the information gathered using the checklist. The compliance was scored as follows: Section A-B (Standards for food premises): 0-6 were non-compliant; 7-13 were partially compliant and 14-20 were compliant. Section C-D (Standards for facilities): 0-2 were non-compliant; 3-4 were partially compliant; and 5-6 were compliant. Section E-F (Standards for food handlers): 0-5 were non-compliant; 6-10 were partially compliant; and 11-14 were compliant.

Where necessary, the mean, standard deviation, and range of continuous data were calculated along with the frequency distribution of categorical variables. The tables of descriptive statistics are presented in the results section.

3.6 **Identification of bacteria on surfaces**

The food handlers in each of the participating schools were informed of the study and had to sign a Letter of Consent (Appendix E) after confidentiality was explained. The samples were collected from various food contact surfaces including chopping boards and utensils in 4 schools and the dominant hand of all the food handlers in the 4 selected schools were swabbed using the swab method (SANS 18593:2004). The swab was collected after food service was complete and the kitchen had been cleaned. The swab was taken out of the sterile packaging, and the tip was moistened in a dilution liquid-filled tube. To get rid of extra water, the swab's tip was rubbed against the tube wall. The swab was rotated between the thumb and fingers in two directions that were at right angles to one another while the tip was put on the surface to be inspected and streaked on an estimated area of 10 cm^2. After being aseptically fractured, the swab was reinserted into the tube. Swabs were labelled and couriered to the laboratory in a cooler box set between 1 °C to 4 °C and processed within 24 hours of collection to determine the content of the bacterial community on food contact surfaces and the hands of food handlers.

3.6.1 **Bacterial DNA extraction**

Microbial DNA was extracted from swabs content using QIAamp DNA Microbiome Kit (Qiagen, Hilden, Germany) as described in the manufacturer's protocol. Briefly, 500 µl of the sample and 500 µl buffer AHL were added to 2 ml tube and incubated for 45 min at room temperature with end-over-end rotation. The sample was centrifuged at 10,000 × *g* for 10 min

and the supernatant was discarded. One hundred ninety microliters and 2.5 µl of Benzonase were added to the sample and thoroughly mixed. The mixture was then incubated for 30 min at 600 rpm in a heating block. Twenty microliters of Proteinase K were added to the mixture and incubated at 56°C for 30 min at 600 rpm in a heating block. The mixture was briefly spun down at low speed. Two hundred microliters of buffer ATL (containing Reagent DX) were added to the mixture and mixed very well. The mixture was transferred into Pathogen Lysis Tube L and then the Pathogen Lysis Tube L was placed into a 2010 Geno/Grinder® (SPEX SamplePrep LLC, New Jersey, United States) for 15 min at 1700 rpm. Thereafter, the Pathogen Lysis Tube L was centrifuged at 10,000 × *g* for 1 min and the supernatant was transferred into a fresh microcentrifuge tube. Forty microliters of Proteinase K were added to the mixture and vortexed and then incubated at 56°C for 30 min at 600 rpm in a heating block. Two hundred microliters of buffer APL2 were added and pulse vortexed for 30 s. The mixture was incubated at 70°C for 10 min and the tube was briefly spun. Two hundred microliter of ethanol was added to the lysate and mixed by pulse-vertexing for 15-30 s. Seven hundred microliters of the mixture was transferred into the QIAamp UCP Mini spin column without wetting the rim. The QIAamp UCP Mini spin column was centrifuged at 6000 × g for 1 min and the flow-through was discarded. The QIAamp UCP Mini spin column was then transferred to a fresh collection tube and a 500 µl buffer AW1 was added to the column. The column was then centrifuged at 6000 × g for 1 min and the filtrate was discarded. The QIAamp UCP Mini spin column was then placed in a fresh collection tube and 500 µl buffer AW2 was added, then the column was centrifuged at 20, 000 × g for 3 min. The column was placed in a fresh collection tube and centrifuged for 20, 000 × g for 1 min. The QIAamp UCP Mini spin column was placed in a fresh 1.5 ml Eppendorf tube and 50 µl buffer AVE was added directly onto the centre of the membrane, the column was incubated for 5 min. The QIAamp UCP Mini spin column was centrifuged at 6000 × *g* for 1 min to elute the DNA. The quality of DNA was assessed by gel electrophoresis in 1% agarose gel run at 100 V for 30 min, and the sizes of the DNA were validated by comparison with a molecular size standard. The quantity and quality of the DNA were evaluated by measuring Qubit@ 2.0 Fluorometer (Thermo Scientific). All microbial genomic DNA was stored at −20 °C before further analysis.

3.6.2 **DNA amplification and amplicon library preparation**

3.6.2.1 Amplicon polymerase chain reaction

The 16S ribosomal RNA (rRNA) gene contains nine species-specific hypervariable regions enclosed by regions of more conserved sequence that contains the base sequence in a DNA molecule has remained relatively unchanged throughout evolution depicted in **Figure 2**. The 16S ribosomal rRNA region of approximately 470 bp and 500 bp encircling the V3-V4 hypervariable region within the 16S rRNA gene was amplified employing a set of commonly used primers for the analysis of bacterial communities. PCR assay reaction contained 5 µl of DNA as the template, 12.5 µl 2x KAPA HiFi HotStart ReadyMix (KAPABIOSYSTEMS, United States) and 5 µl of 10 µM of each primer. PCR reactions was carried out on BIO-RAD T100TM Thermal Cycler (Bio-Rad Laboratories, United Kingdom) using the following protocol: (1) an initial denaturation step performed at 95 °C for 5 min followed by 30 cycles of denaturation (95 °C, 30 s), annealing (56 °C, 30 s) and extension (72 °C, 40 s), and a final elongation of 10 min at 72 °C. PCR amplicon were assessed by gel electrophoresis in 1% agarose gel run at 100 V for 45 min, and the sizes of the products were validated by comparison with a molecular marker.

Primer pairs: 5′-CCTACGGGNGGCWGCAG-3′

5′-GACTACHVGGGTATCTAATCC-3′)

Primer sequence: (5′−3′)

Targeted regions: V3-V4 region

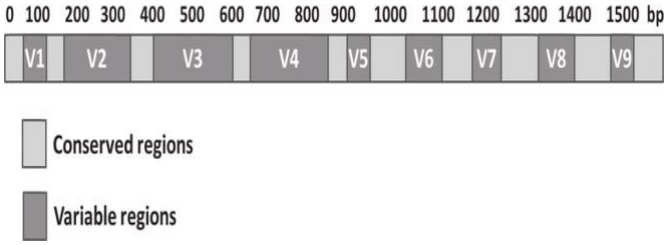

Figure 2:16s ribosomal RNA (bacterial rRNA) gene containing the 9 hypervariable regions *(*shaded) and are enclosed by regions of more conserved sequence (unshaded).

3.7 Ethical considerations

The Department of Basic Education provided permission to conduct research in the KwaZulu-Natal institutions (Appendix B). The primary schools that satisfied the inclusion criteria were approached by the researcher and briefly informed about the research study. The willing

participants, the principal and food handlers were given a Letter of Information (Appendix C) and a consent form (Appendix D), respectively to complete.

The checklist survey and sampling commenced upon receipt of ethical clearance (Appendix B) from the Durban University of Technology Institutional Research Ethics Committee (IREC 027/19). Once permission was obtained from the provincial Department of Basic Education, the district office had to be notified, in writing, of the researcher's intention to conduct research. The following was used to ensure that the study was conducted ethically from start to finish:

- The researcher obtained permission from the KZN Department of Basic Education (Appendix C) to conduct the study in schools.
- A Letter of Information (Appendix D) of the details of the study was provided to the principals of the participating schools.
- Informed consent was obtained from the participants of the microbiological sampling (Appendix E).
- The participants were informed that participation was voluntary and that they were allowed to withdraw at any stage of the study.
- The names of the schools were not used, instead a code was used for the checklist and corresponding samples collected from each school.
- All data, including electronic data, was safely housed in a locked cabinet that was only accessible by the researcher. The information will be kept for five years, after which it will be destroyed properly by shredding.
- Data obtained during this study was kept in a safe, locked cupboard and will be stored for a period of five years. This information will be shredded and disposed of at the end of the five-year period. All information provided was treated with confidentiality.

CHAPTER FOUR: RESULTS

4.1 Socio-demographic profile of the food handlers

Table 3 presents the socio-demographic profile of the respondents, with the results showing most respondents were females (who were 25 years old and above and had at least a secondary education (99%). Of the 140 of the respondents interviewed, approximately 33% received training in the principles and techniques for food hygiene and safety.

Table 3: Demographic profile of the food handlers (N=140)

Variable		Frequency (%)
Gender	Female	139 (99.3%)
	Male	1 (0.7%)
Age	25-35	22 (16%)
	36-45	62 (44.3%)
	46-55	44 (31%)
	56-65	12 (8.6%)
Level of education	Primary	0
	Secondary	140 (100%)
	Tertiary	0
Food hygiene training	Yes	46 (33%)
	No	94 (67%)

4.2 Standard requirements for food premises

Thirty-three primary schools from Vryheid in KwaZulu-Natal, South Africa participated in the study. All the participating schools were “no-fee” government schools, meaning they were classified quintile one, two and three. The overall compliance with the standards and requirements for food premises is shown in **Figure 3**. None of the schools had been issued with a Certificate of Acceptability by Environmental Health Practitioners.

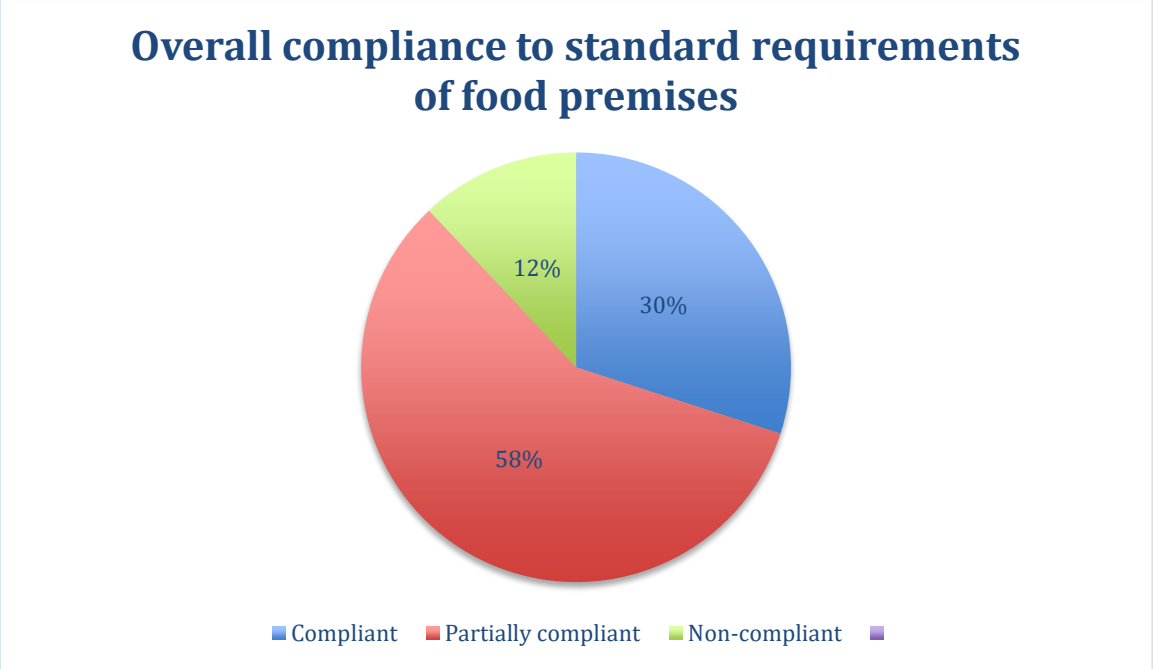

Figure 3: Overall compliance to standards and requirements for food premises

Table 4 shows that 76% of the premises was positioned, planned, built, and kept in the manner intended so that it could always be used for the purpose for which it was planned, built, and equipped—without posing a health risk. Sixty four percent had smooth, cleanable and non-absorbent interior surfaces. All had openable windows that allowed effective cross-ventilation and 91% had windows that admitted daylight. Seventy three percent had hot and cold water available for cleaning facilities.

Approximately 24% of the premises, had pest and vector control measures in place. Fifty two percent had a waste-water disposal system approved by the local authority. Thirty three percent provided separate sanitary facilities for food handlers while hand washing facilities with running water were provided in 39% of premises. Thirty six percent were supplied with soap for hand washing. Refuse bins with close-fitting lids were provided in approximately 30% of the premises. Hygienic storage facilities were available in 55% of premises. Approximately 27% of the premises provided change rooms with storage with food handlers. An adequate supply of water was available in 88% premises. Only 6% of premises had a controlled temperature equipment for food storage which was fridge and/or freezer. Pantry food items were stored on shelves and/or pallets in 58% of the schools and said shelves and/or pallets were generally clean and dust free in 48% of schools.

Table 4: Compliance of schools according to the standard requirements for building structure and storage (N=33)

Standard requirement from R638	No. of compliant schools	%
Premises available and maintained	25	76
All interior surfaces smooth and dust-proof	21	64
Cross-ventilation possible	33	100
Adequate ventilation openings	26	79
Natural light adequate	30	91
Sink with water available	24	73
Pest control in place	8	24
Vector control in place	8	24
Approved waste-water disposal	17	52
Separate toilets for food handlers	11	33
Hand washing facilities available	13	39
Soap and drying mechanism available	12	36
Liquid-proof bin with lid and suitable storage	10	30
Suitable storage space available	18	55
Storage facilities for food handlers	9	27
Adequate water supply	29	88
Fridge was available	2	6
Food not stored directly on the floor	19	58
Food stored on clean shelves	16	48

4.3 Standard requirements for food contact surfaces

In table 5, the results of the food contact surfaces revealed that 67% of the work surfaces were made of smooth, rust-proof, non-toxic and non-absorbent material. There was no chipped or cracked crockery and utensils in 55% of the schools. The surfaces were cleaned before the commencement of each shift in 70% of the schools.

Table 5: Compliance of schools according to the standards for food contact surfaces (N=33)

Standard requirement	Satisfactory observation	%
Working surfaces were made of smooth, rust-proof, non-toxic and non-absorbent material	22	67
Crockery and utensils in good condition	18	55
Work surfaces cleaned and washed before shift	23	70

4.4 Food handlers

The results from the observed practices were reported in one hundred and forty food handlers interviewed from 33 school premises. The observations of the food handler practices are presented in table 6**.** Observation of 140 food handlers was carried out using a checklist. The overall compliance to the standard requirements for food handlers is shown in **Figure 4.** Observational results showed that although only 45% of food handlers were provided with suitable protective clothing, 82% were clean at the beginning of their shift. Thirty three percent had received adequate training in food safety and hygiene but despite the lack of training, 76% had no jewellery on while handling food and 61% had short and clean fingernails. Hands were washed regularly by 56% of food handlers.

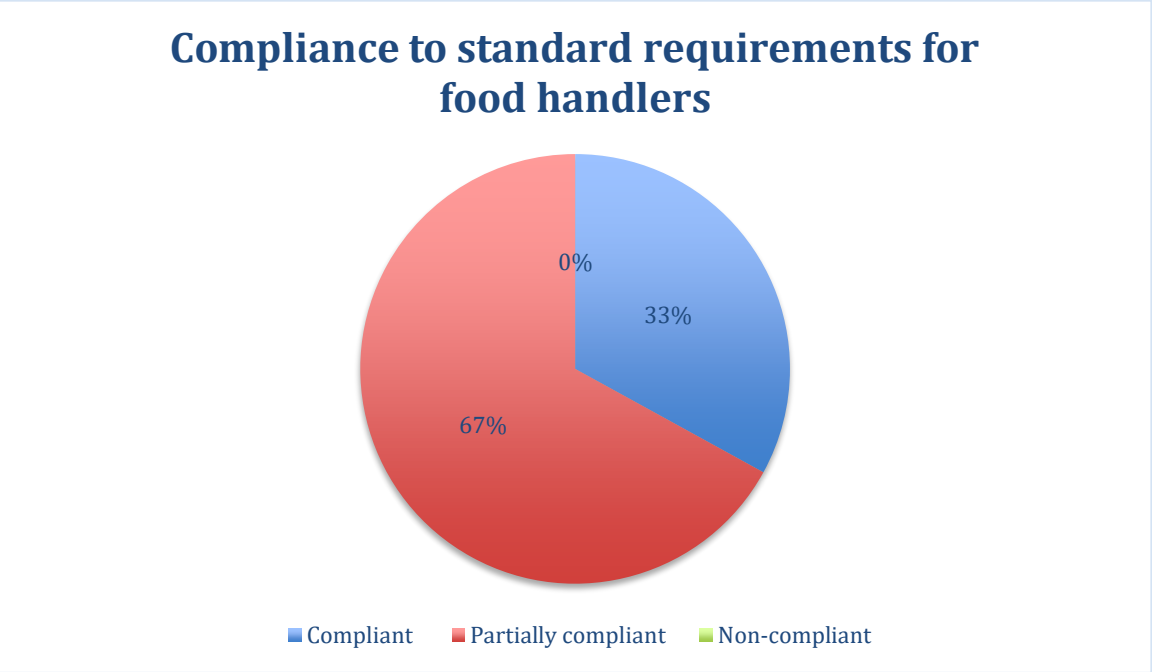

Figure 4: Overall compliance to standard requirements for food handlers

Table 6: Compliance to the standards requirements for food handlers (N=140) according to R638

Standard requirement	**Satisfactory observation**	**%**
Food handlers provided protective clothing	63	45
Food handler adequately trained	46	33
No jewellery while handling food	106	76
Hands and clothes were clean	115	82
Fingernails clean	85	61
Hands washed regularly	78	56
No sores on hands	140	100

No food handler had communicable disease	140	100

4.5 Prevalent bacterial species on food contact surfaces

Metagenomic data analysis was performed on pre-enriched environmental swabs to determine the native microbial community associated with NSNP food contact surfaces and hands of food handlers. A total of 15 samples were collected from the food contact surfaces and 15 collected from the hands of food handlers of four schools. In school A (**Figure 5**), six different types of genera were detected on the food contact surfaces, namely, *Serrattia* sp., (43%), *Pseudomonas* sp. (39%), *Stenotrophomonas* sp. (8%), *Bacillus* sp. (5%) and *Rahnella1* sp. (0.8%). The observation survey revealed that the food preparation area of school A had an overall compliance of 30% and was non-compliant in all areas of the assessment, notably lacking in hand washing facilities, separate sanitary facilities for food handlers and designated food storage. Refuse bins were also not provided and food was stored in direct contact with the floor. The food contact surfaces were not made of smooth and non-absorbent material, nor were they cleaned at the beginning of each shift.

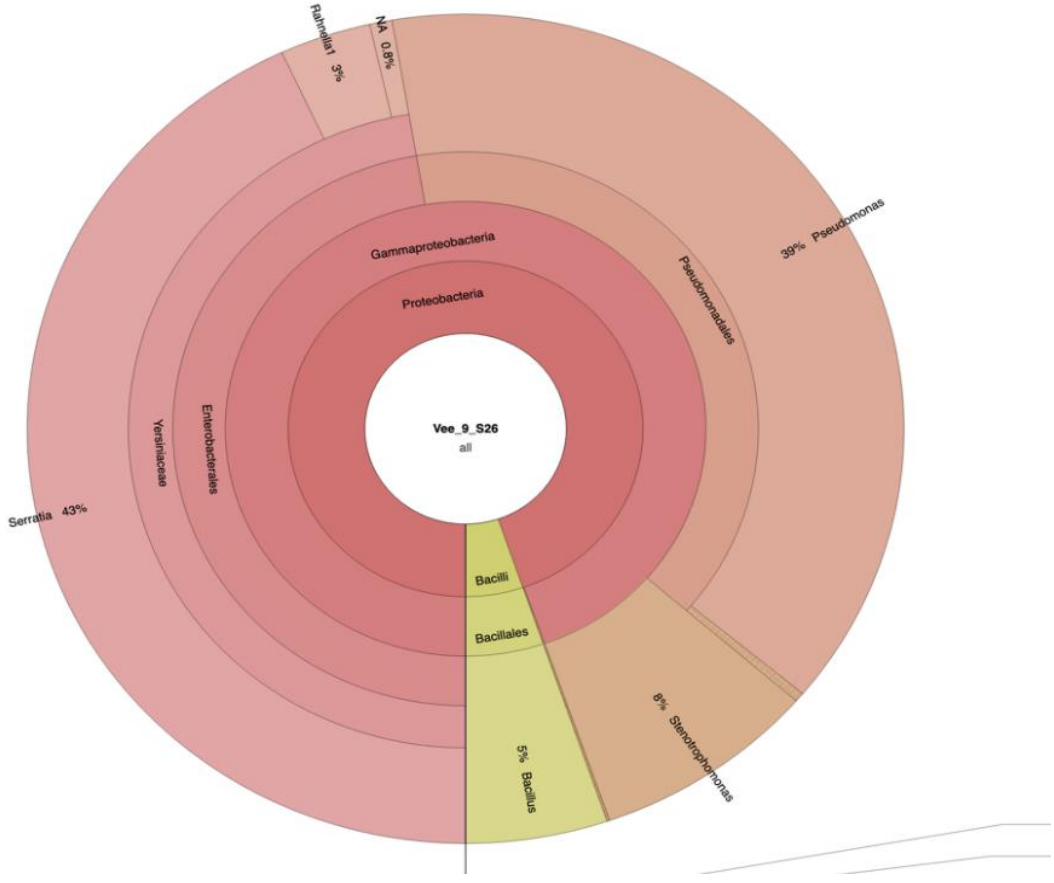

Figure 5: Microbiological results for food contact surfaces of school A

In school B (Figure 6), 10 different genera were detected on the food contact surfaces, namely, *Pseudomonas* sp., 25%), *Psychobacillus* sp. (22%), *Brevundimonas* sp. (19%), *Flavobacterium* sp. (7%), *Acinetobacter* sp. (4%), *Stenotrophomonas* sp. (3%), *Chryeobacterium* sp. (2%), *Rahnella1* sp. (1%), *Comamonas* sp. (1%) and *Exiguobacterium* sp. (1%). The observational survey revealed that the food preparation area of school B had an overall compliance of 70%. It was partially compliant in the structural, facilities and storage criteria of the assessment, although the school did not have plumbing or separate sanitary facilities for food handlers, make-shift hand washing mechanism in the form of "tippy taps" were provided to promote hand washing after using the toilet. The food contact surfaces were made of smooth and non-absorbent material, and they were cleaned at the beginning of each shift.

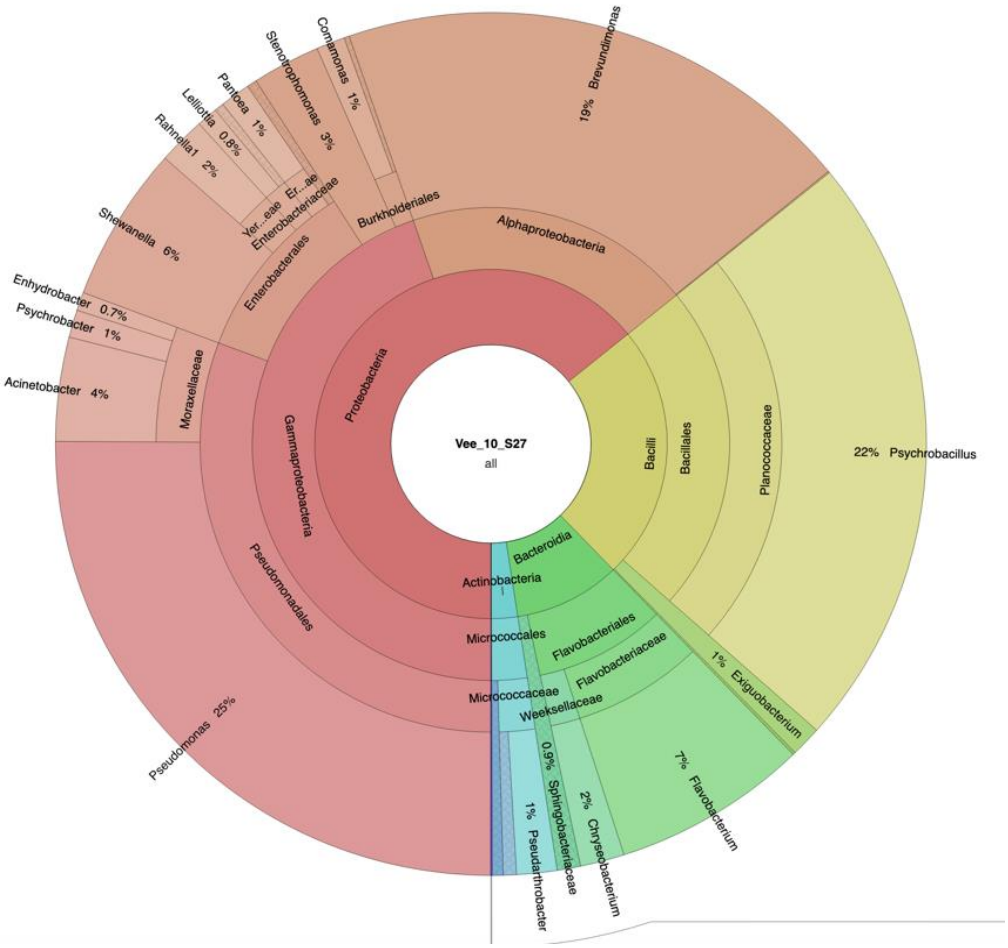

Figure 4: Microbiological results of the food contact surfaces for school B

In school C (Figure 7), 10 different genera were detected on the food contact surfaces, namely, *Pseudomonas* sp. (47%), *Exiguobacterium* sp. (15%), *Acinetobacter* sp. (9%),

Stenotrophomonas sp. (9%), *Pantoea* sp. (6%), *Shewanella* sp. (3%), *Chryseobacterium* sp. (2%), *Planomicrobium* sp. (2%), *Aerococcus* sp. (1%) and *Raoutella* sp. (1%). The observation survey revealed that the food preparation area of school C had an overall compliance of 80% and it was partially compliant in all areas of the assessment. The school had separate sanitary facilities for food handlers and hand washing facilities in the food preparation area and in the toilet to promote hand washing before the commencement of the shift and after using the toilet respectively. The food contact surfaces were made of smooth and non-absorbent material, and they were cleaned at the beginning of each shift.

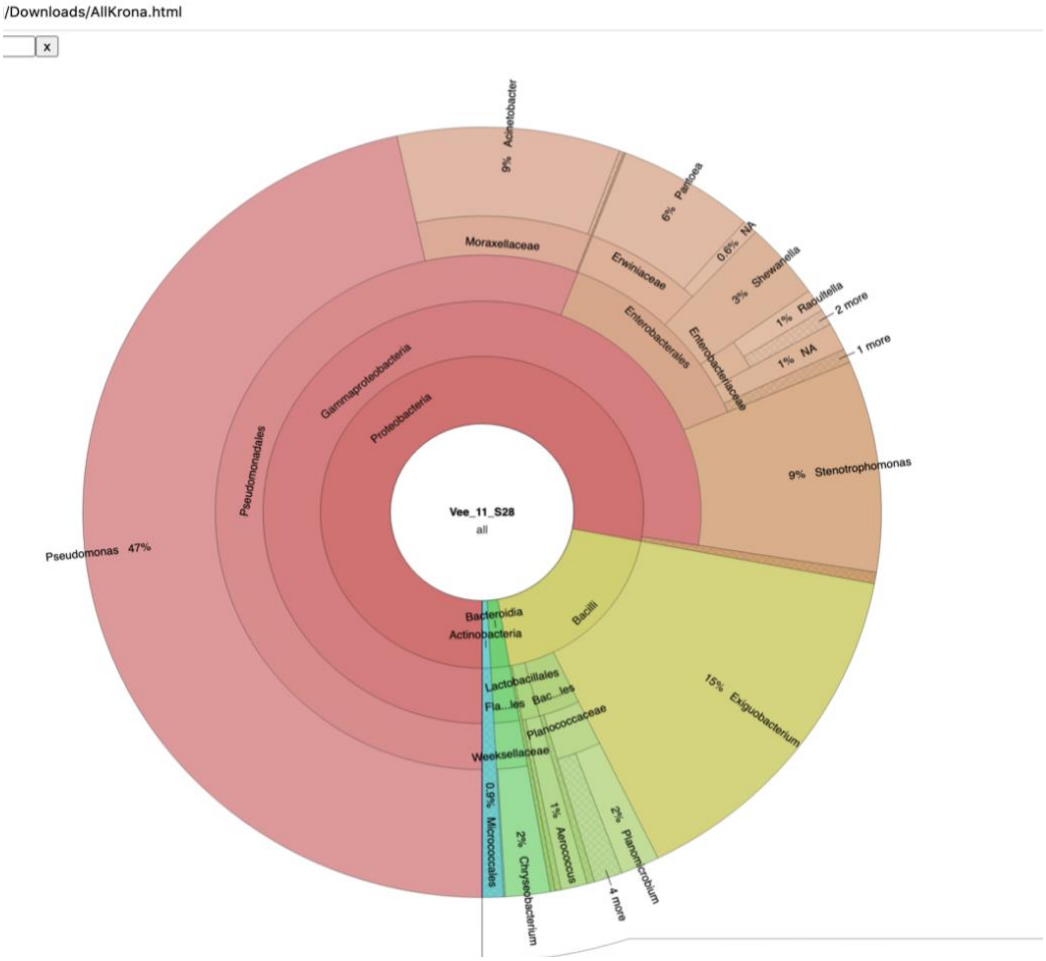

Figure 7: Microbiological results of the food contact surfaces for school C

In school D (Figure 8), 8 different genera were detected on the food contact surfaces, namely, *Pseudomonas* sp. (84%), *Pantoea* sp. (6%), *Pedobacter* sp. (2%), *Acinetobacter* sp. (1%), *Enterobacter* sp. (1%), *Kosakonia* sp. (1%), *Massillia* sp. (1%) and *Stenotrophomonas* sp. (0.9%). The observation survey revealed that the food preparation area of school D had an overall compliance of 30% as it was non-compliant in all areas of the assessment, especially in the building and storage requirements. The roof of the food preparation area was not dust-proof,

ventilation was poor, and hands were washed in a plastic basin where the water was shared by all food handlers. The school did not have a pest control programme in place and there was no designated food storage. The food contact surfaces were absorbent and were not cleaned at the beginning of the work shift.

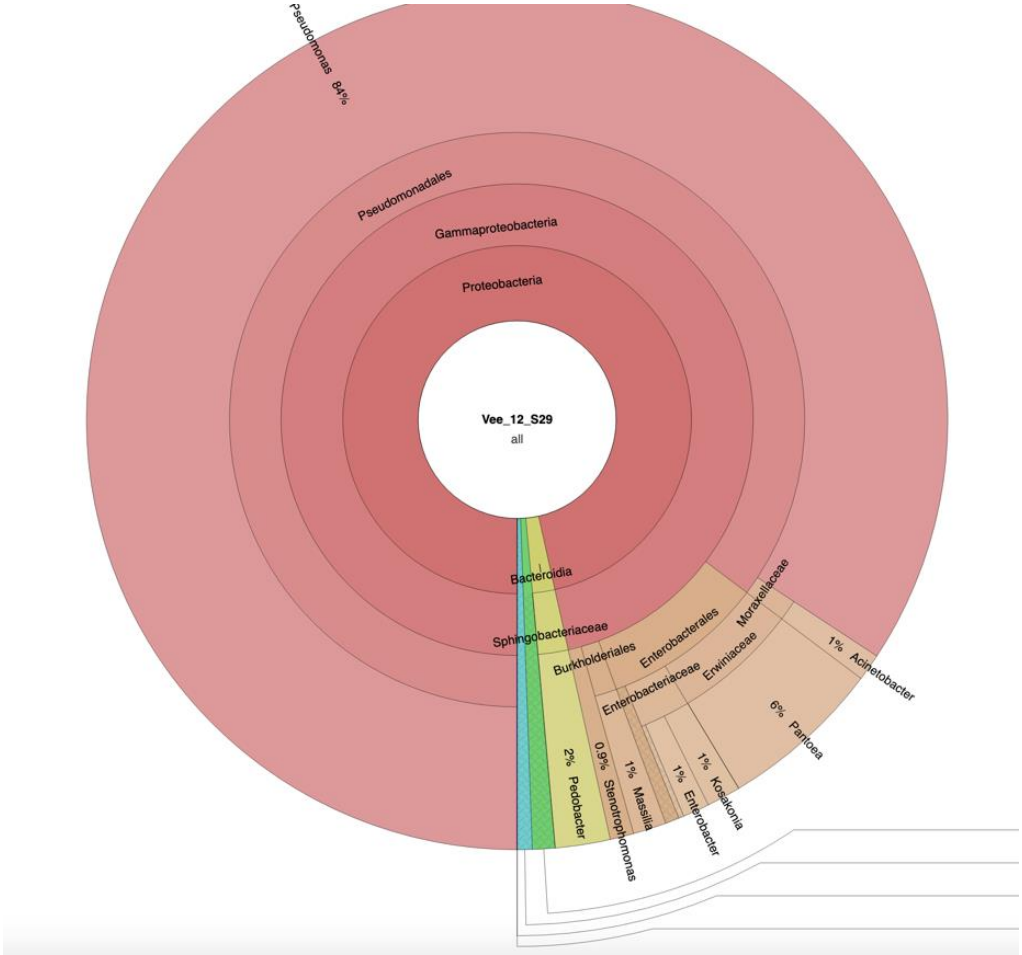

Figure 8: Microbiological results of the food contact surfaces of school D

The results revealed the 7 most common genera on the food contact surfaces of all four schools with *Pseudomonas* sp. being the highest (25-84%) followed by *Stenotrophomonas* sp. (0.9%-9%); *Acinetobacter* sp. (1-9%); *Rahnella1* sp. (2-3%); *Pantoea* sp. (6%) with *Chryseobacterium* sp. (2%) and *Exiguobacterium* sp. occurring only in two schools. Although a diverse microbial community was detected in all the sampled school, the results show 50% and higher compliance with standards for food contact surfaces.

4.6 Prevalent bacterial species on the hands of food handlers

In the school A (**Figure 7**), 9 different genera were detected on the hands of food handlers, namely, *Pseudomonas* sp. (64%), *Rahnella1* sp. (16%), *Stenotrophomonas* sp. (5%), *Glutamicibacter* sp. (4%), *Pantoea* sp. (3%), *Erwinia* sp. (2%), *Lelliottia* sp. (2%), *Serrattia* sp. (1%) and *Sporosarcinia* sp. (0.8%).The food handlers in school A were not provided with protective clothing, 67% had long fingernails and nail polish and none had received any training in food safety and hygiene.

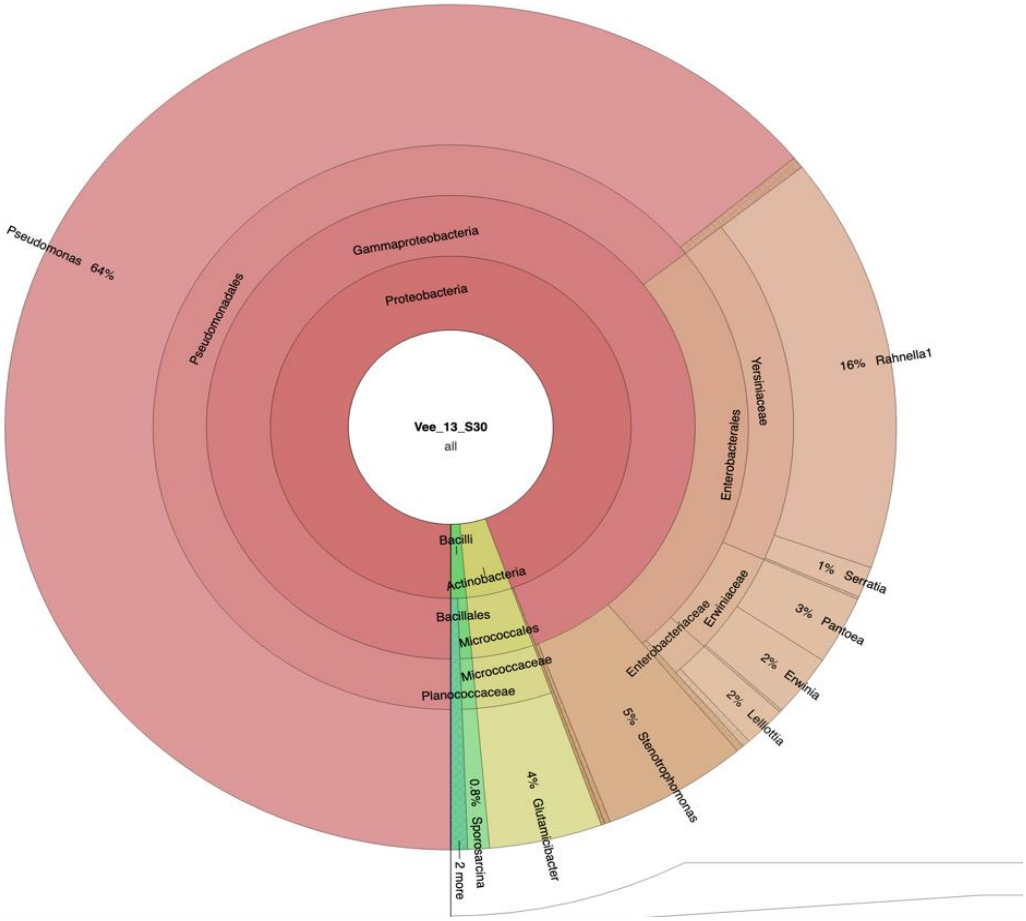

Figure 7: Microbiological results for the hands of food handlers of school A

In school B (**Figure 8**), 4 different genera were detected on the hands of food handlers, namely, *Pseudomonas* sp. (83%), *Pantoea* sp. (12%), *Stenotrophomonas* sp. (2%) and *Acinetobacter* sp. (0.9%). The food handlers in school B were provided with protective clothing and had received training in food safety and hygiene.

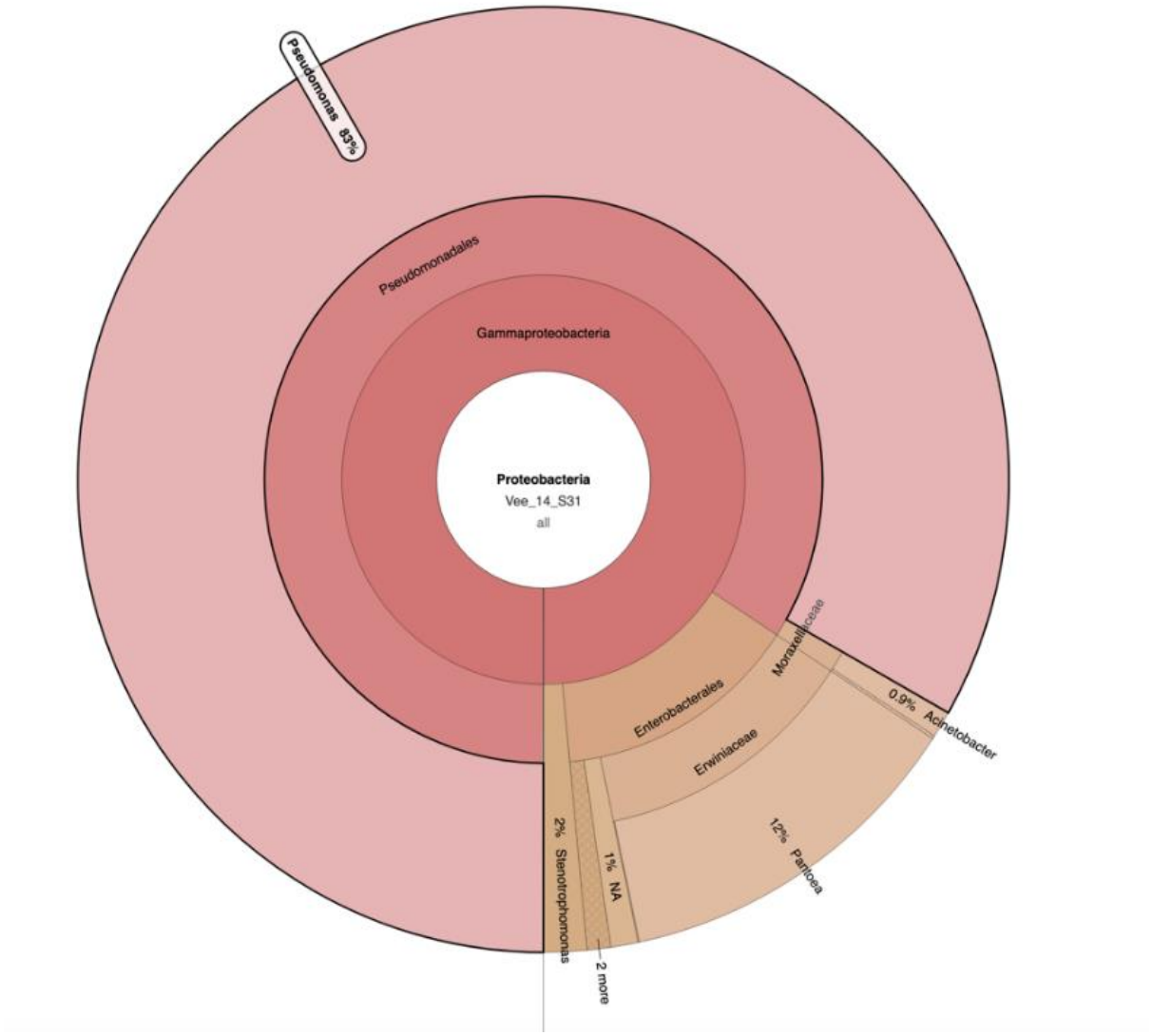

Figure 8: Microbiological results of the hands of food handlers for school B

In the school C (**Figure 9**), 10 different species were detected on the hands of food handlers, namely, *Flavobacterium* sp. (44%), *Pseudomonas* sp. (27%), *Chryseobacterium* sp. (10%), *Serrattia* sp. (5%), *Planomicrobium* sp. (3%), *Comamonas* sp. (2%), *Stenotrophomonas* sp. (2%), *Pantoea* sp. (1%), *Acinetobacter* sp. (1%) and *Rahnella1* sp. (1%). The food handlers were provided with protective clothing and had received training in food safety and hygiene.

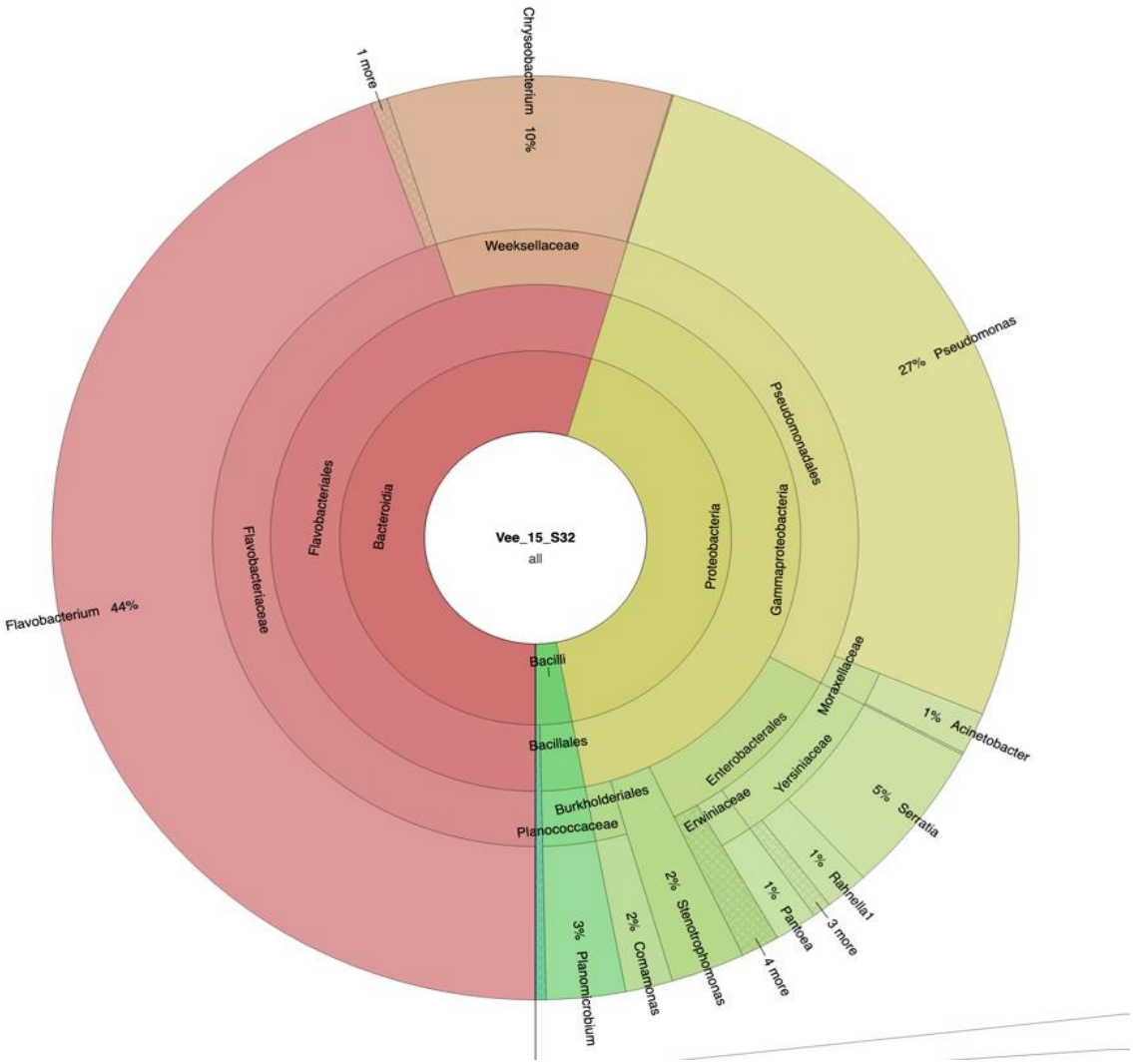

Figure 9: Microbiological results of the hands of food handlers of school C

In the school D (**Figure 10**), 8 different genera were detected on the hands of food handlers, namely, *Pseudomonas* sp. (34%), *Shewanella* sp. (18%), *Acinetobacter* sp. (16%), *Stenotrophomonas* sp. (15%), *Erwinia* sp. (7%), *Raoultella* sp. (4%), *Serrattia* sp. (3%), *Exiguobacterium* sp. (1%) and *Aeromonas* sp. (0.9%). The food handlers were provided with protective clothing, had been trained in food safety and hygiene but it was noted that some had long fingernails and there was no soap provided to promote hand washing. The food handlers also shared the sanitary facilities with the educators and hand washing facilities were not provided.

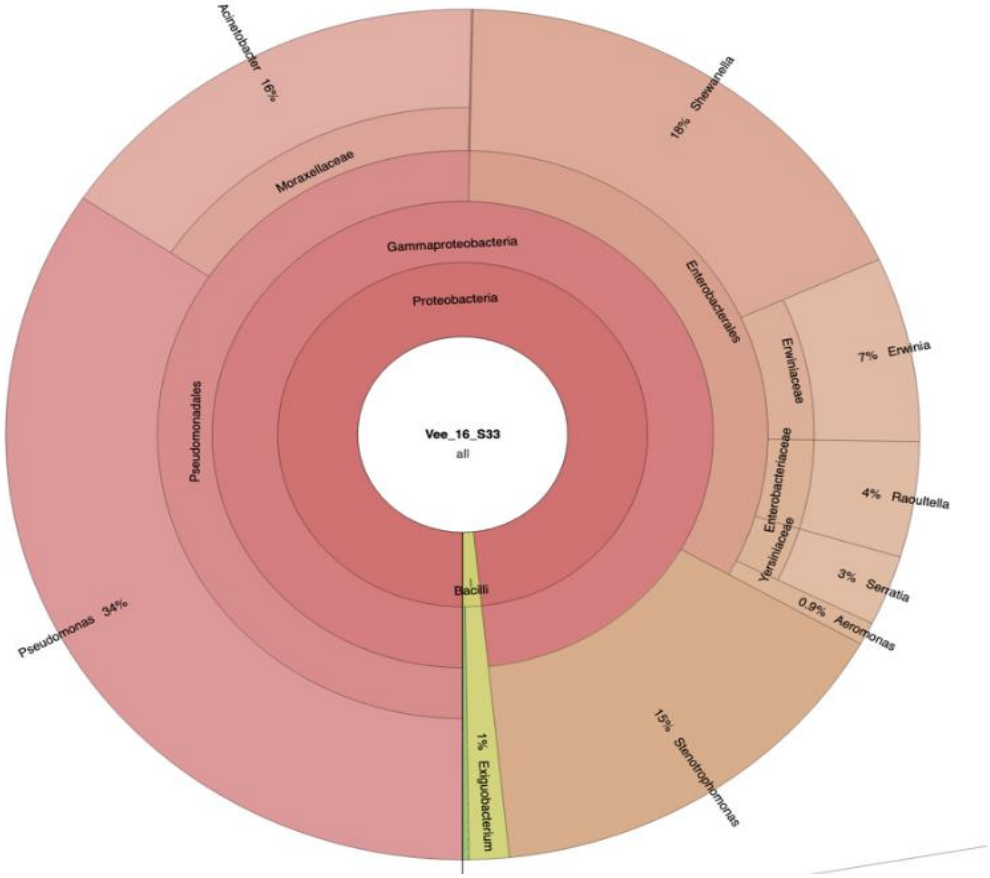

Figure 10: Microbiological results of the hands of food handlers of school D

The results revealed the 7 most common genera on the hands of all 15 food handlers were *Pseudomonas* sp. (27-83%), followed by *Stenotrophomonas* sp. (2-15%), *Acinetobacter* sp. (0.9-16%), *Pantoea* sp. (1-12%,), *Serrattia* sp. (1-5%) and *Rahnella1* sp. and *Erwinia* sp. occurring in only 2 schools.

CHAPTER FIVE: DISCUSSION

5.1 Compliance of National Schools Nutrition Programme food preparation and storage areas

The first objective of the study was to assess the compliance of food preparation and storage areas in primary schools offering NSNP meals to R638 of the Act. Compliance to the provisions of the regulation determines the quality of the NSNP meals offered to learners. The findings revealed that majority of the school food preparation and storage areas in Vryheid, KwaZulu-Natal were only partially compliant with the regulated standard requirements for food premises. The five most prevalent non-compliances were poor pest and vector control, inadequate provision of sanitary and hand washing facilities for food handlers, inadequate waste management and the lack of training for food handlers in the 33 schools surveyed. The results of this study were consistent with previous studies that showed poor compliance of school kitchens (Rendall-Mkosi, Wenhold et al. 2013, Martins and Rocha 2014, Dlova 2018, Mafugu 2021, Sharma, Gangopadhyay et al. 2021, Mafani, Kwatsha et al. 2022). Shrestha, Sharma *et al*. (2017) observed similar results in Nepal, where more than a quarter of the schools surveyed for water, sanitation and hygiene (WASH) conditions, lacked essential hand hygiene materials. Observational results suggest that there are several structural shortfalls that need to be addressed to make sure that meals served at schools are cooked and stored in a clean and safe manner.

Regulation 638 of 2018 (regulations governing general hygiene requirements for food premises), promulgated under the Foodstuffs, Cosmetics and Disinfectants Act, No. 54 of 1972 of the Republic of South Africa states that food may not be handled on premises without a current Certificate of Acceptability. In this study, it was revealed that none of the participating schools had been issued with a Certificate of Acceptability. This finding was also prevalent in a study evaluating the sanitary conditions and food handlers' practices in the Philippines, where the majority of the canteens of selected public and private schools were not possession of health cards such as sanitary permits (Ministry of Food and Agriculture/World Bank 2007, Pascual, Olobia *et al.* 2019). In South Africa, the Certificate of Acceptability is issued to premises that are fully compliant with all the minimum requirements of R638. The majority (76%) of the schools had designated food preparation areas, which was consistent with the results of Rendall-Mkosi *et al*. (2013) whose evaluation of the NSNP in Mpumalanga revealed that approximately 85% of schools prepared meals in designated food preparation areas. The lack of appropriate

infrastructure and equipment in food service establishments has been the most important issues in food safety (Lockis *et al.*, 2011). Gas was used to prepare food in 100% of the participating schools in Vryheid and although a fire extinguisher was available, none of the food handlers were trained on its used. Moreover, 79% of the food preparation areas had windows that allowed cross ventilation. This was in line with the NSNP guidelines that advised precautionary and safety measures such as opening windows when cooking with gas (DBE, 2011).

This study identified poor pest and vector control in many (24%) of the schools (N=33) surveyed and 75% of those selected (N=4) for microbiological assessment. Pests may act as carriers for various bacteria, including foodborne pathogens (Da Costa, Pelli *et al*. 2006) as they traverse different environments and that they can deposit onto food contact surfaces, such as chopping boards and dishes (Simothy, Mahomoodally et al. 2018). Therefore, it is crucial to eliminate them from locations where food is prepared in order to prevent contamination (Fouque and Reeder 2019). The World Health Organisation (WHO) Global Vector Control Response 2017–2030 (GVCR) estimates that approximately 80% of the human population is at risk to contract at least one vector-borne disease in their lifetime, and more than 700,000 people lose their lives annually due to vector-borne illnesses (Fouque and Reeder 2019). Filling or sealing cracks and crevices, using a detergent to clean around common access points to get rid of the chemical pheromone trail that follows them in and out of food sources, or using a non-repellent residual insecticide can all be used to control pests and vectors (Sarwar 2015) and storing food in sealed containers.

Designated sanitary facilities were available in 33% of the schools and hand washing facilities were provided in 39% of the surveyed schools. This was consistent with a study assessing the minimum requirements of WASH in rural schools in Kenya where WHO and UNICEF (2018) found that useable improved facilities and hand washing facilities with available water and soap were also not provided. Many diseases are attributable to inadequate drinking water, sanitation and hygiene (WASH) (WHO/Europe 2019) therefore restroom availability and hand washing stations use are critical to preventing contamination of food by food handlers (Guzewich and Ross 1999). The data show that many schools in South Africa do not comply with the regulations governing the hygienic standards for food establishments, food transportation, and related matters. As a result, the relevant department should address the resource and infrastructure issues in the school nutrition programs and ensure that all applicable food safety regulations are adhered to in full (Singh, Dudeja *et al*. 2016).

Most food handlers had short, clean nails (61%) and had removed jewellery before commencing with their duties (76%). Sub-regulation 11 of regulation 638 states that food, a person must wash their hands thoroughly with soap and water right before the start of each work shift, right after a break, and before touching a facility or container. Their fingernails must also be short, clean, and free of any adornments., after visiting the latrine and every time they have blown their nose or touched their nose or mouth (Department of Health 2018). According to a study examining the role of contributing factors and the spread of foodborne disease in school foodborne outbreaks, the data showed outbreaks generally involved food handlers (Venuto, Garcia *et al*. 2015). Microorganisms on food handlers' hands enhanced the likelihood that contaminated hands would become a source of contamination, therefore practicing good personal hygiene is imperative in ensuring the preparation of food that is safe for consumption.

Only 33% of the food handlers had received previous food safety training and they revealed that they had undergone training the previous year from Environmental Health Practitioners. Rendall-Mkosi *et al*., (2013), also found that some voluntary food handlers (VFHs) were not trained regularly enough. This was consistent with the findings of Sibanyoni and Tabit (2017) whose research revealed that only 27% of the schools in Mpumalanga had trained food handlers; and the data of Neme *et al*. (2017) who found that 87.5% of food handlers in Ethiopian restaurants had not been trained in food hygiene. Sub-regulation 10 of R638 states that it is the duty of a person in charge of food premises to ensure that they, and any other person working on the premises are adequately trained in the principles of food safety and arrange follow-up training as applicable (Department Of Health, 2018). As a consequence of the lack of training, food handlers have been found to have poor food safety knowledge and unsafe food handling skills in Malaysia (Sani and Siow, 2014, Shinbaum *et al.*, 2016). The lack of trained food handlers should be a concern in schools, as NSNP meals are served to children who could easily contract foodborne diseases due to their weak immune systems (Scallan *et al.*, 2013). In Saudi Arabia, 68.1% of foodservice staff in Al Madinah hospitals had received food safety training (Alqurashi *et al*., 2019a). Food establishments in Brazil, such as hospitals (92%) (Ferreira *et al*., 2013) and schools (93%) have likewise found a high incidence of trained food handlers (da Cuhna *et al*., 2012), where training courses are legally mandated. Training in the hygiene and food safety practices and principles is therefore necessary as it promotes and improves safe handling of food and includes procedures to prevent food contamination and risk of food

pathogens. Food handlers need regular training on maintaining the quality and safety of the meals they produce (Kibret and Abera, 2012).

5.2 Prevalent bacteria on food contact surfaces

The second objective of the study was to detect the bacteria prevalent on food contact surfaces of school kitchens. School C revealed the most diverse microbial community on food contact surfaces and hands of food handlers with *Pseudomonas* being the most abundant genus on both Food handlers' hands and food contact surfaces. This was an indicator of cross-contamination, poor hand hygiene, faecal contamination and poor water quality (Akusu, Kiin-Kabari *et al.* 2016). Moreover, the results of the samples collected from the food contact surfaces revealed a great diversity and abundance of microbial species, despite the >50% compliance to the minimum standards for food premises.

Schools have often been implicated as one of the sources contributing to foodborne disease outbreaks (Ababio & Lovatt, 2015) with risk factors improper time/temperature control, improper food handling practices and poor personal hygiene commonly identified as causes (Wu, Yuan *et al.* 2018) as well as improper storage, inadequate cooking and cross-contamination (Kennedy, Jackson *et al.* 2005). Despite the presence of various regulations to insure safe meals are offered in school canteens, safety measures taken during school meal preparation are still inadequate (Pascual, Olobia *et al.* 2019). School cafeterias were responsible for the second highest number of reported foodborne diseases outbreak cases (14163 cases, 23%) in China from 2003 to 2008 (Wu, Yuan *et al.* 2018). Learners who had contracted a foodborne illness during the academic year had a considerably greater rate of sickness than those who had not, and the prevalence of foodborne infections was higher than the annual incidence of 1 in every 40 Ghanaians (Ministry of Food and Agriculture/World Bank, 2007). Sourou-Bankole *et al.*, (2012) from Benin also reported that due to the unsanitary circumstances at boarding schools, learners were made to consume unhygienic meals. Several lines of prevention were proposed following a *S. aureus*-induced disease outbreak in a Vietnam school canteen, including monitoring the cleanliness of the food preparation process; ensuring that raw meat meets standards for microbiological quality before cooking (such as Salmonella spp., S. aureus, and E. coli); educating food handlers on HACCP principles to prevent cross-contamination between raw and cooked foods, ensuring hand hygiene by hand washing with

soap and water as well as disinfecting with alcohol 70 percent or other antimicrobial reagents, and wearing gloves, a mask, and a hair net during food preparation; periodic inspection of prepared food at school canteens to evaluate the standard of preparation (Le, Dalsgaard *et al.* 2021).

Figures 3–10 illustrate the relative amounts of bacteria found on each of the food contact surfaces and hand samples analysed in the current study. Based on their abundance in 4 different schools, *Pseudomonas*, *Stenotrophomonas*, *Exiguobacterium*, *Acinetobacter*, *Rahnella*, *Pantoea* and *Chryseobacterium* were the core species of the bacterial community on food contact surfaces and *Pseudomonas*, *Stenotrophomonas*, *Acinetobacter*, *Rahnella*, *Pantoea*, *Erwinia*, and *Serrattia* were the core species from the hand samples evaluated. The noted species were more abundant on the hands of the food handlers than on food contact surfaces. A greater diversity of bacterial community was detected in school C. This could be due to ineffective hand washing which has been previous mentioned as the leading cause of cross-contamination in food service establishments. An assessment of theoretical and practical food safety training based on the microbiological counts on food contact surfaces and hand washing practices showed that the success in microbiological reduction could be attributed to the tailored practical approach of a training programme, which did not focus just on theoretical concepts (Soares, Garcia-Diez *et al.* 2013). At genus level, *Pseudomonas* occurred at a high abundance on both hands (27-83%), and food contact surfaces (25-84%) and this is a concern as it is a spoilage agent. *P. aeruginosa* is one of the most common causative agents of food contamination, which is a significant public health concern (Nahar, Ha *et al.* 2021). It is an opportunistic pathogen and a common cause of spoilage in a wide range of vegetables, milk, and meat products (Raposo, Pérez *et al.* 2017) that has the ability to create biofilms that enable it to cling to processing surfaces for extended periods of time and play a significant part in the cross-contamination of food during handling and processing (Lim, Koo *et al.* 2019). According to a study by Nahar, Ha *et al.*, (2021) on the ability of three different bacterial strains to produce biofilms on frequently used food-contact materials, *P. aeruginosa* was able to contaminate food with biofilms that could pose health risks. *Stenotrophomonas*, which are commonly isolated from soil, plants, water and raw milk, (Wisplinghoff and Seifert, 2010) showed abundance on food contact surfaces (0.9%-9%) only, the genus *Acinetobacter*, typically present on a variety of food products, particularly refrigerated fresh foods, was most prevalent on surfaces that came into contact with food (1-9%). This result was expected because it is frequently isolated from a

wide range of food products, however Kampfer (1999) suggests initial numbers be kept low to extend shelf life. This becomes a concern since 75% of the schools did not have refrigerators. *Exiguobacterium* which was most abundant on food contact surfaces (15%) of school C has been extensively studied for the biodegradation of complex organic and inorganic compounds (Pandey, 2020). Although rarely considered a pathogen, the *Pantoea* which was most abundant on the hands (1%-12%) has been widely known in both the pre- and post-harvest stages of fruit as a biological control agent(Grimont and Grimont, 2005) (Nunes *et al*., 2001). *Pantoea* produces toxin(s) with a broad antimicrobial range, according to reports (Völksch and Sammer, 2008) that had been confirmed by Johnson *et al*., (2000) who reported that its successful spread was affected by temperature control.

The bacterial community in a food processing environment may differ by various environmental factors (Lim *et al*., 2021) and in this study, the results of the food contact surface, and hand samples were not too significantly different, but highlighted the complexity of the bacterial community. *Pseudomonas* which accounted for 34 % to 83 % of the hand samples, had the highest abundance, according to the results. The species was also the most abundant species on the food contact surfaces and accounted for 27%-84%. This finding was not unusual for food handling premises as attested by Gu *et al*. (2019) who identified *Pseudomonas* as the significant bacterial taxa in food processing in eastern United States. All food companies employ frequent cleaning and sanitizing techniques, however it is acknowledged that these are not always successful in getting rid of the resident bacterial communities unique to each food plant (Griffith, 2005).

While the common transmission of the isolated bacteria is from person to food via contact with fomites or by ingestion of contaminated food and water it can be best controlled by provision of hand wash facilities with running water and soap, and food contact surfaces made of suitable material that would ensure effective cleaning and disinfection. Given the ability of most of the bacteria isolated, to survive on surfaces for weeks under dry conditions, hand hygiene and the routine disinfection of equipment and surfaces touched by food handlers are basic but essential steps to prevent food contamination (Bennet, 2020). Although the microbiology of food contact surfaces and hands of food handlers is normally limited to more common food pathogens, the research revealed that the diversity of the bacterial community associated with food contact surfaces is broader than the commonly investigated food pathogens. Metagenomic analysis revealed not only the presence of spoilage or pathogenic bacteria, but also bacteria whose

impact in the food processing environment is unknown and therefore has the potential to spread and contaminate food (Rodriguez-Lopez *et al*., 2018). Metagenomics, which has been primarily used in dairies and butcheries, has started bacterial community mapping in food handling or processing facilities in the last ten years. This work has demonstrated that these environments are inhabited by a resident microbiome that endures despite routine cleaning procedures and may be easily transferred to the final product (De Filippis *et al*., 2021).

CHAPTER SIX: CONCLUSION & RECOMMENDATIONS

The study aimed to assess the compliance of NSNP food preparation and storage areas to the minimum standards of R638 and to determine the presence food pathogens on food contact surfaces. The data suggests that school food preparation areas were not compliant as none of the participation schools were in possession of a Certificate of Acceptability, which was a legal requirement for all food premises. Majority of the school kitchens surveyed had poor provision of separate sanitary facilities for food handlers, hand washing facilities with running water, refrigeration facilities to prevent spoiling of foodstuffs, shelving to ensure no foodstuffs comes in contact with a ground surface and training of food handlers in the principles of food hygiene and food safety practices. This, compounded by the food handlers' poor knowledge of food safety and the lack of HACCP program implementation may have had a negative impact on the sanitary quality of these food contact surfaces (Sibanyoni, Tshabalala, & Tabit, 2017).

This study is unique as it attempted to detect the variability of microbial communities on food contact surfaces, especially in the school feeding environment. The microbiological community in the school nutrition setting was assessed by metagenomics, using samples taken from the food contact surfaces and the hands of food handlers. Cross-contamination between food ingredients and food contact surfaces, as well as the subsequent development of microorganisms in biofilms, are both responsible for the abundance of bacteria (Faour-Klingbeil, Kuri, & Todd, 2016). The formation of food waste and germs in biofilms on food contact surfaces is also encouraged by some of these schools' subpar cleaning and sanitizing of food contact surfaces and the general sanitary conditions of their food preparation facilities.es (Losito, Visciano, Genualdo, & Satalino, 2017). Dairy environments and, to a lesser degree, raw meat processing environments are where metagenomics has been used most frequently (e.g., facilities producing fresh sausages, butchers). According to studies, there is a resident microbiome in food processing facilities that endures despite usual cleaning procedures and can readily be transferred to the finished food product (Griffith, 2005), the use of strong disinfectants could assist in this regard. The findings of this study give a foundational understanding of the microbial ecology of various bacterial populations on various types of surfaces in school kitchens., which is useful for future research on the impact of microbial populations and their dynamics in the food processing environment remain understudied (Johnson et al., 2021). Using modern sequencing-based techniques, it is possible to monitor the

environmental microbiome of the food sector, which is a potential tool that could assist comprehensive quality and safety monitoring measures (De Filippis *et al*., 2021).

This study was limited to school kitchens that may not be representative of most school kitchens in more developed towns or cities in South Africa who fall under the same quintiles due to the socio-economic conditions that prevail in those communities. However, the results provide information regarding major food hygiene gaps in the NSNP and could be a practical reference when reviewing guidelines.

Recommendations

- The Department of Basic Education should make food safety a public health priority in the Nation School Nutrition Programme, as it plays a pivotal role in developing policies and regulatory frameworks and establishing and implementing effective food safety systems. Food handlers need to understand how to safely handle food and practicing the WHO Five keys to safer food, this could be achieved by ensuring training before assumption of duties.
- Strengthen the relationship between municipal health and the Department of Basic Education so that rectification identified improper food safety practices is prioritised.
- NSNP and Municipal Health Services should work collaboratively to ensure the safe implementation of NSNP and bridge the gaps in food safety practices.
- Further investigation of the impact of identified bacterial species on food safety.

REFERENCES

Ababio, P. F., Taylor, K. D. A., Daramola, B. A. and Swainson, M. 2016. Food law compliance in developed and developing countries: comparing school kitchens in Lincolnshire-UK and Ashanti region of Ghana. Food Control, 68: 167-173.

Adimasu, A., Mekonnen, B., Guadu, T., Gizaw, Z. and Adane, T. 2016. Bacteriological quality assessment of selected street foods and their public helth importance in Gondar town, northwest Ethopia. Global veterinaria. 17(3): 255-264

Afolaranmi, T. O., Hassan, Z. I., Bello, D. A. and Misari, Z. 2015. Knowledge and practice of food safety and hygiene among food vendors in primary schools in Jos, Plateau State, North Central Nigeria. Journal of Medical Research, 4(2): 16-22.

Akbar, A. and Anal, A. K. 2013. Prevalence and antibiogram study of Salmonella and Staphylococcus aureus in poultry meat. Asian Pacific Journal of Tropical Biomedicine, 3(2): 163-168.

Akusu, O. M., Kiin-Kabari, D. B. and Wemedi, S. A. 2016 Microbiological quaity of selected street vended foods in Port Harcourt metropolis, River State, Nigeria. Sky Journal of Food Science, 5(2): 9-11.

Ali, A. I. and Immanuel, G. 2017. Assessment of Hygienic Practices and Microbiological Quality of Food in an Institutional Food Service Establishment. Journal of Food Processing Technology, 8: 8.

Alkema, W., Boekhorst, J., Wels, M. and van Hijum, S. A. 2016. Microbial bioinformatics for food safety and production. Briefings in bioinformatics 17(2): 283-292.

Alqurashi, N. A., Priyadarshini, A. & Jaiswal, A. 2019. Evaluating food safety knowledge and practices among foodservice staff in Al Madinah hospitals, Saudi Arabia. Safety, 2019**,** 9.

Al-Shabib, N. A., Mosilhey, S. H. and Husain, F. M. 2015. Cross-sectional study on food safety knowledge, attitude and practices of male food handlers employed in restaurants of King Saud University, Saudi Arabia. Food Control, 59: 212–217.

Alves da Silva, S., Cardoso, R. C. V., Góes, J. Â. W., Santos, J. N., Ramos, F. P., Bispo de Jesus, R. and Teles da Silva, P. S. 2014. Street food on the coast of Salvador, Bahia, Brazil: a study from the socio economic and food safety perspectives. Food Control, 40: 78–84.

Anderson, M., Sansonetti, P. and Marteyn, B. 2016. Shigella diversity and changing landscape: insights for the Twenty-First Century. Fronteirs in cellular and infection microbiology, 6 (45).

Angelillo, I. F., Viggiani, N. M., Rizzo, L. and Bianco, A. 2000. Food handlers and foodborne diseases: Knowledge, attitudes, and reported behavior in Italy. Journal Food Protection, 63: 381–385.

Angelo, K. M., Nisler, A. L., Hall, A. J., Brown, L. G., and Gould, L. H. 2017. Epidemiology of restaurant-associated foodborne disease outbreaks, United States, 1998-2013. Epidemiology and Infection, 145 (3): 523-534.

Asiegbu, C. V., Lebelo, S. L. and Tabit, F. T. 2016. The food safety knowledge and microbial hazards awareness of consumers of ready-to-eat street-vended food. Food Control, 60: 422-429.

Association L´eo Lagrange. 2014. Recommendations of good practices of hygiene for the consumers. Editor French Ministry of Agriculture, Food and Forestry, Paris, France.

Avait, F., Gerhards, C., Rodriguez, J., Michel, V., Le Bayon, I., Ismail, R. and Federighi, M. 2016. Microbial safety of wood in contact with food: a review. Comprehensive Reviews in Food Science and Food Safety, 15: 491-505.

Aycicek, H., Oguz, U. and Karci, K. 2006. Determination of total aerobic and indicator bacteria on some raw eaten vegetables from wholesailers in Ankara, Turkey. Inernational. Journal of Hygiene and Environmental Health, 209: 197-201.

Azelmad, K., Hamadi, F., Mimoumi, R. and Amzil, K. 2017. adhesion of Staphylococcus aureus xylosus to materials commonly found in catering and domestic kitchens. Food Control, 73: 156-163.

Baluka, S. A. M., RA; Kaneene, J B. 2015. Hygiene practices and food contamination in managed food service facilities in Uganda. African Journal of Food Science 9(1): 31-42.

Baylis, C. L. 2006. Food Spoilage Microorganisms, Woodhead Publishing Series.

Beuchat, L. R. 2002. Ecological factors influencing survival and growth of human pathogens on raw fruits and vegetables. Microbes Infect., 4: 413-423.

Bhunia, A. 2018. Shigella Species. New York: Springer.

Booth, S. J. 2014. Chryseobacterium Related Genera Infections Reference Module in Biomedical Sciences, Elsevier.

Branson, N. Lam, D. and Zuze, L. 2012. Southern Africa Labour and Development Research Unit. National Income Dynamics Study, 81.

Bremer, P. J., Fillery, S. and McQuillan, A. J. 2006. Laboratory scale clean-in-place (CIP) studies on the effectiveness of different caustic and acid wash steps on the removal of dairy biofilms. International Journal of Food Microbiology, 106: 254–262.

Brooks, J. D. and Flint, S. H. 2008. Biofilms in the food industry: problems and potential solutions. International Journal of Food Science Technology, 43: 2163–2176.

Burke, T., Young, I. and Papadopoulos, A. 2016. Assessing food safety knowledge and preferred information sources among 19-29 year olds. Food Control, 69: 83-89.

Çakiroğlu, F.P., Uçar, A., 2008. Employees' perception of hygiene in the catering industry in Ankara, Turkey. Food Control, 19: 9-15.

Canini, N. D., Bala, J. J. O., Maraginot, E. N. and Mediana, B. C. B. 2013. Evaluation of street food vending in Ozamiz city. Journal of Multidiscilinary Studies, 1: 104–124.

Centers for Disease Control and Prevention (CDC). 2010. OPRP-Handwashing guidelines. Atlanta: Georgia, USA: CDC.

Chinakwe, E. C., Nwogwugwu, N. U., Nwachukwu, I. N., Okorondu, S. I., Onyemekara, N.N. and Ndubuisi-Nnaji, U. U. 2013. Microbial quality and public health implications of hand-wash water samples of public adults in Owerri, South-east Nigeria. International Research Journal of Microbiology, 3: 144–146.

Cliver, D. and Riemann, H. 2002. Foodborne diseases, Gulf Professional Publishing.
Commission regulation (EU), 2013. no. 209/2013 of 11March 2013 amending Regulation (EC) no. 2073/2005 as regards microbiological criteria for sprouts and the sampling rules for poultry carcases and fresh poultry meat. Offi. J. Eur. Union L68, 19-23.

Crandall, P. G., O'Bryan, C. A., Grinstead, D. A., Das, K., Rose, C. and Shabatura, J. J. 2016. Role of ethnographic research for assessing behaviour of employees during cleaning and sanitation in food preparation areas. Food Control, 59: 849-853.

Curtis, V. and Cairncross, S. 2003. Effect of washing hands with soap on diarrhoea risk in the community: A systemic review. Lancet Infectious Diseases, 3: 275–281.

Da Costa, S., A. Pelli and G. de Carvalho (2006). "Ants as mechanical vectors of microorganisms in the school hospital of the universidade federal do TrÎangulo Mineiro." Rev Soc Bras Med Tro **39**: 527–529.

Da Cuhna, D. T., Stedefeldt, E. & De Rosso, V. 2014. The role of theoretical food safety training on Brazilian food handlers' knowledge, attitude and practice. Food Control, 43**,** 167-174.
Da Cuhna, D. T., Stedefelt, E. & De Rosso, V. V. 2012. Perceived risk of foodborne disease by school food handlers and principals: the influence of frequent training. Journal of Food Safety, 32**,** 219-225.

Das, A., Nagananda, G. S., Bhattacharya, S. and Bhardwaj, S. 2010. Microbiological quality of street vended Indian Chaat sold in Bangalore. Journal Bioscience, 10: 255-60.

Dass, S. C., Wang, B., Stratton, J., Bianchini, A., Anandappa, A. 2018. Food processing environment surveillance using amplicon metagenomics: Assessing the change in the microbiome of a fluid milk processing facility before and after cleaning. BAOJ Food science and technology, 2:12.

De Filippis, F., Valentino, V., Alvarez-Ordo, A., Cotter, P. D. & Ercolini, D. 2021. Environmental microbiome mapping as a strategy to improve quality and safety in the food industry. Food Science, 38**,** 168–176.

De Sousa, G. B., Tamagnini, L. M., Olmos, P. D. and Gonzalez, R. D. 2002. Microbial enumeration in ready-to-eat foods and their relationship to good manufacturing practice. Journal of Food Safety, 22: 27–38.

den Besten, H. M. W., Amézquita, A., Bover-Cid, S., Dagnas, S., Ellouze, M., Guillou, S., Membré, J. M. (2018). Next generation of microbiological risk assessment: Potential of omics data for exposure assessment. International Journal of Food Microbiology, 287, 18–27.

Department of Basic Education and Unicef. 2013. Atlas of Education Districts in South Africa.

Department of Basic Education. 2015. Education statistics in South Africa 2013. Available at http://www.education.gov.za (Accessed 24 November 2018).

Department Of Health 2018. Regulations governing general hygiene requirements for food premises, the transport of food and related matters. In: HEALTH, D. O. (ed.) R638. Pretoria: Government Gazette.
Department Of Health 2018. Regulations governing general hygiene requirements for food premises, the transport of food and related matters. In: HEALTH, D. O. (ed.) R638. Pretoria: Government Gazette.

Department of Health. 2003. Foodstuff, cosmetics and disinfectants act. (1972). Regulation relating to the application of the hazard analysis and critical control point system (R 908). South Africa: National Department of Health. Available at www.ehrn.co.za/download/reg_haccp.pdf (Accessed 24 November 2018).

Department of Health. 2018. Regulations governing general hygiene requirements for food premises, the transporting of food and related matters. Pretoria

Department of. Basic Education, KwaZulu-Natal. 2019. National School Nutrition Programme (NSNP) - payment of Volunteer Food handlers through Persal and the adjustment of wood/gas allocation effective from July 2019 to 31 March 2020. Pietermaritzburg: Department of Basic Education, KwaZulu-Natal.

Domenech, E., Jimenez-Belenguer, A., Amoros, A. J., Ferrus, A. M. and Escriche, I. 2014. Prevalence and antimicrobial resistance of Listeria monocytogenes and Salmonella strains isolated in ready-to-eat foods in Eastern Spain. Food Control, 47: 120-125.

Du, X.-J., Zhang, X., Wang, X.-Y. and Su, Y.-L. 2017. Isolation and characterisation of Listeria monocytogenes in Chinese food obtained from the central area of China. Food Control, 74: 9-16.

EFSA Panel on Biological Hazards (BIOHAZ). 2014. Scientific opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (Salmonella and Norovirus in leafy greens eaten raw as salads). EFSA Journal, 11(36): 118.

European Food Safety Authority & European Centre for disease prevention and control. 2012. The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2010. EFSA Journal, 10.
European Union. (2004). Council Regulation 852/2004 of 29.4.04a on the hygiene of foodstuffs. Official Journal of the European Communities. Brussels.

Euzeby, J. P. 1997. List of bacterial names with standing in nomenclature: a folder available on the internet Int. J. Syst. Bacteriol., 47**,** 590-592.

Evans, E. W. and Redmond, E. C. 2014. Behavioural risk factors associated with listeriosis in the home: A review of consumer food safety studies. Journal of Food Protection, 3: 352-521.

Farahat, M. F., Ei-Shafie, M. M. and Waly, M. I. 2015. Food safety knowledge and practices among Saudi women. Food Control, 47: 427-435.

Feglo, P., & Sakyi, K. 2012. Bacterial contamination of street vending food in Kumasi, Ghana. Journal of Medical and Biomedical Sciences, 1: 1-8.

Ferone, M., Gowen, A., Fanning, S. And Scannell, A.G. M. 2020. Microbial detection and identification methods: benchtop assays to omics approaches. Comprehensive reviews in food science and food safety. 19: 3106-3129.

Ferreira, J., Cerqueira, E., Carvalho, J., Oliveira, L., Costa, W. & Almeida, R. 2013. Food safety knowledge, attitudes and practices of food handlers in public hospitals in Salvador, Bahia. Revista Baiana de Saude Publica, 37**,** 35-55.

Fletcher, S.M., Stark, D., Ellis, J. 2011. Prevalence of gastrointestinal pathogens in sub-Saharan Africa: systematic review and meta-analysis. Journal of Public Health Africa, 2:127-137.

Food Agricultural Organization of the United Nation – FAO. 2012. Street food vending in West African cities: Potential and challenges. Rome.

Food and Agriculture Organization (FAO). 2002. Global forum of food safety regulators, Marrakesh, Morocco, 28-30 January 2002. Escherichia coli O157:H7 outbreak in Scotland in 1996/97 submitted by the United Kingdom.

Fouque, F. and J. C. Reeder (2019). "Impact of past and on-going changes on climate and weather on vector-borne diseases transmission: A look at the evidence." Infect. Dis. Poverty **8**(51).

Galvao, J. A., d'Ovidio, L., Buzi, K. A., Yamatogi, R. S. and Rall, V. L. M. 2017. Meals, preparation environment and hands of food handlers-microbiological status in hospital kitchen. Journal of food science and nutrition, 3.

García-López, M.-L., Santos, J.-A. & Otero, A. 1999. Flavobacterium. In: Robinson, R. K. (ed.) Ecyclopedia of Food Microbiology. Elsevier.

Gil, M. I., Selma, M. V., Suslow, T. V., Jacxens, L., Uyttendaele, M., & Allende, A. 2015. Pre- and post-harvest preventive measures and intervention strategies to control microbial food safety hazards of fresh leafy vegetables. Critical Reviews in Food Science and Nutrition, 55: 453-468.

Giritlioglu, I., Batman, O., and Tetik, N. 2011. The knowledge and practice of food safety and hygiene of cookery students in Turkey. Food Control, 22: 838-842.

Gitahi, M. G., Wangoh, J. and Njape, P. M. K. 2012. Microbial safety of street foods in industrial area. Nairobi Research Journal of Microbiology, 7: 297-308.

Götz, F. 2002. Staphylococcus and biofilms. Molecular Microbiology, 43: 1367–1378.

Gounadaki, A. S., Skandamis, P. N., Drosinos, H. and Nychas, G. E. 2008. Microbial ecology of food contact surfaces and products of small-scale facilities producing traditional sausages. Food Microbiology, 25: 313–323.

Griffith, C. 2005. Improving surface sampling and detection of contamination. In: Lelieveld, H., Holah, J. & Mostert, M. (eds.) Handbook of Hygiene Control in the Food Industry. Woodhead Publishing.

Grimont, P. A. D. & Grimont, F. (eds.) 2005. Genus XXIII Pantoea: Mergaert, Verdonck and Kersters

Grützke, J., Malorny, B., Hammerl, J. A., Busch, A., Tausch, S. H., Tomaso, H., & Deneke, C. (2019). Fishing in the soup – Pathogen detection in food safety using metabarcoding and metagenomic sequencing. Frontiers in Microbiology, 10(AUG), 1–15.

Gu, G., Ottesen, A., Bolten, S., Wang, L., Luo, Y., Rideout, S., Lyu, S. & Xiangwu Nou, X. 2019. Impact of Routine Sanitation on the Microbiomes in a Fresh Produce Processing Facility. International Journal of Food Microbiology, 294**,** 31-41.

Guzewich, J. and M. Ross (1999). "Evaluation risks of microbiological contaminations."
Health, D. o. (2018). Regulations governing general hygiene requirements f or food premises, the transport of of food & related matters. Pretoria.

Halpern, M., Waissler, A., Dror, A. & Lev-Yadun, S. 2011. Chapter 4 - Biological Warfare of the Spiny Plant: Introducing Pathogenic Microorganisms into Herbivore's Tissues. In: Allen I.

Henroid, D., Jr., and Sneed, J. 2004. Readiness to implement hazard analysis and critical control point (HACCP) systems in Iowa schools. Journal of the American Dietetic Association, 104: 180-185.

Herpertz Dahlmann, B., Seitz, J. And Baines, J. 2017. Food matters: how the microbiome and gut-brain interaction might impact the development and course of anorexia nervosa. European Child Adolescence Psychiatry 26(9): 1031-1041.

Herrera, F. C., Santos, J. A., Otero, A. and García-López, M. L. 2006. Occurrence of foodborne pathogenic bacteria in retail prepackaged portions of marine fish in Spain. Journal of Applied Microbiology, 100: 527–536.

Hoelzer, K., Sauders, B. D., Sanchez, M. D., Olsen, P. T., Pickett, M. M. and Mangione, K. J. 2011. Prevalence, distribution, and diversity of Listeria monocytogenes in retail environments, focusing on small establishments and establishments with a history of failed inspections. Journal of Food Protection, 74: 1083-1095.

Hussain, B., Chen, J-S., Hsu, B-M., Chu, I-T., Koner, S., Chen, T-H., Rathod, J. and Chan, M. W. Y. 2021. Deciphering bacterial community structure, functional prediction and food safety assessment in fermented fruits using next-generation 16S rRNA amplicon sequencing. Microorganisms. 9, 1574.

Jacxsens, L., Luning, P. A., Marcelis, W. J., van Boekel, T., Rovira, J. and Oses, S. 2011. Tools for the performance assessment and improvement of food safety management systems. Trends in Food Science & Technology, 22: 80-89.

Johnson, J., Curtin, C. & Waite-Cusic, J. 2021. The cheese production facility microbiome exhibits tempotal and spatial variability. Frontiers in Microbiology, 12.

Johnson, K. B., Stockwell, V. O., Sawyer, T. L. & SUGAR, D. 2000. Assessment of environmental factors influencing growth and spread of Pantoea agglomerans on and among blossoms of pear and apple. Phytopathology, 90**,** 1285-1294.

Jones, S. L., Parry, S. M., O'Brien, S. J. and Palmer, S. R. 2008. Operational practices associated with foodborne disease outbreaks in the catering industry in England and Wales. Journal of Food Protection, 71: 1659-1665.

Jorgensen, F., Sadler-Reeves, L., Shore, J., Aird, H., Elviss, N., Fox, A., Kaye, M., Willis, C., Amar, C., De Pinna, E. and McLauchlin, J. 2017. An assessment of the microbiological quality of lightly cooked food (including sous-vide) at the point of consumption in England. Epidemiology Infections, 145: 1500-1509.

Karaman, A. D., Cobanoglu, F., Tunalioglu, R. and Ova, G. 2012. Barrier and benefits of the implementation of food safety management systems among the Turkish dairy industry: A case study. Food Control, 25: 732-739.

Kennedy, J., V. Jackson, I. S. Blair, D. A. McDowell, C. Cowan and D. J. Bolton (2005). "Food Safety Knowledge of Consumers and the Microbiological and Temperature Status of their Refrigerators." Journal of food protection **68**(7): 1421-1430.

Kergourlay, G., Taminiau, B., Daube, G. and Champomier Verges, M. C. 2015. Metagenomic insights into the dynamics of microbial communities in food. International Journal of Food Microbiology 213: 31-39.

Khalil, R. K., Gomaa, M. A. and Khalil, M. I. 2015. Detection of shiga-toxin producing E. coli (STEC) in leafy greens sold at local retail markets in Alexandria, Egypt. International Journal of Food Microbiology, 197: 58-64.

Kharel, N., Palni, U., Tamang, J. P. 2016. Microbiological assessment of ethnic foods of the Himalayas. Journal of ethnic foods, 3: 235-241.

Kibret, M. & Abera, B. 2012. The sanitary conditions of food service establishments and food safety and knowledge and practices of food handlers in Bahir Dar town, Ethiopia. Journal of Health Sciences, 22**,** 27-37.

Kotloff, K., Nataro, J., Blackwelder, W., Nasrin, D., Farag, T. and Panchalingam, S. 2013. Burden and etiology of diarrhoeal disease in infants an young children in developing countries (Global Enteric Multicenter Study, GEMS): a prospective, case-control study. Lancet, 382: 209-222.

Kubheka, L. C., Mosupye, F. M., von Holy, A. 2001. Microbiological survey of street-vended salad and gravy in Johannesburg city, South Africa. Food Contro,l 12: 127–131.

Lambrechts, A. A., Human, I. S., Doughari, J. H. and Lues, J. F. R. 2014. Bacterial contamination of the hands of food handlers as indicator of hand washing efficacy in some convenient food industries. Pakistan Journal of Medical Science, 30(4):755-758.

Laskin, S. S., Geoffrey M. Gadd (ed.) Advances in Applied Microbiology. Academic Press,.

Lazou, T., Georgiadis, M., Pentieva, K., McKevitt, A., & Iossifidou, E. 2012. Food safety knowledge and food-handling practices of Greek university students: a questionnaire-based survey. Food Control, 28: 400-411.

Le, H. H. T., A. Dalsgaard, P. S. Andersen, H. M. Nguyen, Y. T. Ta and T. T. Nguyen (2021). "Large-Scale Staphylococcus aureus Foodborne Disease Poisoning Outbreak among Primary School Children." Microbiological research **12**: 43-52.

Le Loir, Y., Baron, F. and Gautier, M. 2003. Staphylococcus aureus and foodpoisoning. Genetic Molecular Research, 2: 63–76.

Leonard, S. R., Mammel, M. K., Lacher, D. W., & Elkins, C. A. (2015). Application of metagenomic sequencing to food safety: Detection of shiga toxin-producing Escherichia coli on fresh bagged spinach. Applied and Environmental Microbiology, 81(23), 8183–8191.

Lianou, A., and Sofos, J. N. 2007. A review of the incidence and transmission of Listeria monocytogenes in ready-to-eat products in retail and food service environments. Journal of Food Protection, 70: 2172-2198.

Lim, E., O. Koo, M. Kim and J. Kim (2019). "Bio-enzymes for inhibition and elimination of Escherichia coli O157: H7 biofilm and their synergistic effect with sodium hypochlorite." Sci. Rep.: 9920.

Lim, E.S., Kim, J.J., Sui, W.J., Kim, B., Kim, H. And Koo, O.K. 2021. Metagenomic analysis of microbial composition revealed cross-contamination pathway of bacteria at a foodservice facility. Frontiers in Microbiology. 12: 636329.

Liu, S., Liu, Z., Zhang, H., Lu, L., Lingling, J., Liang, J. and Huang, Q. 2015. Knowledge, attitude and practices of food safety amongst food handlers in the coastal resort of Guangdong, China. Food Control, 47: 457–461.

Liu, Z., Zhang, G. and Zhang, X. 2014. Urban street foods in Shijiazhuang city, China: current status, safety practices and risk mitigating strategies. Food Control, 41: 212–218.

Lockis, V., Cruz, A. G., Walter, E. H. M., Faria, J. A., Granato, D. & Sant'ana, A. S. 2011. Prerequisite programmes at schools: diagnosis and economic evaluation. Foodborne Pathogens and Diseases, 8**,** 213-220.

Lockis, V., Cruz, A. G., Walter, E. H. M., Faria, J. A., Granato, D. & Sant'ana, A. S. 2011. Prerequisite programmes at schools: diagnosis and economic evaluation. Foodborne Pathogens and Diseases, 8**,** 213-220.

Makelele, L. K., Kazadi, Z. A., Oleko, R. W., Foma, R., Mpalang, R., Ngbolua, K. N. and Gedeon, B.N. 2015. Microbiological quality of food sold by street vendors in Kisangani, Democratic Republic of Congo. African journal of Food science, 9(5): 285-290.

Malm, K. L., Nyarko, K. M., Yawson, A. E., GOGO, B., Lawson, A. 2015. Foodborne illness among school children in Ga East, Accra. Ghana Medical Journal, 49(2): 72-76.

Mama, M. and Alemu, G. 2016. Prevalence, antimicrobial suscepibility patterns and associated risk factors of Shigella and Salmonella among foodhandlers in Arba Minch University, South Ethophia. BMC Infectious Diseases, 16 (1): 1-7.

Manguiat, L. S. and Fang, T. J. 2013. Microbiological quality of chicken- and pork-based street-vended foods from Taichung, Taiwan and Laguna, Philippines. Food Microbiology, 36(1): 57-62.

Marzano, M.A and Balzaretti, C. 2013. Protecting child health by preventing school-related foodborne illnesses: Microbiological risk assessment of hygiene practices, drinking water and ready-to-eat foods in Italian kindergartens and schools. Food Control 34: 560-567.

Mashak, Z., Langroodi, A. M., Ehsani, A., Fathabad, A.E. and Ilkhanipoor, A. 2015. Microbiological quality of ready-to-eat foods of Tehran province. African journal of food science, 9(5): 257-261.

Mayo, B., Rachid, C. T. C. C., Alegria, A., Leite, A. M. O., Peixoto, R. S. and Delgrado, S. 2014. Impact of next generation sequencing techniques in food microbiology. Current Genomics 15(4): 293-309.

McGill, C. R., Fulgoni, V. L. and Devareddy, L. 2015. Ten year fiber and whole grain intakes and food sources for the United States Population: National health and nutrition examination survey 2001-2010. Nutrients, 7: 1119-1130.

McLinden, T., Sargeant, J. M., Thomas, M. K., Papadopoulos, A. and Fazil, A. 2014. Component costs of foodborne illness: A scoping review. Bio-Medicine Public Health, 14: 509.

Mellou, K., Sideroglou, T., Potamiti-Komi, M., Kokkinos, P., Ziros, P. and Georgakopoulou, T. 2013. Epidemiological investigation of two parallel gastroenteritis outbreaks in school settings. BMC Public Health, 13: 241-248.

Mepba, H. D., Achinewhu, S. C., Aso, S. M. and Wachukwu, C. K. 2007. Microbiological quality of selected street foods in Port Harcourt. Journal of Food Safety, 27(12): 1202-1211.

Michaels, B., Keller, C., Belvins, M., Paoli, G., Ruthman, T., Todd, E. and Griffith, C.J. 2004. Ministry of Health (MOH). 2010. Annual Report 2010. MOH: Putrajaya, Malaysia.

Ministry of Health (MOH). 2014.The National Level 2014 Clean, Safe and Healthy Canteen Award; Department of Food Safety and Food Quality, Ed.; MOH: Putrajaya, Malaysia.

Mosupye, F. M. and von Holy, A. 2013. A.Microbiological quality and safety of ready-to-eat street vended foods in Johannesburg, South Africa. Journal of Food Protection, 62(11): 1278-1284.

Muimba-Kankolongo, A. 2018. Fruit Production. Food Crop Production by Smallholder Farmers in Southern Africa, Challenges and opportunities for improvement. Academic Press.

Mulugeta, K. and Abera, B. 2012. The sanitary conditions of food service establishments and food safety knowledge and practices of food handlers in Bahir Dar Town. Ethopian Journal of Health Science, 22 (1): 27-35.

Murwira, T. S., Amosu, A. M. & Nemathaga, L. H. 2017. The level of compliance of food handlers with National Regulations on food hygiene and safety practices: A case of selected fast-food outlets in Thohoyandou, South Africa Universal Journal of Public Health 5**,** 85-92.

Myskova, P. and Karpiskova, R. 2014. Diversity of human Salmonella isolates in the South Moravian Region 2009-2012. Epidemiology, Microbiology. Immunology, 63: 116-120.

Nahar, S., A.-W. Ha, K.-H. Byun, I. Hossain, F. Mizan and S. Ha (2021). "Efficacy of flavourzyme against Salmonella Typhimurium, Escherichia coli, and Pseudomonas aeruginosa biofilms on food-contact surfaces." International Journal of Food Microbiology **33**.

National Restaurant Association. 2011. Inside the minds of today's consumers. Available from http://www.restaurant.org/pdfs/research/forecast_2011.pdf. Accessed 28 November 2018.

Neal, J. A., Binkley, M. and Henroid, D. 2012. Assessing factors contributing to food safety culture in retail food establishments. Food Protection Trends, 3: 468-476.

Neme, K., Hailu, B. & Belachew, T. 2017. Assess sanitary condition and food handling practices of restaurants in Jimma town, Ethiopia: Implication of foodborne infection and food intoxication. Food Science and Quality Management 60**,** 62-69.

Nguz, K. 2007. Assessing food safety system in sub-Saharan countries: An overview of key issues. Food Control, 18: 131-134.

NHS Plus. 2008. Royal College of Physicians, Faculty of Occupational Medicine management. A national guideline. RCP, London.

Nkosi, B. 2018. Please sir, may we have some more ...teachers. IOL Available: www.iol.co.za (Accessed 3 September 2019).

Nunes, C., Usall, J., Teixido, N. & Vinas, I. 2001. Biological control of postharvest pear diseases using a bacterium, Pantoea agglomerans CPA-2. Int. J. Food Microbiol, 70**,** 53-61.

Nzimande, B. 2014. Suspected food poisoning kills three pupils. ENCA, news. Available at http://www.enca.com/suspected-food-poisoning-kills-three-pupils (Accessed 27 November 2018).

O'Connell, A., Ruegg, P. L., Jordan, K., O'Brien, B., and Gleeson, D. 2016. The effect of storage temperature and duration on the microbial quality of bulk tank milk. Journal of Dairy Science, 99(5): 3367-3374.

Odu, N. N. and Akani, U. M. 2012. The microbiological assessment of ready-to-eat food (Shawarma) in Port Harcourt City, Nigeria. Nature and Science, 10(8): 1-8.

Olumakaiye, M. F. and Bakare, K. O. 2013. Training of food providers for improved environmental conditions of food service outlets in urban area Nigeria. Food Nutrition Science, 4: 99-105.

Owusu, P. 2010. Food safety in the School Feeding Programmes in the Ga East Municipal Area. 18-26.

Pascual, P. A. L., L. P. Leonido P. Olobia, G. Ludevese-Pascual and N. F. L. D. D. Abenis (2019). "Knowledge, Attitudes and Practices (KAPs) on Food Safety Among Food Handlers in School Canteens in Eastern Visayas, Philippines." Journal of Science, Engineering and Technology **7**: 58-67.

Powell, D. A., Jacob, C. J. and Chapman, B. J. 2011. Enhancing food safety culture to reduce rates of foodborne illness. Food Control, 22: 817-822.

Prevention of food worker transmission of foodborne pathogens: Risk assessment and evaluation of effective hygiene intervention strategies. Food Service Technology, 4: 31–49.

Programme, N. S. N. Department of Basic Education. 2012. Food preparation rules Available: https://www.education.gov.za/Portals/0/Documents/Publications/NSNP%20Food%20Preparation%20Rules%20poster.pdf?ver=2012-03-05-125642-903 (Accessed 15 June 2019).

Proietti, I., Frazzoli, C. and Mantovani, A. 2014. Identification and management of toxicological hazards of street foods in developing countries. Food and Chemical Toxicology, 63:143–152.

Quinlan, J. J. 2013. Foodborne illness incidence rates and food safety risks for populations of low socioeconomic status and minority race/ethnicity: A review of the literature. International Journal of Environmental Resesearch Public Health, 10: 3634-3652.

Rasool Hassan, B. A. (2012). Importance of personal hygiene. Pharmaceut Analitica Acta, 3, 126. Available at www.omicsonline.org/importance-of-personalhygiene (Accessed 24 November 2018).

Raposo, A., E. Pérez, C. T. de Faria, F. MA., C. Carrascosa and O. V. Singh (2017). "Food Borne Pathogens and Antibiotic Resistance." John Wiley and Sons, Inc.: 41-72.

Redmond, E. C., and Griffith, C. J. 2003. A comparison and evaluation of research methods used in consumer food safety studies. International Journal of Consumer Studies, 27(1): 17-33.

Réglier-Poupet, H., Paraina, C., Beauvais, R., Descamps, P. and Gillet, H. 2005. Evaluation of the quality of hospital food from the kitchen to the patient. Journal of Hospital Infections, 59: 131-137.

Rendall-Mkosi, K., Wenhold, F., & Sibanda, N. B. 2013. Case study of the national school nutrition programme in South Africa. PCD, NEPAD, University of Pretoria. Available at http://hgsf-global.org/en/component/docman/doc_details/404-case-study-of-the-national-school-nutrition-programme-in-south-africa (Accessed 24 November 2018).

Rode, T. M., Langsrud, S., Holck, A. and Møretrø, T. 2007. Different patterns of biofilm formation in Staphylococcus aureus under food-related stress conditions. International Journal of Food Microbiology, 116:372–383.

Samapundo, S., Climat, R., Xhaferi, R. and Devlieghere, F. 2015. Food safety knowledge, Attitudes and practices of street food vendors and consumers in Port-au-Prince, Haiti. Food Control, 50: 457–466.

Sani, N. A. and Siow, O. N. 2014. Knowledge, Attitudes and practices of food handlers on food safety in food service operations at the Universiti Kebangsaan Malaysia. Food Control, 37: 210-217.

Sarwar, S. (2015). "Insect vectors involved in mechanical transmission of human pathogens for serious diseases." Int J Bioinform Biomed Eng **1**: 300-306.

Scallan, E., Mahon, B. E., Hoekstra, R. M. and Griffin, P. M. 2013. Estimates of illnesses, hospitalizations, and deaths caused by major bacterial enteric pathogens in young children in the United States. Pediatrician Infectious Diseases Journal, 32: 217-221.

Scallen, E. A., & Weissenberger, G. (2013). California Evidence 2013 Courtroom Manual: LexisNexis. Retrieved from http://www.fao.org/docrep/ globalissues-criticalissuesschoolfeeding.

Silage review: Using molecular approaches to define the microbial ecology of silage – Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Organization-of-hypervariable-and-conserved-regions-of-16S-rRNA-gene_fig3_324827602 [accessed 24 Mar, 2023]
Seow, J., Agoston. R., Phua, L. and Yuk, H. G. 2012. Microbiological quality of fresh vegetables and fruits sold in Singapore. Food Control, 25: 39-44.

Shinbaum, S., Crandall, P. G. & O'bryan, C. A. 2016. Evaluating your obligations for employee training according to the Food Modernization Act. Food Control, 60**,** 12-17.

Sibanyoni, J. and Tabit, F. 2019. An assessment of the hygiene status and incidence of foodborne pathogens on food contact surfaces in the food preparation facilities of schools. Food Control,

Sibanyoni, J. J. & Tabit, F. T. 2017. Assessing the food safety attitudes and awareness of managers of school feeding programmes in Mpumalanga, South Africa. Journal of Community Health, 42**,** 664-673.

Sibanyoni, J. J., Tshabalala, P. A. and Tabit, F. T. 2017. Food safety knowledge and awareness of food handlers in school feeding programmes in Mpumalanga, South Africa. Food Control, 73: 1397-1406.

Silva, E., Carvalho, J., Aires, W. and Nitschke, M. 2017. Disruption of Staphylococcus aureus biofilms using rhamnolipid biosurfacants. Journal of Dairy Science, 100 (10): 7864-7873.

Simothy, L., F. Mahomoodally and H. Neetoo (2018). "A study on the potential of ants to act as vectors of foodborne pathogens." AIMS Microbiology **4**(2): 310-333.

Sinclair, R. and Gerba, C. 2011. Microbial contamination in kitchens and bathrooms of rural Combodian village households. Letters in Applied Microbiology, 52: 144-149.

Singh, A., P. Dudeja, N. Kaushal and S. Mukherji (2016). "Impact of health education intervention on food safety and hygiene of street vendors: a pilot study." Med. J. Armed Forces India, **72**(3): 265-269.

Smigic, N., Djekic, I., Martins, M. L., Rocha, A., Sidiropoulou, N. and Kalogianni, E. P. 2016. The level of food safety knowledge in food establishments in three European countries. Food Control, 63: 187-194.

Statistics South Africa (Stats SA). 2014. Mortality and causes of death in South Africa, 2012: Findings from death notification. Statistics South Africa. Pretoria. Available at http://beta2.statssa.gov.za/publications/P03093/P030932011.pdf Accessed 22 December 2018).

Steinberg, J. P. & Burd, E. M. 2015. 238 - Other Gram-Negative and Gram-Variable Bacilli. In: John E. Bennett, R. D., Martin J. Blaser, (ed.) Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases. W.B. Saunders.

Stellato, G., La Storia, A., Cirullo, L. and Ercolini, D. 2015. Bacterial biogeographical patterns in a cooking center for hospital foodservice. International Journal of Microbiology. 193: 99-108.

Swaminathan, B. and Gerner-Smidt, P. 2007. The epidemiology of human listeriosis. Microbes Infect. 9: 1236-1243.

Tambekar, D. H., Jaishwal, V. J., Dhanorkar, D. V., Gullhane, P. B. and Dudhane, M. N. 2008. Identification of microbiological hazards and safety of ready-to-eat food vended in streets of Amravati city. India Journal of Applied Bioscience, 7: 195-201.

Tan, S. L., Bakar, F. A., Karim, M. S. A., Lee, H. Y. and Mahyudi, N. A. 2013. Hand hygiene knowledge, attitudes and practices among food handlers at primary schools in Hulu Langat district, Selangor (Malaysia). Food Control, 34: 428-435.

Todd, E., Greig, J., Bartleson, C. and Michaels, B. 2009. Outbreaks where food workers have been implicated in the spread of foodborne disease. part 6. Transmission and survival of pathogens in the food processing and preparation environment. Journal of food protection, 72 (1): 202-219.

Tomasevic, I., Kuzmanovic, J., AnCelkovic, A., Saracevic, M., Stojanovic, M. M. and Djekic, I. 2016. The effects of mandatory HACCP implementation on microbiological indicators of process hygiene in meat processing and retail establishments in Serbia. Meat Science, 114: 54-57.

Toth, A. J., Kollr, Z., Illes, C. B. and Bittsanszky, A. 2017. Development of conscious food handling in Hungarian school cafeterias. Food Control, (73): 644-649.

U.S. Food and Drug Administration. 2012. Foodborne Pathogenic Microorganisms and Natural Toxins Handbook, The bad bug book, 2nd edition.

USDA Food and Nutrition Service. 2000. Changing the scene: Improving the school nutrition environment. A guide to local action. Washington DC: US Department of Agriculture.

USDA. 2013. Cutting boards and food safety. Resources: USDA. Available from: http://www.fsis.usda.gov/wps/portal/fsis/topics/food-safetyeducation/get-answers/food-safety-fact-sheets/safe-food-handling/cuttingboards-and-food-safety. Accessed 2 February 2019.

Van Reckem, E., De Vuyst, L., Weckx, S. & Leroy, F. 2021. Next-generation sequencing to enhance the taxonomic resolution of the microbiological analysis of meat and meat-derived products. Current Opinion in Food Science, 35**,** 58-65.

Vitas, A.I., Aguado, V. and Garcia-Jalon, I. 2004. Occurrence of Listeria monocytogenes in fresh and processed foods in Navarra (Spain). International Journal of Food Microbiology, 90: 349-356.

Vo, T. H., Le, N. H., Le, A. T. N. and Minh, N. N. T. 2015. Knowledge, attitudes, practices and training needs of food-handlers in large canteens in Southern Vietnam. Food Control, 57: 190-194.

Vojkovska, H., Myskova, P., Gelbicova, T., Skockova, A., Kolackova, I. and Karpiskova, R. 2017. Occurrence and characterisation of food-borne pathogens isolated from fruit, vegetables and sprouts retailed in the Czech Republic. 63: 147-152.

Völksch, B. & Sammer, U. 2008. Characterization of the inhibitory strain Pantoea sp. 48b/90 with potential as a biocontrol agent for bacterial plant pathogens. In: M. Fatmi, A. C., N.S. Lacobellis, J.W. Mansfield, J. Murillo, N.W. Schaad, M. Ullrich (ed.) Pseudomonas syringae Pathovars and Related Pathogens. Springer Science Business Media.

Wallace, C. and Williams, T. 2001. Pre-requisites: a help or a hindrance to HACCP? Food Control, 12: 235-240.

Watson, J., R., Wallihan, R. & Antonara, S. 2018. Less Commonly Encountered Enterobacteriaceae. In: Sarah S. Long, C. G. P., Marc Fischer (ed.) Principles and Practice of Pediatric Infectious Diseases (Fifth Edition). Elsevier.

Webb, M. and Morancie, A. 2015. Food safety knowledge of foodservice workers at a university campus by education level, experience, and food safety training. Food Control, 50: 259-264.

Willis, C., McLaughlin, J., Amar, C., Sadler-Reeves, L., Elviss, N., Aird, H., Fox, A. and Kaye, M. 2016. An assessment of the microbiological safety of pre-cut fruit from retail and catering premises in the United Kingdom. Journal of Food Protection, 79: 598–604.

Wisplinghoff, H. 2017. Pseudomonas spp., Acinetobacter spp. and Miscellaneous Gram-Negative Bacilli. In: Jonathan Cohen, W. G. P., Steven M. Opal, (ed.) Infectious Diseases. Fouth ed.: Elsevier.

World Health Organization. 2009. Evidence of hand hygiene to reduce transmission and infections by multidrug resistant organisms in health-care settings. In WHO Guidelines on Hand Hygiene in Health Care; Clean Care is Safer Care Team, Ed.; WHO: Geneva, Switzerland.

World Health Organisation/Food and Agriculture Organisation. 2009. Codex Alimentarius-food hygiene basic Text (4TH ed.). Rome.

World Health Organisation. 2012. Manual for integrated foodborne disease surveillance in the World Health Organisation African Region. Brazzaville: WHO Regional Office for Africa.

World Health Organisation. 2014. World Health Organization (WHO) initiative to estimate the global burden of foodborne diseases: fourth formal meeting of the Foodborne Disease Burden Epidemiology Reference Group (FERG): Sharing New Results, Making Future Plans, and Preparing Ground for the Countries.

World Health Organisation. 2015. WHO estimates of the global burden of foodborne diseases. Available at http://apps.who.int accessed 18 October 2019.

World Health Organisation. 2018. Listeriosis, South Africa. Available: http://www.who.int/csr/don/28-march-2018-listeriosis-south-africa (Accessed https://www.who.int/foodsafety/areas_work//5keys Accessed: 17 October 2018

World Health Organisation and UNICEF (2018). "Core questions on drinking Water, Sanitation and Hygiene for household surveys."

World Health Organisation/Europe (2019). Improving health and learning through better Water, Sanitation and Hygiene in schools. An information package for school staff

Wu, G., Q. Yuan, L. Wang, J. Zhao, Z. Chu and M. Zhuang (2018). "Epidemiology of foodborne disease outbreaks from 2011 to 2016 i Shandong Province, China." Medicine **97**(45).

Yang, L., Liu, Y., Wu, H., Song, Z., Hoiby, N., Molin, S. and Givskov, M. 2012. Combating biofilms. FEMS Immunology and Medical Microbiology, 65:146 –157.

Youn, S. and Sneed, J. 2003. Implementation of HACCP and prerequisite programs in school foodservice. Journal of the American Dietetic Association, 103: 55-60.

Zhao, X., Lin, C., Wang, J., & Oh, D. (2014). Advances in rapid detection methods for foodborne pathogens. Journal of Microbiology and Biotechnology, 24(3), 297–312.

Zilelidou, E. A., Tsourou, V., Poimenidou, S., Loukou, A., & Skandamis, P. N. 2015. Modelling transfer of Escherichia coli O157:H7 and Listeria monocytogenes during preparation of fresh-cut salads: Impact of cutting and shredding practices. Food Microbiology, 45: 254-265.

Ababio, P. F. and P. Lovatt (2015). "A review on food safety and food hygiene studies in Ghana." Food Control **47**: 92-97.

Akusu, O., D. Kiin-Kabari and S. MWemedo (2016). "Microbiological quality of selected street vended foods in Port Harcourt metropolis, Rivers State, Nigera." Sky Journal of Food Science **5**(2): 8-11.

Choi, M. H., Y. J. Park, M. Kim, Y. H. Seo, Y. A. Kim, J. Y. Choi, D. Yong, S. H. Jeong and K. Lee (2018). "Increasing Incidence of Listeriosis and Infection-associated Clinical Outcomes." Annals of laboratory medicine **28**(2): 102-109.

Da Costa, S., A. Pelli and G. de Carvalho (2006). "Ants as mechanical vectors of microorganisms in the school hospital of the universidade federal do TrÎangulo Mineiro." Rev Soc Bras Med Tro **39**: 527–529.

Department of Health (2001). Regulations governingmicrobiological standards for foodstuffs and related matters. D. o. Health. Pretoria, Government Gazette. **490 of 2001**.

Department of Health (2018). Regulations governing general hygiene requirements f or food premises, the transport of of food & related matters. Pretoria.

Dlova, Z. N. (2018). An investigation of the National School Nutrition Programme in Peddie, Eastern Cape, South Africa. Master of Public Health, University of the Western Cape.

Ehuwa, O., A. K. Jaiswal and S. Jaiswal (2021). "Salmonella, food safety and food handling practices." Foods **10**(5): 907.

Fouque, F. and J. C. Reeder (2019). "Impact of past and on-going changes on climate and weather on vector-borne diseases transmission: A look at the evidence." Infect. Dis. Poverty **8**(51).

Guzewich, J. and M. Ross (1999). "Evaluation risks of microbiological contaminations."

Kazianga, H., D. de Walque and H. Alderman (2009). "Educational and Health Impacts of Two School Feeding Schemes: Evidence from a Randomized Trial in Rural Burkina Faso." World Bank Policy Research Working Paper No. 4976.

Kennedy, J., V. Jackson, I. S. Blair, D. A. McDowell, C. Cowan and D. J. Bolton (2005). "Food Safety Knowledge of Consumers and the Microbiological and Temperature Status of their Refrigerators." Journal of food protection **68**(7): 1421-1430.

Le, H. H. T., A. Dalsgaard, P. S. Andersen, H. M. Nguyen, Y. T. Ta and T. T. Nguyen (2021). "Large-Scale Staphylococcus aureus Foodborne Disease Poisoning Outbreak among Primary School Children." Microbiological research **12**: 43-52.

Lim, E., O. Koo, M. Kim and J. Kim (2019). "Bio-enzymes for inhibition and elimination of Escherichia coli O157: H7 biofilm and their synergistic effect with sodium hypochlorite." Sci. Rep.: 9920.

Mafani, N., N. Kwatsha, M. Mzimasi Neti, H. Hetani Mdose and L. Lazarus Kuonza (2022). Foodborne illness at a Combined School, Eastern Cape Province, South Africa, February 2022. 11th TEPHINET Global Panama.

Mafugu, T. (2021). "Challenges encountered in a South African school nutrition programme." Journal of Public Health Research **10**(1).

Mama, M. and G. Alemu (2016). "Prevalence, antimicrobial susceptibility patterns and associated risk factors of Shigella and Salmonella among food handlers in Arba Minch University, South Ethiopia." BMC Infectious Disseases **16**: 1-7.

Martins, M. L. and A. Rocha (2014). "Evaluation of prerequisite programs implementation at schools foodservice." Food Control **39**: 30-33.

Marzano, M. and C. Balzaretti (2013). "Protecting child health by preventing school-related foodborne illnesses: Microbiological risk assessment of hygiene practices, drinking water and ready-to-eat foods in Italian kindergartens and schools." Food Control **34**: 560-567.

Ministry of Food and Agriculture/World Bank (2007). "Review of food saftey in Ghana."

Morris, M. (2022). "South Africa's National School Nutrition Programme is a success, but shortcomings need fixing." DSI-NRF Centre of Excellence for Food Security.

Motladiile, T., J. Tumbo, A. Malumba, B. Adeoti, N. Masekwane, O. Mokate and O. Sebekedi (2019). "Salmonella food-poisoning outbreak linked to the National School Nutrition Programme, North West province, South Africa." Southern African Journal of Infectious Diseases **34**(1).

Nahar, S., A.-W. Ha, K.-H. Byun, I. Hossain, F. Mizan and S. Ha (2021). "Efficacy of flavourzyme against Salmonella Typhimurium, Escherichia coli, and Pseudomonas aeruginosa biofilms on food-contact surfaces." International Journal of Food Microbiology **33**.

National Institute of Communicable Disease (2018). Situation report on listeriosis outbreak, South Africa, 2018.

Nhlapho, N. (2013). Hygiene and nutritional content of the National School Nutrition Programme in Bloemfontein, South Africa. Master of Technology in Environmental Health, Central University of Technology.

NKosi, B. (2018). Please sir may we have some more... teachers. iol. Gauteng.

Nyawo, T., H. Kesa and E. Onyenweaku (2012). "Food Safety and Hygiene: Knowledge, Attitude and Practices among Food Handlers." African journal of hospitality, tourism and leisure **10**(2): 547-558.

Pascual, P. A. L., L. P. Olobia, G. Ludevese-Pascual and N. F. L. D. D. Abenis (2019). "Knowledge, Attitudes and Practices (KAPs) on Food Safety Among Food Handlers in School Canteens in Eastern Visayas, Philippines." Journal of Science, Engineering and Technology **7**: 58-67.

Putri, M. S. and D. Susanna (2021). "Food safety knowledge, attitudes, and practices of food handlers at kitchen premises in the Port 'X' area, North Jakarta, Indonesia 2018." Italian Journal of Food Safety **10**(4).

Raposo, A., E. Pérez, C. T. de Faria, F. MA., C. Carrascosa and O. V. Singh (2017). "Food Borne Pathogens and Antibiotic Resistance." John Wiley and Sons, Inc.: 41-72.

Rendall-Mkosi, K., F. Wenhold and N. Sibanda (2013). "Case study of the national school nutrition programme in South Africa." University of Pretoria.

Sarwar, S. (2015). "Insect vectors involved in mechanical transmission of human pathogens for serious diseases." Int J Bioinform Biomed Eng **1**: 300-306.

Sharma, A., S. Gangopadhyay, J. K. Agarwal, A. Kumar and K. Ingole (2021). "Hand Contamination among Food Handlers: A Study on the Assessment of Food Handlers in Canteen of Various Hospitals in Solapur City, Maharashtra." Journal of Pure and Applied Microbiology **15**(3): 1536-1547.

Shrestha, A., S. Sharma, J. Gerold, S. Erismann, S. Sagar, R. Koju, C. Schindler, P. Odermatt, J. Utzinger and G. Cisse (2017). "Water quality, sanitation and hygiene conditions in schools and households in Dolakha and Ramechhap Districts, Nepal: Results from a cross-sectional survey." International Journal Environmental Research and Public Health **14**(89).

Simothy, L., F. Mahomoodally and H. Neetoo (2018). "A study on the potential of ants to act as vectors of foodborne pathogens." AIMS Microbiology **4**(2): 310-333.

Singh, A., P. Dudeja, N. Kaushal and S. Mukherji (2016). "Impact of health education intervention on food safety and hygiene of street vendors: a pilot study." Med. J. Armed Forces India, **72**(3): 265-269.

Soares, K., J. Garcia-Diez, A. Estevez, I. Oliviera and C. Saraiva (2013). "Evaluation of food safety training on hygienic conditions in food establishments." Food Control **34**: 613-618.

Venuto, M., K. Garcia and B. Halbrook (2015). "Analyses of the Contributing Factors Associated With Foodborne Outbreaks in School Settings (2000–2010)." Journal of Environmental Health **77**(7): 16-21.

Wall, C., T. Tolar-Peterson, N. Reeder, M. Roberts, A. Reynolds and G. Rico Mendez (2022). "The Impact of School Meal Programs on Educational Outcomes in African Schoolchildren: A Systematic Review." International Journal Environmental Research and Public Health **19**(6).

WHO and UNICEF (2018). "Core questions on drinking Water, Sanitation and Hygiene for household surveys."

WHO/Europe (2019). Improving health and learning through better Water, Sanitation and Hygiene in schools. An information package for school staff

Wu, G., Q. Yuan, L. Wang, J. Zhao, Z. Chu and M. Zhuang (2018). "Epidemiology of foodborne disease outbreaks from 2011 to 2016 i Shandong Province, China." Medicine **97**(45).

APPENDIX A

HYGIENE ASSESSMENT SYSTEM CHECKLIST:

NATIONAL SCHOOL NUTRITION PROGRAMME

Certificate of Acceptability (COA)	**Regulation reference**	**Comments**	**Yes**	**No**
The food premises have been issued with a valid COA?	3(1)			
The COA is displayed in a conspicuous place?	3(7)			
Standards and requirements for food premises				
Was of such location, design, construction and finish and was equipped and maintained in the condition for which it was intended, that it can be used at all times for the purpose for which it was designed, constructed and equipped - without creating a health hazard?	5(2)			
All interior surfaces of walls, sides or ceilings, or of roofs without ceilings, and the surfaces of floors, had no open joints or open seams and were made of smooth, rust-free, non-toxic, cleanable and non-absorbent material that was dust-proof and water-resistant?	5(3)(b)			
Ventilated effectively by means of natural ventilation through openings or openable sections which were directly connected to the outside air and so positioned in the external walls and/or roof that effective cross-ventilation was possible?				
Ventilation openings had a surface area equal to at least 5% of the floor area of the room concerned?				
Was illuminated by means of unobstructed transparent surfaces in the external walls and/or roof which admit daylight, with an area equal to at least 10% of the floor area in the room concerned?				
Had a wash-up facility with hot and cold water for the cleaning of facilities?	5(3)(c)			
Was pest proof in accordance with the best available method?				

Was provided with effective means of controlling and preventing access of flies, cockroaches, or other insects?				
Had a waste-water disposal system approved by the local authority?				
Provided separate sanitary facilities for food handlers?	5(3)(d)			
Hand-washing facilities were provided with cold and/or hot water?				
Supplied with soap and clean disposable hand-drying material or other hand-cleaning facilities or hand-drying equipment for the cleansing and drying of hands?				
Liquid proof, easy-to-clean refuse containers with close-fitting lids suitable for the hygienic storage of refuse pending its removal were provided?				
Storage space for the hygienic storage of food, facilities and equipment and a suitable separate area for the hygienic storage of refuse containers?				
Separate changing area with storage facilities for clothes of workers?				
An adequate supply of water was available?				
No gas, fumes, dust, soot deposits, offensive odours or any other impurity was present or could arise in such a manner that food in the food-handling room could be contaminated or spoilt?	5(3)(e)			
No act was performed in any manner or where any condition exists that could contaminate or spoil food in the food handling area?				
Standards and requirements for facilities				
Working surfaces on which unwrapped food was handled and any equipment, utensil or basin or any other surface which came into direct contact with food was made of smooth, rustproof, non-toxic and non-absorbent material that was free of open joints or seams?	6(1)			
Crockery, cutlery, utensils, basins or any other such facilities used for the handling of food was clean or not used if chipped, split or cracked?	6(2)			
Working surfaces were cleaned and washed before food came into direct contact with it for the first time during each work shift?	6(4)			
The fridge and freezer was provided with a thermometer and positioned so that the reading may be taken unhampered?	6(5)			
Standards and requirements for the storage of food				

Food was not stored in direct contact with a floor or any ground surface.	8(1)			
Any shelf or display case used for storing food or any container was kept clean and free from dust or any other impurity?	8(2)			
Protective Clothing				
No person was allowed to handle food without wearing suitable protective clothing?	9(1)			
Was clean and neat when food handler began shift?	9(2)			
Was of such design and material that it could not contaminate the food; was so designed that the food could not come into direct contact with any part of the body, excluding the hands?				
Visitors were provided with suitable protective clothing?	9(3)			
Food handler				
Was suitably qualified or adequately trained in the principles and practices of food safety and hygiene?	10(1)			
Routine assessments were conducted to determine the impact of the training?				
No person handling non-pre-packed food wore any jewellery or adornment that could come into contact with the food, unless it was suitably covered?	10(9)			
Hands and clothes were clean?	11(1)			
Fingernails were short, trimmed, clean and free of adornment?				
Washed their hands thoroughly with soap and water or cleaned them in another effective manner - immediately prior to the commencement of each work shift; at the beginning of the day's work or after a rest period; after every visit to a latrine or urinal?				
Did not have sores/cuts/abrasions, including infected skin lesions, unless covered with a moisture proof dressing which is firmly secured to prevent contamination of the food?	11(2)			
Was not suffering from or was a carrier of a disease or condition in its contagious stage likely to be transmitted through food including jaundice; diarrhoea; vomiting; fever; sore throat with fever and discharges from the ear, eye or nose?				

No smoking was allowed in an area where food was handled?				

APPENDIX B

LETTER OF INFORMATION: PARTICIPANT

Title of the research study: Food hygiene practices in the National Schools Nutrition Programme among primary schools in Vryheid.

Principal Investigator: Sithembile Sindisiwe Madlala

Co-investigators: Prof. P. Reddy, Dr. N. Mchunu & Ms M. Dalasile

Brief introduction and purpose of the study: The National School Nutrition Programme targets all pupils in quintile 1-3 government schools, which makes up 60% of the poorest schools in South Africa. The implementation of the programme has met some challenges with regards to food preparation and hygiene, such as inadequate food storage and preparation areas. Therefore, the purpose of this study will be to determine hygiene of food handlers and to assess the compliance of food preparation areas in schools.

Outline of procedures: A minimum of 33 primary schools are required for the study sample. Schools that meet the sampling criteria will be included in the study and data will be collected by the researcher by visiting the school food preparation and storage area and food handlers who consent to microbiological sampling will be swabbed during the visit.

Risks or discomforts to the participant: There are no perceived risks to participants during this study.

Benefits: This study will assist the Department of Basic Education in improving food safety in schools. It will also highlight areas of concern and their potential risk and provide recommendations to improve food hygiene in schools.

Reasons why the participant may withdraw from the study: Participation in this study is voluntary, therefore if at any time during the study the participating school chooses to withdraw, it is free to do so without any consequences.

Remuneration: There is no remuneration for participating in this study.

Costs of the study: The participating school is not required to pay for the study.

Confidentiality: The schools' name will be always kept confidential.

Research-related injury: There will be no exposure to any harmful act during the study.

Persons to contact in the event of any problems or query:

Sithembile Sindisiwe Madlala (Researcher): 073 339 4632

Prof. Reddy (Research Supervisor): 031 373 2808

Ms Dalasile (Research Co-Supervisor): 031 373

Institutional Research Ethics Administrator: 031 373 2900

APPENDIX C

LETTER OF CONSENT

To take part in this study, you need to fill in this form stating that you agree to take part in this study.

Statement of Agreement to participate in the research study:

- I hereby confirm that I have been informed by the researcher, Sithembile Sindisiwe Madlala, about the nature, conduct, benefits and risks of this study- Research Ethics Clearance Number: 027/19
- I have also received, read and understood the above information (Appendix D Letter of Information) regarding the study.
- I know that the results of the study will be included into a study report without using the name of the school anywhere in the study report.
- In view of the requirements of research, I agree that the information collected can be entered into a computer by the researcher.
- I may, at any time, drop out of the study without any consequences.
- I have had sufficient opportunity to ask questions and consent to information being collected at the school.
- I understand that important new findings from this study which in any way relates to the school's participation will be made available to the school.

_____	_____	_____
Name of the school	Date	Principals Signature

I, Sithembile Sindisiwe Madlala, hereby confirm that the above participant has been fully informed about the nature, conduct and the risks of the study.

_____	_____
Date	Signature

_____	_____	_____
Name of Witness	Date	Signature

APPENDIX D

GATEKEEPERS PERMISSION

APPENDIX E

IREC APPROVAL