FOOD SAFETY KNOWLEDGE AND HYGIENE PRACTICES AMONG ORANGE FLESHED SWEETPOTATO (OFSP) PUREE HANDLERS: MICROBIAL CONTAMINATION IN PUREE PROCESSING COMPANY IN KENYA AND IMPACT OF TRAINING

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DEPARTMENT OF FOOD SCIENCE, NUTRITION AND TECHNOLOGY

2017

DECLARATION

I, **Derick Nyabera Malavi,** hereby declare that this Research Dissertation is my original work and has not been presented for a degree in any other institution.

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This Research Dissertation has been submitted with our approval as University supervisors.

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DEDICATION

I dedicate this work to my loving parents Mr. and Mrs. Malavi and all my family members for their love, fervent prayers and unending support.

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LIST OF ACRONYMS AND ABBREVIATIONS

CDC	Centre for Disease Control and Prevention
CFU	Colony forming units
CIP	International Potato Centre
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
GMP	Good Manufacturing Practices
HACCP	Hazard Analysis Critical Control Point
Log cfu	Logarithm colony forming unit
ml	Milliliters
OFSP	Orange Fleshed Sweetpotato
PCA	Plate Count Agar
PDA	Potato Dextrose Agar
SSA	Sub-Saharan Africa
WHO	World Health Organization
ERA	Economic Review of Agriculture

GENERAL ABSTRACT

Orange Fleshed Sweetpotato (OFSP) puree is an important functional food ingredient currently being utilized in bakery applications by one of the largest retail outlet in Kenya. There is, however, limited information on the state of food safety along OFSP puree value chain in Kenya. The current study was designed and conducted in three phases and aimed at determining the level of food safety knowledge and hygiene practices of OFSP puree handlers; determining the sources of microbial contamination in OFSP puree processing plant; and evaluating the impact of food safety training on knowledge and hygiene practices of OFSP puree handlers and microbial contamination levels in OFSP puree processing plant in Kenya. In the first objective, food safety knowledge and practices was assessed separately among 14 food handlers at the OFSP puree processing plant and another 21 food handlers at the bakery using a self-administered structured questionnaire. In the second objective, the level of microbial contamination of equipment, personnel, installations and OFSP samples at different stages of processing was determined in 62 samples. In the third objective, the impact of food safety training on food handlers' knowledge and practices as well as on the level microbial contamination in OFSP puree processing plant was evaluated based on results from objective 1 and 2.

Results showed low but significant ($p<0.05$) level of knowledge on food safety among food handlers at the puree processing plant and at the bakery with scores of 72% and 75%, respectively. OFSP puree handlers at the bakery demonstrated significantly ($p<0.05$) better practices (84%) compared to food handlers at the puree processing plant with a score of 73%. Training had a significant impact on knowledge ($p=0.020$) and practices ($p=0.006$)

with majority of the OFSP puree handlers (63%) having received a training on food safety. A significant moderate positive correlation existed between knowledge and practices ($r=0.358$, $p=0.035$). As per adjusted linear regression analysis, food hygiene practices significantly ($p=0.045$) increased by 0.32% with one unit increase in knowledge. Unacceptably high microbial counts (>10^5 cfu) were detected on food equipment surfaces, installations, personnel hands and in packaged sweetpotato puree. The counts in OFSP cooked roots significantly ($p<0.05$) reduced after steaming but the counts significantly ($p<0.05$) increased in the puree due to post-processing contamination. Total counts, yeast and molds, Enterobacteriaceae, total coliforms, *E. coli* and *S. aureus* counts in OFSP puree were 8.0, 4.0, 6.6, 5.8, 4.8 and 5.9 log10 cfu/g, respectively. The level of food safety knowledge and practices of food handlers at the OFSP puree processing plant significantly ($p<0.05$) improved after training. Similarly, microbial counts on equipment surfaces, installations, personnel and in OFSP puree significantly ($p<0.05$) declined to acceptable levels for food processing after food safety training. In conclusion, food handlers at the puree processing plant displayed low level food safety knowledge and poor hygiene practices that contributed to high microbial contamination in OFSP puree. The current study also reveals food safety training as an effective tool for improving knowledge and hygiene practices of food handlers and microbial quality foods. The study recommends hygiene inspection of the puree processing plant and training in food safety be carried out frequently to improve the quality and safety of OFSP puree for use as a ready-to-eat food or as a food ingredient.

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background Information

Sweetpotato (*Ipomoea batatas* Lam) is one of the high yielding crops and an important staple food in the world (Teow et al., 2007). In Kenya, sweetpotato is the third most important root and tuber crop after potato and cassava. It is often consumed as boiled or steamed by majority of the households in rural areas in Kenya (Ndolo et al., 2007). High perishability nature of sweetpotatoes and lack of high technology storage facilities limits market reach and results in large post-harvest losses in Africa (Oke and Workneh, 2013).

Orange fleshed sweetpotato (OFSP) is an important sweetpotato variety for food security and nutrition in Kenya. Other than being a good source of energy (carbohydrates), OFSP is rich in beta-carotene (provitamin A), fiber, antioxidants and minerals (Carey et al., 1995; Low et al., 2007; Low et al., 1997). Currently, the International Potato Center (CIP-Kenya) partners with a new OFSP puree processing company and one of the country's largest supermarket chain with 52 stores country-wide and outlets in neighboring countries, in production of bread and other baked products based on OFSP puree (Tedesco and Stathers, 2015). The use of OFSP puree (steamed and mashed roots) as a substitute for wheat flour has proven to be cost-effective as opposed to the use of OFSP flour. High profit margins have been realized since the launch of OFSP puree baked products in Kenyan markets and particularly with the use of high fiber puree (Bocher et al., 2017). Baked products made using 20-45% OFSP puree are highly nutritious and acceptable to consumers (Low and Van Jaarsveld, 2008; Muzhingi et al., 2016).

Currently, the OFSP puree value chain in Kenya is operated on a small-scale basis. Small-scale and medium scale business enterprises (SMEs) involved in food production are often faced with challenges of establishing, implementing and maintaining food safety programs due to lack of skilled personnel, training, funding and resources to identify microbial food hazards (Bertolini et al., 2007; Taylor, 2001). Due to the highlighted factors, level of hygiene in SMEs is generally low. Despite the nutritional and economic benefits accrued along the OFSP puree value chain, food safety issues remain overlooked. Food safety and quality concerns such as violation of food hygiene practices and microbial contamination are issues that are yet to be investigated to ensure compliance to food safety regulations along the OFSP puree value chain in Kenya. Sweetpotato puree is a medium acid food highly prone to post-process microbial contamination attributed to poor food handling practices (Perez-Diaz et al., 2008). There is lack of information on whether there are food safety issues facing the OFSP puree value addition in Kenya and how to address them. The level of food safety knowledge and hygiene practices among OFSP puree handlers and state of microbial contamination in puree processing is yet to be established. There is also lack of information on the effectiveness of food safety training as an intervention for improving food handlers' knowledge and hygiene practices as well as improving microbial quality along OFSP puree value chain. The current study was therefore designed to determine the level of food safety knowledge and hygiene practices of OFSP puree handlers, determining the sources of microbial contamination in OFSP puree processing plant and evaluating the impact of food safety training on knowledge and hygiene practices of OFSP puree handlers and microbial contamination in the only puree processing plant in Kenya.

1.2 Problem Statement

The use of OFSP puree as an ingredient in bakery applications and consumption of OFSP puree based products is on the rise in Kenya. Commercial processing and handling of orange fleshed sweetpotato (OFSP) puree and related processed products is, however, highly prone to microbial contamination that can be attributed to low food safety knowledge and violation of food hygiene practices by food handlers. Lack of food safety knowledge, poor hygiene practices and microbial contamination during food processing are leading causes of food spoilage and foodborne illnesses (Aluko et al., 2014; Anurahda and Dandekar, 2014; Sharif et al., 2013; Todd et al., 2007; Tolulope et al., 2014). The level of knowledge and practices among orange fleshed sweetpotato puree handlers in Kenya is yet to be established. The level and sources of microbial contamination at the only sweetpotato puree processing plant in the country is not known. Additionally, the impact of food safety training programs on food handlers' knowledge, hygiene practices and in controlling contamination is yet to be elucidated.

1.3 Justification

There is a need to determine the prevailing level of food safety knowledge and hygiene practices of orange fleshed sweetpotato puree handlers and potential sources of microbial contamination in OFSP puree processing environment for designing training programs and other mitigative measures necessary for improving food hygiene, safety and quality of OFSP puree and related processed products. The processing of OFSP puree following set codes of hygiene, food safety standards and regulations will reduce losses resulting from microbial spoilage, instill confidence and attract more potential investors, expand market for sweetpotato roots and sweetpotato puree based products and consequently improve uptake and nutrition among consumers. Through adoption and adaption, the training module from the study will be useful in enhancing food safety in other food processing environments. The current study will also enhance capacity building among food handlers in processing and provide information for enhancing compliance to Good Manufacturing Practices (GMPs) as a foundation for developing and implementing HACCP plans in puree processing.

1.4 Overall Objective

To assess the level of food safety knowledge and hygiene practices among food handlers; microbial contamination and impact of food safety training in orange fleshed sweetpotato (OFSP) puree value chain in Kenya.

1.4.1 Specific Objectives

1. To determine the level of food safety knowledge and hygiene practices among orange fleshed sweetpotato puree handlers in Kenya.
2. To determine the levels and sources of microbial contamination in orange fleshed sweetpotato puree processing plant in Kenya.
3. To assess the impact of food safety training on the level of food safety knowledge, hygiene practices and microbial quality in orange fleshed sweetpotato puree processing plant in Kenya.

1.4.2 Hypotheses

1. There is a significant difference in the level of food safety knowledge and practices among OFSP puree handlers along the value chain.
2. Microbial contamination in orange fleshed sweetpotato puree processing plant is associated with poor hygiene practices.

3. Food safety training has a significant impact on knowledge and practices of OFSP puree handlers as well as microbial quality of OFSP puree.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Production of Sweetpotatoes in Kenya

Sweetpotato is the seventh most important food crop in the world after wheat, rice, maize, barley and cassava (Fischer et al., 2014). Sweetpotato is a staple food in many African countries namely: Kenya, Tanzania, Angola, Burundi, Angola, Nigeria and Rwanda (Carrey et al., 1997). Sweetpotato is increasingly becoming an important food security and famine relief crop during seasons of crop failure in Kenya (Kibwage et al., 2009). Kenya is the sixth largest producer of sweetpotato in Africa with an average yield of 8.2 tons/ha (Mukras et al., 2013). As per the year 2014, the major sweetpotato producing counties in Kenya were Homabay, Busia, Migori and Bungoma (ERA, 2015). Many cultivars of sweetpotatoes differentiated by color and shape are cultivated in Kenya. The flesh color ranges from white, cream, purple, yellow and orange (Vimala et al., 2011). Orange fleshed sweetpotato (OFSP) is one of the sweetpotato varieties introduced in Kenya and other sub-Saharan countries due its high beta-carotene content (Donado-Pestana et al., 2012; Low et al., 1999; Nungo et al., 2007; Tumwegamire et al., 2007). Depending on the region, OFSP cultivars grown in Kenya include Kabode, Vitaa, SPK 004, and Ejumula (HarvestPlus, 2012).

2.2 Utilization of Sweetpotatoes in Kenya

Sweetpotatoes are highly perishable due to their relatively high-water activity. Hence, the roots must be consumed within a few weeks after harvest or be processed into several products (Abong' et al., 2016). In Kenya, sweetpotato is mainly consumed as boiled, steamed or roasted by majority of households in rural areas. There have, however been tremendous expansion in its potential utilization through value addition into products such as crisps, flakes, puree and flour (Odongo et al., 2015; Tedesco and Stathers, 2015). Currently, OFSP is being processed into puree for use in bakery applications as a strategy for improving Vitamin A intake through consumption of OFSP puree based products especially among the urban population. Consumption of OFSP has been found as a technically feasible and cost-effective method towards reducing Vitamin A deficiency among poor households in Kenya and other SSA countries (Hagenimana, 1999; Kurabachew, 2015; Low et al., 1997). Carey et al. (1995) clearly illustrated that small amounts of OFSP (less than 100g) supplies Vitamin A dietary requirement in children below five years. On contrary, this study revealed that consumption of impossibly larger amounts of white and yellow fleshed sweetpotatoes was required to provide the same amount of pro-vitamin A. According to Low et al. (1997), consumption of OFSP alone or as an ingredient in processed products was highly acceptable by consumers in Western Kenya region. A follow up of the same study showed that increased consumption of OFSP led to reduced cases of Vitamin A deficiency (VAD) in households that were selected for the study (Low et al., 1999).

In other countries, sweetpotato is the primary raw material for host secondary products such as noodles, sugar syrup, pasta and alcohol (Padmaja et al., 2012). High amounts of pectin and starch in white and purple fleshed sweetpotatoes in combination with different fruits like orange, guava and pineapple has previously been utilized in India in the manufacture of colored and flavored jams (Padmaja and Premkumar, 2002).

2.3 Orange fleshed sweetpotato puree in baked products in Kenya

A puree (or mash) is cooked food, usually vegetables or legumes, that has been ground, pressed, blended or sieved to the consistency of a soft creamy paste or thick liquid. During processing of sweetpotato puree, good quality and cured sweetpotato roots are washed to remove soil, hand-peeled, and sliced. The slices are washed and steamed in a cooker for about one hour. Cooked OFSP roots are then cooled on trays at room temperature to prevent moisture loss and comminuted into a puree (Brinley et al., 2008; Perez-Diaz et al., 2008). The puree is vacuum packaged in plastic bags and stored frozen for distribution (Tedesco and Stathers, 2015).

In Kenya, processing of sweetpotato puree from OFSP is done by a private processor in Homabay County through partnership between International Potato Centre and one of the largest supermarkets in the country (Tedesco and Stathers, 2015). This initiative was launched to create a ready market for OFSP farmers, employment for the locals in the community and promote intake of Vitamin A among the urban population who are unable to access and consume boiled/steamed OFSP roots. Currently, OFSP puree is used to substitute up to 40% of wheat flour in bakery applications. The processor produces about 500 kilograms of OFSP puree per day, enough to produce 3,155 sweetpotato loaves by the bakery (Tedesco and Stathers, 2015). OFSP puree based baked products have been shown to be highly acceptable by consumers in Rwanda as opposed to similar products formulated with OFSP flour (Sindi et al., 2013). Furthermore, laboratory analysis indicates that OFSP puree bread is a good source of pro-vitamin A (beta-carotene) than OFSP flour bread providing 50 Retinol Activity Equivalents (RAE) per 30 grams slice (Muzhingi et al., 2016).

2.4 Risk factors associated with microbial contamination in foods and food processing environments

Foods can be contaminated with microorganisms during processing through contaminated equipment surfaces, water, food handling personnel, packaging materials and environment

(Barros et al., 2007; Gungor and Gokoglu, 2010; Perez-Diaz et al., 2008; Valero et al., 2016). Microbial hazards lead to deterioration in food quality, reduced shelf-life and incidences of foodborne illnesses (Bohme et al., 2012).

Contamination of foods from contaminated equipment surfaces has been identified as a significant risk factor in processing. Ineffective cleaning and sanitation of equipment and other food preparation surfaces leads to an increase in microbial load in food during processing (Bisbini et al., 2000; Gungor and Gokoglu, 2010). Cleaning and sanitation is important for minimizing microbial food contamination at all food processing stages. Microorganisms can persist on equipment and food preparation surfaces due to inadequate cleaning leading to their growth. Inefficiency in cleaning and sanitation leads to high bacterial counts in food, food contact surfaces and processing equipment (Ajao and Atere, 2009). Foods can be contaminated to higher levels not safe for consumption by microorganisms from the processing environment, equipment, preparation surfaces (Edema et al., 2008).

Food handlers can act as vectors of potential food pathogens such as *Staphylococcus aureus* and *E. coli* (Susanna et al., 2011). Poor personal hygiene and inappropriate food handling practices by food handlers leads to food contamination along the process line (Valero et al., 2016). A study by Nel et al. (2004) reported high microbial load of up to 10^7 beneath food handlers' finger nails attributable to poor hand washing hygiene practices. Hand-washing hygiene is considered as the simplest and quickest way of preventing the risk of cross-contamination and the presence of high microbial loads in foods. However, reduction in microbial load depends on the strict adherence to good hand-washing hygiene principles (Todd et al., 2010).

Water is used in the food industry as an ingredient, as a processing aid and for cleaning. High microbial load in water can contaminate food contact surfaces, personnel hands and foods (Valero et al., 2016). Decontamination and verification of water quality is essential for ensuring food safety in food processing environment.

Even though packaging majorly functions to protect food from external contamination, it can serve as a source of food contamination. It is documented that food contamination can occur even from packages with very low microbial concentration (Wirtanen and Salo, 2007). Packaging materials should be frequently tested to prevent food contamination during packaging.

Floors are also important source of contamination as they easily transfer microorganisms to shoes worn by food handling personnel. This is in turn circulated at different points by through personnel's movements in and out of the factory. Floors can also transfer contamination to other in-contact equipment such as storage boxes, holding pallets, plastic crates and refrigerators. Floors and drains provide a conducive environment for microbial growth especially if cleaning and sanitation is not done appropriately (Barros et al., 2007).

2.5 Microbial contaminants of foods and food processing environments

Microbial indicator microorganisms are useful in providing evidence of deficiencies in hygiene and sanitary food quality (Baylis et al., 2011). The quality of processed foods and processing environment is assessed based on the levels of indicator microorganisms mainly total aerobic mesophilic bacteria, total coliforms, enterobacteriaceae, *Escherichia coli* and *Staphylococcus aureus* (Valero et al., 2016).

Aerobic mesophilic counts comprise of all bacteria (total counts), yeast and molds able to grow under aerobic conditions. The presence of total counts in foods shows the efficiency of hygiene procedures during processing, handling and storage (Barros et al., 2007; Valero et al., 2016). High total counts in foods is usually correlated spoilage and reduced shelf life (Barros et al., 2007). Yeast and mold are also known for causing spoilage of foods during storage. Some mold species such as *Aspergillus*, *Penicillium* and *Fusarium* can grow even at low moisture and pH values and produce mycotoxins in several food commodities (Akiyama et al., 2001; Oladoye et al., 2014; Zinedine et al., 2006). Some fungi species also adhere on food preparation surfaces and can rapidly grow and serve as a potential source of food contamination (Barros et al., 2007).

Enterobacteriaceae are considered as food quality indicators comprising of Gram negative, non-spore forming bacteria widely known in the food industry. Enterobacteriaceae are wide spread in the environment and can easily contaminate foods during processing and handling. The family enterobacteriaceae includes important food pathogens such as *Yersinia enterocolitica*, *Salmonella* spp., *Shigella* spp., *E. coli*, *and Cronobacter* spp. and opportunistic pathogens such as *Klebsiella* spp., *Serratia* spp. and *Citrobacter* spp (Baylis et al., 2011). Other members of Enterobacteriaceae family such *Erwinia* spp. are associated with food spoilage especially in fruits and vegetables. The presence of enterobacteriaceae in foods is closely linked with implementation of poor personal hygiene, poor handling practices, inefficient heat treatment and cross-contamination from equipment and food contact surfaces (Baylis et al., 2011; Rodriguez-Caturla et al., 2011).

Coliforms and *E. coli* are considered as reliable indicators of fecal contamination in water and foods and poor hygiene in food processing environments (Valero et al., 2016). Contamination of foods by coliforms and *E. coli* is attributed to contamination in food processing environments, poor hygiene practices, inadequate heat treatment and post-processing contamination. Most *E. coli* strains are harmless commensals but some harbor pathogenic strains. Enteropathogenic *E. coli* is known to be comprised of different strains that can be present in contaminated foods (Susanna et al., 2011). Most of the serotypes produce shiga-like toxins and cytotoxins that cause diarrheagenic illnesses in humans. Most outbreaks attributed to *E. coli* serotypes have been reported to originate from catering services and restaurants (EFSA, 2010). *E. coli* can be present in fresh food produce or can enter the food chain through cross-contamination from personnel, food contact surfaces or by use of contaminated water (Perez-Rodriguez et al., 2007).

Staphylococcus aureus has been reported as an indicator in ready-to-eat foods (Khakhria et al., 1997; Wallin-Carlquist et al., 2010). Staphylococcal food poisoning (SFP) occurs through ingestion of food contaminated with staphylococcal toxins (Argudin et al., 2010). The onset of SFP symptoms occurs rapidly after 2-8 hours and is usually characterized by nausea, abdominal cramps and diarrhea. Food handling personnel, equipment and food preparation surfaces are potential sources of food contamination by *S. aureus* (Kluytmans and Wertheim, 2005). Food contamination by *S. aureus* is associated with improper food handling during processing and storage (Perez-Rodriguez et al., 2007).

2.6 Food Safety Knowledge, Hygiene Practices and Training of food handlers

Training and comprehensive information on knowledge and hygiene practices on food safety by food handlers has an impact on food quality (Vo et al., 2015). Howes et al. (1996) and Powell et al. (1997) have shown that food safety training has an impact on food safety knowledge among food handlers though it doesn't guarantee an improvement in food handling practices. Other studies by Bas et al. (2006) and Kibret and Abera, (2012) have revealed that food handling personnel do not effectively apply appropriate food handling practices as demonstrated by results through intensive observation and microbial quality assessment of foods. Previous research studies have shown that educated and trained food handling personnel are conversant with proper food hygiene and food hygiene practices (Baluka et al., 2014; Bas et al., 2006). Bas et al. (2006) indicated that majority of food handlers (47.8%) in Turkey had not been trained on the importance of food safety and demonstrated poor knowledge and practices. The study, however, reported positive attitude by majority food handlers (82.9%) who agreed that the use of protective clothing, caps, masks and protective clothing enhances food safety.

2.7 Knowledge Gaps

Even though it is documented that lack of food safety knowledge and poor hygiene practices among food handlers are leading causes of food contamination, there is lack of information on the level of food safety knowledge and hygiene practices among orange fleshed sweetpotato (OFSP) puree handlers in Kenya. The levels and potential sources of microbial contamination in OFSP puree processing are yet to be elucidated. The use and extent of food safety training as a tool for improving food safety knowledge, hygiene practices and microbial quality of foods in food processing has also not been fully documented.

3 CHAPTER THREE: FOOD SAFETY KNOWLEDGE AND HYGIENE PRACTICES OF ORANGE FLESHED SWEETPOTATO PUREE HANDLERS IN KENYA

ABSTRACT

Orange Fleshed Sweetpotato (OFSP) puree handlers along the OFSP value chain play an important role in ensuring production of consistently safe and quality OFSP puree and its processed products. However, there is lack of information on the level of food safety knowledge and hygiene practices among OFSP puree handlers along the value chain. The current study assessed levels of food safety knowledge and hygiene practices among OFSP puree handlers in Kenya. A cross-sectional study using a structured questionnaire was conducted among food handlers both at the OFSP puree processing plant and at the bakery. Exhaustive sampling included 14 food handlers at the OFSP puree processing plant and 21 food handlers at the bakery during the period of July and August 2016. Results showed low but significant ($p<0.05$) level of knowledge on food safety among food handlers at the puree processing plant and at the bakery with scores of 72% and 75%, respectively. OFSP puree handlers at the puree processing plant displayed low level of knowledge (<80%)on aspects of personal hygiene, foodborne illnesses, cleaning and sanitation and cross-contamination with scores of 79%, 75%, 62% and 50%, respectively. OFSP puree handlers at the bakery demonstrated significantly ($p<0.05$) better hygiene practices (84%) compared to food handlers at the puree processing plant (73%). Training had a significant impact on knowledge ($p=0.020$) and practices ($p=0.006$) with majority of the OFSP puree handlers (63%) having received a training on food safety. A significant moderate positive correlation existed between knowledge and practices ($r=0.358$, $p=0.035$). As per adjusted linear regression analysis, food hygiene practices significantly ($p=0.045$) increased by 0.32% with

one unit increase in knowledge. Food handlers at the puree processing plant displayed low level of knowledge on food safety and poor hygiene practices. Frequent food safety training is needed to improve knowledge and hygienic practices of food handlers specifically in OFSP puree processing plant.

3.1 INTRODUCTION

Orange Fleshed Sweetpotato (OFSP) is an important crop for food security and combating Vitamin A deficiency in Kenya (Low et al., 2007; Low et al., 1999; Low et al., 1997). Sweetpotato roots are, however, highly perishable resulting in huge economic losses in most developing African countries that are unable to adopt high-tech storage facilities (Oke and Workneh, 2013). Currently, OFSP roots in Kenya are processed into puree that is used in substantial proportion (30-50%) for wheat flour substitution in production of OFSP puree baked products. OFSP puree processing is primarily done by one processor and solely distributed to one of the largest retail stores in Kenya for use in baked products such as bread, scones, doughnuts, cookies and cakes (Tedesco and Stathers, 2015). It is, however, important to enforce stringent quality control and assurance measures to uphold food safety along OFSP puree value chain to enhance the quality and safety of OFSP puree and related processed products. This is dependent on hygienic measures from processing environments and handling practices from food handlers.

Food safety is a global public health concern and foodborne diseases are leading causes of morbidity and mortality, and a significant impediment to socio-economic development (Abdullahi et al., 2010; WHO, 2015). For over years, poor food handling and sanitation practices have been identified among major factors for an increase in the number of reported foodborne illnesses in developing countries. A surveillance report by Centre for Disease Control and prevention (CDC, 2015) reported 818 cases of foodborne illnesses in the United States that resulted in 13,360 illnesses, 1,062 hospitalizations, 16 deaths, and 14 food recalls in 2013. In another global report by WHO (2015), it is reported that 600 million people suffer from foodborne illnesses worldwide. From this figure, death occurs to 420,000 people of which 125,000 are children below five years.

Food handlers play vital roles in ensuring food safety along the food chain. Lack of knowledge on food safety and poor food handling practices among food handlers contributes to deterioration in food keeping quality and incidences of foodborne diseases (Aluko et al., 2014; Sharif et al., 2013). It is documented that about 15% of foodborne disease outbreaks result from contamination by food handlers (Anurahda and Dandekar, 2014). Lack of food safety knowledge, poor personal hygiene and poor hand washing hygiene have been documented as major causes of food contamination by food handlers (Baluka et al., 2014; Todd et al., 2007; Tolulope et al., 2014). Implementation of good hygiene practices by food handlers is a key element to enhancing food safety in food processing environments. Several studies have previously been conducted to determine knowledge and practices of food handlers in different countries. Soares et al. (2012) indicated that most food handlers had insufficient knowledge on food safety and practices in Brazil. A similar study in Turkey by Bas et al. (2006) demonstrated insufficient knowledge on food hygiene among food handling personnel. There is, however, limited data on food safety knowledge and practices among food handlers in Kenya.

Sweetpotato puree is highly susceptible to microbial contamination and inappropriate food handling practices from food handlers has been highlighted as one of the potential source of contamination (Perez-Diaz et al., 2008). The level of food safety knowledge and hygiene practices among OFSP puree handlers along the OFSP value chain in Kenya is not known. There is a need to generate this information for enforcing food safety, improving keeping quality of the puree and related products and providing information necessary for developing food safety trainings. The objective of the current study was therefore to determine the level of food safety knowledge and hygiene practices of food handlers at the orange fleshed sweetpotato puree processing plant and at the bakery in Kenya.

3.2 MATERIALS AND METHODS

3.2.1 Study Setting

The current study was conducted among food handlers both at the puree processing plant in Homa Bay County and at a retail chain supermarket's bakery in Nairobi County, Kenya. The puree processing plant and the bakery are the only establishments with orange fleshed sweetpotato puree handlers in Kenya.

3.2.2 Study Design

A cross-sectional study design using structured questionnaires was conducted in July and August 2016. Exhaustive sampling was used to target all food handlers working both at the puree processing plant and at the bakery. Pre-tested questionnaires were self-administered separately to 14 food handlers at the OFSP puree processing plant and another 21 food handlers at the bakery. A modified structured questionnaire was designed based on previous similar studies by Mohd.Firdaus Siau et al. (2015), Soares et al. (2012) and Talaei et al. (2015). The questionnaire was divided into three sections (Appendix 2). The first part captured socio-demographic characteristics of respondents that included gender, age, level of education, length of employment in the food industry and training in food safety. The second section included 27 items with choices being True, False and Don't Know that covered respondent's food safety knowledge on personal hygiene, foodborne illnesses, food contamination, temperature control, use of personal protective clothing, cleaning and sanitation. The third and last section of the questionnaire consisted of 19 food handler's hygiene practices questions with options of Always, Sometimes, Rarely and Never. The accuracy of responses in questionnaires was validated by a face to face interview with each respondent. The questionnaire clearly stated the information was for research purposes and each respondent was required to sign a consent form (Appendix 1).

3.2.3 Data Analysis

Data analysis was done using Statistical Package for Social Sciences software (IBM SPSS version 20). Each food safety knowledge response was transformed and categorized as either correct or incorrect. Each correct answer was awarded one point while every incorrect response was awarded zero point. Similarly, one point was awarded for each appropriate hygiene practice while unhygienic practice was not awarded any point. All correct scores for food safety knowledge and practices for each respondent were summed up and calculated as a percentage. Frequencies were used to summarize scores for each question on knowledge and practices. One-way ANOVA and independent t-test were appropriately used to compare mean scores for knowledge and practices among respondents in different socio-demographic categories. Independent t-test was used to compare mean scores of knowledge and practices between food handlers in OFSP puree processing plant and at the bakery. High level of knowledge on food safety and hygienic practices were considered for mean scores above 80%. This level of score was chosen based on previous studies (Samapundo et al., 2015; Sharif et al., 2013; Talaei et al., 2015; Thimoteo et al., 2014). Pearson's correlation was used to establish an association between knowledge and practices of food handlers. Adjusted linear regression was used to assess the effect of food safety knowledge on hygiene practices. Multiple regression was used to assess the effect of socio-demographic factors (education level, length of employment and training in food safety) on food safety knowledge and hygiene practices. All the last three associative analysis tests were done inseparably for all the 35 food handlers that were involved in the study. Statistical significance was set at $p < 0.05$.

3.3 RESULTS AND DISCUSSION

3.3.1 *Socio-demographic characteristics of orange fleshed sweetpotato puree handlers*

Table 1 shows socio-demographic characteristics of the respondents at the puree processing plant and at the bakery. Majority of the respondents were male for the two groups. Half of the respondents at the puree processing plant were within the age group 18-25 years while the majority (66%) at the bakery were within 26-35 years. Majority of the respondents at the bakery (86%) had attained tertiary education contrary to only 14% in OFSP puree processing plant. Most food handlers both at the puree processing plant and the bakery had been working in the food industry for a period of 1-5 years. More than half of the respondents at the bakery (67%) had received a training on food safety as opposed to only 43% in OFSP puree processing plant.

Table 1. Socio-demographic characteristics of OFSP puree handlers

Socio-demographic variables		OFSP Puree plant (N=14)	Bakery (N=21)
Gender	Male	71.4	81.0
	Female	28.6	19.0
Age	18-25	50.0	19.0
	26-35	42.9	66.7
	36-60	7.1	14.3
Highest Education level	Primary	42.9	0.0
	Secondary	42.9	14.3
	Tertiary	14.3	85.7
Length of Employment (Years)	Less than 1	28.6	19.0
	1-5	71.4	42.9
	Above 5	0.0	38.1
Training on food safety	Yes	42.9	66.7
	No	57.1	33.3

3.3.2 *Level of Food Safety Knowledge of orange fleshed sweetpotato puree handlers*

Orange fleshed sweetpotato puree handlers both at the puree processing plant and the bakery had low level of knowledge with mean scores of 72% and 75%, respectively (Figure 1). The mean difference in knowledge scores between the two groups was, however, statistically different ($p<0.05$).

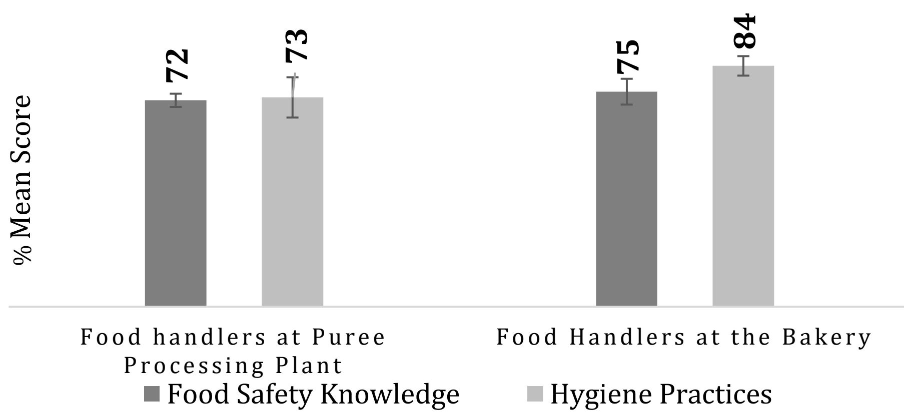

Figure 1: Mean scores for food safety knowledge and hygiene practices of OFSP puree handlers at the OFSP puree processing plant and the bakery

Male respondents in both groups had a higher knowledge score compared to females but it was not statistically different ($p>0.05$). High knowledge scores were expressed by respondents within the age of 36-60 years both at the puree processing plant and the bakery (Table 2). The scores were, however, not influenced by age differences ($p>0.05$). Food handlers with college/university education in both groups showed high knowledge on food safety, followed by those with secondary education and lastly, by those with primary education. Food handlers in OFSP puree processing plant with tertiary education had a significantly ($p<0.05$) higher level of knowledge than those who had only attained primary education. There was, however, no statistical difference ($p>0.05$) in knowledge scores among food handlers with different level of education at the bakery. Food handlers at the puree processing plant with a training in food safety displayed significantly ($p<0.05$) high knowledge score (80.9±5.5) compared to those who had not received any training (64.8±6.6). The difference in scores was, however, not different among the trained and untrained food handlers at the bakery ($p>0.05$). Other studies have found food handler's knowledge being influenced by gender (Sharif et al., 2013), age (Rahman et al., 2012) and education level (Talaei et al., 2015). Food handlers with a training in food safety have been reported to display high level of knowledge and better practices on food safety (Park et al., 2010). Trained food handlers at the OFSP puree processing plant demonstrated high level of knowledge as compared to untrained food handlers. This is similar to findings by Bas et al. (2006) that reported better knowledge among trained food handlers in Turkey. On the contrary, Soares et al. (2012) in Brazil reported insufficient knowledge among food handlers despite majority of them having attended a training in food safety. This can be related to low food safety knowledge scores displayed by both trained and trained food handlers at the bakery in our study. Food handlers need to be trained from time to time to improve their knowledge and practices on food handling (Rennie, 1995).

Table 2. Mean scores for Food Safety Knowledge and Practices as per socio-demographic characteristics

		OFSP Puree Processing Plant (N=14)				Food handlers at the Bakery (N=21)			
Demographic variable		Knowledge		Practices		Knowledge		Practices	
		Mean ± SD	p-value	Mean ± SD	p-value	Mean ± SD	p-value	Mean±SD	p-value
Gender	Male	71.9±11.6	0.93	70.5±10.5	0.470	75.2±9.0	0.577	87.0±11.0	0.062
	Female	71.3±6.3		80.3±3		72.2±11.1		71.1±10.1	
Age (Years)	18-25	67.2±8.3		66.9±17.3		70.3±13.5		79.7±16.4	
	26-35	75.9±11.2	0.265	76.3±6.3	0.505	75.3±8.3	0.614	90.8±9.2	0.198
	36-60	77.8		100		75.7±8.5		94.7±5.2	
Education	Primary	66.0±9.1		70.2±12.2					
	Secondary	72.8±8.0	0.049*	73.7±12.8	0.886	74.1±9.8	0.917	83.0±10.5	0.519
	Tertiary	85.2±5.2		81.6±11.6		74.7±9.3		89.5±16.2	
Employment	< 1 year	66.7±3.0		55.3±11.3		72.2±9.8		75.0±21.6	
	1-5 years	73.7±11.3	0.256	80.5±11.7	0.106	73.3±8.8	0.583	84.2±12.6	0.413
	> 5 years					77.3±9.8		87.7±15.4	
Training	Yes	80.9±5.5	0.000*	86.0±14.0	0.043*	75.1±9.3	0.719	87.2±15.1	0.179
	No	64.8±6.6		63.8±10.2		73.5±9.4		77.4±15.1	
Mean		**71.7±10.1**		**73.3±26.3**		**74.6±20.8**		**84.0±15.4**	

** Mean difference significant at the 0.05 level*

The main food safety knowledge components and food safety knowledge responses by food handlers at the puree processing plant and the bakery are shown in Figure 2 and Tables 3a and 3b respectively. Food handlers at the bakery significantly ($p<0.05$) displayed better knowledge on personal hygiene and process control than food handlers at the puree processing plant. This can be attributed to the fact that majority of food handlers at the bakery had been trained on proper hygiene practices in food handling. Poor knowledge scores were, however, displayed on items that covered foodborne illness, cleaning and sanitation and cross-contamination by the two groups of food handlers in the study.

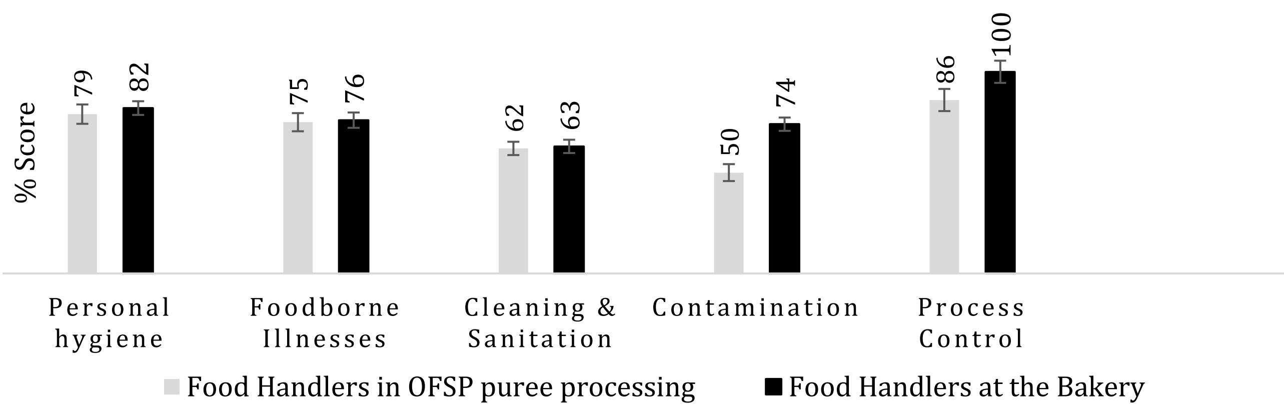

Figure 2: Mean scores for main food safety knowledge components of OFSP puree handlers at the OFSP puree processing plant and the bakery

Inappropriate personal hygiene practices and inefficient cleaning and sanitation of equipment are key factors leading to food contamination and incidences of foodborne diseases (Todd et al., 2007). In comparison with a similar study by Bas et al. (2006), food handlers had poor scores on overall food safety knowledge, personal hygiene, cross-contamination, food poisoning and temperature control. It should also be emphasized that appropriate control and monitoring of process parameters such as processing and storage temperatures is necessary in destroying or reducing microorganisms in food to a level safe for consumption and shelf life stability.

Table 3a. Food Safety Knowledge responses by Orange Fleshed Sweetpotato Puree handlers

	OFSP Puree Processing Plant (N=14)		Food handlers at the Bakery (N=21)	
Food Safety Items	With Knowledge (%)	Without Knowledge (%)	With Knowledge (%)	Without Knowledge (%)
1. Preparation of food disregarding hygiene rules causes food-borne illnesses	92.9	7.1	100.0	0.0
2. Food borne diseases are transmitted by food contamination	92.9	7.1	100.0	0.0
3. Food borne diseases are transmitted by contaminated water	57.1	42.9	81.0	19.0
4. Improper heating of food causes food-borne illnesses	71.4	28.6	71.4	28.6
5. During infectious disease of the skin, it is necessary to take leave from work	85.7	14.3	95.2	4.8
6. Only sick people carry bacteria which causes food poisoning	85.7	14.3	95.2	4.8
7. Microbes are in the skin, nose and mouth of healthy food handlers	57.1	42.9	42.9	57.1
8. Children, healthy adults, pregnant women and older individuals are at equal risk for food poisoning	64.3	35.7	76.2	23.8
9. Typhoid fever can be transmitted by food	78.6	21.4	42.9	57.1
10. Food production staff should have health checkups every two years	57.1	42.9	28.6	71.4
11. Contaminated food can be detected by taste	35.7	64.3	47.6	52.4
12. Washing hands before work reduces the risk of food contamination	100	0.0	100.0	0.0
13. Working without protective clothing in is sometimes allowed in a food factory	78.6	21.4	76.2	23.8
14. Using gloves while handling food reduces the risk of food contamination	85.7	14.3	95.2	4.8
15. Eating and drinking in the work place increases the risk of food contamination	85.7	14.3	61.9	38.1
16. Proper cleaning and sanitization of equipment reduces the risk of food contamination	78.6	21.4	90.5	9.5
17. Working with jewelry is allowed in a processing plant	78.6	21.4	95.2	9.5

Table 3b. Food Safety Knowledge responses by Orange Fleshed Sweetpotato Puree handlers

	OFSP Puree Processing Plant (N=14)		Food handlers at the Bakery (N=21)	
Food Safety Items	With Knowledge (%)	Without Knowledge (%)	With Knowledge (%)	Without Knowledge (%)
18. Washing equipment with detergent does not completely leave them free from contamination.	42.9	57.1	23.8	76.2
19. Clean is the same as sanitize	42.9	57.1	57.1	42.9
20. Cleaning chemicals and food ingredients should be kept together in one store	64.3	35.7	100.0	0.0
21. Food can be prepared on dirty surfaces/equipment	92.9	7.1	100.0	0.0
22. Cleaning of equipment should always be done at the end of processing	50.0	50.0	33.3	66.7
23. Cross contamination is when microorganisms from a contaminated food are transferred by the food handler's hands or kitchen utensils to another food	71.4	28.6	66.7	33.3
24. Contaminated foods can be detected by changes in color, odor or taste.	28.6	71.4	33.3	66.7
25. Raw food and processed food should be kept separate	85.7	14.3	100.0	0.0
26. Temperature control is important in storage and processing of safe food	92.9	7.1	100.0	0.0
27. Temperature readings for equipment and other installations like refrigerators should be checked and recorded from time to time	78.6	21.4	100.0	0.0

3.3.3 *Food Hygiene Practices of orange fleshed sweetpotato puree handlers*

Besides knowledge, food safety is highly dependent on food hygiene practices. Several cases of food borne illnesses are attributed to inappropriate food handling practices by food handlers. Adherence to good personal hygiene practices by OFSP puree handlers is crucial in controlling cross-contamination during processing, packaging, storage and distribution of sweetpotato puree and processed products. Frequency of scores on food hygiene practices by food handlers both at the OFSP puree plant and the bakery are shown in Table 4. Orange fleshed sweetpotato puree handlers at the bakery displayed significantly ($p<0.05$) higher hygiene practices (84%) compared to food handlers at the puree processing plant (73%) (Table 3). High scores on food hygiene practices were demonstrated by female food handlers at the puree processing plant with a score of 80% but it was not significant ($p>0.05$). On the contrary, male food handlers at the bakery displayed high scores on food hygiene practices (87%) compared to female food handlers (71%). The difference in their scores was not statistically different ($p>0.05$). Food hygiene practices increased with age, level of education, length of employment and training in food safety. Food hygiene practices of food handlers at the puree processing plant was only influenced by training in food safety ($p<0.05$). OFSP puree handlers who had previously received a training in food safety demonstrated hygienic food practices with a score of 86% as compared to untrained food handlers who expressed poor practices with a score of 64%. Several studies have indicated that food handlers' practices can be enhanced through a training in food safety (Kassa et al., 2010; Park et al., 2010; Roberts et al., 2008; Soon et al., 2012).

Table 4. Frequency of scores on Food Hygiene Practices by Orange Fleshed Sweetpotato puree handlers

Food Hygiene Practices Questions	OFSP Puree Processing Plant (N=14)		Food handlers at the Bakery (N=21)	
	Hygienic Practice (%)	Unhygienic Practice (%)	Hygienic Practice (%)	Unhygienic Practice (%)
1. Do you wear jewelry and a watch while working?	71.4	28.6	95.2	4.8
2. Do you rub your hands on your face, hair etc. while working?	71.4	28.6	81.0	19.0
3. Do you smoke/chew gum while working?	78.6	21.4	100.0	0.0
4. Do you use detergent whenever you wash your hands?	85.7	14.3	76.2	23.8
5. Do you wash your hands with soap after visiting the toilet?	78.6	21.4	90.5	9.5
6. Do you use gloves when you touch or distribute unwrapped foods?	42.9	57.1	95.2	4.8
7. Do you wash your hands before wearing gloves?	42.9	57.1	61.9	38.1
8. Do you wash your hands after using gloves?	64.3	35.7	66.7	33.3
9. Do you wear nail polish when handling food?	92.9	7.1	100.0	0.0
10. Do you wear an apron/PPE while working?	78.6	21.4	90.5	9.5
11. Do you use protective clothing when you touch or distribute unwrapped foods?	78.6	21.4	85.7	14.3
12. Do you wash your hands before touching unwrapped raw foods?	64.3	35.7	71.4	28.6
13. Do you wash your hands before touching unwrapped cooked foods?	85.7	14.3	85.7	14.3
14. Do you wash your hands after touching unwrapped cooked foods?	57.1	42.9	95.2	4.8
15. Do you wipe your hands with your apron/PPE?	85.7	14.3	57.1	42.9
16. Do you clean your working area before food preparation?	71.4	28.6	85.7	14.3
17. Do you check shelf life of foods/ingredients at the time of delivery?	85.7	14.3	90.5	9.5
18. Do you check the packing integrity of foods at the time of dispatch/delivery?	78.6	21.4	81.0	19.0
19. Do you properly clean the food storage area before storing new products?	78.6	21.4	85.7	14.3

3.3.4 *Association of food safety knowledge and hygiene practices of OFSP puree handlers*

Food safety knowledge and hygiene practices were positively associated in this study. From Pearson's correlation analysis, a moderate positive correlation existed between food safety knowledge and practices (r=0.358, p=0.035). This is contrary to findings by Ansari-Lari et al. (2010) that reported a negative association between knowledge and practices. Adjusted linear regression was used to assess the effect of food safety knowledge on food hygiene practices. Food safety knowledge had a significant(p=0.045) impact on food hygiene practices. An increase in food safety knowledge by 1%, increased food hygiene practices by 0.32%. It can therefore be predicted that an increase in food safety knowledge ultimately leads to an improvement in food hygiene practices (Bendigeri, 2016; Mendagudali et al. 2016).

3.3.5 *Effect of education level, length of employment and food safety training on food safety knowledge and hygiene practices*

A combination of prognostic factors (education level, length of employment and training in food safety) had a significant impact on knowledge and practices (Table 5). An increase in education level, length of employment and training among food handlers increased food safety knowledge by 0.24%, 0.09% and 0.29%, respectively (p=0.045, F=3.004). A combination of these predictive factors improved food hygiene practices by 0.03%, 0.17% and 0.39%, respectively (p=0.039, F=3.143). It can arguably be stated that hiring personnel with a better education, considerably long work experience and with a training in food safety can significantly create a work force with better food safety knowledge and hygiene practices appropriate for food processing. A study by Talaei et al. (2015) found that combination of education and job category factors had a significant effect on knowledge and practices of food handlers.

Table 5. Adjusted multiple regression assessing the effect of education level, length of employment and food safety training on food safety knowledge and hygiene practices.

	Food safety knowledge			Food hygiene practices		
Variables	Coefficient	Std Error	p-value	Coefficient	Std Error	p-value
Education level	0.242	2.532	0.177	0.027	1.046	0.876
Length of employment	0.088	2.473	0.623	0.169	1.022	0.348
Training on food safety	-0.287	3.341	0.105	-0.385	1.381	0.031*
	R^2=0.225, F=3.004, p=0.045			R^2=0.233, F=3.143, p=0.039		

**Coefficient factor significant at the 0.05 level (2-tailed)*

3.4 CONCLUSION

The current study shows low level of knowledge and poor hygiene practices among food handlers at orange fleshed sweetpotato puree processing plant. Food safety inspection guidelines and trainings should be developed and implemented to improve OFSP puree handlers' knowledge and food handling practices important in improving the quality and safety of OFSP puree.

4 CHAPTER FOUR: SOURCES OF MICROBIAL CONTAMINATION IN ORANGE FLESHED SWEETPOTATO (OFSP) PUREE PROCESSING PLANT IN KENYA

ABSTRACT

Orange Fleshed Sweetpotato (OFSP) puree is used as an ingredient in production of sweetpotato baked products in Kenya. The puree is, however, highly prone to microbial contamination attributable to poor food hygiene practices thus impairing its quality and safety. The levels and sources of microbial contamination in OFSP puree processing are yet to be established. The current study was aimed at determining major sources of microbial contamination in OFSP puree processing in Kenya. A total of 62 samples from personnel hands, equipment, installations and OFSP samples at different stages of processing were collected and analyzed for aerobic plate counts, yeast and molds, Enterobacteriaceae, total coliforms, *Escherichia coli* and *Staphylococcus aureus* as per standard microbiological methods.

Results showed that unacceptably high counts (>10^5 cfu) for most of the microbial parameters on food equipment surfaces, installations, personnel hands and in packaged OFSP puree. The counts in OFSP cooked roots significantly ($p<0.05$) reduced after steaming but the counts significantly ($p<0.05$) increased in the puree due to post-processing contamination. Total counts, yeast and molds, Enterobacteriaceae, total coliforms, *E. coli* and *S. aureus* counts in OFSP puree were 8.0, 4.0, 6.6, 5.8, 4.8 and 5.9 $\log_{10}$ cfu/g, respectively. In conclusion, equipment surfaces, personnel hands and processing water were major sources of contamination in OFSP puree processing and handling. It is therefore recommended that plant hygiene inspection, environmental hygiene monitoring and food safety trainings be carried

out frequently to improve hygiene in processing environment as well as microbial quality and safety of OFSP puree.

4.1 INTRODUCTION

Sweetpotato (*Ipomoea batatas*) is an important food security crop in the world. The biofortified Orange Fleshed Sweetpotato (OFSP) is rich in beta-carotene vital in addressing vitamin A deficiency and food security problems especially in sub-Saharan Africa (Jenkins et al., 2015; Low et al., 2007). OFSP fresh roots are often processed into puree that is subsequently incorporated as an ingredient in foods such as baby foods, puddings, doughnuts, buns, breads, cookies, soups and beverages (Low and van Jaarsveld, 2008; Perez-Diaz et al., 2008; Tedesco and Stathers, 2015). In Kenya, the International Potato Center (CIP) is partnering with a privately owned OFSP puree processing company and one of the largest retail chain stores in Kenya to promote utilization of OFSP puree in bakery products (Tedesco and Stathers, 2015).

Most studies have focused on nutritional and economic benefits of OFSP but little effort has been directed towards enhancing food safety along OFSP puree value chain that has gained prominence in Kenya (Bocher et al., 2017; Low et al., 2007; Muzhingi et al., 2016). Food safety problems are more pronounced in developing countries where food production is frequently done under unsanitary conditions (Sousa, 2008). There is a potential of contamination in sweetpotato puree along the process line resulting from poor hygiene practices and contamination from the processing environment (Perez-Diaz et al., 2008). Food contamination by microorganisms is associated with incidences of foodborne illness and food spoilage (Othman, 2015). Food contamination emanates from use of contaminated raw materials and ingredients in processing, poor personal hygiene, ineffective cleaning and sanitation of food contact surfaces and contamination from food processing environment (Addis and Sisay, 2015; Barros et al., 2007; FAO, 2003; Sousa, 2008).

Several microorganisms ranging from spoilage, pathogenic and indicator microorganisms are important in assessing hygiene, sanitary quality and safety and of foods and processing environments. These classes of microorganisms comprise of Total Viable Counts (TVC), yeast and molds, *Staphylococcus aureus*, Enterobacteriaceae, coliforms and *Escherichia coli*. TVC, yeast and molds are indicators of hygiene, sanitation and microbial quality of raw and processed foods. High TVC, yeast and mold counts in foods are often associated with accelerated spoilage hence deterioration in quality (Ali et al., 2010). High counts of *S. aureus* in foods and processing environment depicts extensive handling and poor hand washing hygiene practices by food handlers. Consequentially, *S. aureus* counts above 10^5 CFU/g produce heat stable toxins responsible for staphylococcal food poisoning (Buchanan, 2012). Coliforms, *E. coli* and Enterobacteriaceae are useful indicators of water quality, personnel hygiene and efficiency of sanitation programs in food processing plants (Gwida et al., 2014; Schlegelova et al., 2010; Tassew et al., 2010)

Like many small-scale food processing industries, OFSP puree processing is prone to microbial contamination attributed to poor hygiene practices within the processing environment (Mukantwali et al., 2013). There is, however, lack of information on the levels and sources of microbial contamination in orange fleshed sweetpotato puree processing. There is need to identify harborage niches for pathogens, spoilage and hygiene indicator microorganisms that may act as a source of contamination and provide recommendations for improving microbial quality and safety of OFSP puree. The objective of the current study was therefore to determine major sources of microbial contamination in orange fleshed sweetpotato puree processing plant in Homa Bay County, Kenya.

4.2 MATERIALS AND METHODS

4.2.1 Study Setting and Design

The study was conducted at a privately owned OFSP puree processing plant in Homa Bay County, Kenya. The study employed the analytical study design. Samples for microbiological analysis were randomly collected from OFSP puree processing environment as described by Barros et al. (2007). A total of 62 samples comprising of swab samples, processing water and OFSP samples were collected for microbial analysis (Table 6). Swab samples from equipment, walls, floors, drains and personnel hands were collected using 3M buffered swab sponges (Gungor and Gokoglu, 2010). Sterile papers were used to outline areas of 30 cm^2 and 60 cm^2 on surfaces for swabbing. Samples from equipment and installations were collected after cleaning of these surfaces. Samples from personnel hands were collected during working hours. OFSP samples were collected in three different batches at different processing stages: after washing; steaming; cooling and cutting; and packaging. All samples were transported in a cold box packed with ice to the Department of Food Science, Nutrition and Technology, Upper Kabete Campus, University of Nairobi and immediately analyzed for total aerobic counts, yeast and molds, Enterobacteriaceae, coliforms, *Escherichia coli* and *Staphylococcus aureus*.

Table 6. Sampling points in OFSP puree processing plant

Sample	N	Swabbed Area/Weight
OFSP Buckets	3	60 cm^2
OFSP Scrub Brushes	3	Surface area
Knives	3	Surface area
Tables	3	60 cm^2
Cooling Trays	3	60 cm^2
Puree machine components	3	60 cm^2
Weighing Spoons	2	30 cm^2
Packaging bags	3	60 cm^2
Vacuum Packaging Machine	1	60 cm^2
Freezers	3	60 cm^2
Cold boxes	3	60 cm^2
Vehicle for puree shipment	1	60 cm^2
Personnel	8	30 cm^2
Floors	3	60 cm^2
Walls	3	60 cm^2
Drains	3	Surface area
Water for Processing	2	50 ml
Raw OFSP	3	50 g
OFSP after Steaming	3	50 g
Steamed, Cooled and Cut OFSP	3	50 g
Packaged OFSP puree	3	50 g
Total (n)	**62**	

4.2.2 Sample preparation, microbial analysis and enumeration

All swab sample sponges (each presoaked in 10 ml buffer) were diluted with 90 ml sterile saline water (0.85% NaCl). The swab sponges were squeezed to release microbes from the surface before making successive serial dilutions. Twenty five grams of process water and

OFSP samples were each diluted with 225 ml of 0.85% NaCl before making subsequent serial dilutions as described by Gungor and Gokoglu (2010).

4.2.2.1 Determination of Total Viable Counts (TVC)

Total Viable Counts (TVC) were determined by spread plate method on Plate Count Agar (PCA, LAB, UK). The plates were incubated at 35°C for 48 hours as described by Perez-Diaz et al. (2008).

4.2.2.2 Determination of Yeast and Molds

Yeast and molds were enumerated by plating 0.1 mL of each sample on petri dishes with solidified Potato Dextrose Agar (PDA) (Oxoid, Hampshire). The plates were incubated at 25°C for 5 days as previously done by Gungor and Gokoglu (2010).

4.2.2.3 Determination of Enterobacteriaceae

Enterobacteriaceae group of microorganisms were determined by spread plating 0.1 mL of each sample on Violet Red Bile Glucose (VRBG) Agar (Oxoid, Hampshire, England). The plates were incubated at 37 °C for 24 hours as described in a method by Hervert et al. (2016).

4.2.2.4 Detection of Coliforms and **Escherichia coli**

The presence of coliforms and *E. coli* were examined by plating 0.1 mL of each sample on Brilliance *E. coli*/coliform agar (Oxoid, Hampshire, England) as described in a study by Baluka et al. (2015). The plates were incubated at 37 °C for 24 hours.

4.2.2.5 Detection of **Staphylococcus aureus**

Staphylococcus aureus was determined as per the method previously described by Gungor and Gokoglu (2010). Plating of 0.1 mL of each sample was done on Baird Parker (Oxoid, Hampshire, England). The plates were incubated at 37°C for 48 hours. Typical *S. aureus* colonies were enumerated and streaked in Brain Heart Infusion broth (BHI) (Oxoid) and further incubated at 37°C for 24 h. Typical *S. aureus* colonies were confirmed by coagulase test. Test for coagulation was done by aseptically adding 0.1 mL of BHI culture to 0.3 mL of rabbit plasma in sterile hemolysis tubes. The tubes were incubated at 37°C and observed for coagulation after 6 hours.

4.2.2.6 Enumeration of microbial colonies

Enumeration was done for plates with 30-300 colonies. All microbial counts were expressed as $\log_{10}$ CFU/g for OFSP samples, $\log_{10}$ CFU/ml for water sample and $\log_{10}$ CFU/cm^2 for swab samples.

4.2.3 Statistical Data Analysis

TVC, yeast and molds, *S. aureus*, Enterobacteriaceae, coliforms and *E. coli* counts were converted to $\log_{10}$ CFU units in Microsoft Excel (MS Office 365) and exported to SPSS (IBM SPSS Version 20) for analysis. Results with means and standard deviations were tabulated to show the level of microbial contamination for all the samples. Analysis of variance and Tukey's test were used to determine statistical differences in microbial counts among the samples with a preset *p*-value of 0.05.

4.3 RESULTS AND DISCUSSION

4.3.1 *Microbial load on equipment used for OFSP puree processing*

Microbial load on equipment surfaces used for OFSP puree processing is shown in Table 7. Lowest Total Viable Counts (TVC) were detected on packaging bags (6.57±0.32 log $cfu.cm^{-2}$) and the highest level of contamination was detected from weighing spoons (9.47±0.03 log $cfu.cm^{-2}$). The pureeing machine was least contaminated with yeast and molds (4.29±1.03 log $cfu.cm^{-2}$). Low enterobacteriaceae counts were detected in packaging bags and cooling trays with mean counts of 5.83±0.64 and 5.83±1.20 log $cfu.cm^{-2}$, respectively. Highest counts of *Staphylococcus aureus*, Enterobacteriaceae and coliform counts with means 6.45±0.02, 7.03±0.03 and 6.68±0.01 log $cfu.cm^{-2}$, respectively were detected on the inside cabin surface of the truck used in transportation of OFSP roots and OFSP puree. Highest yeast and mold and *E. coli* counts with means 6.79±0.45 and 5.29±0.75 log $cfu.cm^{-2}$, respectively were obtained from buckets used for washing OFSP roots. The mean counts among different food equipment surfaces were statistically different ($p<0.05$).

Table 7. Microbial Counts on equipment surfaces in OFSP puree processing plant[1] (Log Mean CFU.cm^{-2})

Sample	TVC	Yeast-Molds	*S. aureus*	Enterobacteriaceae	Coliforms	*E. coli*
OFSP Buckets	7.71±0.24[bcde]	6.79±0.45[ef]	5.08±0.32[bcd]	7.33±0.09[bcd]	6.51±0.10[efgh]	5.29±0.75[b]
OFSP Scrub Brushes	7.83±0.02[bcde]	6.32±0.01[def]	4.52±0.21[bcd]	7.28±0.03[bcd]	6.44±0.13[efgh]	4.34±0.15[b]
Knives	6.57±0.32[bc]	4.35±0.29[bcde]	5.06±0.13[bcd]	6.24±0.02[bcd]	5.51±0.15[def]	4.79±0.33[b]
Tables	8.12±1.24[bcde]	5.73±1.13[cdef]	4.44±0.84[bcd]	6.71±0.07[bcd]	6.35±0.54[defgh]	2.16±3.74[a]
Cooling Trays	7.45±1.37[bcde]	4.74±0.27[cdef]	4.68±0.55[bcd]	5.83±1.20[bcd]	5.45±1.16[cde]	2.68±2.10[a]
Puree machine	7.63±0.81[bcde]	4.29±1.03[bcd]	4.43±0.63[bcd]	6.34±0.45[bcd]	5.58±0.20[defg]	2.04±2.23[a]
Weighing Spoons	9.47±0.03[e]	6.45±0.08[def]	5.41±0.14[cd]	6.43±0.10[bc]	6.17±0.12[defgh]	1.81±2.57[a]
Packaging bags	6.28±0.09[bc]	4.83±1.35[cdef]	3.16±0.43[bc]	5.83±0.64[bc]	5.65±0.73[defgh]	nd*
Packaging Machine	9.10±0.74[de]	6.15±0.51[cde]	5.15±0.04[bcde]	6.77±0.05[cde]	6.45±0.02[defg]	3.58±0.08[b]
Freezers	7.46±0.13[bcde]	5.95±0.83[cdef]	4.89±1.53[bcd]	6.64±0.11[bcd]	6.32±0.40[defgh]	1.21±2.11[b]
Cold boxes	7.97±0.13[bcde]	5.48±0.55[cdef]	5.65±0.11[cd]	6.27±0.17[cd]	5.58±0.24[defg]	4.36±0.76[b]
Shipment vehicle	8.33±0.01[bcde]	5.28±0.00[cde]	6.45±0.02[e]	7.43±0.03[e]	6.68±0.01[fgh]	4.70±0.96[b]

[1]*All values reflect mean counts and standard deviation. Values bearing different superscript letters in each column are significantly different ($p<0.05$)*
** nd- not detected*

High counts above 10^5 CFU.cm^{-2} for aerobic plate counts, *Staphylococcus aureus*, yeast and molds, coliforms and enterobacteriaceae were detected on more than 90% of all equipment surfaces indicating inadequate cleaning and sanitation procedures. This is similar to findings by Schlegelova et al. (2010) that reported relatively high counts for TVC, enterococci, *E. coli* and *Staphylococci spp.* on food equipment surfaces in dairy and meat processing plants. The high contamination level from equipment could be attributed to lack of adherence to documented cleaning procedures by food handling personnel and lack of sanitation program at the establishment. Inefficient cleaning and sanitation of equipment surfaces leads to formation of biofilms, a potential source of food contamination (Othman, 2015; Schlegelova et al., 2010). High counts on knives, cooling trays, pureeing machine and tables were identified as primary causes of contamination in OFSP puree. Efficient cleaning and sanitation following documented procedures should always be done at the beginning of each work day; after every batch process; and at the end of the day after processing to prevent formation of biofilms on equipment surfaces in OFSP processing.

4.3.2 *Quality of water used for processing OFSP puree*

The level of microbial contamination in water for processing OFSP puree is shown in Figure 3.

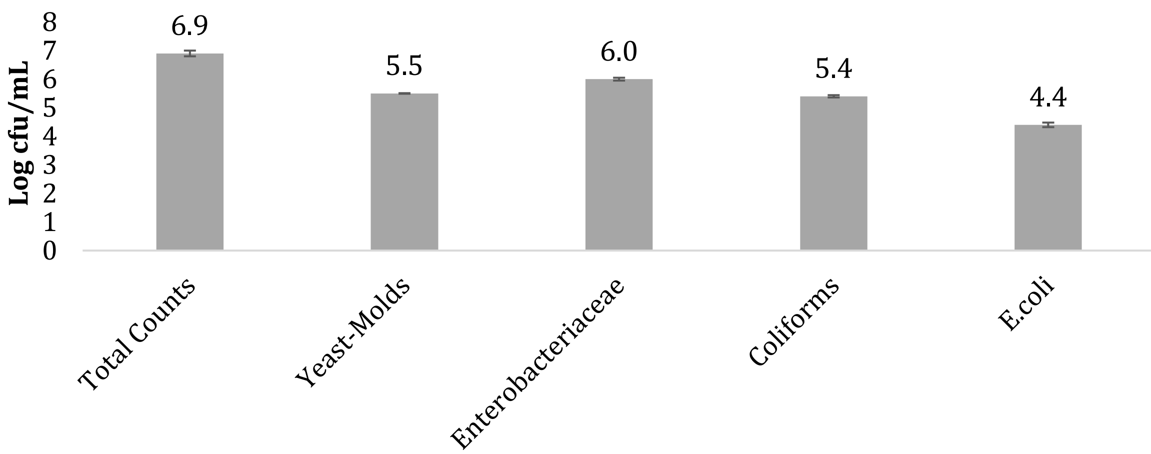

Figure 3. Microbial load in water for processing OFSP puree

It was highly contaminated (>10^4 cfu/ml) with enterobacteriaceae, coliforms and *Escherichia coli* due to non-existent of water treatment (disinfection) program at the facility. As stipulated by Environmental Protection Agency (2012), total coliforms and *E. coli* should be absent in 100 ml of water sample to be deemed suitable for drinking and processing. It further recommends total counts not to exceed 500 cfu/ml. Use of untreated water from unknown sources contaminates equipment and foods prepared on these surfaces (Liguori et al., 2010). High Enterobacteriaceae, coliforms and *E. coli* counts in water for puree processing indicated contamination with fecal matter, deterioration in quality and likelihood presence of enteric pathogens (Fawell et al., 2010; Rompre et al., 2002). Water at the facility was not suitable for use in OFSP processing and it was a possible source of contamination on equipment, personnel hands and consequently in OFSP puree. There was an urgent need to establish water disinfection program involving chlorination at the facility for preventing water to puree contamination.

4.3.3 *State of hygiene of walls, floors and drains in OFSP puree processing environment*

The level of microbial contamination of installations in OFSP puree processing is shown in Table 8.

Table 8. Microbial Counts of installations in OFSP puree processing plant [1] (Log Mean CFU.cm^{-2})

Sample	TVC	Yeast-Molds	*S. aureus*	Enterobacteriaceae	Coliforms	*E. coli*
Floors	8.03±0.87^{bcde}	5.71±0.94^{cdef}	5.31±0.40^{cd}	6.98±0.35^{cd}	6.66±0.22^{gh}	2.75±3.20^{a}
Walls	8.69±0.65^{bcde}	6.17±0.56^{cdef}	5.54±0.03^{cd}	7.00±0.26^{cd}	6.43±0.54^{defgh}	1.45±2.51^{a}
Drains	8.71±0.73^{bcde}	5.46±1.29^{cdef}	5.33±0.90^{cd}	7.20±0.06^{cd}	6.80±0.36^{h}	3.50±3.14^{b}

[1]*All values reflect mean counts and standard deviation. Values bearing different superscript letters in each column are significantly different ($p<0.05$)*

Aerobic counts from floors, walls and drains were identical with lowest counts (8.03±0.87 log cfu.cm^{-2}) recorded from floors and highest counts (8.71±0.73 log cfu.cm^{-2}) from drains. Yeast and molds counts were above 10^5 CFU.cm^{-2} but insignificant ($p>0.05$) among the three installation points. The drains had the lowest contamination level for yeast and molds (5.46±1.29 log cfu.cm^{-2}) while the walls had the highest counts (6.17±0.56 log cfu.cm^{-2}). The level of *Staphylococcus aureus* was low on floors (5.31±0.40 log cfu.cm^{-2}) and almost identical but high on walls (5.54±0.03 log cfu.cm^{-2}). Low and high enterobacteriaceae counts were obtained from floors and drains with mean counts 6.98±0.35 and 7.20±0.06 log cfu.cm^{-2}, respectively. The level of contamination with coliforms was not significantly ($p>0.05$) different. The lowest coliform counts were recorded from walls (6.43±0.54 log cfu.cm^{-2})

while highest counts were from drain surfaces (6.80±0.36 log $cfu.cm^{-2}$). *E. coli* counts from drains were significantly ($p<0.05$) high compared to floors and walls.

Floors, walls and drains are high risk areas for bacterial growth and contamination in food processing plants (Barros et al., 2007). Floors transfer contamination to food handlers' shoes who consequently circulate and disseminate the microorganisms within the establishment. Drains and floors offer a favorable environment for microbial growth if cleaning and sanitation is not done appropriately. High total counts, coliforms and Enterobacteriaceae counts ($>10^5$ log $CFU.cm^{-2}$) from walls, floors and drains in OFSP puree processing facility was attributed to inefficient cleaning of these areas. Similar results have been reported from meat processing environments in studies by Ali et al. (2010) and Barros et al. (2007). Other than transferring contamination to trolleys and food handler's shoes, contaminated floors and walls in the facility can re-contaminate personnel hands and equipment such as buckets, pallets, brushes and cold boxes stored on the floor. Routine inspections, supervision of cleaning process and maintenance of installations and sanitary facilities can help in preventing proliferation and spread of microbial contamination within the OFSP puree processing facility.

4.3.4 *Microbial load on hand surfaces of Orange Fleshed Sweetpotato puree handlers*

The level of contamination on personnel hands in OFSP puree processing is shown in Figure 4.

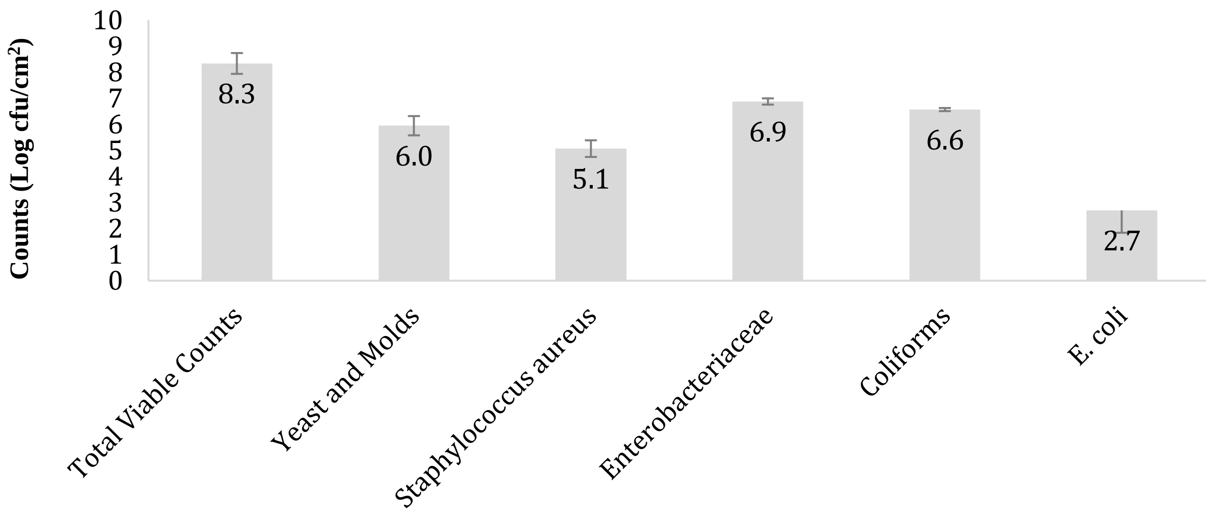

Figure 4. Microbial counts from OFSP puree handlers' hands

High total counts and presence of potential pathogens (*S. aureus* and *E. coli*) on OFSP puree handlers' hands indicates low compliance to hand washing hygiene practices by puree handlers and thus a potential source of contamination during processing of OFSP puree. Adherence to good personal hygiene by food handlers is important in preventing cross-contamination in food processing (Todd et al., 2010). The contact between food handlers and contaminated surfaces of equipment, phones, walls, garbage and classifies them as a potential source of contamination (Al-Abdallal, 2010). It is estimated that 10-20% of foodborne disease outbreaks occur as a result of contamination by food handlers (Anuradha and Dandekar, 2014). All counts from personnel hands in this study were >10^5 log CFU.cm^{-2} except for *E. coli*. *Staphylococcus aureus* was detected from all hand swab samples (100%)

from OFSP puree handlers. This is contrary to findings by Mahmoud and Sivakumar (2014) that reported positive results for *S. aureus* in only 34% of asymptomatic food handlers in their study. Provision of necessary food safety resources in a food production facility enhances food safety (Green and Selman, 2005). Gloves for handling OFSP puree and paper towels for hand drying were not provided at the facility. Gloves are crucial in preventing personnel hands to food contamination (Michaels et al., 2004; Montville et al., 2001). Huang et al. (2012) have previously reported higher chances of bacterial transfer from wet hands as compared to dry hands. This makes proper hand drying an essential component for effective hand hygiene in food processing facilities. Another study by Choi et al. (2016) argues that provision of appropriate hand washing resources is not enough in enforcing proper hand hygiene. Results from their study indicated that 50% of food handlers in retail establishments failed to practice good hand washing hygiene despite being provided by necessary resources. Training on personal hygiene, management support and provision of food safety supplies such as gloves and paper towels should be considered in efforts towards improving food safety in OFSP puree processing.

4.3.5 *Changes in microbial load in OFSP puree during processing*

The changes in microbial load during processing of Orange Fleshed Sweetpotato puree is shown in Table 9.

Table 9. Microbial Counts at different stages in processing of OFSP puree[1] (Log Mean CFU/g)

Processing Stages	TVC	Yeast-Molds	*S. aureus*	Enterob	Coliforms	*E. coli*
Raw OFSP	7.19±0.27[bcd]	2.51±0.30[b]	3.01±0.15[b]	4.57±0.20[b]	3.74±0.19[b]	nd*
Steaming	nd*	nd*	nd*	nd*	nd*	nd*
Slicing	7.12±0.21[bcd]	nd*	2.93±2.54[b]	4.62±0.15[b]	4.37±0.13[bc]	nd*
Packaging	7.96±0.57[bcde]	4.01±0.33[bc]	5.88±0.53[cd]	6.55±0.18[cd]	5.82±0.13[defgh]	4.77±0.45[b]

[1]All values reflect mean counts and standard deviation. Values bearing different superscript letters in each column are significantly different (p<0.05)
nd-not detected*

Total Viable Counts, yeast and molds, *S. aureus*, Enterobacteriaceae and coliforms were destroyed after steaming OFSP roots. Steaming is the main critical control point (CCP) for enhancing keeping quality and safety of OFSP puree. Several studies have reported cooking as an effective method in eliminating or reducing microorganisms in foods to critical acceptable levels (Gungor and Gokoglu, 2010; Perez-Diaz et al., 2008). It is, however, a challenge destroying heat resistant spores and heat stable toxins produced by pathogens such as *S. aureus* by mild heat treatment. *S. aureus* counts in foods above 10^5 CFU/g initiates production of heat-stable enterotoxins (Mahmoud and Sivaumar, 2014). Staphylococcal food poisoning is one of the leading causes of foodborne illnesses worldwide caused by ingestion of food contaminated with preformed *S. aureus* enterotoxins (Kadariya et al., 2014). Routine implementation of appropriate hygiene procedures and process control in OFSP puree processing can be an effective tool in reducing or eliminating contamination by pathogens or their toxins.

The microbial load significantly increased after cutting, cooling, pureeing and packaging processes. High TVC and yeast and molds counts in the puree indicated deterioration in keeping quality and hence accelerated spoilage. Haile et al. (2015) reported lower total, yeast and counts in porridge prepared from OFSP contrary to the current findings. The high counts are attributed to contamination from equipment such as knives, cooling trays, pureeing machine and packaging bags; contaminated water and poor personal hygiene by OFSP handlers. The presence of enterobacteriaceae, coliforms and *E. coli* in OFSP puree indicate fecal contamination and presence of entero-pathogens due to cross-contamination from equipment, processing water and food handling personnel. Additionally, high *S. aureus* counts detected in the puree was associated with contaminated equipment and poor hand hygiene practices by OFSP puree handlers. Contamination in OFSP puree can be eliminated by use of clean and sanitized equipment; clean and disinfected water; and adherence to good personal hygiene and handling practices by OFSP puree handlers.

4.4 CONCLUSION

The present study reveals unacceptably high levels of microbial contamination on equipment, processing environment, food handling personnel and in OFSP puree. Microbial contamination in OFSP puree resulted from use of contaminated food equipment, contaminated water and poor hygiene practices by food handlers. The high counts confirmed poor food hygiene practices within the establishment. It is therefore recommended to ensure adherence to good personal hygiene and implementation of appropriate cleaning and sanitation regimes to eliminate or reduce microbial contaminants to safe levels and consequently control contamination. Environmental sampling and microbial risk evaluation should frequently be conducted monitor the level of hygiene in OFSP puree processing environment.

5 CHAPTER FIVE: IMPACT OF FOOD SAFETY TRAINING ON KNOWLEDGE, HYGIENE PRACTICES AND LEVEL OF MICROBIAL CONTAMINATION IN ORANGE FLESHED SWEETPOTATO PUREE PROCESSING PLANT IN KENYA

ABSTRACT

Our baseline study results indicated low level of food safety knowledge and poor hygiene practices among orange fleshed sweetpotato (OFSP) puree handlers and high level of microbial contamination in OFSP puree processing plant. The extent of food safety training in enhancing food safety in food processing environments has not been fully investigated. The current study was aimed at evaluating the impact of training on food safety knowledge and practices of food handlers and in control of microbial contamination in OFSP puree processing plant in Kenya. Food safety training and assessments using a cross-sectional study design was used evaluate food safety knowledge and practices of OFSP puree handlers as well as the level of microbial contamination in OFSP puree processing plant. Swabs and OFSP samples were collected and analyzed for total viable counts, yeast and molds, enterobacteriaceae, total coliforms, *Escherichia coli* and *Staphylococcus aureus*. In comparison with the baseline results, the level of food safety knowledge and practices of OFSP puree handlers significantly ($p<0.05$) improved after training. Similarly, microbial counts on equipment surfaces, installations, personnel and in OFSP puree significantly ($p<0.05$) declined to acceptable levels for food processing after food safety training. Total viable counts, yeast and molds, enterobacteriaceae, total coliforms and *E. coli* counts in OFSP puree were 2.6, 1.8, 1.5, 1.9 and 1.2 log_{10} cfu/g respectively. The findings from this study recommends training as an appropriate tool for improving food handler's knowledge and

practices as well as enhancing microbial quality of processed foods if necessary food safety support resources are provided.

5.1 INTRODUCTION

Orange Fleshed Sweetpotato (OFSP) is rich in provitamin A and freshly roots are often processed into puree used as an ingredient in baked products by one of the largest retail chain stores in Kenya (Tedesco and Stathers, 2015). OFSP puree processing is, however, faced by food safety challenges largely attributed to inappropriate food handling practices and contamination from processing environment. Food safety is an integral part of food security inextricably linked to food nutrition. Food safety issues are sometimes overlooked since the international community has focused more on strategies for combating hunger and malnutrition (WHO, 2014). Non-compliance to food safety regulations in food processing environments often leads to microbial contamination that results in incidences of foodborne diseases and food spoilage (Mahmoud and Sivakumar, 2014). Multiple and frequent foodborne disease outbreaks indicate food safety as global public health concern (FAO, 2003). Foodborne diseases cause morbidity, mortality and reduced socio-economic development (CDC, 2013; WHO, 2015). Several cases of foodborne illnesses remain unreported in least developed and developing countries. This fails to fully provide information on true dimension of food safety problem (WHO, 2015). Quality and safety of processed foods is undermined by use of contaminated raw materials, equipment and processing environments, poor personal hygiene and failure in process control (Roberts et al., 2008). These can however, be enhanced through implementation of strict hygienic measures during processing, handling, storage and distribution.

Food handlers are essentially important in ensuring food safety along the food chain. They are known to be carriers of potent pathogens and serve as a potential source of contamination (Argudin et al., 2010; Soares et al., 2012). *Escherichia coli*, *Staphylococcus aureus* and *Salmonella spp* are major pathogens associated with violation of food handling practices (Sousa, 2008). Food contamination from food handlers is linked to poor personal hygiene and inappropriate food handling practices (Baluka et al., 2015; Gungor and Gokoglu, 2010). Food safety training can be an approach for improving food handling practices and eliminating microbial contamination during food handling (Adesokan et al., 2015). It has previously been reported that food safety training can reduce incidences of foodborne illnesses if it increases employee's motivation, and the frequency of appropriate food handling practices (Soon and Baines, 2012).

Several studies have identified food safety training as an effective tool for improving food handlers' knowledge and practices (Husain et al., 2016; Kassa et al., 2010; Park et al., 2010; Roberts et al., 2008; Soon and Baines, 2012). On the contrary, another study by Thimoteo et al. (2014) argues that food safety training does not necessarily lead to improved practices. These contradicting results reveal that the efficiency of food safety training on improving knowledge and practices is still unclear and inconclusive. There is also limited information on the effectiveness of training programs in reducing or eliminating microbial contaminants in food processing environments. Our baseline study findings indicated low level of knowledge and hygiene practices among OFSP puree handlers and high level of microbial contamination in puree processing environment. There is limited information on whether food safety training can be a tool for addressing food safety challenges in OFSP puree processing. The current study therefore aimed at evaluating the impact of food safety training on knowledge and practices of food handlers and in control of microbial contamination in OFSP puree processing plant in Homa Bay County, Kenya. This information is required to improve food safety knowledge and practices of OFSP puree handlers; and eliminate microbial contamination from all food safety risk points in OFSP puree processing environment to enhance food safety and elongate shelf life of OFSP puree.

5.2 MATERIALS AND METHODS

5.2.1 Research population and data collection

The study was done in OFSP puree processing plant located in Homa Bay County, Kenya. A total of 14 respondents who voluntarily agreed to participate in the current study were exclusively sampled. All respondents were involved in handling of orange fleshed sweetpotato during washing, peeling, cooking, pureeing, packaging and storage. Data on food safety knowledge and hygiene practices of food handlers was collected through self-administered questionnaires. Food safety knowledge was assessed by a close-ended questionnaire (Appendix 2) from our baseline study (objective 1) with 27 questions with items on personal hygiene, foodborne illnesses, food contamination, temperature control, use of personal protective clothing, cleaning and sanitation with respect to orange fleshed sweetpotato puree processing. The respondents were asked to circle correct response for each food safety statement as either 'True', 'False' or 'Don't Know'. For self-reported food hygiene practices, the questionnaire consisted of items majorly on personal hygiene. Food handlers were requested to rate the extent of their agreement/disagreement with the statements on a four-point response scale ranging from "never" to "always"

5.2.2 Training plan and materials

Development of content for food safety training module was based on literature (Park et al., 2010; Seaman and Eves, 2006; Simonne et al., 2010) and baseline data that revealed low level of knowledge, poor food hygiene practices and high microbial contamination in orange fleshed sweetpotato puree processing. The training targeted to improve knowledge and hygiene practices of food handlers in OFSP puree processing by providing information on the hazards likely to be present if food safety regulations are violated. The food safety training covered topics on personal hygiene, the risk of cross-contamination, burden associated with foodborne illnesses, environmental hygiene, process control and food storage, pest control, cleaning and sanitation. The training session involved power point presentation and practical demonstrations on procedures for hand washing, cleaning and sanitation of equipment, water treatment, cleaning of walls, floors and drains. As part of the intervention program and recommendations based on our baseline findings, the management provided necessary resources such as gloves, paper towels and chlorine tablets for water disinfection. After one month, a field visit was conducted at the OFSP puree processing factory to continuously motivate the food handlers to implement food safety behaviors, to reinforce gained knowledge and skills and help solve any barriers, if present.

Three months after training, food safety knowledge and self-reported practices were tested for comparison with the results from our baseline study. Collection of samples for microbial analysis was also done to ascertain the state of hygiene at the establishment after training. Buffered swab sponges were used to collect samples for microbial analysis from equipment, personnel hands, walls and floors as described by Gungor and Gokoglu (2010). OFSP samples were collected at three different stages: after washing, steaming, cooling and slicing, and packaging. All samples were transported to the Department of Food Science, Nutrition and Technology, University of Nairobi in a cooler box filled with ice packs and immediately analyzed for Total Viable Counts (TVC), yeast and molds, *Staphylococcus aureus*, enterobacteriaceae, coliforms and *Escherichia coli.*

5.2.3 Sample preparation and Microbiological Analysis

Samples were prepared as described by Gungor and Gokoglu, (2010); Gwida et al. (2014); Perez-Diaz et al. (2008); Schlegelova et al. (2010). Swab samples from equipment, personnel, floors and walls were diluted with 90 ml of buffered peptone water (BPW, Oxoid, UK). Twenty-five grams of OFSP samples and 25 ml of water were homogenized with 225 ml of BPW saline water. Subsequent serial dilutions were made using 0.85% sodium chloride (Oxoid) and analyzed for TVC, yeast and molds, *Staphylococcus aureus*, enterobacteriaceae, Total coliforms and *Escherichia coli*. Triplicate plates with counts between 30 and 300 colonies were enumerated and the average was expressed as $\log_{10}$ colony forming units.

5.2.3.1 Total Viable Counts

TVC analysis was done by spread plating 0.1 mL of each sample on Plate Count Agar (PCA, LAB, UK) followed by incubation of plates at 35°C for 48 hours as described by Gungor and Gokoglu, (2010); Liguori et al. (2010); Perez-Diaz et al. (2008).

5.2.3.2 Yeast and Molds

Analysis of Yeast and Molds was carried out using n Potato Dextrose Agar (PDA, Oxoid, Hampshire). The plates were then incubated at 25°C for 5 days as described by Gungor and Gokoglu, (2010).

5.2.3.3 Enterobacteriaceae

Enterobacteriaceae were determined by spread plate method of samples on Violet Red Bile Glucose (VRBG) Agar (Oxoid) followed by incubation of plates at 35°C for 24 hours as described by Hervert et al. (2016).

5.2.3.4 Coliforms and **Escherichia coli**

Analysis for coliforms and *Escherichia coli* was performed by plating 0.1 mL of each sample on triplicate petri dishes with Brilliance *E. coli*/coliform agar (Oxoid, Hampshire, England). The plates were incubated in an oven set at 37 °C for 24 hours as described in a method by Baluka et al. (2015).

5.2.3.5 **Staphylococcus aureus**

Detection, identification enumeration of *S. aureus* in the samples was done by spread method on Baird Parker medium and followed by incubation at 37 °C for 24 hours as described by Gungor and Gokoglu, (2010); Mahmoud and Sivakumar, (2014).

5.2.4 Data Analysis

Data analysis was done using the Statistical Package for the Social Sciences (IBM SPSS Statistics 20.0). Responses for both knowledge and practices were coded on a two-point scale with 0 for incorrect response and 1 for every correct response. All correct answers were totaled and converted to a percentage score. Frequencies and descriptive statistics were used to summarize scores for each knowledge and practice item. The level of knowledge and practices were considered high for scores above 80% and low for scores below 80% (Sharif et al., 2013; Talaei et al., 2015). Independent t-test was used to compare mean scores for food safety knowledge and hygiene practices at baseline and after food safety training. Mean and standard deviation were used to present data on microbial counts in Tables. Analysis of variance was used to test for statistical differences in counts. The level of statistical significance was set at $p < 0.05$.

5.3 RESULTS AND DISCUSSION

5.3.1 *Impact of training on food safety knowledge and practices of OFSP puree handlers*

The level of food safety knowledge and hygiene practices by OFSP puree handlers at baseline and after food safety training is shown in Table 10.

Table 10. Food safety knowledge and practices scores of OFSP puree handlers before and after training[1]

Variable	Baseline	Post-Training	p-value
Knowledge on Food-borne Illnesses	75.0±17.0	96.4±9.1	0.023*
Knowledge on Personal Hygiene	78.9±15.4	90.8±12.9	0.021*
Knowledge on Cleaning and Sanitation	61.6±12.5	96.4±7.1	0.004*
Knowledge on Cross contamination	50.0±19.9	89.0±11.4	0.002*
Overall Knowledge score	71.7±10.1	91.8±8.2	0.004*
Food Hygiene Practices score	73.3±26.3	94.5±9.3	0.020*

*[1]Values represent mean scores and standard deviation; *Mean difference significant at ($p<0.05$)*

Food safety knowledge significantly (p=0.004) increased after training. Food hygiene practice scores also increased significantly (p=0.020) after training. There was a significant ($p<0.05$) increase in knowledge scores on personal hygiene, foodborne illnesses, cross contamination, cleaning and sanitation ($p<0.05$) after food safety training. Training food handlers on food safety can be an important strategy for enhancing food safety in food industries. A closer association has been established between knowledge and practices of food handlers (Adesokan et al., 2015). The results from this study indicate that training improves food safety knowledge and practices of food handlers. OFSP puree handlers had low level of knowledge and practices which significantly improved after training. Other research studies have also reported training having a positive impact on food safety knowledge and practices (Husain et al., 2016; Park et al., 2010; Roberts et al., 2008; Soon and Baines, 2012).

The frequency of responses to food safety knowledge and hygiene practices items at baseline and after training by OFSP puree handlers is shown in Tables 11a and 11b and 12 respectively. Only half of food handlers (50%) knew that equipment should always be cleaned and sanitized after use in processing. More than half of OFSP puree handlers (64.3%) demonstrated poor knowledge on hand washing hygiene practices and 57% did not know proper cooking during processing is effective in destroying most pathogenic and spoilage microorganisms. These findings closely relate to findings by Adesokan et al. (2015) and Park et al. (2010) which reported poor knowledge scores by untrained food handlers on temperature control, sources of microbial food contamination and personal hygiene. An increase in about 90% correct response rate was recorded from all food safety questions after food safety training.

Poor hand washing practices were demonstrated by OFSP puree handlers during handling of raw OFSP and puree. Only 64% of all OFSP puree handlers washed their hands before handling raw sweetpotato roots and 57% admitted having not washed hands before processing. Poor hand washing practices by OFSP puree handlers is a potential source of contamination in OFSP puree processing. An increase in frequencies of appropriate food handling practices by OFSP puree handlers was also found in post-training hygiene practices assessment.

Table 11a. Frequency of food safety knowledge scores among OFSP puree handlers at baseline and after training (N=14)

	Before Training		After Training	
Food Safety Items	With Knowledge (%)	Without Knowledge (%)	With Knowledge (%)	Without Knowledge (%)
1. Preparation of food disregarding hygiene rules causes food-borne illnesses	92.9	7.1	100.0	0.0
2. Food borne diseases are transmitted by food contamination	92.9	7.1	100.0	0.0
3. Food borne diseases are transmitted by contaminated water	57.1	42.9	78.6	21.4
4. Improper heating of food causes food-borne illnesses	71.4	28.6	85.7	14.3
5. During infectious disease of the skin, it is necessary to take leave from work	85.7	14.3	100.0	0.0
6. Only sick people carry bacteria which causes food poisoning	85.7	14.3	100.0	0.0
7. Microbes are in the skin, nose and mouth of healthy food handlers	57.1	42.9	92.7	7.1
8. Children, healthy adults, pregnant women and older individuals are at equal risk for food poisoning	64.3	35.7	85.7	14.3
9. Typhoid fever can be transmitted by food	78.6	21.4	100.0	0.0
10. Food production staff should have health checkups every two years	57.1	42.9	92.9	7.1
11. Contaminated food can be detected by taste	35.7	64.3	100.0	0.0
12. Washing hands before work reduces the risk of food contamination	100	0.0	100.0	0.0
13. Working without protective clothing in is sometimes allowed in a food factory	78.6	21.4	92.9	7.1
14. Using gloves while handling food reduces the risk of food contamination	85.7	14.3	95.2	4.8
15. Eating and drinking in the work place increases the risk of food contamination	85.7	14.3	95.2	4.8
16. Proper cleaning and sanitization of equipment reduces the risk of food contamination	78.6	21.4	85.7	14.3
17. Working with jewelry is allowed in a processing plant	78.6	21.4	100.0	0.0

Table 11b. Frequency of food safety knowledge scores among OFSP puree handlers at baseline and after training (N=14)

	Before Training		After Training	
Food Safety Items	With Knowledge (%)	Without Knowledge (%)	With Knowledge (%)	Without Knowledge (%)
18. Washing equipment with detergent does not completely leave them free from contamination.	42.9	57.1	78.6	21.4
19. Clean is the same as sanitize	42.9	57.1	85.7	14.3
20. Cleaning chemicals and food ingredients should be kept together in one store	64.3	35.7	100.0	0.0
21. Food can be prepared on dirty surfaces/equipment	92.9	7.1	100.0	0.0
22. Cleaning of equipment should always be done at the end of processing	50.0	50.0	92.9	7.1
23. Cross contamination is when microorganisms from a contaminated food are transferred by the food handler's hands or kitchen utensils to another food	71.4	28.6	85.7	14.3
24. Contaminated foods can be detected by changes in color, odor or taste.	28.6	71.4	78.6	21.4
25. Raw food and processed food should be kept separate	85.7	14.3	100.0	0.0
26. Temperature control is important in storage and processing of safe food	92.9	7.1	100.0	0.0
27. Temperature readings for equipment and other installations like refrigerators should be checked and recorded from time to time	78.6	21.4	100.0	0.0

Table 12. Frequency of food hygiene practices scores among OFSP puree handlers at baseline and after training (N=14)

	Before Training		After Training	
Food Hygiene Practices Questions	Hygienic Practice (%)	Unhygienic Practice (%)	Hygienic Practice (%)	Unhygienic Practice (%)
1. Do you wear jewelry and a watch while working?	71.4	28.6	85.7	14.3
2. Do you rub your hands on your face, hair etc. while working?	71.4	28.6	92.9	7.1
3. Do you smoke/chew gum while working?	78.6	21.4	100.0	0.0
4. Do you use detergent whenever you wash your hands?	85.7	14.3	92.9	7.1
5. Do you wash your hands with soap after visiting the toilet?	78.6	21.4	92.9	7.1
6. Do you use gloves when you touch or distribute unwrapped foods?	42.9	57.1	95.2	4.8
7. Do you wash your hands before wearing gloves?	42.9	57.1	85.7	14.3
8. Do you wash your hands after using gloves?	64.3	35.7	92.9	7.1
9. Do you wear nail polish when handling food?	92.9	7.1	100.0	0.0
10. Do you wear an apron/PPE while working?	78.6	21.4	100.0	0.0
11. Do you wash your hands after touching unwrapped cooked foods?	57.1	42.9	95.2	4.8
12. Do you use protective clothing when you touch or distribute unwrapped foods?	78.6	21.4	100.0	0.0
13. Do you wash your hands before touching unwrapped raw foods?	64.3	35.7	100.0	0.0
14. Do you wash your hands before touching unwrapped cooked foods?	85.7	14.3	100.0	100.0
15. Do you wipe your hands with your apron/PPE?	85.7	14.3	100.0	0.0
16. Do you clean your working area before food preparation?	71.4	28.6	85.7	14.3
17. Do you check shelf life of foods/ingredients at the time of delivery?	85.7	14.3	92.9	7.1
18. Do you check the packing integrity of foods at the time of dispatch/delivery?	78.6	21.4	92.9	7.1
19. Do you properly clean the food storage area before storing new products?	78.6	21.4	95.2	4.8

5.3.2 *Post-training microbial load of equipment used for OFSP puree processing*

Tables 13 and 14 shows the level of microbial counts from equipment surfaces in OFSP puree processing at baseline and after training respectively. After training, aerobic counts (TVC) were not detected from packaging bags but highest counts with mean counts of 4.9±0.1 log cfu.cm^{-2} were detected from freezers. Yeast and Molds (YM) were not detected in 22% of all equipment surfaces. High YM counts were also detected from freezers. More than half of the equipment (56%) were absent of *S. aureus* counts; highest counts (2.7±0.03 log cfu.cm^{-2}) were however detected from knives. Enterobacteriaceae (EB) and total coliforms (TC) were not detected from packaging bags but higher counts with means 3.8±0.4 and 3.6±0.3 log cfu.cm^{-2} respectively were detected from freezers. *E. coli* (EC) was not detected on any equipment used in OFSP puree processing.

Table 13. Baseline Microbial Counts on equipment surfaces in OFSP puree processing plant[1] (Log Mean CFU.cm^{-2})

Sample	TVC	Yeast-Molds	*S. aureus*	Enterobacteriaceae	Coliforms	*E. coli*
Knives	6.57±0.32^{bc}	4.35±0.29^{bcde}	5.06±0.13^{bcd}	6.24±0.02^{bcd}	5.51±0.15^{def}	4.79±0.33^{b}
Tables	8.12±1.24^{bcde}	5.73±1.13^{cdef}	4.44±0.84^{bcd}	6.71±0.07^{bcd}	6.35±0.54^{defgh}	2.16±3.74^{a}
Cooling Trays	7.45±1.37^{bcde}	4.74±0.27^{cdef}	4.68±0.55^{bcd}	5.83±1.20^{bcd}	5.45±1.16^{cde}	2.68±2.10^{a}
Puree machine	7.63±0.81^{bcde}	4.29±1.03^{bcd}	4.43±0.63^{bcd}	6.34±0.45^{bcd}	5.58±0.20^{defg}	2.04±2.23^{a}
Weighing Spoons	9.47±0.03^{e}	6.45±0.08^{def}	5.41±0.14^{cd}	6.43±0.10^{bc}	6.17±0.12^{defgh}	1.81±2.57^{a}
Packaging bags	6.28±0.09^{bc}	4.83±1.35^{cdef}	3.16±0.43^{bc}	5.83±0.64^{bc}	5.65±0.73^{defgh}	nd*
Packaging Machine	9.10±0.74^{de}	6.15±0.51^{cde}	5.15±0.04^{bcde}	6.77±0.05^{cde}	6.45±0.02^{defg}	3.58±0.08^{b}
Freezers	7.46±0.13^{bcde}	5.95±0.83^{cdef}	4.89±1.53^{bcd}	6.64±0.11^{bcd}	6.32±0.40^{defgh}	1.21±2.11^{b}
Cold boxes	7.97±0.13^{bcde}	5.48±0.55^{cdef}	5.65±0.11^{cd}	6.27±0.17^{cd}	5.58±0.24^{defg}	4.36±0.76^{b}
Shipment vehicle	8.33±0.01^{bcde}	5.28±0.00^{cde}	6.45±0.02^{e}	7.43±0.03^{e}	6.68±0.01^{fgh}	4.70±0.96^{b}

[1]*All values reflect mean counts and standard deviation. Values bearing different superscript letters in each column are significantly different (p<0.05)*
** nd-not detected*

Table 14. Post-training microbial counts on equipment surfaces in OFSP puree processing plant[1] (Log Mean CFU.cm^{-2})

Sample	TVC	Yeast-Molds	*S. aureus*	Enterob.	Coliforms	*E. coli*
Knives	3.8 ± 0.1^{fg}	2.1 ± 0.77^{bc}	2.7 ± 0.03^{b}	2.8 ± 0.02^{cdef}	2.7 ± 0.22^{de}	nd*
Tables	3.7 ± 0.18^{fg}	2.2 ± 0.22^{bc}	1.5 ± 1.68^{ab}	2.9 ± 0.40^{cdef}	2.5 ± 0.31^{cde}	nd*
Cooling Trays	2.5 ± 0.32^{de}	2.3 ± 0.08^{bc}	nd*	1.9 ± 0.11^{bcd}	1.8 ± 0.13^{bcd}	nd*
Puree machine	3.0 ± 0.52^{e}	2.1 ± 0.03^{bc}	nd*	2.0 ± 0.11^{bcd}	1.6 ± 0.32^{bcd}	nd*
Weighing Spoons	3.6 ± 0.04^{f}	nd*	nd*	2.4 ± 0.06^{defg}	2.9 ± 0.01^{de}	nd*
Packaging bags	1.1 ± 0.12^{b}	nd*	nd*	nd*	nd*	nd*
Freezers	4.9 ± 0.10^{i}	3.7 ± 0.11^{e}	1.3 ± 1.45^{ab}	3.8 ± 0.38^{fg}	3.6 ± 0.27^{a}	nd*
Cold boxes	1.6 ± 0.43^{bc}	1.6 ± 0.10^{bc}	0.6 ± 0.59^{ab}	0.9 ± 0.02^{ab}	0.9 ± 0.01^{ab}	nd*
Truck	3.8 ± 0.04^{fg}	3.1 ± 0.02^{cde}	nd*	1.8 ± 0.07^{bcd}	1.1 ± 0.17^{abc}	nd*

[1]All values reflect mean counts and standard deviation. Values with different superscript letters in each column are significantly different ($p<0.05$)

nd-not detected*

Table 15 summarizes average microbial load for each parameter before (baseline) and after food safety training.

Table 15. Pre- and post-training microbial contamination load summary on equipment used in OFSP puree processing[1]

Parameter	Baseline counts (Log cfu.cm^{-2})	Post-Training counts (Log cfu.cm^{-2})	*p* value
Total Viable Counts	7.8±0.87	3.1±1.1	0.00*
Yeast and Molds	5.5±0.80	1.9±1.2	0.00*
S. aureus	4.9±0.76	0.7±0.9	0.00*
Enterobacteriaceae	6.6±0.52	2.1±1.1	0.00*
Total coliforms	6.1±0.40	1.9±1.1	0.00*
E. coli	3.1±1.60	nd[2]	0.00*

[1]All values reflect average counts and standard deviation for equipment

[2]nd-microbial parameter not detected

**Mean difference significant at ($p<0.05$)*

Microbial counts on equipment for all parameters significantly ($p<0.05$) reduced after training to levels acceptable for food processing. Reduction in counts could be attributed to improved food handling practices and implementation of effective cleaning and sanitation procedures as demonstrated and recommended during food safety training session. Effective cleaning and sanitation reduces up to 99.9% of both spoilage and pathogenic microorganisms from equipment (Schlegelova et al., 2010). Appropriate cleaning and sanitation is an important practice for controlling cross contamination between food and food preparation surfaces. Total counts on most equipment surfaces in this study were below 10^4 CFU.cm^{-2}, a critical value for formation of biofilms (Ali et al., 2010). Levels below 10^5 on equipment have previously been reported in a study by Gungor and Gokoglu (2010) that assessed the level of microbial contamination along frankfurter sausage processing line. The findings from the current study identified that sanitation could not eliminate all microbial species from equipment surfaces. Ali et al. (2010) and Barros et al. (2010) assert that several species of yeasts and molds, Enterobacteriaceae and *S. aureus* can adhere and survive on damp equipment surfaces presenting a problem in cleaning and sanitation. Therefore, effective cleaning following documented procedures and use of approved detergents; sanitation; and draining of equipment to allow drying should be a regular practice in OFSP puree processing to prevent formation of biofilms and cross-contamination.

5.3.3 *Post-training microbial load on installations in OFSP puree processing*

Tables 16 and 17 the state of hygiene with respect to microbial level for walls, floors and drains in OFSP puree processing plant before and after food safety training.

Table 16. Baseline Microbial Counts of installations in OFSP puree processing plant [1] (Log Mean CFU.cm^{-2})

Sample	TVC	Yeast-Molds	*S. aureus*	Enterobacteriaceae	Coliforms	*E. coli*
Floors	8.03±0.87^{bcde}	5.71±0.94^{cdef}	5.31±0.40^{cd}	6.98±0.35^{cd}	6.66±0.22^{gh}	2.75±3.20^{a}
Walls	8.69±0.65^{bcde}	6.17±0.56^{cdef}	5.54±0.03^{cd}	7.00±0.26^{cd}	6.43±0.54^{defgh}	1.45±2.51^{a}
Drains	8.71±0.73^{bcde}	5.46±1.29^{cdef}	5.33±0.90^{cd}	7.20±0.06^{cd}	6.80±0.36^{h}	3.50±3.14^{b}

[1]*All values reflect mean counts and standard deviation. Values bearing different superscript letters in each column are significantly different (p<0.05)*

Table 17. Post-training Microbial counts on walls, floors and drains in OFSP puree processing plant[1] (Log Mean CFU.cm^{-2})

Sample	TVC	Yeast-Molds	*S. aureus*	Enterob.	Coliforms	*E. coli*
Floors	4.3±0.15^{ghi}	3.6±0.32^{de}	nd*	3.6±0.45^{efg}	2.2±0.31^{bcde}	nd*
Walls	4.5±0.06^{hi}	1.2±1.32^{ab}	1.1±0.92^{ab}	1.8±0.9^{bc}	1.7±0.07^{bcd}	nd*
Drains	6.2±0.02^{j}	4.1±0.03^{e}	nd*	4.6±0.03^{g}	3.7±0.04^{e}	2.5±0.02^{b}

[1]*All values reflect mean counts and standard deviation. Values with different superscript letters in each column are significantly different (p<0.05)*

nd-not detected*

Low TVC counts was recorded from floors (4.3±0.15 log cfu.cm^{-2}) while significantly (p<0.05) higher counts (6.2±0.02 log cfu.cm^{-2}) were detected from drains. YM was detected on all the surfaces with significantly (p<0.05) lower counts being recorded from walls (1.2±1.3 log cfu.cm^{-2}) and highest counts from drains (4.1±0.03 log cfu.cm^{-2}). *S. aureus* was only detected from walls (1.1±0.92 log cfu.cm^{-2}). Lowest EB and TC counts were detected from walls with mean counts 1.8±0.9 and 1.7±0.07 log cfu.cm^{-2} respectively while high counts were detected from drains with counts 4.6±0.03 and 3.7±0.04 log cfu.cm^{-2} respectively. *E. coli* was only detected from drains with mean counts 2.5±0.02 log cfu.cm^{-2}. Average pre- and post-training microbial contamination levels on walls, floors and drains are summarized in Table 18.

Table 18. Summary for microbial contamination load on installations before and after food safety training[1] (Log cfu.cm^{-2})

Parameter	Baseline counts	Post-Training counts	p value
Total Viable Counts	8.5±0.38	5.0±1.0	0.01*
Yeast and Molds	5.8±0.36	3.0±1.6	0.04*
S. aureus	5.4±0.12	0.3±0.1	0.00*
Enterobacteriaceae	7.1±0.12	3.3±1.4	0.00*
Total coliforms	6.6±0.19	2.5±1.0	0.00*
E. coli	2.6±1.0	0.8±0.2	0.17

[1]All values reflect average counts and standard deviation for equipment

**Mean difference significant at ($p<0.05$)*

Microbial counts for most parameters from the present study significantly (p<0.05) reduced after food safety training except for *E. coli*. Even though there was significant reduction in microbial counts, the current level of total counts (10^5 cfu.cm^{-2}) indicated need for improvement in efficiency during cleaning of walls, floors and drains. Floors and walls in OFSP puree processing plant were cleaner than drains due to adoption of 'clean as you go' principle as recommended during food safety training and regular cleaning of these surfaces before, during, and after production. The drains' surface area was not large enough for holding large volumes of waste water. Frequent water stagnation at these surfaces provided a conducive environment for microbial proliferation thus resulting in higher total counts. Effectual cleaning of floors, walls and drains is important in controlling growth and circulation of microbial contaminants in a food processing environment (Ali et al., 2010; Barros et al., 2007). In comparison with our preliminary study findings, food safety training improved environmental hygiene in OFSP puree processing.

5.3.1 *Post-training hand hygiene and process water quality in OFSP puree processing*

Our preliminary study findings indicated high microbial contamination level on personnel hands and in water for OFSP puree processing. Poor water quality was attributed to lack of water disinfection program at the plant while high microbial counts from personnel hands resulted from poor hand washing hygiene practices. Enterobacteriaceae, total coliforms and *E. coli* counts in water were 6.0, 5.4 and 4.4 cfu/ml respectively before food safety training. Similarly, total counts, yeast and molds, *S. aureus,* Enterobacteriaceae, total coliforms and *E. coli* counts from personnel hands were 8.3, 6.0, 5.1, 6.9, 6.6 and 2.7 cfu.cm^{-2} respectively. Food safety training on hand hygiene and commendation for water treatment significantly (p<0.05) improved hand hygiene practices and water quality for OFSP puree processing (Table 19).

Table 19. Level of microbial contamination on personnel hands and processing water in OFSP puree processing after food safety training

Sample	TVC	Yeast-Molds	*S. aureus*	Enterobacteriaceae	Coliforms	*E. coli*
Personnel	3.6 ± 0.29^{f}	1.3 ± 0.98^{ab}	1.8 ± 1.39^{ab}	2.7 ± 0.15^{cdef}	2.4 ± 0.28^{cde}	nd*
Water	2.1 ± 0.13^{cd}	nd*	nt[2]	nd*	nd*	nd*

[1]All values reflect mean counts and standard deviation. Values with different superscript letters in each column are significantly different (p<0.05)

[2]nt-not tested

nd-not detected*

Low counts from personnel hands and water was attributed to good hand washing hygiene and regular water chlorination as part of recommendation from food safety training session. Total counts in treated water were within acceptable levels recommended by EPA (2012) for use in processing. Yeast, Molds, Enterobacteriaceae, coliforms and *E. coli* were absent in chlorinated water at the facility. A study by Rompre et al. (2002) has reported chlorination process as being effective in destroying all water quality indicator microorganisms. Contaminated water has been reported as a major source of contamination for personnel hands, equipment and food during processing (Liguori et al., 2010). Our baseline study results also indicated water as a major source of contamination in OFSP puree processing.

Low counts from personnel hands indicated improved hand hygiene practices by food handlers following food safety training. Cross contamination of food from personnel hands is a significant factor contributing to foodborne disease outbreaks and food spoilage (Green et al., 2006). Training and monitoring of food handler's hand washing hygiene together with provision of adequate hand washing resources are prime factors for enhancing hand hygiene (Pfuntner, 2011). Hand washing did not, however, eliminate all microorganisms from personnel hands (Montville et al., 2002). Studies thereby recommend use of disposable gloves to prevent contamination from personnel hands to foods (Michaels et al., 2004; Montville et al., 2001).

5.3.2 *Post-training quality and safety assessment of OFSP puree*

Before food safety training, the microbial load in orange fleshed sweetpotato puree was high as shown in Table 20. The microbial load, however, reduced significantly ($p<0.05$) after food safety training (Figure 5).

Table 20. Baseline Microbial Counts of OFSP at different stages of processing in OFSP puree processing plant[1] (Log Mean CFU/g)

Processing Stages	TVC	Yeast-Molds	*Staph. aureus*	Enterobacteriaceae	Coliforms	*E. coli*
Raw OFSP	7.19±0.27^{bcd}	2.51±0.30^{b}	3.01±0.15^{b}	4.57±0.20^{b}	3.74±0.19^{b}	nd*
Steaming	3.85±0.72^{a}	nd*	nd*	2.76±0.21^{a}	2.44±0.19^{a}	nd*
Slicing	7.12±0.21^{bcd}	nd*	2.93±2.54^{b}	4.62±0.15^{b}	4.37±0.13^{bc}	nd*
Packaging	7.96±0.57^{bcde}	4.01±0.33^{bc}	5.88±0.53^{cd}	6.55±0.18^{cd}	5.82±0.13^{defgh}	4.77±0.45^{b}

[1]All values reflect mean counts and standard deviation. Values bearing different superscript letters in each column are significantly different ($p<0.05$)

nd-not detected*

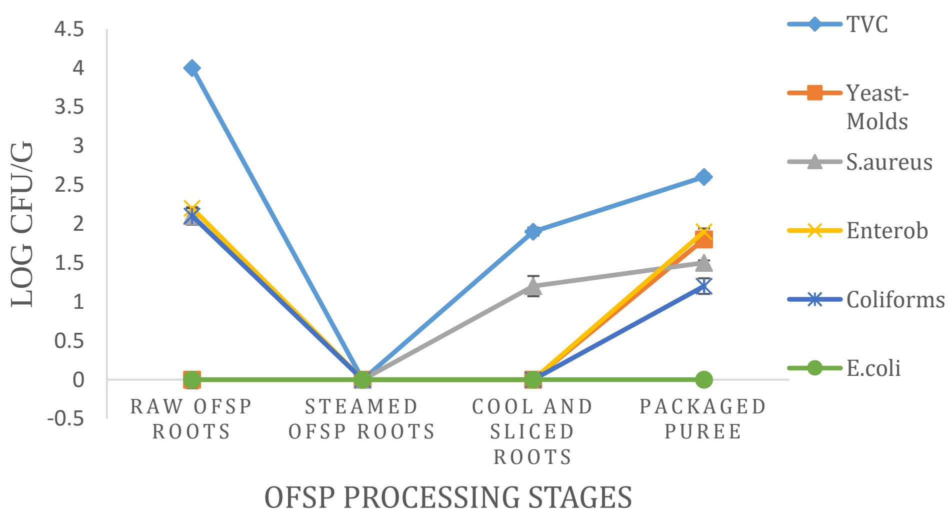

Figure 5. Changes in microbial in OFSP puree processing

TVC, *S. aureus*, Enterobacteriaceae (EB) and total coliforms in raw OFSP roots were destroyed during steaming. Yeast, molds (YM) and *E. coli* (EC) were not detected in raw OFSP roots. *E. coli* was not detected at any of the processing stages but YM was detected in the puree after packaging. TVC and *S. aureus* counts increased after cooling, slicing, pureeing and packaging processes but the growth was only significant ($p<0.05$) for TVC. Enterobacteriaceae and coliforms were detected in the puree after packaging. Adequate heat treatment is effective in reducing microbial load in sweetpotato puree during processing (Perez-Diaz et al., 2008). Post-processing contamination from OFSP puree handlers and equipment such as knives, cooling trays, pureeing machine and weighing spoons increased microbial counts in packaged puree. The counts in the puree were however within limits for use as a food ingredient. Total counts ($<10^5$ cfu/g) was insufficient for initiating deterioration in OFSP puree; it was of good keeping quality. This is contrary to our preliminary study findings that recorded high microbial counts in OFSP puree ($>10^5$ cfu/g). Food safety training significantly improved microbial safety and quality of OFSP puree. This resulted from improved food safety knowledge and handling practices by OFSP puree handlers; improved handwashing hygiene; improved environmental hygiene; enhanced efficiency in cleaning and sanitation; improved water quality; and provision of necessary food safety resources such as paper towels for hand drying.

5.4 CONCLUSION

Training in food safety significantly improved food safety knowledge and practices of Orange Fleshed Sweetpotato puree handlers. Improvement in food safety knowledge and handling practices led to a significant reduction in microbial count in puree processing environment. Frequent food safety training, monitoring, management support through provision of necessary food safety resources are key factors to enhancing quality and safety in OFSP puree.

CHAPTER SIX: GENERAL CONCLUSION AND RECOMMENDATIONS

5.5 General Conclusion

The current study sought to identify food safety challenges faced by Orange Fleshed Sweetpotato puree processing in Kenya and provide measures for enhancing quality and safety of processed puree and related products. Based on the current findings, food handlers at the puree processing plant displayed low level of food safety knowledge and poor hygiene practices. However, food handlers at the bakery displayed good hygiene practices necessary for food safety and quality assurance in processing. Poor hygiene and violation of food hygiene practices resulted in high microbial load in OFSP puree that originated from contaminated processing environment, contaminated equipment, contaminated water and food handling personnel. Food safety training as an intervention improved food safety knowledge and practices of food handlers at the puree processing plant as well as the microbial quality and safety of orange fleshed sweetpotato puree.

5.6 Recommendations

There is a need to foster continual improvement through frequent trainings on food safety. This can be instrumental in improving food safety knowledge and practices of food handlers as well as influencing positive food safety behaviors. Regular inspection of the plant and personnel for compliance to good hygiene practices through self-internal audit; environmental sampling and monitoring levels of microbial hazards in processing environments should be done from time to time to identify food safety areas that need immediate corrective actions. However, the success of a food safety program in food processing requires management support, employee's motivation and provision of necessary food safety resources such as gloves, paper towels for hand drying and personal protective clothing to food handlers.

REFERENCES

Abdullahi, A., Hassan, A., Kadarman, N., Saleh, A., Baraya, Y.S., and Lua, P.L. (2016). Food safety knowledge, attitude, and practice toward compliance with abattoir laws among the abattoir workers in Malaysia. *International Journal of General Medicine,* 9: 79-87.

Abong', O.G., Ndanyi, V.M.C., Kaaya, A., Shibairo, S., Okoth, M.W., Lamuka, P.O., Odongo, N.O., Wanjekeche, E., Mulindwa, J., and Sopade, P. (2016). A Review of Production, Post-harvest Handling and Marketing of Sweetpotatoes in Kenya and Uganda. *Current Research in Nutrition and Food Science,* 4 (3): 162-181.

Addis, M., and Sisay, D. (2015). A Review on Major Food Borne Bacterial Illnesses. *Journal of Tropical Diseases*, 3 (4):176-183.

Adesokan, H. K., Akinseye, V. O., and Adesokan, G. A. (2015). Food Safety Training Is Associated with Improved Knowledge and Behaviors among Foodservice Establishments' Workers. *International Journal of Food Science*, 2015: 1-8.

Ajao, A.T., and Atere, T. G. (2009). Bacteriological Assessment and Hygienic Standard of Food Canteens in Kwara State Polytechnic, Ilorin, Nigeria. *African Scientist,* 10 (3): 173-180.

Akiyama, H., Goda, Y., Tanaka, T., and Toyoda, M. (2001). Determination of aflatoxins B1, B2, G1 and G2 in spices using a multifunctional column clean-up. *Journal of Chromatography*, 932 (1):153–157.

Al-Abdallal, A.H. (2010). Isolation and identification of microbes associated with mobile phones in Dammam in eastern Saudi Arabia. *Journal of Family Community Medicine*, 17 (1):11-14.

Ali, N. H., Farooqui, A., Khan, A., Khan, A. Y., and Shahana, U. (2010). Original Article Microbial contamination of raw meat and its environment in retail shops in Karachi, Pakistan.

Journal of Infection in Developing Countries, 4 (6):382-388.

Aluko, O.O., Ojeremi T.T., Olaleke, D.A., and Ajidagba, E.B (2014). Evaluation of food safety and sanitary practices among food vendors at car parks in Ile Ife, southwestern Nigeria. *Journal of Food Control*, 40: 165-71.

Anuradha, M., and Dandekar, R.H. (2014). Knowledge , Attitude and Practice among food handlers on food borne diseases : A hospital based study in tertiary care hospital. *International Journal of Biomedical and Advance Research,* 3809: 5-7*.*

Argudin, M.A., Mendoza, M.C., and Rodicio, M.R. (2010). Food Poisoning and *Staphylococcus aureus* Enterotoxins*. Journal of Toxins, 2*: 1751-1773.

Baluka, S.A., Miller, R., and Kanene, J.B. (2015). Hygiene practices and food contamination in managed food service facilities in Uganda. *African Journal of Food Science*, 9 (1): 31-42.

Barros, A.F., Nero, A., Monteiro, A.A., and Beloti, V. (2007). Identification of main contamination points by hygiene indicator microorganisms in beef processing plants. J*ournal of Food science and Technology*, 27 (4): 856-862.

Bas, M., Ersun, S.A., and Go khan Kıvanc, G. (2006). The evaluation of food hygiene knowledge, attitudes, and practices of food handlers in food businesses in Turkey*. Journal of Food Control,* 17: 317-322.

Baylis, C., Uyttendaele, M., Joosten, H., and Davies, A. (2011). The Enterobacteriaceae and their significance to the food industry. Report Commissioned by the ILSI Europe Emerging Microbiological Issues Task Force, December 2011.

Bendigeri, N. A. D. (2016). Knowledge, attitude, and practices of food safety among women of Khaza bazar, the urban field practice area of KBN Institute of Medical Sciences. *International Journal of Medical Science and Public Health*, 5 (3): 516-20.

Bertolini, M., Rizzi, A., and Bevilacqua, M. (2007). An alternative approach to HACCP implementation. *Journal of Food Engineering*, 79 (4): 1322-1328.

Bisbini, P., Leoni, E., and Nanetti., A. (2000). An outbreak of Salmonella Hadar associated with roast rabbit in a restaurant. *European Journal of Epidemiology*, 16: 613-618.

Bocher, T., Low, J.W., Muoki, P., Magnaghi, A., and Muzhingi, T. (2017). From lab to life: Making storable orange-fleshed sweetpotato puree a commercial reality. *Open Agriculture*, 2(1): 148-154.

Bohme, K., Inmaculada, C., Fernandez-No, I.C., Barros-Velazquez, J., Gallardo, J.M., Benito, C., and Calo-Mata, P. (2012). Species Identification of Food Spoilage and Pathogenic Bacteria by MALDI-TOF Mass Fingerprinting. *Journal of Food Quality*, 32 (21): 29-46.

Brinley, T.A., Truong, V.D., Coronel, P., Simunovic, J., and Sandeep, K.P. (2008) Dielectric Properties of Sweet Potato Purees at 915 MHz as Affected by Temperature and Chemical Composition. *International Journal of Food Properties*, 11 (1): 158-172.

Buchanan, R. L. (2012). Use of Microbiological Indicators for Assessing Hygiene Controls for the Manufacture of Powdered Infant Formula. *Journal of Food Protection*, 75 (5): 989-997.

Carey, E.E., Gichuki, S.T., Ndolo, P.J., Turyamureeba, G., Kapinga, R., and Lutaladio, N.B. (1997). Sweet potato breeding for Eastern Central and Southern Africa: An Overview.

In: Proceedings of the 4th Triennial Congress of the African Potato Association. Pretoria South Africa, 23-28 Feb. 1997, pp. 89-93.

Carey, E.E., Oyunga, M.A., K'osambo, L., Smit, N.E.J.M., Ocitti p'Obwoya, C., Turyamureeba, G., Low, J., and Hagenimana, V (1995). Using orange-fleshed sweet potato varieties to combat vitamin A deficiency and enhance market opportunities for smallholder farmers in sub-Saharan Africa. 1995: 1-16.

Centers for Disease Control and Prevention (CDC) (2015). Surveillance for Foodborne Disease Outbreaks, United States, 2013, Annual Report. Atlanta, Georgia: US Department of Health and Human Services, CDC, 2015.

Choi, J., Norwood, H., Seo, S., Sirsat, S. A., and Neal, J. (2016). Evaluation of food safety related behaviors of retail and food service employees while handling fresh and fresh-cut leafy greens. *Journal of Food Control*, 67: 199-208.

Donado-Pestana, C. M., Salgado, J. M., Rios, A.O., Santos, P. R., and Jablonski, A. (2012). Stability of Carotenoids, Total Phenolic and In Vitro Antioxidant Capacity in the Thermal Processing of Orange- Fleshed Sweet Potato (Ipomoea batatas Lam.) Cultivars Grown in Brazil. *Plant Foods Human Nutrition*, 67 (3): 262-270.

Edema, M.O., Osho, A.T., and Diala C.I. (2008). Evaluation of microbial hazards associated with the processing of suya (a grilled meat product). *Scientific Research and essay*, 3 (12): 621-626.

Environmental Protection Agency (EPA) (2012). Drinking Water Contaminants-Standards and Regulations. Retrieved from https://www.epa.gov/dwstandardsregulations/drinking-water-contaminant-human-health-effects-information#dw-standards on January 4, 2017 at 1258hrs.

European Food Safety Authority (EFSA). The European Union summary report on trends and sources of zoonosis, zoonotic agents and foodborne outbreaks in 2009 (2010). *The EFSA Journal*, 8 (1): 1496.

FAO (2003). Assuring Food Safety and Quality: Guidelines for Strengthening National Food Control Systems. Retrieved from http://www.fao.org/docrep/006/y8705e/y8705e03.htm#bm03.1 on December 14, 2016 at 1256 hrs.

Fawell, J., and Njeuwenhuijsen, M.J. (2010). Contaminants in drinking water, environmental pollution and health. *British Medical Bulletin*, 68 (1): 199-208.

Fischer, R. A., Byerlee, D., and Edmeades, G. O. (2014). Crop yields and global food security: will yield increase continue to feed the world? Canberra: Australian Centre for International Agricultural Research. Retrieved from http://aciar.gov.au/publication/mn158 on 30th October 2017 at 1225 hrs.

Green, L. R., and Selman, C. (2005). Factors impacting food workers' and managers' safe food preparation practices: a qualitative study. *Food Protection Trends*, 25 (12): 981-990.

Green, L.R., Selman, C.A., Radke, V., Ripley, D., Mack, C.J., Reimann, D.W., Stigger, T., Motsinger, M., and Bushnell, L. (2006). Food Worker Hand Washing Practices: An Observation Study. *Journal of Food Protection*, 69 (10): 2417-2423.

Gungor, E., and Gokoglu, N. (2010). Determination of microbial contamination sources at a Frankfurter sausage processing line. *Turkish Journal of Veterinary and Animal Sci*ences, 34 (1): 53-59.

Gwida, M., Hotzel, H., Geue, L., and Tomaso, H. (2014). Occurrence of Enterobacteriaceae in Raw Meat and in Human Samples from Egyptian Retail Sellers. *International Scholarly Research Notices*, 2014: 1-6.

Hagenimana, V. (1999). Potential of orange-fleshed sweet potato in raising vitamin A intake in Africa. International Potato Centre, SSA.

Haile, F., Admassu, S., and Fisseha, A. (2015). Effects of Pre-treatments and Drying Methods on Chemical Composition, Microbial and Sensory Quality of Orange-Fleshed Sweet Potato Flour and Porridge. *American Journal of Food Science and Technology*, 3 (3): 82-88.

HarvestPlus (2012). Disseminating Orange Fleshed Sweetpotato: Uganda Country Report. Washington, D.C.

Hervert, C. J., Alles, A. S., Martin, N. H., Boor, K. J., and Wiedmann, M. (2016). Evaluation of different methods to detect microbial hygiene indicators relevant in the dairy industry. *Journal of Dairy Science*, 99 (9): 7033-7042.

Howes, M., McEwen, S., Griffiths, M., and Harris, L. (1996). Food handler certification by home study: Measuring changes in knowledge and behavior. *Dairy, Food and Environmental Sanitation*, 16: 737-744.

Huang, C., Ma, W., and Stack, S. (2012). The Hygienic Efficacy of Different Hand-Drying Methods: A Review of the Evidence. *Mayo Clinic Proceedings*, 87 (8): 791-798.

Husain, N.R.N., Muda, W.M.W., Jamil, N.I.N., Hanafi, N.N.N., and Rahman, R.A. (2016). Effect of food safety training on food handlers' knowledge and practices A randomized controlled trial. *British Food Journal*, 118 (4): 795-808.

Jenkins, M., Shanks, C.B., and Houghtaling, B. (2015). Orange-Fleshed Sweet Potato: Successes and Remaining Challenges of the Introduction of a Nutritionally Superior Staple Crop in Mozambique. *Food and Nutrition Bulletin*, 1-25.

Kadariya, J., Smith, T. C., and Thapaliya, D. (2014). Staphylococcus aureus and Staphylococcal Food-Borne Disease : An Ongoing Challenge in Public Health. *BioMed Research International,* 2014.

Kassa, H., Silverman, G. S., and Baroudi, K. (2014). Effect of a Manager Training and Certification Program on Food Safety and Hygiene in Food Service Operations. E*nvironmental Health Insights,* 2010 (4): 13-20.

Khakhria, R., Woodward, D., Johnson, W.M., and Poppe, C. (1997). *Salmonella* isolated from humans, animals, and other sources in Canada. *Epidemiology and Infection*, 119: 15–23.

Kibret, M., and Abera, B. (2012). The sanitary conditions of food service establishments and food safety knowledge and practices of food handlers in Bahir Dar town. *Ethiopian Journal of Health Sciences,* 22: 27-35.

Kibwage, J. K., Odondo, A.J. and Momanyi, G.M (2009): Assessment of Livelihood Assets and Strategies among Tobacco and Non-Tobacco Farmers in South Nyanza region, Kenya.

Kluytmans, J.A.J.W., and Wertheim, H.F.L. (2005). Nasal carriage of Staphylococcus aureus and prevention of nosocomial infections. *Journal of Infection,* 33: 3-8.

Kurabachew, H. (2015). The Role of Orange Fleshed Sweet Potato (Ipomea batatas) for Combating Vitamin A Deficiency in Ethiopia. *International Journal of Food Science and Nutrition Engineering*, 5 (3): 141-146.

Liguori, G., Cavallotti, I., Arnese, A., Amiranda, C., Anastasi, D., and Angelillo, I. F. (2010). Microbiological quality of drinking water from dispensers in Italy. *BioMed Central Microbiology*, 2010: 10-19.

Low, J., and van Jaarsveld, P. (2008). The potential contribution of bread buns fortified with beta-carotene-rich sweet potato in Central Mozambique. *Food Nutrition Bulletin*, 29 (2): 98-107.

Low, J., Hagenimana, V., Anyango, O.M., Njoroge, S.M., Gichuki, S. T., and Kabira, J. (1999). Effects of Women Farmers' Adoption of Orange-Fleshed Sweet Potatoes: Raising Vitamin A Intake in Kenya. International Potato Centre annual report.

Low, J., Kinyae, P., Gichuki, S., Oyunga, M.A., Hagenimana, V., and Kabira, J. (1997). Combating Vitamin, A deficiency through the use of sweet potato. International Potato Center, Lima, Peru.

Low, J.W., Arimond, M., Osman, N., Cunguara, B., Zano, F., and Tschirley, D. (2007). A Food-Based Approach Introducing Orange-Fleshed Sweet Potatoes Increased Vitamin A Intake and Serum Retinol Concentrations in Young Children in Rural Mozambique. *Journal of Food. Nutrition*, 137: 1320-1327.

Mahmoud, I. Y., Al-Bahry, S. N., Al-Musharafi, S. K., and Sivakumar, N. (2014). *Staphylococcus aureus* contamination during food preparation, processing and handling. *International Journal of Chemical Engineering and Applications*, 5 (5): 388-392.

Mahmoud, I.Y., Al-Bahry, S.N., and Sivakumar, N. (2014). Staphylococcus aureus Contamination during Food Preparation , Processing and Handling. *International Journal of Chemical Engineering and Applications*, 5 (5): 388-392.

Mendagudali, R.R., Akka, D.K., Swati, A.I., Shedole, D.T., and Bendigeri, D.A.N. (2016). Knowledge, attitude, and practices of food safety among women of Khaza bazar, the urban field practice area of KBN Institute of Medical Sciences, Kalaburagi, Karnataka. *International Journal of Medical Science and Public Health*, 5 (3): 516-520.

Michaels, B., Keller, C., Blevins, M., Paoli, G., Ruthman, T., Todd, E., and Griffith, C. (2004). Prevention of food worker transmission of foodborne pathogens; risk assessment and evaluatio of effective hygiene interventions strategies. *Food Service Technology*, 4: 31-49.

Mohd. Firdaus Siau, A., Son, R., Mohhiddin, O., Toh, P.S., and Chai, L.C. (2015). Food court hygiene assessment and food safety knowledge, attitudes and practices of food handlers in Putrajaya. *International Food Research Journal*, 22 (5): 1843-1854.

Montville, R., Chen, Y., and Schaffner, D. (2001). Glove barriers to bacterial cross-contamination between hands to food. *Journal of Food Protection*, 64: 845-849.

Mukantwali, C., Laswai, H., Tiisekwa, B., and Wiehler, S. (2013). Good Manufacturing and Hygienic Practices at Small and Medium Scale Pineapple Processing Enterprises in Rwanda. *Food Science and Quality Management*, 13: 15-31.

Mukras, M.S., Odondo, J.M., and Momanyi, G. (2013). Determinants of Demand for Sweet Potatoes at the Farm, Retail and Wholesale Markets in Kenya. *Advances in Economics and Business,* 1 (2): 150-158.

Muzhingi, T. (2016). Effect of Baking on the β-carotene Content of Orange Flesh Sweetpotato (Ipomoea batatas) Puree Bread and OFSP Flour Bread. Presentation made at the 2016 Marketing, Processing and Utilization Cop Meeting in Tanzania.

Ndolo, P.J., Nungo, R.A., Kapinga, R.E., and Agili S. (2007). Development and promotion of orange-fleshed sweetpotato varieties in Western Kenya. Proceedings of the 13th ISTRC Symposium, 2007, pp. 689-695.

Nel, S., Lues, J.F.R., Buys, E.M., and Venter, P. (2004). The personal and general hygiene practices in the deboning room of a high throughput red meat abattoir. *Journal of Food Control*, 15: 571-578.

Nungo, R.A., Ndolo, P.J., Kapinga, R., and Agili, S. (2007). Development and promotion of sweet potato products in Western Kenya, Proceedings of the 13th ISTRC Symposium, pp. 790-794.

Odongo, N.O., Abong', O.G., Okoth, M.W., and Karuri, E.G. (2015). Development of High Protein and Vitamin A Flakes from Sweet Potato Roots and Leaves. *Open Access Library Journal*, 2: e1573.

Oladoye, C.O., Connerton, I.F., Kayode, R.M.O., and Omojasola, P.F. (2014). Investigation on the activities of Yeasts in the Post-Harvest Spoilage of Sweetpotato (Ipomea Batatas L.). *Ethiopian Journal of Environmental Studies and Management*, 7 (5): 499-507.

Othman, A. S. (2015). Isolation and microbiological identification of bacterial contaminants in food and household surfaces : how to deal safely. *Egyptian Pharmaceutical Journal*, 14: 50-55.

Padmaja, G., and Premkumar, T. (2002). Tuber Crops Recipes. Technical Bulletin Series, CTCRI, Kerala, India.

Padmaja, G., Sheriff, J.T., and S. Sajeev, S.M. (2012). Food Uses and Nutritional Benefits of Sweet Potato. *Fruit, Vegetable and Cereal Science and Biotechnology,* 6 (1): 115-123.

Perez-Diaz, I.M., Truong, V., Webber, A., and McFeeters, R.F. (2008). Microbial Growth and the Effects of Mild Acidification and Preservatives in Refrigerated Sweet Potato Puree. *Journal of Food Protection,* 71 (3):639-642.

Perez-Rodriguez, F., Valero, A., Todd, EC.D., Carrasco, E., Garcia-Gimeno, R.M., and Zurera, G. (2007). Modeling transfer of Escherichia coli O157:H7 and Staphylococcus aureus during slicing of a cooked meat product. *Journal of Meat Science*, 76(4): 692-699.

Pfuntner, A. (2011). Proper Hand washing: A Vital Food Safety Step. Food Safety Magazine. Accessed from http://www.foodsafetymagazine.com/magazine-archive1/februarymarch-2011/proper-hand-washing-a-vital-food-safety-step/ on May 2, 2017 at 1829 hrs.

Powell, S. C., Attwell, R. W., and Massey, S. J. (1997). The impact of training on knowledge and standards of food hygiene-a pilot study. *International Journal of Environmental Health Research*, 7: 329-334.

Rahman, M., Arif, T.M., Bakar, K., and Tambi, Z. (2012). Food safety knowledge, attitude and hygiene practices among the street food vendors in Northern Kuching city, Sarawak. *Borneo Science*, 31: 95-103.

Rennie, D. M. (1995). Health education models and food hygiene education. *Journal of the Royal Society of Health*, 115: 75-79.

Republic of Kenya. Ministry of Agriculture, Livestock and Fisheries: Economic Review of Agriculture (ERA): (2015).

Roberts, K. R., Barrett, B. B., Howells, A. D., Shanklin, C. W., Pilling, V. K., and Brannon, L. A. (2008). Food Safety Training and Foodservice Employees' Knowledge and Behavior. *Food Protection Trends*, 28 (4): 252-260.

Rodriguez-Caturla, M., Valero, A., Carrasco, E., Perez-Rodriguez, F., Posada-Izquierdo, G.D., and Zurera, G. (2011). Hygienic conditions and microbiological status of chilled ready-to-eat products served in Southern Spanish hospitals. *Journal of Food Control,* 22 (6): 874–882.

Rompre, A., Servais, P., Baudart, J., De-Roubin, M. R., and Laurent, P. (2002). Detection and enumeration of coliforms in drinking water: Current methods and emerging approaches. *Journal of Microbiological Methods*, 49 (1): 31-54.

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. *Journal of Food Control*, 50: 457-466.

Schlegelova, J., Babak, V., and Holasova, M. (2010). Microbial Contamination after Sanitation of Food Contact Surfaces in Dairy and Meat Processing Plants. *Czech Journal of Food Science*, 28 (5): 450-461.

Seaman, P., and Eves, A. (2006). The management of food safety-the role of food hygiene training in the UK service sector. *International Journal of Hospitality Management*, 25 (2): 278-296.

Sharif, L. Obaidat, M.M., and Al-Dalalah, M. (2013). Food Hygiene Knowledge, Attitudes and Practices of the Food Handlers in the Military Hospitals. *Food and Nutrition Sciences*, 2013 (4): 245-251.

Simonne, A., Brecht, J., Sargent, S., Ritenour, M., and Schneider, K.R. (2010). Good worker health and hygiene practices: training manual for produce handlers. *Food and Agricultural Sciences' General Collection*, University of Florida IFAS Extension, Florida, pp. 1-11.

Sindi, K., Kirimi, L., and Low, J. (2013). Can Biofortified Orange Fleshed Sweetpotato Make Commercially Viable Products and Help in Combatting Vitamin A Deficiency? Invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013, Hammamet, Tunisia.

Soares, L.S., Almeida, R.C.C., Cerqueira, S.E., Carvalho, J.S., and Nunes, L.I. (2012). Knowledge, attitudes and practices in food safety and the presence of coagulase- positive staphylococci on hands of food handlers in the schools of Camacari, Brazil. *Journal of Food Control*, 27: 206-213.

Sousa, C.P.D. (2008). The Impact of Food Manufacturing Practices on Food borne Diseases. *Brazilian Archives of Biology and Technology*, 51 (4): 815-823.

Susanna, D., Eryando, T. and Indrawani, M.Y. (2011). The level of Escherichia coli contamination in foods and drinks sold at canteens campus. *Medical Journal of Indonesia*, 20 (1): 66-70.

Talaei, M., Holakouie-Naienib, K., Foroushanib, A.R., and Asl, H.M. (2015). Knowledge, attitude and practice of people about foodborne outbreak in Isfahan city, Iran. *Journal of Food Safety and Hygiene,* 1(2): 39-45.

Taylor, E. (2001). HACCP in small companies: Benefit or burden? *Journal of Food Control*, 12 (4): 217-222.

Tedesco, I., and Stathers, T. (2015). Sweetpotato value chains in Kenya: a business opportunity for puree processing and the potential role for commercial fresh root storage. NRI report, February 2015, University of Greenwich, Chatham: UK. 117

Teow, C. C., Truong, V.D., McFeeters, R.F., Thompson, R.L., Pecota, K.V., and Yencho. G.C. (2007). Antioxidant activities, phenolic and β-carotene contents of sweet potato genotypes with varying flesh colors. *Journal of Food Chemistry,* 103:829-838.

Thimoteo, D., Stedefeldt, E., and Rosso, V. (2014). The role of theoretical food safety training on Brazilian food handlers' knowledge, attitude and practice. Food Control, 43 (2014): 167-174.

Todd, E., Michaels, B., Greig, J., Smith, D., and Bartleson, C. (2010). Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 9. Washing and drying of hands to reduce microbial contamination. *Journal of Food Protection*, 73 (10): 1937-1955.

Tolulope, O.A., Zuwaira, I.H., Danjuma, A.B., Yetunde, O.T., Chundung, A.M., and Ayuba, I.Z (2014). Training: a vital tool for improving the knowledge and practice of food safety and hygiene among food handlers in boarding schools in Plateau state. *Journal of Tropical Medicine*, 16(2): 87-92.

Tumwegamire, S., Kapinga, R., Mwanga, R., Niringiye, C., Lemaga, B., and Nsumba, J. (2007). Acceptability studies of orange fleshed sweet potato verities in Uganda. In: proceeding of the 13th ISTRC Symposium, pp.807-813, Kampala, Uganda.

Valero, A., Rodriguez, M., Posada-Izquierdo, G.D., Perez-Rodriguez, F., Carrasco, E., and Garcia-Gimeno, R.M. (2016). Risk Factors Influencing Microbial Contamination in Food Service Centers, Significance, Prevention and Control of Food Related Diseases. Available from: https://www.intechopen.com/books/significance-prevention-and-control-of-food-related-diseases/risk-factors-influencing-microbial-contamination-in-food-service-centers

Vimala B., Nambisan, B., and Hariprakash, B. (2011). Retention of carotenoids in orange-fleshed sweetpotato during processing. *Journal of Food Science and Technology*, 48 (4): 520-524.

Vo, T.H., Lea, N.H., Lea, A.T.N., Minh, N.N.T., and Nuorti, J.P (2015). Knowledge, attitudes, practices and training needs of food-handlers in large canteens in Southern Vietnam. *Journal of Food Control*, 57: 190–194.

Wallin-Carlquist, N., Marta, D., Borch, E., and Radstrom, P. (2010). Prolonged expression and production of *Staphylococcus aureus* enterotoxin A in processed pork meat. *International Journal of Food Microbiology,* 141: 69-74

WHO (2014). Food safety must accompany food and nutrition security. Accessed from http://www.who.int/entity/foodsafety/areas_work/nutrition/Lancetfoodsafety_nov2014.pdf?ua=1 on March 16, 2017 at 1345 hrs.

WHO (2015). Estimates of the Global burden of foodborne diseases; foodborne diseases burden epidemiology reference group 2007-2015. http://www.who.int/foodsafety/publications/foodborne_disease/fergreport/en/ [Accessed December 7, 2016 at 1213 hrs].

Wirtanen, G., and Salo, S. (2007). Microbial Contaminants and Contamination Routes in Food Industry. 1st Open Seminar Arranged by Safoodnet-Food Safety and Hygiene Networking Within New Member States and Associated Candidate Countries; Fp6-022808-200, Espoo, Finland.

Zinedine, A., Brera, C. and Elakhdari, S. (2006). Natural occurrence of mycotoxins in cereals and spices commercialized in Morocco. *Journal of Food Control*, 17 (11): 868–874, 2006

APPENDICES

Appendix 1: Consent form

VOLUNTEER AGREEMENT FORM

Title: Food Safety Knowledge and Hygiene Practices of Orange Fleshed Sweetpotato (OFSP) Puree handlers in Kenya.

General Information about the Research

The study will investigate food safety knowledge and practices of OFSP puree handlers in Kenya.

Possible Benefits, Risks and Discomforts

There are no direct benefits associated from this study immediately, neither are there any risks associated with it. The only inconvenience might emerge from the time you will spend completing the questionnaire. The information gathered from this study will be used for developing a Masters Dissertation.

Confidentiality

Your identity and participation in this study will be kept confidential. The information we will obtain from you will not be shared with anybody, except the study investigators. Your identity remains secret since your personal information will only be designated by a unique participant number. Your name will not appear in any reports or publications resulting from this study. After the is completed, you may request information about the study outcomes.

Voluntary Participation and Right to Leave the Research

Your participation in this study is entirely voluntary. You have the right to refuse participating in the study. You also have the right to stop your participation in the study at any time, even after you have signed the informed consent form. The withdrawal of your consent will not cause any disadvantage or loss of privileges.

VOLUNTEER AGREEMENT

The information above describing the benefits, risks and procedures for the research ‘‘Food safety knowledge and hygiene practices OFSP puree handlers in Kenya’’ has been read and explained to me. I have accepted to give an opportunity to have any questions about the research answered to my satisfaction. I agree to participate as a volunteer.

Date	Name of volunteer	Signature
....	....	....

Appendix 2: Food Safety Knowledge and Hygiene Practices Questionnaire

Questionnaire No: ....

Food Safety Knowledge and Hygiene Practices of Orange Fleshed Sweetpotato Puree Handlers in Kenya

Section 1-Demographic characteristics

1. Gender [] Male [] Female
2. Age [] 18-25 [] 26-35 [] 36-55 [] Above 55
3. Highest Educational level [] Illiterate [] Primary [] Secondary [] Tertiary
4. Length of employment in the food sector (Years) [] Less than 1 [] 1 to 5 [] 6 to 10 []11 to 20 [] Above 20 years
5. Have you received any training on Food safety and hygiene practices? [] Yes [] No

Section 2-Food Safety Knowledge

Statement	True	False	Don't Know
1. Preparation of food disregarding hygiene rules causes food-borne illnesses			
2. Food borne disease is transmitted by food contamination			
3. Food borne disease is transmitted by water contamination			
4. Improper heating of food causes food-borne illnesses			
5. During infectious disease of the skin, it is necessary to take leave from work			
6. Only sick people carry bacteria which causes food poisoning			
7. Microbes are in the skin, nose and mouth of health food handlers			
8. Children, healthy adults, pregnant women and older individuals are at equal risk for food poisoning			
9. Typhoid fever can be transmitted by food			
10. Food production staff should have health check-ups every two years			
11. Contaminated food can be detected by taste			
12. Washing hands before work reduces the risk of food contamination			
13. Working without protective clothing in a factory is sometimes allowed			
14. Using gloves while handling food reduces the risk of food contamination			
15. Eating and drinking in the work place increase the risk of food contamination			
16. Proper cleaning and sanitization of equipment increase the risk of food contamination			
17. Working with jewellery is allowed in a processing plant			
18. Washing equipment with detergent leaves them free of contamination.			

19. Clean is the same as sanitized			
20. Cleaning chemicals and food ingredients should be kept together in one store			
21. Food can be prepared on dirty surfaces/equipment			
22. Cleaning of equipment should always be done at the end of processing			
23. Cross contamination is when microorganisms from a contaminated food are transferred by the food handler's hands or kitchen utensils to another food			
24. Contaminated foods always have some change in colour, odor or taste.			
25. Raw food can be mixed/kept together with processed food			
26. Temperature control is important in storage and processing of safe food			
27. Temperature readings for equipment and other installations like refrigerators should be checked and recorded from time to time			

Section 3-Food hygiene practices

Statement	Always	Sometimes	Rarely	Never
1. Do you wear jewellery and a watch while working?				
2. Do you rub your hands-on face, hair etc. while working?				
3. Do you smoke/chew gum while working?				
4. Do you use detergent whenever you wash your hands				
5. Do you wash your hands with soap after visiting the toilet?				
6. Do you use gloves when you touch or distribute unwrapped foods?				
7. Do you wash your hands before wearing gloves?				
8. Do you wash your hands after using gloves?				

9. Do you wear nail polish when handling food?				
10. Do you wear an apron/PPE while working?				
11. Do you use protective clothing when you touch or distribute unwrapped foods?				
12. Do you wash your hands before touching unwrapped raw foods?				
13. Do you wash your hands before touching unwrapped cooked foods?				
14. Do you wash your hands after touching unwrapped cooked foods?				
15. Do you wipe your hands with your apron/PPE?				
16. Do you clean your working area before food preparation?				
17. Do you check shelf life of foods/ingredients at the time of delivery?				
18. 5 Do you check the packing integrity of foods at the time of dispatch/delivery?				
19. Do you properly clean the food storage area before storing new products?				