Status assessment and roadmap for improvement of food safety management systems in Africa: the case of Tanzania

Jamal Bakari Kussaga

UNIVERSITEIT GENT

FACULTY OF BIOSCIENCE ENGINEERING

For Makighenda, Jalees and Mahreen

Promotors:

Prof. dr. ir. Liesbeth Jacxsens

Department of Food Safety and Food Quality

Faculty of Bioscience Engineering, Ghent University

Prof. dr. ir. Pieternel A. Luning

Food Quality and Design

Department of Agrotechnology and Food Sciences

Wageningen University

Prof. Bendantunguka P.M. Tiisekwa

Department of Food Science and Technology

Faculty of Agriculture

Sokoine University of Agriculture

Dean: **Prof. dr. ir. Guido Van Huylenbroeck**

Rector: **Prof. dr. ir. Anne De Paepe**

Examination Committee Chairman: **Prof. dr. ir. Filip Tack**

Examination Committee Secretary: **Prof. dr. ir. Marijke D'Haese**

Examination Committee: **Prof. dr. ir. Liesbeth Jacxsens** (UGent), **Prof. dr. ir. Pieternel Luning** (Wageningen University), **Prof. Bendantunguka Tiisekwa** (Sokoine University of Agriculture), **Prof. dr. ir. Mieke Uyttendaele** (UGent) and **Dr. Patrick Kamau Njage** (University of Pretoria)

Jamal Bakari KUSSAGA

Status assessment and roadmap for improvement of food safety management systems in Africa: the case of Tanzania

Thesis submitted in fulfilment of the requirements for the degree of Doctor (PhD) in Applied Biological Sciences

Dutch translation of the title:

Onderzoek van status van voedselveiligheidsbeheerssystemen en draaiboek voor hun verbetering in Afrika: de case van Tanzania

To refer to this thesis:

Kussaga, J.B. 2015.Status assessment and roadmap for improvement of food safety management systems in Africa: the case of Tanzania. Thesis submitted in fulfilment of the requirements for the degree of doctor (Ph.D.) in Applied Biological Sciences. Faculty of Bioscience Engineering, Ghent University.

ISBN number: 978-90-5989-831-8

ACKNOWLEDGEMENTS

All praise is due to God, the Almighty, for his blessings to accomplish this work. Various institutions and people have contributed to the successful completion of this PhD thesis. First and foremost my heartfelt appreciation goes to my promotor Prof. dr. ir. Liesbeth Jacxsens for her insight, professional guidance, constructive comments and wavering support during my PhD study. My sincere gratitude also goes to my co-promoters Prof. dr. ir. Pieternel Luning and Prof. Bendantunguka Tiisekwa for their inspirations, invaluable comments, professional guidance and wavering support which made this doctorate thesis possible. Prof. dr. ir Pieternel Luning, I sincerely appreciate your mentorship and supervision for more than eight years. To all my supervisors, your supervision, mentorship and dedication of your time have enabled the achievement of this work. May God, bless you abundantly!

I would like to thank the management of Sokoine University of Agriculture (SUA) for granting me the study leave to pursue my PhD studies in Ghent. My special appreciation also goes to the Heads of Department of Food Science and Technology (Prof Bernard Chove and Prof, John Msuya) for all the facilitations and negotiations to secure the study leave extensions and financial assistance from SUA. Furthermore, I would like to extend my special thanks to the International Foundation for Science (IFS), Sokoine University of Agriculture (SUA), and FP5 European PathogenCombat Project for their financial assistance which made this study possible.

Moreover, my sincere gratitude goes to the staff of accredited National Fish Quality Control Laboratory at Nyegezi in Mwanza (particularly, Mr. Ofred Mhongole, Mrs. Nyambuli Sosthenes, Mrs. Theresia Linus, Mr. Zebedayo Baniga, Mr. Kadashi, Mr. Michael Mhina, Mr. Salum Kisaka and Mr. Steven Lukanga) for their assistance in microbiological sampling and analysis. My heartfelt gratitude also goes to the staff of regional fisheries offices in Mara and Kagera regions for their assistance during the interviews. Besides, my sincere thanks to the Permanent Secretary, Ministry of Livestock and Fisheries Development for granting me a permission to conduct my research in fish and dairy processing companies in Tanzania and utilise the accredited laboratory facilities for microbiological analysis. I would like to extend my sincere gratitude to the management of all fish and dairy processing companies involved in this study for their time and cooperation during the interviews and microbiological sampling.

My PhD journey would not have been possible without initiation from Prof. dr. ir. Roland Verhe and support of Prof. dr. ir. Mieke Uyttendaele and Prof.dr. ir. Frank Devlieghere, from the Department of Food Safety and Food Quality, Ghent University. Moreover, I would like to extend my sincere appreciation to Dr. ir.William Marcelis and Dr. ir. Marjolein Spiegel for their moral support and inspirations at the beginning of this PhD. My special appreciation also goes to my colleagues from the Department of Food Science and Technology, SUA) and Dr. John Thomas Mgonja (Department of Wildlife Management, SUA) for their support.

Furthermore, my special thanks to iAGRI (USAID) management for handling the video conference during my pre-defence. I appreciate the support of IT personnel from Ghent University (Yves De Mol) and iAGRI (Michael) during the pre-defence. My special gratitude also goes to Ariane D'Haese for organising the printing of this thesis.

My heartfelt appreciation also goes to my family, my beloved wife, Mwajabu Dhahabu and children Makighenda-Jasmine, Jalees, and Mahreen for their moral support. However, tiring and difficulty the day might have been, you made my evenings wonderful. You sometimes accepted my absence in your vacations and outings for the sake of this study.

It is not possible to mention all people who in one way or another extended a helping hand to successfully accomplish this study. Sincerely, I thank you all for whatever kind of support offered to make this study successfully. May God Bless You All Abundantly! *Ahsanteni Sana.*

Jamal

21st September 2015, Morogoro

TABLE OF CONTENTS

Table of contents

LIST OF ABBREVIATIONS

List of abbreviations

AFB_1	Aflatoxin B_1
AFIPEK	Kenya Fish Processors and Exporters Association
AGORA	Access to Global Online Research in Agriculture
BRC	British Retail Consortium
BW	Body weight
CAC	Codex Alimentarius Commission
CCP	Critical Control Point
CFU	Colony Forming Unit
CSL	Critical Sampling Location
DDT	Dichlorodiphenyltrichloroethane
DON	Deoxynivalenol
EAC	East African Community
EACM	East African Common Market
ECOL	*Escherichia coli*
EHPEA	Ethiopian Horticulture Producer and Exporters Association
ENTE	*Enterobacteriaceae*
ESADA	Eastern and Southern Dairy Association
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FB_1	Fumonisin B_1
FDA-BAM	Food and Drugs Association-Bacteriological Analytical Manual
FPEAK	Fresh Produce Exporters Association of Kenya
FS	Food Safety
FSA	Food Safety Agency
FSMS	Food Safety Management System(s)
FSMS-DI	Food Safety Management System-Diagnostic Instrument
FVO	Food and Veterinary Organisation of the European Union
G.A.P	Good Agricultural practices
GDP	Gross Domestic Product
GHP	Good Hygiene Practices
GMP	Good Manufacturing Practices
HACCP	Hazard Analysis and Critical Control Points

HSD	Honestly significantly different
ICMSF	International Commission on Microbiological Specifications for Foods
IFS	International Food Standard
ISO	International Organization for Standardization
LFMFP	Laboratory of Food Microbiology and Food Preservation
LGA	Local Government Authority
LIST	*Listeria monocytogenes*
LVFO	Lake Victoria Fisheries Organisation
MAFSC	Ministry of Agriculture, Food Security and Cooperatives
MAS	Microbial Assessment Scheme
MLFD	Ministry of Livestock and Fisheries Development
MOHSW	Ministry of Health and Social Welfare
MRLs	Maximum Residual Levels
NFQCL	National Fish Quality Control Laboratory
OTA	Ochratoxin A
PCA	Plate Count Agar
PRP	Pre-requisite Programme
QA	Quality Assurance
QMS	Quality Management System
RLDC	Rural Livestock Development Cooperation
RTE	Ready-to-eat
SALM	*Salmonella* spp.
SPSS	Statistical Package for Social Sciences
STAPH	*Staphylococcus aureus*
TAHA	Tanzania Horticulture Association
TBS	Tanzania Bureau of Standards
TDB	Tanzania Dairy Board
TFDA	Tanzania Food and Drugs Authority
TFNC	Tanzania Food and Nutrition Centre
TIFPA	Tanzania Industrial Fishing and Processors Association
TVC	Total viable counts
TZS	Tanzania Standards
UFPEA	Uganda Fish Processors and Exporters Association
UHT	Ultra high treated

UNIDO	United Nations Industrial Development Organisation
VEPEAG	Vegetable Producers and Exporters Association of Ghana
VRBG	Violet Red Bile Glucose
WHO	World Health Organisation
ZEA	Zearalenone
ZEGA	Zambian Export Growers Association

RESEARCH OBJECTIVES AND OUTLINE

Research objectives and outline

Introduction

Food safety has become a matter of increasing concern globally (Henson and Jaffee, 2007; Motarjemi, 2014). This is in response to past food crises, like mad cow disease, listeriosis, salmonellosis, and pathogenic *Escherichia coli* contaminations occurring in the agri-food chain (Unnevehr, 2000; Trienekens and Zuurbier, 2008; Motarjemi, 2014; Unnevehr, 2015). Consequently, the most industrialised countries, as major export markets for developing countries have set stringent quality and safety requirements to imported food products (Roth and Rosenthal, 2006; Jongwanich, 2009; Lamuka, 2014). Food importing countries (such as Europe, USA, and Japan) demand exporting countries and their food processing companies to develop inspection systems and food safety management systems (FSMS) based on principles of good practices and Hazard Analysis and Critical Control Point (HACCP) according to the international agreements as defined in the Codex Alimentarius documents (Ropkins and Beck, 2000; Codex Alimentarius Commission, 2003; Trienekens and Zuurbier, 2008; Bagumire et al., 2009a; Lokuruka, 2009). Also, retailers and other trade organisations in importing countries have responded by developing additional (above legal requirements) private quality assurance (QA) standards and other specific requirements to be implemented by all suppliers (Fulponi, 2006; Minten et al., 2009). In the previous decade, food security was the major focus in developing countries including Tanzania, nowadays, there is a shift to improving food safety as significant investment is directed towards food safety assurance (Unnevehr, 2015). In addition, increase in business and consumers' food safety awareness have considerably increased the demand for quality and safer food products in the developing countries' domestic markets (Weatherspoon and Reardon, 2003; Francesconi et al., 2010; Jabbar et al., 2010).

The strict food quality and safety requirements set by importing countries and their retailers, however, pose insurmountable challenges to food exports from developing countries (Giovannucci and Ponte, 2005; Henson et al., 2005; Henson and Reardon, 2005; WB, 2005; Lamuka, 2014). For instance, after the instatement of fish export bans in 1998-2000 several fish exporting companies in Eastern Africa failed to meet the European Union (EU) demands, eventually, they ran out of the business and the rest worked below capacity (Ponte, 2007). As compared to food companies in industrialised countries, the adoption of QA standards and guidelines is still lagging behind (especially to sectors for the domestic market) in most developing countries (Jaffee et al., 2005; Trienekens and Zuurbier, 2008). Moreover, exported food products like fish, fruits and vegetables are still quarantined and or rejected over time (Ababouch et al., 2005; Aksoy and Beghin, 2005; Ababouch, 2006; Rapid Alert System for Food and Feed, 2009, 2014). The Tanzanian food industry is among the largest branches of industries contributing largely to the economic development of the country (Ruteri and Xu, 2009); it accounts for about 34% of manufacturing firms and 50% of total formal employment in the manufacturing industry (Confederation of Tanzania Industries, 2013). Fish and dairy sectors are important segments in the Tanzanian food industry, which is made up of mainly micro-, small-, medium-, and large-scale food processing companies. The micro- and small-scale companies (about 97% of total companies in Tanzania) operate in an informal sector and use labour intensive and basic technology, whereas medium- and large-scale processors operate in a formal sector and use more modern technologies (Ruteri and Xu, 2009; Confederation of Tanzania Industries, 2013). The fish industry is the major player in the food export market, contributing to 1.4% of Gross Domestic Product, GDP (United Republic of Tanzania, 2011b, 2013). Dairy industry is domestic market oriented, contributing to about 5% GDP (Kurwijila and Bennett, 2011). The traditional production system (agro-pastoral, pastoral and mixed farming using traditional animal husbandry) contributes to 70% of the total milk (1.85 billion litres/annum) and the commercial production system (large-scale enterprises like commercial ranches and small-scale units using modern methods of animal husbandry and production) accounts for the rest (Kaijage, 2004; RLDC, 2009; Njombe et al., 2011; United Republic of Tanzania, 2013). More than 90% of the raw milk is sold through the informal market (Kaijage, 2004; RLDC, 2009) of which 38-45% of milk is directly sold to consumers, without cooling or pasteurisation (Anonymous, 2007). The rest (10%) of the milk goes through the formal market chain and some access the dairy processing companies.

Although food processing companies, particularly those in the fish sector, have implemented the principles of HACCP and other stakeholders' requirements into their food safety management systems, they still experience export notifications and rejections of their products (Musonda and Mbowe, 2002; Ponte et al., 2007; Geheb et al., 2008; Njiru et al., 2008; Rapid Alert System for Food and Feed, 2009, 2014). Likewise, domestic market oriented companies, especially in the dairy sector, experience various food safety problems (e.g., microbiological and chemical contamination, spoilage and adulteration) with dairy products (Kurwijila and Boki, 2003; Kivaria et al., 2006; Kivaria et al., 2007; Swai and Schoonman, 2011). Meat production sector is also implicated with various food safety scares including anthrax, brucellosis and rift valley fever (Kurwijila et al., 2011). In 2007, rift valley fever affected more than 1000 people and killed more than 300 people after either handling or consuming contaminated meat (Breiman, 2008; Kurwijila et al., 2011). Given, the poor reporting systems in the developing countries including

Tanzania, the food safety problems reported are a fraction of all the food safety problems occurring in the country.

In spite of the observed food safety problems (which are still occurring) in Tanzanian food industry (Kivaria et al., 2006; Ruteri and Xu, 2009; Kurwijila and Bennett, 2011; Swai and Schoonman, 2011; Rapid Alert System for Food and Feed, 2014), studies to assess the design and set-up of FSMS in Tanzanian food industry are still limited. Moreover, information on factors influencing performance of FSMS in fish and dairy processing companies in Tanzania is not adequate. Food companies, particularly the domestic market oriented, lack expertise and proper information on how they can design their systems to improve food safety to meet the domestic market (with increasing food safety demands due to urbanisation and rise of middle income consumers) and enable access to the regional (East African Common Market) and international export markets (like EU) with more stringent food safety demands. Although, export oriented companies are perceived to have well-designed FSMS as they have managed to export to the most stringent markets in the world like the EU, the status of their FSMS have not been extensively analysed and it is not well-known in which aspects the domestic market oriented companies differ from the export market focused companies. This limits the opportunities of food companies to use the experience of other (best performing) companies to improve their systems.

Typical food production chains involve various players including primary producers, food processors, market/retailers, customers, sector/branch organisations and government (food control organisations). Any food safety problem in one stage of the food supply chain could affect the entire chain. Thus, assessment of food safety problems could be better approached in a chain perspective including the primary producers and food processors (micro level), sector organisations (meso level) and government (macro level). However, for the scope of this study, only the micro level (i.e. industrial processing level) will be considered. Milk and fish processing sectors have been selected in this study because they are comparable in a way; as both sectors deal with high-risk raw materials, product, and production processes. However, dairy sector focuses on the domestic market (with potential to export), while the fish sector is export market oriented. In comparison to other food processing sectors, these sectors have many industrial processing companies in Tanzania. Compared to other domestic market focused sectors (e.g. meat sector), the dairy sector is well-developed with several processing companies across the country. The purpose of conducting this study was therefore, to address some of the issues highlighted above.

›nceptual framework and research objectives

ıe overall objective of this study was to gain an understanding on the underlying factors causing ısufficient performance of food safety management systems in fish (export oriented) and dairy (domestic ıarket oriented) processing companies in order to develop a roadmap for improvement of these systems ı Tanzania. To achieve this overall objective the specific research questions were defined and the study vas organised into seven chapters (Figure 0.1):

Chapter 1 addresses a specific research question "What are the characteristics of food production sectors and the food safety legal framework in Tanzania?" The chapter therefore, provides an overview of characteristics of the food production chain and the legal framework for food safety in Tanzania. It also discusses the principles of the diagnostic tools, particularly, the food safety management systems-diagnostic instrument and microbiological assessment scheme, which were used in the empirical studies to measure the status of food safety management systems.

Chapter 2 addresses a specific research question "What factors contribute to deficiencies in food safety management systems and what are the opportunities for improvement of these systems in African food industries?" The chapter therefore, reviews the hurdles and opportunities in food safety management systems performance in the broader African food industry. It focuses on assessment of safety status of African food products and analysis of food safety management systems performance and context factors to identify deficiencies in current systems and possible intervention strategies for improvement to enable African countries provide safe food to both local and (inter) national markets. In this chapter, the food safety management systems-diagnostic instrument was used to systematically review the available literature.

Chapter 3 addresses specific research questions "What is the current performance status of food safety management systems, and what are the opportunities for improvement towards more effective food safety management systems of dairy processing companies delivering to the local market?" This chapter contains empirical findings on the performance of current food safety management systems in Tanzania. The assessment by using the food safety management systems-diagnostic instrument provided an insight into the system output and performance of core control and assurance activities in twenty-two dairy processing companies in view of their context riskiness. In addition, the actual microbiological assessment was also conducted in one company to get deeper insights into the actual microbiological performance of the system.

Chapter 4 addresses specific research questions "What is the current performance status of food safety management systems, and what are the opportunities for improvement towards more effective food safety management systems in fish processing and exporting companies in Tanzania?" The chapter provides empirical findings on the current performance of food safety management systems of fish processing companies in Tanzania. The food safety management systems-diagnostic instrument was used to assess the performance of food safety management systems in fourteen fish processing companies delivering for the export market.

Chapter 5 addresses a specific research question "What is the actual microbiological performance of current hazard analysis and critical control point-based food safety management systems and points of improvement towards effective systems in the fishery sector?" This chapter enlightens on the actual microbiological output of a hazard analysis and critical control point-based food safety management systems of a fish exporting company in Tanzania. A combined assessment using the food safety management systems-diagnostic instrument and microbiological assessment scheme was applied.

Chapter 6 addresses a specific research question "What are the causes of the differences in performance of food safety management systems between the export and local market oriented companies in Tanzanian food industry?" This chapter provides a comparison in current performance of food safety management systems of fish (i.e. export oriented) and dairy companies (i.e. local market oriented). The study provided an understanding on the underlying causes of the differences in performance of current food safety management systems of export and local market oriented companies, which could be used as input for the development of the roadmap towards more effective systems in Tanzanian food industry.

Chapter 7 provides general discussions, conclusions and future perspectives. It further includes the principles used to design the generic roadmap (which considers managerial and technological aspects) for improvement of existing food safety management systems in Tanzania. The principles of the food quality relationship model and improvement cycle were used to develop the roadmap for improvement towards more effective food safety management systems in fish and dairy processing companies. Other food production sectors could use the generic roadmap to improve their respective FSMS. Figure 0.1 shows the relation between the different chapters of this work.

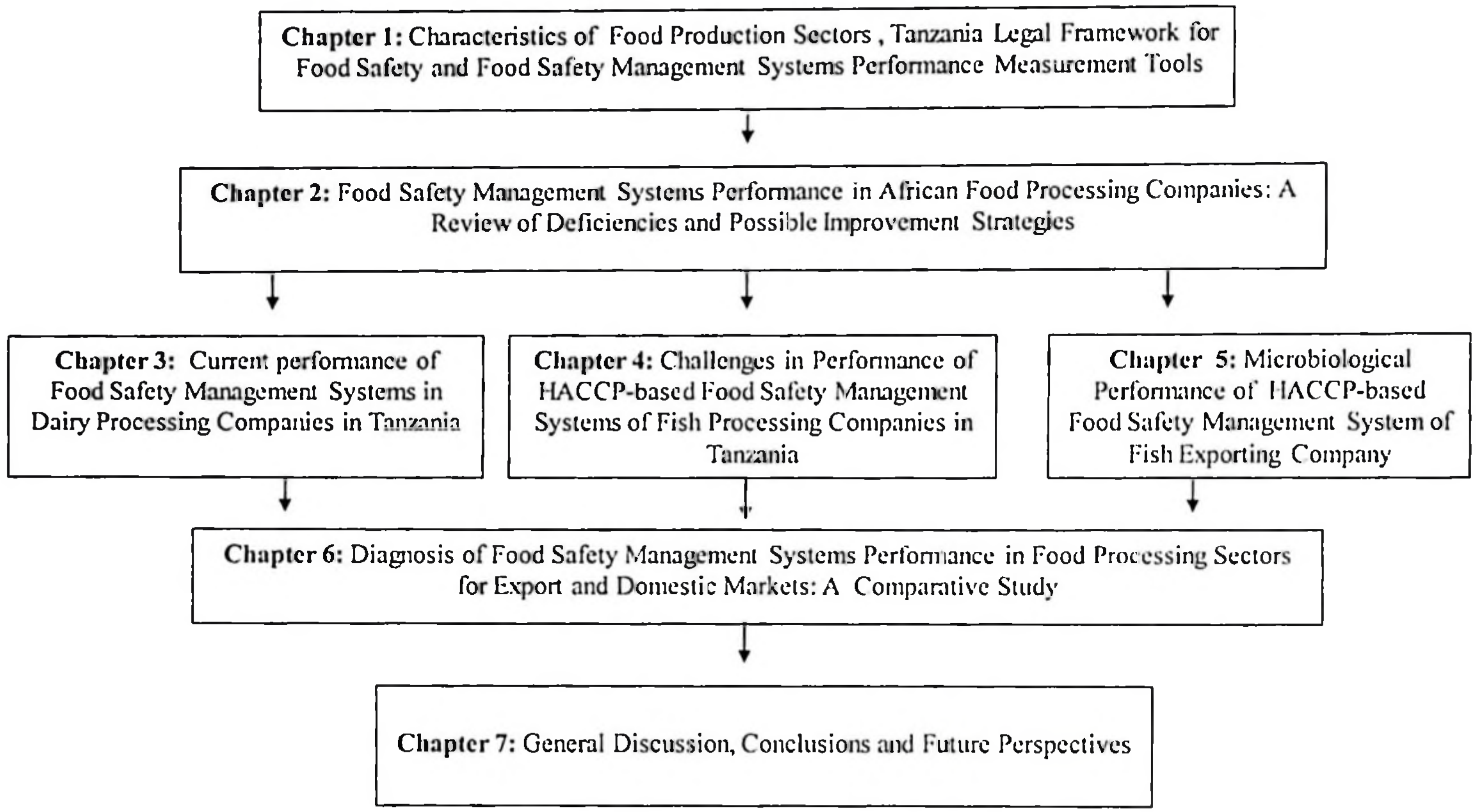


Figure 0.1. The outline of this study

SUMMARY - SAMENVATTING

Summary

Chapter 1 reviews various literature sources to provide an overview of the characteristics of food production sectors and the legal framework for food safety in Tanzania and tools used to measure performance of food safety management systems in the food industry. It was found that Tanzania's economy depends on agriculture; the manufacturing sector being largely agro-based and composed of micro- and small-scale enterprises. Majority of the food companies target the domestic market, especially, the dairy sector, while a few sectors like fish and horticulture produce for the export market. The current food laws and regulations are not yet adequate and well enforced to provide maximum protection to consumers. Besides, there is no national food safety policy as yet. Several institutions are involved in the food control without proper coordination and harmonisation of responsibilities. Furthermore, application of best practices and hazard analysis critical control point principles is not mandatory to food sectors serving the domestic market, limiting their use. This situation could contribute to food safety problems (including microbiological and chemical contamination and foodborne diseases) along the local and export food-value chains. Lastly, the chapter highlights also on the scientific tools, the food safety management system-diagnostic instrument and microbiological assessment scheme, developed by various researchers which were further used in this study.

Chapter 2 provides a broad overview of the deficiencies and opportunities for improvement of food safety management systems of the African food industry. Several literature sources were consulted to provide insights in food safety status of African food products, deficiencies of current food safety management systems, hurdles due to context characteristics and possible improvement strategies. Literature on microbiological and chemical safety of various products including fruits and vegetables, fish, meat, dairy and cereals were analysed to get insights in the current safety status of African food products. It was found that microbiological and chemical contamination exceeded the legal limits in most of the products targeted for export and local markets in the reviewed reports. Analysis of the deficiencies of food safety management systems in the reviewed reports revealed that the majority of core control and assurance activities were not yet developed, whereas for the ones developed (i.e. export oriented and large-scale companies), many were at basic level. The hurdles due to context characteristics in the reviewed reports were observed at government (due to poor legal framework for food safety), sector/branch organisations (lack of sector organisations and guidelines), market/retail (inadequate food safety demands), and company levels (poor workforce quality, high dependency on chain actors, stakeholders' conflicting demands) which affect performance of food safety management system in Africa. Lastly, measures for improvement were proposed at government (strengthen the national legal framework for food safety, formation of accreditation bodies and food safety education at all levels);

sector/branch organisations (formation of sector guidelines and recommended use of traceability systems and auditable standards), market/retail (private certification and price premiums, and expertise support) and company levels (technological innovations in hygienic design of equipment and facilities, set-up assurance activities, and creating supportive administrative structures). These measures were used as inputs for the development of generic roadmap for improvement of FSMS in Tanzanian food industry.

Chapter 3 applied the food safety management system-diagnostic instrument to analyse the set-up and operation of food safety management system (control and assurance) activities in view of system output and context riskiness in 22 dairy processing companies in Tanzania. Hierarchical cluster analysis with the furthest neighbour and squared Euclidean method was used to analyse data; then, Kruskal Wallis Non Parametric test was applied to determine the significant differences among the clusters. Three clusters of companies differing in levels of set-up and operation of the FSMS and system output, but all operated in a similar moderate-risk context were identified. Cluster IA and IB had moderate system output, whereas cluster II had poor-moderate level. The microbiological assessment scheme was applied in one company to get deeper insight on the actual microbiological safety output of the current systems of dairy processing companies. Six indicator micro-organisms for faecal hygiene (*Escherichia coli)*, personal hygiene (*Staphylococcus aureus*), pathogens (*Listeria monocytogenes*, *Salmonella* spp.) and general process hygiene (*Enterobacteriaceae* and total viable counts) were analysed in nine critical sampling locations along the cultured milk production line. The actual microbiological assessment indicated contamination of products, food contact surfaces, and hands of the personnel with indicator microorganisms of faecal hygiene (*Escherichia coli*), personal hygiene (*Staphylococcus aureus*), and pathogens (*Listeria monocytogenes*) beyond the set limits. A two-stage intervention approach was proposed to enable commitment and sustainable improvement on the longer term. In the first stage, less demanding interventions (in terms of expertise/technology, financial and human resources) were recommended, whereas, high demanding measures (expensive and time consuming) were suggested in the second stage. Similarly, these interventions were used to develop the generic roadmap for improvement of food safety management systems in Tanzanian food industry.

Chapter 4 assesses the food safety management system output in view of the current design and operation of food safety management system activities and context riskiness of these systems in order to identify the opportunities for improvement of the risk-based food safety management systems in the fishery sector. The diagnostic instrument was applied to assess the design and operation of core control and assurance activities in view of context riskiness and system output in 14 fish processing companies in Tanzania. Hierarchical cluster analysis with the furthest neighbour and squared Euclidean method revealed 2 clusters (cluster I and II) differing in system output but with similar level of food safety management systems (average level) and context riskiness (moderate-risk). In overall, cluster I companies had good system output while cluster II had moderate to good output. However, majority of the fish companies needed improvement of their FSMS to higher levels and reduce the context riskiness to assure good system output. A two-phase intervention approach was also proposed to implement the suggested measures in the fish companies. The less expensive interventions (like sanitation procedures, recruitment of skilled personnel on permanent basis) that can be implemented in the short- term are recommended for phase I. More expensive interventions (such as setting-up assurance activities, hygienic design of equipment and facilities, automation of the production process and sanitation) to be adopted in the long-term are proposed for phase II. These measures were also used as inputs to develop the generic roadmap for improvement of food safety management systems in Tanzanian food industry.

Chapter 5 describes a combined assessment by the diagnostic instrument and microbiological assessment scheme to assess microbiological safety output of a risk-based food safety management system of a fish exporting company. The food safety management system diagnosis indicated average food safety management system activities which operated in moderate-risk context level but with good system output. The actual microbiological assessment involved 7 microbiological indicators for pathogens (*Vibrio cholerae*, *Listeria monocytogenes* and *Salmonella* spp.), faecal hygiene (*Escherichia coli*), personal hygiene (*Staphylococcus aureus*), and general process hygiene (*Enterobacteriaceae* and total viable counts) analysed in 12 critical sampling locations along the frozen Nile perch fillets processing line. *Enterobacteriaceae* and total viable counts exceeded regulatory limits in raw materials and working tables, whereas *Staphylococcus aureus* on operator's hands were beyond the general microbiological guidelines in the fish industry. Among the intervention measures for improvement included hygienic design, specific production/sanitation procedures and independent validation, process automation and change in personnel recruitment criteria. Likewise, the proposed measures were used to develop roadmap for improvement in the Tanzanian food industry.

Chapter 6 involves a comparative assessment of the design and operation of food safety management system activities between the domestic oriented companies (dairy sector) and export oriented companies (fishery sector). The food safety management system-diagnosis data from Chapter 3 (dairy sector) and Chapter 4 (fishery sector) were evaluated to identify possible causes in the differences in the systems performance between the two sectors. Fish companies had average food safety management system and medium-good system output, while dairy companies indicated basic-average food safety management systems and moderate system output. However, the food safety management systems of both sectors operated in moderate-risk context. This illustrates that both sectors need specific measures to improve their food safety management systems and reduce the risk-level of the context to guarantee food safety.

The measures to reduce the level of context riskiness included putting high and specific requirements on operators' competence level, describing all activities in standard operating procedures, and setting requirements on product use by major customers. The measures on the design and operation of food safety management systems involve use of industrial cooling facilities, hygienic design, strict raw material control, specific sanitation programmes, and analysis of critical control point. Dairy companies need to set-up assurance activities including validation, verification, documentation, and record-keeping system. Enabling regulatory environment (like national food safety policy, proper enforcement of laws and regulations) has to be established for the entire food industry (including the domestic market oriented sectors), to improve the design and operation of current core control and assurance activities and guarantee food safety.

Chapter 7 brings about the general discussion, roadmap for improvement of food safety management systems in the Tanzanian food industry, conclusions and recommendations for further research. Two concepts, the food quality relationship model and the improvement cycle were used to design the roadmap. The food quality relationship describes food quality as a function of food behaviour and human behaviour. Food behaviour is dependent on dynamic product properties (food dynamics) and the applied technological conditions to stabilise the properties. Human behaviour is dependent of the dynamic individual decision-making of employees (human dynamics) and the applied administrative conditions to direct this behaviour (setting procedures and working practices in place). The improvement cycle involves three steps: (1) mapping the problem area (collecting information about the problem and documentation), (2) analysing the problem area (identification of causes and effects), and (3) redesigning (development and implementation of solutions). Based on the food quality relationship model, three levels of increasing improvement efforts were defined; 1) changes in product and people behaviour, 2) changes in technological process conditions and administrative conditions, and 3) changes in the technological infrastructure and organisational arrangements. Fish and dairy processing companies could use the generic roadmap to derive their company specific roadmaps towards more effective food safety management systems. Although this study was exclusively conducted in fish and dairy sectors, the proposed generic measures for improvement could be also used by other food production sectors. However analysis of other sectors like fruits and vegetables, meat and poultry, and hospitality industry would identify specific deficiencies in their food safety management systems and tailor-made measures for each sector could be proposed to ensure supply of safe products for the entire nation. Moreover, this study focused on the techno-managerial approach of food safety management systems, however, the human factor, the so called 'food safety climate or culture' could have an important role in the final

performance of a food company. Therefore, future studies could take into consideration the food safety climate factor.

Samenvatting

Hoofdstuk 1 omvat een literatuurstudie waarin de eigenschappen van voedingsindustrie, export gerichte versus lokaal georiënteerde bedrijven, het wettelijk kader van voedselveiligheid en meetinstrumenten om de status en de performantie te evalueren van voedselveiligheidsborgingssystemen (VVBS) worden besproken in de Afrikaanse en Tanzaniaanse context. Er werd vastgesteld dat de Tanzaniaanse economie vooral afhangt van landbouwactiviteiten, de verwerkende sector vooral een agro-voedselketen is bestaande uit micro- of kleinschalige bedrijfjes. De meerderheid van de bedrijven actief in de zuivelsector zijn gericht op afzet op de lokale markt, terwijl de visverwerkende en groenten en fruit verhandelende bedrijven eerder gericht zijn op export. De aanwezige wetgevingen in Tanzania betreffende hygiëne en veiligheid van levensmiddelen zijn niet voldoende uitgebouwd en beschermen de consumenten onvoldoende. Een echt voedselveiligheidsbeleid ontbreekt en de meeste wetgevingen zijn niet up-to-date. Verschillende instellingen zijn betrokken bij de voedselcontrole en inspecties in de agro-voedselketen zonder een coherentie afstemming van verantwoordelijkheden en harmonisatie van hun werking. Verder werd vastgesteld dat de toepassing van goede praktijken en het uitwerken van HACCP principes niet wettelijk vereist worden voor deze bedrijven die aan de lokale markten leveren. Deze situatie geeft mogelijks aanleiding tot risico's met betrekking tot microbiologische en chemische contaminaties en voedsel gerelateerde toxi-infecties zowel voor levensmiddelen bestemd voor de lokale markt alsook voor producten die geëxporteerd worden. Tenslotte worden in dit hoofdstuk diagnostische tools en een microbiologisch staalnameplan beschreven, die verder in dit doctoraat worden gebruikt voor het meten en evalueren van geïmplementeerde goede praktijken en HACCP in de Tanzaniaanse vis- en zuivelverwerkende bedrijven.

Hoofdstuk 2 beschrijft de tekortkomingen en opportuniteiten voor het verbeteren van voedselveiligheidsborgingssystemen (VVBS) aanwezig in de Afrikaanse voedingsindustrie. Deze borgingssystemen omvatten goede praktijken zoals temperatuursbeheersing, persoonlijke hygiëne, ongediertecontrole etc. en de HACCP principes ter bewaking van het productieproces. Een systematische literatuurstudie werd uitgevoerd zoekend naar informatie betreffende de voedselveiligheidsstatus van producten aanwezig op de Afrikaanse markt, tekortkomingen in de huidige VVBS, barrières in de bredere context van de bedrijven zoals wetgevend kader en relaties in de keten alsook mogelijke verbeterstrategieën. Literatuur betreffende de microbiologische en chemische gevaren van verschillende levensmiddelen zoals groenten en fruit, vis, vlees, zuivel en producten gebaseerd op granen werd nagegaan om inzicht te krijgen in de huidige status van veiligheid van Afrikaanse levensmiddelen. Er werd teruggevonden in de onderzochte rapporten dat vele producten (wettelijke) limieten overschrijden, limieten zowel voor de lokale markten als voor de exportmarkten naar Europa. Analyse van de tekortkomingen in de VVBS in de onderzochte rapporten toonde aan dat de meeste van de controle maatregelen (zoals temperatuursbeheersing, waterkwaliteit, etc.) en de borgingsactiviteiten (zoals interne audit, staalname, validatie en verificatiestudies) nog niet ontwikkeld zijn in de Afrikaanse voedselverwerkende bedrijven, enkel in bedrijven die gericht zijn op de exportmarkt alsook bij grote bedrijven zijn deze aanwezig maar dan eerder op een basis niveau. Geïdentificeerde barrières vanuit de context van de bedrijven zijn terug te vinden op niveau van de overheden (aanwezigheid van zwak wettelijk kader), niveau van sectororganisaties (afwezigheid van sectororganisaties en richtlijnen vanuit sectororganisaties), markt/distributie (onvoldoende eisen met betrekking tot voedselveiligheid),bedrijven zelf (laag niveau van werknemers, hoge afhankelijkheid van leveranciers, tegenstrijdige vereisten tussen diverse stakeholders), deze factoren beïnvloeden de ontwikkeling van VVBS in Afrikaanse bedrijven. Tenslotte werden maatregelen voor de verbetering van VVBS in kaart gebracht op basis van de literatuurstudie oa. op niveau van de overheid door nationale wetgeving op te stellen, organisatie van certificatie-organisaties en bredere voedselveiligheidsopleiding op verschillende niveaus in overheidsinstellingen, op niveau van sectororganisaties werd het opstellen van richtlijnen/gidsen vooropgesteld, alsook de introductie van traceerbaarheidssystemen, en haalbare standaarden, op niveau van demarkt/distributie de ontwikkeling van private certificeringsystemen en correcte prijzen en op niveau van een voedingsbedrijf werden vooral technologische innovaties zoals hygiënisch ontwerp van machines en apparatuur, opstellen van borgingsactiviteiten en het ontwikkelen van ondersteunende administratieve structuren. Deze maatregelen werden later gebruikt in hoofdstuk 7 voor de ontwikkeling van roadmaps voor de verbetering van VVBS in de Tanzaniaanse voedingsindustrie.

In **Hoofdstuk 3** werd gebruik gemaakt van bestaande diagnostische tools om het ontwikkelen en implementeren van VVBS in 22 zuivelverwerkende bedrijven in Tanzania te evalueren. Hiërarchische clusteranalyse met de verste buur- en kwadraat Euclidean methode werd gebruikt om de verkregen data te analyseren, gevolgd door Kruskall Wallis Non parametric testen om significante verschillen tussen de clusters te identificeren. Drie clusters met bedrijven verschillend in hun niveau van ontwikkeling en uitvoeren en hun uiteindelijk niveau van systeemuitkomst maar allen werkend in dezelfde hoog risico context werden geïdentificeerd. Cluster IA en IB waren gekenmerkt door een gemiddelde systeemuitkomst, terwijl cluster II slechts een laag-gemiddeld niveau behaalde als systeemuitkomst. Een systematisch microbiologisch analyseschema werd toegepast in één bedrijf om meer inzicht te krijgen in de verwerkelijke microbiologische besmetting doorheen een productieproces. Zes micro-organismen werden geanalyseerd voor fecale besmetting (*Escherichia coli, Enterobacteriaceae*), persoonlijke hygiëne (*Staphylococcus aureus*), pathogenen (*Listeria monocytogenes, Salmonella* spp.) en algemene processhygiëne (*Enterobactericeae* en totaal kiemgetal) op negen plaatsen doorheen het productieproces. Bij de werkelijke microbiologische doorlichting van het bedrijf werden zowel productstalen, voedselcontactoppervlakken en handstalen van het personeel geanalyseerd en indicatoren voor fecale besmetting (*E. coli*), persoonlijke hygiëne (*S. aureus*), en pathogenen (*L. monocytogenes*) werden teruggevonden in hogere waarden dan de gebruikte limieten voor de beoordeling van de microbiologische stalen. Een twee-stap interventie aanpak werd voorgesteld om betrokkenheid en duurzame verbetering op langere termijn te bereiken in deze sector. In het eerste stadium, minder vereisende interventies (meer bepaald betreffende expertise, nodige technologie, financiële en vereisten naar personeel toe) warden gesuggereerd, terwijl meer eisende aanbevelingen (dit wil zeggen duurder en meer tijdrovend) in een tweede fase werden vooropgesteld. Deze interventies werden verder in hoofdstuk 7 ook gebruikt om een eerder generieke roadmap op te stellen voor de Tanzaniaanse voedingsindustrie.

Hoofdstuk 4 onderzoekt de uitkomst van een voedselveiligheidsborgingsysteem ten opzichte van de opzet en het uitvoeren van voedselveiligheidsborgingsactiviteiten, het risicoprofiel van de bedrijven om opnieuw opportuniteiten in voedselveigheidsborgingssytemen en HACCP principes in de verwerkende vissector in Tanzania te identificeren. Het diagnostische instrument werd toegepast bij veertien visverwerkende bedrijven en zo werd de context-risico, de opgezette controle-activiteiten, de borgingsactiviteiten alsook hun bereikte uitkomst. Hiërarchische cluster analyse werd uitgevoerd met de verste buur- en kwadraat Euclidean methode kon twee clusters aantonen (cluster I en II), verschillend in systeemuitkomst maar hun VVBS was op een gelijkaardig niveau (gemiddeld niveau) alsook hun context-risico (gemiddeld risiconiveau). In het algemeen had cluster I een goede systeemuitkomst terwijl cluster II eerder gemiddeld tot goed scoorde. De meerderheid van de visverwerkende bedrijven had nood aan verbeteracties om hun VVBS tot een hoger en meer performant niveau te brengen alsook de context-risico te verlagen en aldus tot een betere systeemuitkomst te komen. Een twee-stap aanpak werd hier ook voorgesteld om bijkomende maatregelen te implementeren in de visverwerkende bedrijven. Minder dure interventies (zoals reinigingsprocedures, aannemen van ervaren en getraind personeel op een permanente basis) die kunnen worden geïmplementeerd op korte termijn warden aanbevolen als stap 1. Meer dure interventies (zoals opzetten van borgingsactiviteiten als een staalnameplan, hygiënisch ontwerp van machines en afdelingen, automatisatie van productie en reiniging) warden onder de tweede stap gezet. Deze interventies werden verder in hoofdstuk 7 ook gebruikt om een eerder generieke roadmap op te stellen voor de Tanzaniaanse voedingsindustrie.

Hoofdstuk 5 beschrijft het gecombineerd onderzoek door middel van de diagnostische tools met een microbiologisch staalnameplan om de microbiologische veiligheid als uitkomst van een op HACCP gebaseerd VVBS in een visexporterend bedrijf na te gaan. De VVBS diagnostische tools toonden een gemiddeld niveau van de aanwezige controle- en borgingsactiviteiten aan die in een gemiddeld risico-volle context opereren en resulterend in een goede systeemuitkomst.De microbiologische staalname omvatte de opvolging van zeven organismen (*V. cholerae, L. monocytogenes* en *Salmonella* spp.), fecale hygiëne indicatoren (*Enterobacteriaceae*and*E. coli*), indicator voor persoonlijke hygiëne (*S. aureus*), en algemene processhygiëne (*Enterobactericeae* en totaal kiemgetal) geanalyseerd in twaalf staalnameplaatsen doorheen het productieproces van diepgevroren Nijlbaars filets. *Enterobacteriaceae* en totaal kiemgetal overschreden de gestelde limieten voor grondstoffen en contactoppervlakken, terwijl *S. aureus* besmetting op de handen van de operatoren boven de microbiologische richtlijnen voor de visindustrie werden teruggevonden. Ook hier kunnen terug interventies gesuggereerd worden zoals hygiënisch ontwerp, specifieke productie en reinigingsprocedures, en onafhankelijke validatie van het proces, procesautomatisatie en een wijziging in de personeelsrecruteringsvereisten. Ook deze verbeteracties werden finaal in hoofdstuk 7 opgenomen om de eerder generieke roadmaps op te stellen.

Hoofdstuk 6 omvat een vergelijkende studie in de opzet en werking van controle- en borgingsactiviteiten tussen bedrijven gericht op de lokale markt (zuivelbedrijven) en exportgerichte bedrijven (visverwerkende sector). De data van het diagnostisch instrument uit hoofdstuk 3 en 4 werden samen geanalyseerd om deze vergelijking te maken.Visverwerkende bedrijven hadden een VVBS op gemiddeld niveau en een gemiddelde tot goede systeemuitkomst. Terwijl zuivelverwerkende bedrijven eerder een basis tot gemiddeld VVBS hadden, en een gemiddelde systeemuitkomst. Niettegenstaande beide sectoren in een gemiddeld tot risico-volle context werken. Deze bevindingen illustreren dat beide sectoren nood hebben aan specifieke maatregelen om hun VVBS te verbeteren en het risico-niveau van de context te verlagen. Maatregelen die de context risico-niveau kunnen verlagen zijn eisen stellen aan het niveau van de operatoren in de bedrijven, alle activiteiten en werkmethodieken vastleggen in procedures, alsook eisen stellen met afnemers inzake voedselveiligheid. Maatregelen betreffende de controle-activiteiten in het VVBS zijn oa. het gebruik van industriële koelingsinstallaties, hygiënisch ontwerp, strikte controle op grondstoffen, reinigingsprogramma's, en de correcte analyse van kritieke controlepunten. De zuivelverwerkende bedrijven hebben ook nood aan de ontwikkeling van borgingsactiviteiten zoals validatie van hun proces, verificatie op goede werking van het VVBS, documentatie en registratiebeheer. Een wettelijk kader (zoals de aanwezigheid van een nationale competente controle-organisatie, effectieve implementatie van hygiëne- en voedselveiligheidswetgeving) is noodzakelijk voor de ganse voedingsindustrie zowel voor exporterende bedrijven als bedrijven met bestemming de lokale markten om de VVBS's alsook de veiligheid van levensmiddelen te verbeteren.

Hoofdstuk 7 bevat de algemene discussie, roadmap voor verbetering van VVBS in Tanzania, de conclusies en verdere perspectieven voor onderzoek. Twee concepten, namelijk 'voedselkwaliteit relatiemodel' en 'verbetercirkel' werden toegepast voor de uitwerking van de roadmap. Het voedselkwaliteit relatiemodel beschrijft voedselkwaliteit als een functie van eigenschappen van het voedsel en van het menselijk gedrag. De eigenschappen van het voedsel op zich zijn afhankelijk van de voedseleigenschappen (vb. samenstelling) en de gebruikte technologie om het voedsel te stabiliseren (vb. pasteurisatie, gebruik van additieven). Menselijk gedrag is afhankelijk van de individuele beslissing van de werknemers in een bedrijf en de gebruikte administratieve condities om dit gedrag te sturen (vb. opzetten van procedures en werkmethodiek). De verbetercirkel omvat op zich drie stappen (1) het probleem in kaart brengen (door informatieverzameling betreffende het probleem alsook de documentatie ervan), (2) analyseren van het probleem (identificatie van oorzaken en gevolgen), (3) herontwerpen (ontwikkeling en implementatie van oplossingen). Op basis van de voedselkwaliteit relatiemodel, drie niveaus van toenemende verbeteracties warden gedefinieerd: (1) verandering in product en menselijk gedrag, (2) verandering in de technologische procescondities en administratieve condities, (3) verandering in de technologische processen en organisatie van het bedrijf. De vis- en zuivelverwerkende bedrijven kunnen deze generieke roadmaps gebruiken om hun bedrijfsspecifieke roadmap op te stellen en zo naar een meer effectief VVBS te komen. Alhoewel in deze studie gebruik gemaakt werd van zuivel- en visverwerkende bedrijven kunnen de generieke maatregelen ook door andere sectoren en buiten Tanzania gebruikt worden. Bijvoorbeeld de groente- en fruitverwerkende industrie, vlees- en gevogelte-industrie, alsook de toeristische sectoren zoals restaurants en catering zouden deze kunnen gebruiken om de voedselveiligheid en hygiëne uiteindelijk te verbeteren. Deze studie focusseerde vooral op de 'techno-managerial' aanpak van een VVBS maar ook de menselijke factor in een bedrijf mag niet onderschat worden, de zogenaamde 'voedselveiligheidscultuur' of '-klimaat' kan ook een belangrijke rol spelen in de uiteindelijke veiligheid en hygiëne van geproduceerde levensmiddelen. Dit kan aanleiding zijn tot verder onderzoek inzake de performantie van voedselveigheidsbeheerssytemen in voedingsbedrijven.

CHAPTER 1

Literature review: Characteristics of food production sectors, Tanzania legal framework for food safety, and food safety management systems performance measurement tools

Chapter 1. Literature review: characteristics of food production sectors, Tanzanian legal framework for food safety and food safety management systems performance measurement tools

1.1. Characterisation of food production sectors in Tanzania

1.1.1 Agriculture

Agriculture is the mainstay of Tanzania's economy; contributing to about half of the national income and three quarters of merchandise exports, and employing more than 74% Tanzanians (United Republic of Tanzania, 2011a, 2013). The major food crops produced include cereals (maize, paddy, sorghum, millets, barley, and wheat), pulses and legumes (beans, soy beans, pigeon peas, cowpeas, and peanuts), root crops (cassava, yams, and potatoes), fruits and vegetables, oil seeds (sunflower and sesame), banana and plantains (United Republic of Tanzania, 2011a, 2013). The major cash crops comprise of tea, coffee, sugar, cashew nuts, cloves, cotton, pyrethrum, tobacco, and sisal (United Republic of Tanzania, 2011a, 2013). For the year 2012, the quantities of maize, rice, sorghum and millets, beans, sweet potatoes, and cassava produced were 5,104,000 tons, 1,170,000 tons, 1,053,000 tons, 1,827,000 tons, 1,418,000 tons, and 1,821,000 tons, respectively (United Republic of Tanzania, 2013). The quantities of animal products were 1.85 billion litres of milk, 3.5 billion eggs, and 532,711 tons of meat (i.e., 289,835 tons of beef, 111,106 tons of mutton/lamb, 47,246 tons of pork, and 84,524 tons of poultry) (United Republic of Tanzania, 2013). Fish and fishery products comprised of both marine and fresh water species, with a total annual harvest of 365,023 tons in 2012 (United Republic of Tanzania, 2013). The marine fishes include the finfish (like tuna, Spanish mackerel, red snapper, and trevally), cephalopods (octopus, squids, and cuttlefish), and crustaceans (prawns, lobsters, and crabs). Fresh water fish species involve Nile perch (*Lates niloticus*), tilapia (*Oreochromis species*), and sardines (*Rastrineobola argentea, Stolothrissa tanganicae, Limnothrissa miodon*). However, **postharvest losses** (i.e., both in quality and quantity) are among the major problems perpetuating the food insecurity in developing countries including Tanzania (Rembold et al., 2011). For instance, it is estimated that about 16-25% of milk (Kurwijila and Boki, 2003; Kivaria et al., 2006), 22% of cereals (Rembold et al., 2011), and more than 20% of fish and fishery products for the domestic market are lost annually along the food value chain (i.e., from primary production, transport, processing, storage and distribution to consumers) with quality loss contributing to about 70% of the total loss (Akande and Diei-Ouadi, 2010).

1.1.2. Food processing or manufacturing

The **food manufacturing sector** is largely agro-based, made up of micro- and small-scale companies with a few large-scale processors (Milanzi, 2012). The large-scale companies include cereal (like Bakhresa Group and Mikoani Traders Ltd), alcohol (e.g. Tanzanian Breweries Ltd and Serengeti Breweries Ltd), vegetable oil (Murzah Oil Mils, Mukwano Industries Ltd and Mohamed Enterprises Ltd) and fish processing companies (e.g. Vick Fish Ltd, Nile Perch Ltd, Tanzania Fish Processors Ltd and Prime Catch Exporters Ltd) (Ruteri and Xu, 2009). Other large-scale companies specialise in soft drinks manufacture (e.g. Bakhresa Group, Mohamed Enterprises Ltd, Bonite Bottlers Ltd and Coca-Cola Kwanza Bottlers Ltd), ethyl alcohol distillation (e.g. Tanzania Distillers Ltd), dairy processing (e.g. Tanga Fresh Ltd), and bottling of natural spring and mineral waters (e.g. Bakhresa Group, Mohamed Enterprises Ltd, and Bonite Bottlers Ltd). Food and beverages account for about half of the manufactured value-added products in Tanzania (Ruteri and Xu, 2009; UNIDO and United Republic of Tanzania, 2012). The micro- and small-scale companies operate in an informal sector and use labour intensive and poor technologies, while the medium- and large-scale processors use improved and modern technologies with relatively large capacity output (Ruteri and Xu, 2009). The majority of small- and medium-scale companies are local manufacturers of consumer goods (Ruteri and Xu, 2009; Milanzi, 2012). It is estimated that about 97% of all manufacturing companies have fewer than 10 employees, with majority being family-owned businesses (United Republic of Tanzania, 2011a).

1.1.3. Food distribution

The **food distribution chain** in Tanzania is composed of both wholesalers and retailers (supermarkets and retail shops) (Ruteri and Xu, 2009). Food products from manufacturers or producers are distributed via the company or specialised agents to wholesalers and/ or retailers. For the dairy sector there are no specialised distributors, products are directly distributed by the processors to the retailers or to their own outlets (Dillman and Ijumba, 2011). For other food production sectors, the wholesalers could also purchase food products directly from the processors. Then, retailers sell the products to end-users, the consumers. Marketing of cereals like maize involves four main channels: (1) the large traders/processors (like Mohammed Enterprises Tanzania Limited) purchasing maize directly from large producers; (2) the Strategic Grain Reserve (SGR) purchasing grains for food security reasons, and the World Food Programme (WFP) buying maize for food relief; (3) agents, brokers and traders who buy from large/medium-scale farmers either directly or from village collectors and small farmers; and (4) small producers selling their maize to village collectors and via brokers to large traders or small wholesalers buying from village collectors and selling to small shops and sometimes to exporters (USAID, 2010).

Small scale producers/processors sell their products directly to retailers and consumers or through middlemen (USAID, 2010). Lack of reliable electricity, good infrastructure (roads/railways), and proper storage facilities and knowledge on good storage and hygienic practices (by most traders) limits the availability of quality and safe products in the local market (Ruteri and Xu, 2009; Dillman and Ijumba, 2011).

1.2. Domestic versus export-oriented food production sectors

The food manufacturing sectors produce either for export/domestic market or for both markets. However, the majority are dedicated for the domestic market, with exception to a few sectors like fishery, horticulture (flowers, fruits, and vegetables), meat (goat and lamb), cashew nuts, tea, and coffee (United Republic of Tanzania, 2011a, 2013). In the year 2012, Tanzania exported 130,900 tons of cashew nuts, 54,800 tons of coffee, 41,291 tons of fisheries products, 27,783 tons of tea, and 133 tons of meat (United Republic of Tanzania, 2013). The most important markets are Europe (for fish, fruits, vegetables and flowers), South East Asia (fish maws, belly flaps, dried sea weeds, and other marine shell-fish), South Africa (frozen shrimps, fruits and vegetables), Middle East (various fish products, fruits and vegetables, and meat), Japan (shrimps), Hong Kong (shrimps) and India (cashew nuts) (United Republic of Tanzania, 2013). Tanzanian coffee and tea are exported to several countries in the world with the European Union (EU) being the major export market (United Republic of Tanzania, 2013). In addition, significant quantities of cereals and cereal products are exported to neighbouring countries including Kenya, Uganda, Rwanda, Burundi, and Democratic Republic of Congo (Eskola, 2005).

For the scope of this study, food processing sectors for export (fish) and domestic (dairy) oriented markets will be further discussed.

1.2.1 Fish processing sector

Fish processing companies are basically for the export market focused, ranging from small- to large-scale companies (World Bank, 2005; United Republic of Tanzania, 2010). In 2012, a total of 365,023 tons of fish and fishery products valued at US$ 800,000 were harvested. Out of those, a total of 314,944 tons (84%) were harvested from freshwater while the remaining amount (50,079 tons, 16%) was harvested from seawater (United Republic of Tanzania, 2011a). Aquaculture production is not well developed in Tanzania; most of the fish is from wild capture. About 30% of fish catches in Tanzania is exported (United Republic of Tanzania, 2013). For example in the same year, a total of 45,550 tons of ornamental fish and 41,291 tons of fisheries products altogether worth US$ 159.1 million were exported (United Republic of Tanzania, 2013). Nile perch fillets, however, dominate Tanzanian fish exports, contributing to more than 80% by value (United Republic of Tanzania, 2011a). Nile perch products (including belly flaps and fish maws) accounted for 7% and prawns made another 7% of the export (United Republic of Tanzania, 2011a). The remainder comprised of marine products as seaweeds, crabs, lobsters, octopus, seashells, squids, shark-fins, and sardines (commonly known as *Dagaa*). The export of other fin fishes like Tilapia is prohibited by the government for food security reasons to ensure availability of fish to local consumers (Bagumire, 2009). Thus, the contribution of industrial fish processed products to the domestic market is insignificant, mostly less than 5% of the total production. However, for the fish species not aimed for export like Tilapia, the domestic market plays a vital role.

Fishery sector provides substantial employment, income and foreign exchange and revenue to the nation (United Republic of Tanzania, 2013). It employs more than 4 million people engaged in fishery and fishery related activities with more than 400,000 fisheries operators directly employed in the sector (United Republic of Tanzania, 2010). Fishing activities contribute to 1.4% of the national GDP (United Republic of Tanzania, 2011a). Fish export is organised by the companies, the modes of transport are air (for chilled fish products and live fish) and marine (for frozen fish products, Figure 1.1). Currently, chilled fish fillets are transported via roads to Nairobi, Kenya, where they are air freighted to the destination markets. Moreover, frozen Nile perch fillets from Mwanza could be transported by road or rail either to Mombasa (Kenya) or to Dar es Salaam (Tanzania) ports, where they are further shipped in reefer containers to the destination markets (Fig. 1.1) (Board of External Trade, 2003; Josupeit, 2006). For marine fish processing companies which are located along the coast, they utilise sea transport through Dar es Salaam or Tanga ports. Chilled fish products are packaged in Styrofoam boxes/containers, whereas frozen fish products are wrapped in polythene sheets and packaged in waxed corrugated paper boxes/cartons (Board of External Trade, 2003; Josupeit, 2006). The time taken for the fish products to reach the destination markets depends on distance and mode of transport used. Chilled products which are air freight transported to Europe could take 2-3 days because there are no direct flights from Tanzania, so products have to be transported from Mwanza by road to Nairobi, Kenya, where they are air freighted (Josupeit, 2006). For frozen products which use sea transport, shipping a container of frozen fish could take about three to four weeks for the products to reach the destination markets.

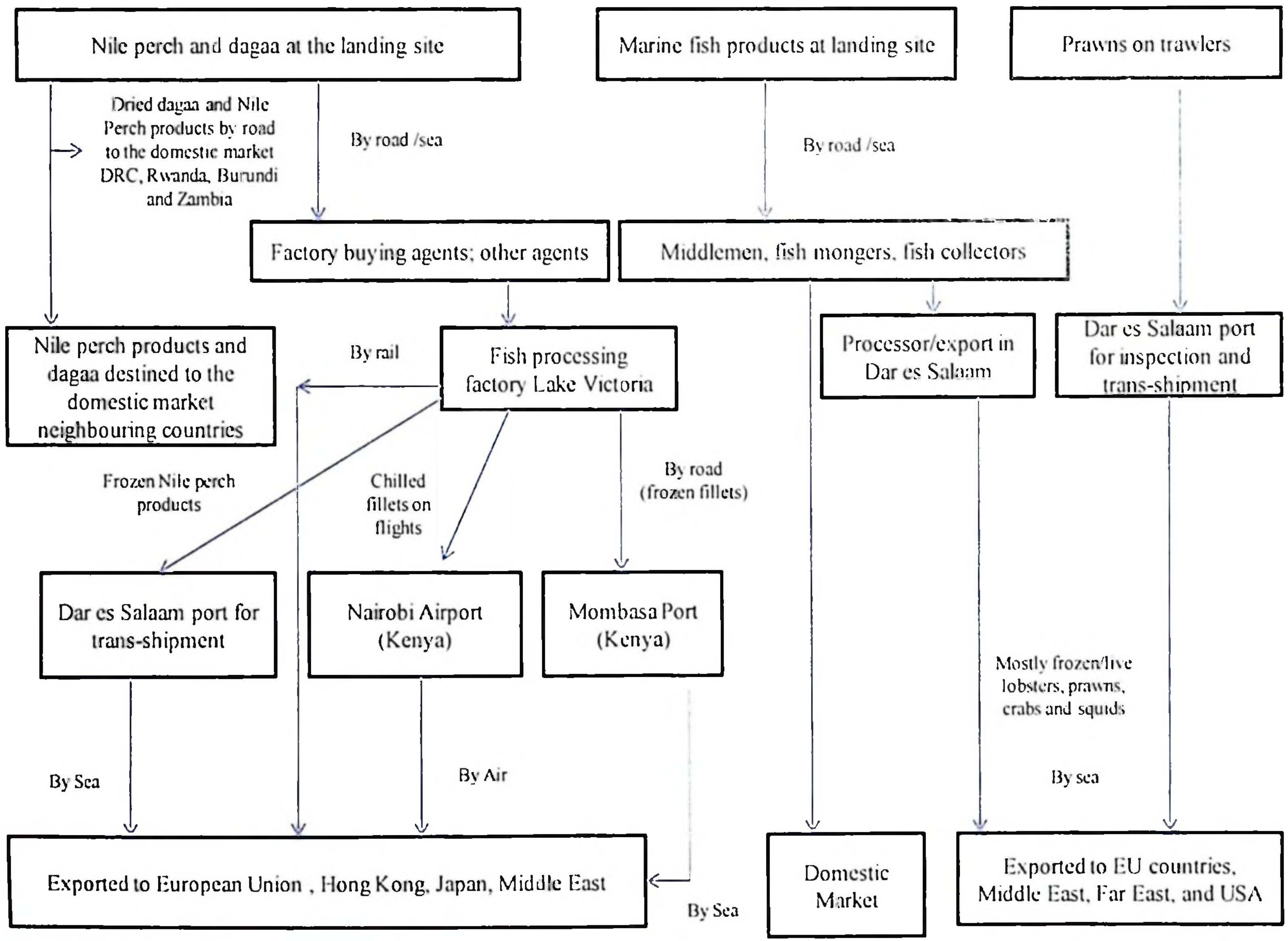


Figure1.1. Schematic presentation of fish value chain in Tanzania (modified from Board of External Trade, 2003; Josupeit, 2006)

1.2.2. Dairy processing sector

Dairy processing companies are oriented for the domestic market. In 2012, 1.85 billion litres of milk were produced: 0.597 billion litres were from high-breed cows and 1.256 billion litres were from traditional breeds (United Republic of Tanzania, 2013). The informal market channels dominate the marketing of milk, with 90% of market share (Kaijage, 2004; RLDC, 2009). Of the total milk produced in the country (1.85 billion litres), less than 2% is processed by dairy companies into various products including cultured milk, pasteurised and ultra-high-treated milk, yoghurt, cheese, ghee and ice creams (RLDC and NIRAS, 2010). The actors in the Tanzanian dairy value chain are producers, service providers, milk importers, processors, distributors, hawkers, retailers and consumers (Fig. 1.2). Although some dairy processing companies have improved their physical infrastructure and adopted good hygienic practices, poor quality and unsafe milk products are still common (Kurwijila and Boki, 2003; Kivaria et al., 2006; Kivaria et al., 2007; Swai and Schoonman, 2011). Moreover, preferences of raw to processed milk (Omore et al., 2009), increase the risk of consumers to access food safety hazards. The major packaging materials for dairy products are plastics (i.e. bags, cups and bottles), waxed paper packets, box cartons (to package the packets or sachets), and wax for cheese (RLDC and NIRAS, 2010). Also, plastic crates are used for storage and distribution purposes of milk to avoid package collapse. Refrigerated transport is necessary for pasteurised and fermented milk products (RLDC and NIRAS, 2010).

1.2.3. Conclusion on domestic versus export oriented markets

The dairy sector consists of mainly micro- and small-scale companies, which use poor technology and operate in non-hygienically designed facilities and inadequately regulated market. These conditions create higher possibilities for consumers to contract food safety hazards. Therefore, the dairy sector could implement best practices along the milk value chain to guarantee supply of safe products to the domestic market. The fishery sector could continue strengthening the FSMS to maintain export market access and competitiveness (Day et al., 2012b). Therefore, this study investigated the following:

- Current performance status of FSMS and opportunities for improvement towards more effective FSMS of dairy processing companies delivering for the local market. The FSMS-DI (as illustrated in section 1.5) was applied to assess the performance of FSMS in 22 dairy processing companies and actual microbiological assessment conducted in one company as a case study to determine the actual microbiological output of current systems. This provides general view of microbiological performance of FSMS in the dairy sector. The study proposed intervention measures that could be implemented in two stages to improve the current FSMS in dairy processing companies. Stage I intervention measures could be implemented in the short-term.

while stage II intervention measures are more costly (expertise, financial and time consuming) that will be implemented in the long term.

- The performance status of FSMS and opportunities for improvement towards more effective FSMS of fish exporting companies in Tanzania were analyzed. The FSMS-DI was applied to evaluate the performance of FSMS in 14 fish processing companies. The strengths and weaknesses of current FSMS were identified and possible improvement measures are proposed. Likewise, the measures were proposed in two stages: stage I involves the less demanding interventions (i.e., time, expertise and resources) while stage II pertains to high demanding ones (in terms of resources, expertise and time).
- The actual microbiological performance of current HACCP-based FSMS and points of improvement towards effective systems in the fishery sector. Combined assessment by FSMS-DI and MAS was conducted in one fish processing company as a case study to get a deep understanding on the causes of unsatisfactory performance of HACCP-based FSMS in the fishery sector. This provides a typical microbiological output of FSMS in the fishery sector and opportunities for improvement.
- The causes of the differences in performance of FSMS between the export and local market oriented companies in Tanzanian food industry. The FSMS-DI results (for fish and dairy processing companies) were used to make a comparison between export (fish) and domestic (dairy) market oriented sectors. This indicates the underlying causes of the differences in performance of FSMS between the two sectors and provides learning experiences among the sectors.
- Lastly, the generic roadmap for improvement of current FSMS in fish and dairy processing companies will be developed. The roadmap indicates how information on food safety problems is collected, how the collected information is analysed and then how solutions of the identified problems are developed and implemented. This generic roadmap for improvement could also be used by other food companies in Tanzania to develop their company specific measures.

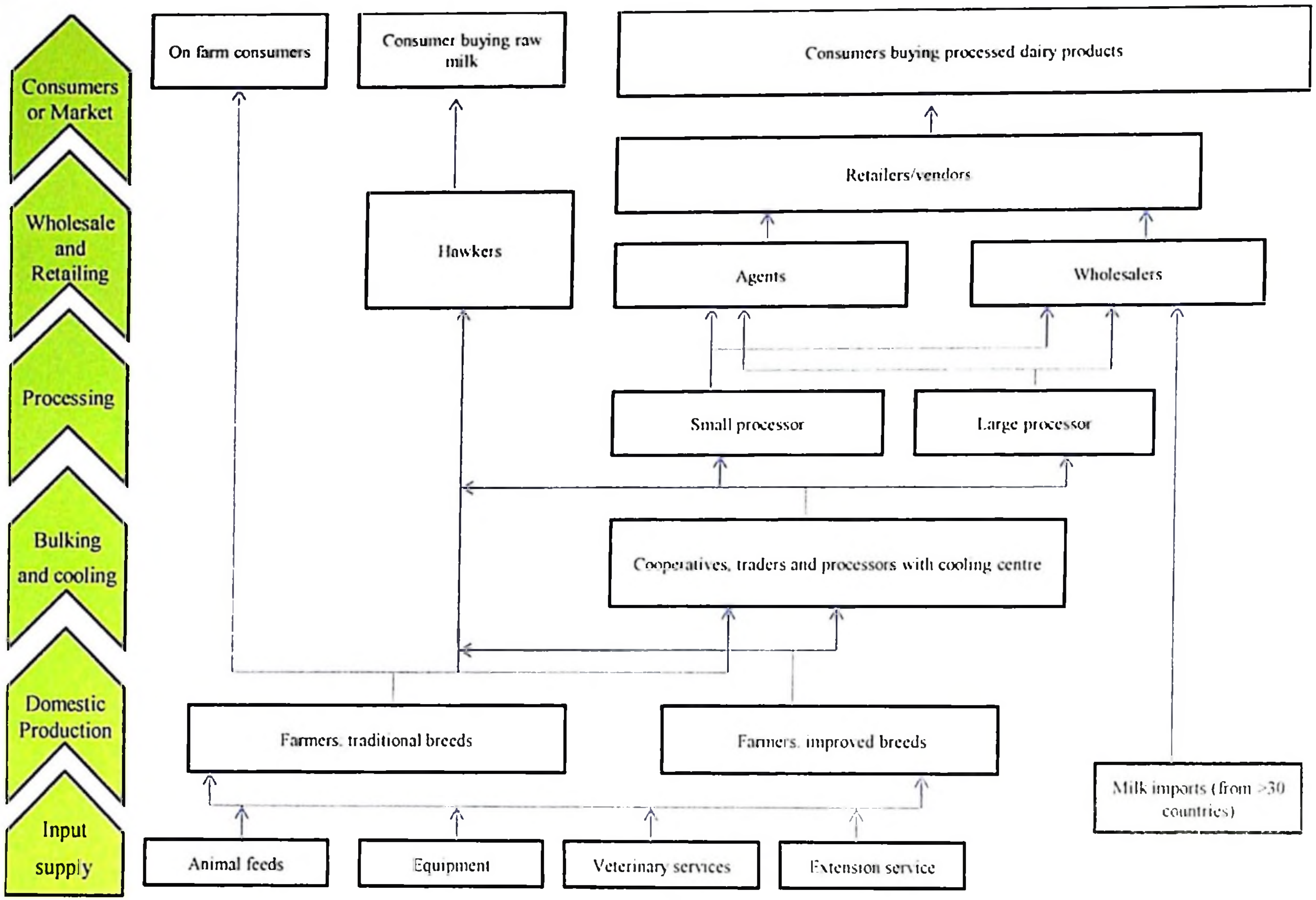


Figure 1.2. Schematic presentation of milk value chain in Tanzania (Kurwijila and Boki, 2003; RLDC and NIRAS, 2010).

1.3. Legal framework on food safety in Tanzania

1.3.1. Standards and legislation

The Codex Alimentarius provides a collection of food standards, guidelines and codes of practice recognised by the World Trade Organization as the benchmark standards for national food safety regulations (www.codexalimentarius.org). These science-based standards are adopted through global consensus forming the basis for international food trade. Tanzania is among several African countries with well established codex focal/contact point located at Tanzania Bureau of Standards (TBS). It is a central coordination and consultative point for all codex activities and standards within Tanzania (www.codexalimentarius.org). The TBS was formulated in 1975 as the statutory national standards body for Tanzania, mandated to formulate, promulgate and implement national standards (United Republic of Tanzania, 2009). It uses Codex Alimentarius standards as benchmarking or reference standards to formulate the respective national food standards (Food and Agriculture Organisation, 2007). However, for international trade reasons, regional and international standards (particularly, the major food export markets like EU and USA) are also adapted to suit national needs and conditions (Food and Agriculture Organisation, 2007). Tanzania has more than 250 food related standards (out of 1500 standards, test methods, codes of practices and hygiene) covering compositional and microbiological specifications (www.tbs.co.tz). Table 1.1 illustrates some of the Tanzania food standards for milk and milk products TZS 1625:2013, TZS 626:2009, TZS 251:2009 (Tanzania Standard, 2009b, a, 2013); prawns, shrimps and lobsters, TZS 576:1999 (Tanzania Standard, 1999); and fish and fish products, TZS 402:1988 (Tanzania Standard, 1988).

1.3.2. Enforcement of food laws and regulations in Tanzania

The current legal framework is inadequate to sustainably perform its functions effectively (Food and Agriculture Organisation, 2007; United Republic of Tanzania, 2014). The food laws and regulations lack proper enforcement and monitoring procedures. Strikingly, Tanzania mainland and Zanzibar have different food legislation; and there is no national food safety policy as yet. Moreover, the current food legislation does not offer adequate recognition of consumers' basic right to safe and wholesome food or clearly state the responsibility of producers and processors to provide safe and wholesome food (Food and Agriculture Organisation, 2007). Tanzania has many food laws (more than 17) and multiple agencies (i.e. more than 18 institutions and product regulatory boards) involved in food standards setting and food control management without proper coordination and adequate laboratory capacities (Table 1.2). Food safety responsibilities are split between number of ministries and departments, and are not well-harmonized (Table 1.2).

Table 1.1 Microbiological specifications for fish and dairy products according to Tanzanian standards: TZS 1625:2013, TZS626:2009 TZS 251:2009, TZS 402:1998 and TZS 576:1999.

Fish products		Dairy products	
Products and microorganisms	**Maximum limit (CFU/g)**	**Products and microorganisms**	**Maximum limit (CFU/g or mL)**
Frozen raw prawns, shrimps and lobster tails	TZS 402:1988[1] and TZS 576:1999[2]	Raw milk	(TZS 626:2009)[3]
Total plate count	10^7	Total plate count	Grade I ($<2x10^5$), II ($m= 2x10^5$; $M=1x10^6$), and III ($m=1x10^6$; $M=2x10^6$)/mL
Escherichia coli (faecal coliforms)	$4x10^2$	Coliforms	Very good ($m=0$, $M =10^3$) and good ($m=1x10^3$; $M=5x10^4$)/mL
Faecal streptococci	-		
Staphylococcus aureus	$2x10^3$		
Salmonella spp.	Absent in 1g		
Shigella spp.	Absent in 1g		
Listeria monocytogenes	-		
Vibrio parahaemolyticus	10^2		
Frozen cooked prawns, shrimps and lobster tails		**Pasteurised milk (CFU/mL)** (TZS 251:2009)[4]	
Total plate count	10^7	Total plate count	30,000/mL
E. coli (faecal coliforms)	$4x10^2$	Coliforms	10/mL
Faecal streptococci	-	*E. coli*	Absent in 1 mL
S. aureus	$2x10^3$		
Salmonella spp.	Absent in 1g		
Shigella spp.	Absent in 1g		
L. monocytogenes	-		
V. parahaemolyticus	$1x10^2$		
Fresh/frozen fin fish		**Fermented milk (TZS 1625:2013)**[5]	
Total plate count	10^7	Total plate count	
Coliforms	-	Coliforms	Absent in 1 mL
E. coli (faecal coliforms)	$4x10^2$	*E. coli*	Absent in 1 mL
S. aureus	$5x10^3$		$<10^2$/mL
Salmonella spp.	Absent in 1g		Absent in 1 mL
Shigella spp.	Absent in 1g		
Vibrio spp.	10^2		
Clostridium perfringens	-		
Cooked fin fish		**Dried milk** (TZS 185:1983)	
Total plate count	10^5	Total plate count	
Coliforms	-	Coliforms	10^2/g

E. coli (faecal coliforms)	Absent in 1g	*E. coli*	Absent in 1g
S. aureus	Absent in 1g	*S. aureus*	$<10^2$/g
Salmonella spp.	Absent in 1g	*Salmonella* spp.	Absent in 1g
Shigella spp.	Absent in 1g	Yeasts and moulds	-
Vibrio spp.	Absent in 1g		
C. perfringens	-		
Smoked fish		**Cheese** (TZS 1201:2009)[6]	
Total plate count	10^6	*E. coli*	Absent in 1g
Coliforms	-	*S. aureus*	$<10^2$/g
E. coli	10^2	*Salmonella* spp.	Absent in 25g
S. aureus	$5x10^3$	*L. monocytogenes*	Absent in 25g
Salmonella spp.	Absent in 1g	Yeast and mould	$<10^2$/g
Shigella spp.	Absent in 1g		
V. parahaemolyticus	10^1		
Clostridium perfringens	-		
Frozen Octopus		**Ice cream** (TZS 185:1983)[7]	
Total plate count	10^5	Total plate count	$2.5x10^5$/g
Coliforms	10^2	Coliforms	10^2/g
E. coli	Absent in 1g	*E. coli*	Absent in 1g
S. aureus	10^2	*S. aureus*	10^3/g
Salmonella spp.	Absent in 1g	*Salmonella* spp.	Absent in 1g
Yeasts and moulds	-	Yeasts and moulds	-
V. parahaemolyticus		*L. monocytogenes*	-
Vibrio cholerae			

[1](Tanzania Standard, 1988), [2](Tanzania Standard, 1999), [3](Tanzania Standard, 2009b), [4](Tanzania Standard, 2009a), [5](Tanzania Standard, 2013), [6](Tanzania Standard, 2009c) and [7](Tanzania Standard, 1983)

For instance, food companies experience multiple uncoordinated inspections of the premises with various regulations targeting food hygiene and safety of workers (Confederation of Tanzania Industries, 2013). Also, food companies are subjects to multiplicity of licences/permits for premises and products, most of which have to be renewed annually. In addition, the current legal framework does not provide for a clear division of responsibilities (e.g. premise inspection and market surveillance) of for coordination and communication between inspecting authorities (Confederation of Tanzania Industries, 2013). This leaves institutions and ministries without clear mandate and authority to control food quality and safety. This could hamper the national food control system to set strategies and priorities, prepare national plans and programmes, undertake proper enforcement actions, and provide adequate and proper information and education (Food and Agriculture Organisation, 2007). The food control laboratories are few and understaffed, without proper equipment and physical infrastructure. Public awareness about food quality/safety is also inadequate due to lack of information and education. Consumer organisations that would put pressure on producers, processors, and traders to ensure safety and quality of food products are undeveloped and non-operational (Food and Agriculture Organisation, 2007). Although food laws address some food safety issues like implementation of good hygienic practices, product certification, and registration of food premises, there are inconsistencies and gaps in the enforcement, surveillance and monitoring system (Food and Agriculture Organisation, 2007).

Tanzania Food and Drugs Authority (TFDA) is a regulatory body for all matters relating to quality and safety of food, drugs, herbal drugs, medical devices, poisons, and cosmetics (United Republic of Tanzania, 2003). It conducts premise (food companies, shops and restaurants) inspection and registration, and microbiological and chemical analyses of food and pharmaceutical products (Table 1.2). The food safety laboratory has ISO 17025 and International Atomic Energy Agency accreditations (United Republic of Tanzania, 2014). It performs uninformed inspection and sampling of food products on the market, food companies and points of entry including airports, ports/harbours, and borders (United Republic of Tanzania, 2003). The TFDA has also developed various guidelines on food safety; for instance, guidelines for conducting risk-based inspection in food premises, guidelines for investigation and control of foodborne diseases, and guidelines for import and export of food. Food standards are set by the TBS (www.tbs.co.tz). Most of the food standards are derived from the Codex Alimentarius standards and adapted to country specific situations. Currently, food standards of all member countries of the Eastern African Community (including Tanzania) have to be harmonised with the East African Community standards.

Although, the standards are based on the Codex Alimentarius Commission (CAC), the level of enforcement and monitoring differs between the export and domestic market-oriented products. Products for the export markets often receive more attention than ones for the domestic market (Food and Agriculture Organisation, 2007). For instance, food processing companies for export market are comprehensively audited by both public (national food control authorities and the competent authority) and private auditors (accredited third parties and buyers). Food companies or products for domestic market mostly receive audits from public auditors, i.e. food control authorities and local government health officers, and sometimes other companies or products are not regulated (Food and Agriculture Organisation, 2007). Similar level of control is however, necessary to food production sectors for the domestic market as for the export to guarantee safety and quality of products for local consumers (Larcher, 2006).

1.3.3. Conclusion on legal framework in Tanzania and implications for export

The current structure of responsibilities of various food control institutions does not promote good co-ordination and institutional collaboration. Instead, it creates inter-institutional conflicts (Food and Agriculture Organisation, 2007). Due to the weakness in local food control, food companies in Tanzania are only allowed to export products to the EU after being approved by the designated competent authority and European Commission, Directorate General for Health and Consumers, Food and Veterinary Office (FVO). In principle, potential animal products manufacturing companies for export have to be inspected and audited by the competent authority to assess whether the hygiene requirements are in compliance with the EU demands. If the hygiene requirements are in compliant with the EU, the request is made by the competent authority to European Commission, Directorate General for Health and Consumers for creation of a new list of establishments or for modifications to existing lists. Then a company could export to the EU (http://ec.europa.eu/food/food/biosafety/establishments/third_country/proc_intro_request_en.htm, accessed 11/09/2014). This literature enlightens on the status and weaknesses of the current legal framework in Tanzania; it could be used as an input in proposing intervention measures for improvement to a better legal framework for food safety.

Table 1.2. Tanzania food safety and quality institutional framework

Institution	Affiliations or executive branch	Responsibilities
Tanzania Food and Drugs Authority (TFDA)*	Ministry of Health and Social Welfare (MOHSW)	Food standard setting, food product and processing/handling establishment registration, food safety control, food inspection, audit local council inspections, food export certification, enforcing HACCP and GMP in the entire food industry, truth in labelling and advertising, and consumer information
Tanzania Bureau of Standards (TBS)*	Ministry of Industries and Trade	Standard setting, technical assistance to exporters, training on quality and safety assurance, enforcement, testing, product certification and registration, control of imports, consumer education, information dissemination, calibration of industrial and commercial measuring equipment, EAC standard harmonization, metrology and focal point for World Trade Organisation, ISO, and CAC
Tanzania Atomic Energy Commission	Ministry of Energy and Minerals	Monitoring of radioactive contaminants in foods
Tanzania Meat Board	Ministry of Livestock and Fisheries Development (MLFD)	Meat and meat products regulations
Tanzania Tea Board	Ministry of Agriculture, Food Security and Cooperatives (MAFSC)	Regulations of the tea industry
Tanzania Coffee Board	MAFSC	Regulations of the coffee industry
Sugar Board of Tanzania	MAFSC	Regulations of the sugar industry
Tanzania Cashew nut Board	MAFSC	Regulations of the cashew nut industry
Tanzania Dairy Board	MLFD	Milk and dairy product regulations
Cereals and Other Produce Board of Tanzania	MAFSC	Regulations of cereals and other produce.
Department of Beekeeping and Forestry	Ministry of Natural Resources and Tourism	Honey production, processing, quality and safety
Directorate of crop development (e.g. Plant Health Services)	MAFSC	Phytosanitary issues including plant health, plant protection, pesticide registration (by TPRI), postharvest pest management, use approval and monitoring; export certification, regulation of biological control, promotion of integrated pest management, and control of genetically modified organisms (GMO), International Plant Protection Commission (IPPC) contact point

Directorate of Food Security	MAFSC	Postharvest handling and quality, control of imports, and mycotoxin monitoring
Directorate of Marketing	Ministry of Industries and Trade	Monitoring national compliance with WTO trade agreements on the application of SPS and technical barriers of trade
Fisheries Department	MLFD	Fish regulations and inspection, training of fishermen and processors, certification of fish exports, focal point of Lake Victoria Fisheries Organization (LVFO), harmonization of fish and fisheries standards with EAC
Livestock Department (Veterinary Services)	MLFD	Meat hygiene, animal health, animal health certification, abattoir inspection, animal traceability, veterinary drug control, milk quality and safety control
Government Chemical Laboratory	MOHSW	Food and chemical analytical services (including forensics)
Ministry of Water and Irrigation	Ministry of Water and Irrigation	Water safety and quality
Office of the Vice President - Directorate of Environment	Office of the Vice President	Water protection, solid and effluent wastes, old pesticide stocks, bio-safety and regulation of GMO
Office of the Vice President-National Environment Management Council	Autonomous	Water protection, solid and effluent wastes, old pesticide stocks, bio-safety and regulation of GMO
Local Government authorities (District, town or municipal councils)	Ministry of Local Government	Food hygiene control and preparation of food establishment sanitation ordinances, food inspection

Adapted from (Food and Agriculture Organisation, 2007; Kurwijila et al., 2011; Day et al., 2012b)

*Food control laboratories with ISO17025:2005 certification

1.4. Microbiological safety of dairy and fish products in Tanzania

1.4.1. Official monitoring and foodborne disease outbreak investigations in Tanzania

Cases of microbiological and chemical contamination of food products including milk are common in Tanzania (Kivaria et al., 2006; Kurwijila et al., 2006b; Swai and Schoonman, 2011). However, the reported cases are just a fraction of the total contaminations occurring as the majority could go unreported as a result of poor disease monitoring and surveillance systems (TFDA, 2011). Although, the Ministry of Health and Social Welfare is responsible for diseases monitoring and surveillance. Tanzania has no institutionalised foodborne diseases surveillance system in place (TFDA, 2011). However, on ad-hoc basis certain research and academic institutions including the food control authorities in Tanzania conduct various researches/surveys on foodborne diseases outbreak. These research and academic institutions including the National Institute of Medical Research (NIMR), SUA, Muhimbili University of Health and Allied Sciences (MUHAS), Tanzania Industrial Research Development Organisation (TIRDO) and Tanzania Food and Nutrition Centre (TFNC) have well equipped laboratories (some are accredited) with competent personnel to conduct foodborne diseases and health risks analysis (Kurwijila et al., 2011).

1.4.2. Microbiological safety of fish and dairy products in Tanzania

A search in literature and databases such as RASFF give limited data related to the actual status of dairy and fish products from Tanzania. Fish products have been occasionally rejected because of poor microbiological safety (Rapid Alert System for Food and Feed, 2009, 2014). *Salmonella* spp. is the frequently reported microbiological hazard in the exported fish products (Rapid Alert System for Food and Feed, 2009, 2014). For the dairy companies, *Brucella* spp. and coliforms (up to 4.2×10^6 CFU/mL) (Swai and Schoonman, 2011), total bacterial counts (1×10^7 CFU/mL higher than regulatory limit 5×10^6 CFU/mL) and total coliforms were detected in raw milk (Karimuribo et al., 2005). Also, total bacterial counts, *E. coli* and *Salmonella* spp. were found in raw milk, whereas coliforms were detected in milk products (Schoder et al., 2013). Moreover, the mean total bacterial count in marketed milk was $8.2 \pm 1.9 \times 10^6$ CFU/mL (higher than regulatory limit 5×10^6 CFU/mL); with *E. coli, Bacillus cereus, Staphylococcus aureus* and *Streptococcus agalactiae* as the major bacterial isolates (Kivaria et al., 2006).

1.5. Food safety management systems performance measurement

An FSMS is a company specific system of control and assurance activities to realise and guarantee food safety. Control activities aim at keeping product and process conditions within acceptable limits in order to realise food safety, whereas assurance activities concern the evaluation of system performance and organising necessary changes (Luning et al., 2008; Luning et al., 2009). Prior to application of HACCP to any sector of the food chain, that sector should have in place PRPs such as the appropriate Codex Codes of Practice and food safety requirements (Codex Alimentarius Commission, 2003). These prerequisite programmes to HACCP, including training, should be well established, fully operational and verified in order to facilitate the successful application and implementation of the HACCP system (Codex Alimentarius Commission, 2003). Thus, a company specific FSMS is a translation of GHP, HACCP, management policies and traceability into company specific settings (Jacxsens et al., 2009a).

Performance of FSMS in food processing companies could be measured by various methods including regulatory inspections, auditing, verification, products testing, and surveillance. Inspection is the examination of food or systems for control of food, raw materials, processing and distribution, including in-process and finished product testing, in order to verify that they conform to requirements (Powell et al., 2013). In Tanzania, inspection is basically done by the regulatory agencies including TFDA, TBS, competent authorities (fisheries department), national produce boards (e.g. TDB) as well as the Local Government Authorities (LGAs). The purpose of regulatory inspection is to evaluate current conditions and whether they are in compliance with desired standard conditions (Powell et al., 2013). Audit is a systematic and independent examination to determine whether quality/safety activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives (Luning and Marcelis, 2009b; Powell et al., 2013). It provides feedback on the completeness and effectiveness of the FSMS, and indicates the elements of the system that are inadequate or need improvement (Jacxsens et al., 2009a). Both audit and inspection are conducted to demonstrate and provide evidence on the effectiveness of a system/quality assurance program (Alli, 2003; Jacxsens et al., 2009a; Luning and Marcelis, 2009b). Audits are either self-audits (internal by food safety team), or second-party (by downstream company or buyer or company's paid consultants) or third-party (by outside accredited company/organisation) for certification purposes (Jacxsens et al., 2009a; Luning and Marcelis, 2009b; Powell et al., 2013). A general procedure for auditing includes collection of information, verification of information, establishing objective evidence, summarising audit findings and preparation of a report (Luning and Marcelis, 2009b). Third-party audits examine compliance with laws and codes of practice and provide insight into management controls and supervision (Powell et al., 2013). Third-party audits are non consultative; thus, the auditor is not permitted to instruct or advise the facility on how to meet the requirements. A registration/certification audit is a third-party audit carried out for the purpose of registering/certifying the company to a recognised standard, such as the ISO 9001:2008 QMS standard (Alli, 2003). When satisfied that the FSMS/QMS have been effectively implemented and is maintained, a certificate is issued (Tanner, 2000). A certificate indicates that the company/organisation at the time of assessment had FSMS which complied with the specified requirements (Jacxsens et al., 2009a).

Verification is a process designed to confirm (through objective evidence by independent person) that the system is working properly, specified requirements are met, and the hazards are effectively kept under control (Jacxsens et al., 2009a; Luning and Marcelis, 2009b; Milios et al., 2014). It can be carried out through sampling and analysis (products and environment), audits (GMP, HACCP) and complaint analysis (Jacxsens et al., 2009a). It concerns checking afterwards (after implementing/applying the measure) if control activities are operating in practice as designed or intended (Jacxsens et al., 2009a; Luning and Marcelis, 2009b; van Schothorst et al., 2009). A proper verification procedure should be based on evaluating the microbiological results within the same company during different periods of time and comparing them with the standards set by legislation (Milios et al., 2014). Verification can be performed internally by the company or cooperate HACCP team (Sperber, 1998). Moreover, food companies need to validate that their food safety system is capable of controlling the hazard of concern, i.e., to provide evidence that control measures can meet the targets (van Schothorst et al., 2009; Milios et al., 2014). For HACCP-based FSMS, it is essential to validate the HACCP plan to determine whether it is accurate in all aspects and that the identified hazards have been controlled at each CCP (Sperber, 1998). Validation is checking in advance the effectiveness of activities aimed at realising food quality and safety (Luning and Marcelis, 2009b), including the pre-requisite programmes. Food companies are responsible for validation of control measures, whereas the food control authorities ensure that food companies have effective systems for validation and that control measures checked during the audit are appropriately validated (Codex Alimentarius Commission, 2008).

Products testing includes chemical and/or microbiological food safety hazards testing of raw materials, in-process and final products. Microbiological testing is one of the potential tools that can be used to evaluate whether a FSMS is providing the level of control it was designed to deliver (van Schothorst et al., 2009). It can be used for surveying the microbiological condition of the product, for deciding between acceptance or rejection of batches of product, or for purposes related to the implementation and maintenance of HACCP-based FSMS (Brown et al., 2000). When microbiological testing is used correctly, it can provide industry and regulatory authorities with tangible evidence of control (van Schothorst et al., 2009). The food safety criteria are set by different stakeholders or regulatory bodies (like EU and/or country regulations and/or customers' requirements), but can also be used to guide the evaluation of a manufacturing process to define preventive actions (Kvenberg et al., 2000; Martins and Germano, 2008). Microbiological criteria are designed to determine adherence to GHPs and HACCP when more effective and efficient means are not available (van Schothorst et al., 2009).

However, traditional inspection and audits do not assess the influence of the context characteristics. Moreover, assessment of major technology-dependent (like equipment and facilities) and managerial activities (e.g. people requirements and behaviours) in design and operation of preventive measures, intervention processes and monitoring systems is not carried out. Unless recommended, microbiological assessment of products, food contact surfaces and hands of the personnel along the product manufacturing line is not conducted during audits in the food industry. In contrast to typical auditing and inspection which are typical point-in-time assessments (Powell et al., 2013), microbiological assessment is normally conducted three times in three consecutive months giving a greater opportunity to identify the typical weaknesses and strengths in the current FSMS (Jacxsens et al., 2009b).

For the scope of this study, the diagnostic tools including the FSMS-DI and MAS were applied and are therefore discussed further in this section. The purpose of the FSMS activities and context diagnostic tool is to obtain an indication of the design and operation of FSMS activities and the risk level of the context wherein the FSMS operate (Luning et al., 2011a). Similarly, microbiological safety diagnosis is aimed at giving an indication about the system output based on a restricted number of samples (taken from selected critical sampling locations (CSL)) for analysis of a few selected indicator micro-organisms (Jacxsens et al., 2009b; Luning et al., 2011a). These tools could be either used separately or together to diagnose the causes of insufficient performance of an FSMS and could serve as basis for improvement strategies (Luning et al., 2011a) towards more effective systems to guarantee production of safer food products for both export and domestic markets.

1.5.1. Food safety management system diagnostic instrument

The FSMS-DI is a tool that enables systematic analysis and assessment of a company's specific FSMS (Luning et al., 2008; Luning et al., 2009; Luning et al., 2011b). This diagnostic tool (Fig. 1.3) was used to diagnose the performance status of FSMS in African food industry based on literature review (Chapter 2) and applied to evaluate the performance of FSMS in fish and dairy processing companies in Tanzania (Chapter 3-6). The FSMS-DI (Fig. 1.3) comprises of four parts assessment: (1) context riskiness, (2) design and operation of control activities (3) design of assurance activities, and 4) system output.

The diagnostic tool involves a set of 58 indicators representing four crucial parts; part 1 describes set of indicators of context factors including product (3 indicators), process (3), organisational (7), and chain environment (4) characteristics that affect performance of FSMS. Context factors are structural elements of a system environment that can affect decision making activities in the FSMS and system output, and cannot (easily) be changed. The FSMS context is narrower than the overall environment of a company (Luning et al., 2015). For each context indicator a grid was designed including three situational descriptions, corresponding with a low (score 1), moderate (score 2), and high-risk situation (score 3) indicating levels of riskiness for decision-making in the FSMS activities (Luning et al., 2011b). The description for low, moderate, and high-risk situations for product and process characteristics pertains to low, potential, and high likelihood of contamination, growth and survival of pathogens. For organisational characteristics, low, moderate, and high-risk situations respectively represent supportive, constrained/restricted, and lack of administrative conditions to support appropriate decision-making in the FSMS. Concerning chain environment characteristics; low, moderate, and high-risk situations correspond to low, restricted, and high dependability on other chain actors resulting in a more vulnerable decision-making situation, respectively (Luning et al., 2011b).

Part 2 includes sets of indicators that represent core control activities such as design of preventive measures (6), design of intervention processes (4), monitoring system design (8), and actual operation of control strategies (8) (Luning et al., 2008). Control activities are aimed at keeping products and processes within acceptable tolerances. For each control activity indicator a grid with description of four different performance levels, i.e. low (score 0), basic (score 1), average (score 2), and advanced (score 3) was constructed (Luning et al., 2008; Luning et al., 2009). A low level represents that an activity is not possible in the given production circumstances (e.g. in freshly packed fish, commonly no physical interventions can be applied), just not applied, or when information is not known. The basic level for control activities is typified by use of own experience, general knowledge, ad-hoc analysis, incomplete, not standardised, unstable, and regularly problems. The average level for control activities is characterised by being based on expert (supplier) knowledge, use of sector/legislative guidelines, best practices, standardised, sometimes problems. The advanced level indicates that the control activity is characterised by use of specific information, scientific knowledge, critical analysis, procedural methods.

Part 3 pertains to set of indicators of core assurance activities including setting system requirements (2), validation (3), verification (2), documentation (1), and record keeping (1) (Luning et al., 2009). Assurance activities aim at providing evidence and confidence that control activities are effective and function well in actual practice. Likewise, for each assurance activity indicator a grid with description of four different performance levels, i.e. low (score 0), basic (score 1), average (score 2), and advanced (score 3) was constructed (Luning et al., 2008; Luning et al., 2009). A low level represents that an activity is not applied, or when information is not known. The basic level is characterised by problem driven, only checking, scarcely reported, and no independent positions. The average level corresponds with active, additional analysis, regular reporting, and experts support. The advanced means that the assurance activity is characterised by use of specific information, scientific knowledge, procedural methods, systematic activities, and independent positions.

Part 4 involves assessment of external (4) and internal (3) system output indicators (Jacxsens et al., 2010b). Moreover, for each system output indicator, four levels were described: level 0 (no indication of system output) refers to absent, not present or not conducted. Level 1 (poor system output) is characterised by aspects like ad-hoc sampling, minimal criteria used for FSMS evaluation, and having various food safety problems due to different problems in the FSMS. Level 2 (moderate system output) corresponds to regular sampling, several criteria used for FSMS evaluation, and having restricted food safety problems mainly due to one (restricted) type of problem in the FSMS. Level 3 (good system output) pertains to a systematic evaluation of the FSMS using specific criteria and having no safety problems (Jacxsens et al., 2010b). The basic principle behind the FSMS-DI is that companies operating in a high-risk context require core control and assurance activities at an advanced, fit-for-purpose level, whereas in a low-risk context, activities at a lower level could be sufficient to guarantee good system output (Luning et al., 2008; Luning et al., 2009; Luning et al., 2011b).

The FSMS assessment produces a list of scores for all indicators analysed. The mean scores were calculated and transformed to assigned scores as indicated by Jacxsens et al. (2010b) and Luning et al. (2011a). For the indicators of context factors if the mean risk-level is between 1 and 1.2, then score 1 is assigned. If the mean risk-level score is between 1.3 and 1.7, then score 1-2 is assigned. If the mean risk-level is between 1.8 and 2.2, then score 2 is assigned. If the mean risk-level is between 2.3 and 2.7, then score 2-3 is assigned. Lastly, if the mean risk-level is between 2.8 and 3.0, then score 3 is assigned (Luning et al., 2011a). For the indicators of core FSMS activities and system output, if the mean level is between 0 and 1.2, then an assigned score of 1 is defined. If the mean level is between 1.3 and 1.7, then an assigned score of 1-2 is attributed. If the mean level is between 1.8 and 2.2, then an assigned score of 2 is defined. If the mean level is between 2.3 and 2.7, then an assigned score of 2-3 is given. Finally, if the mean level is between 2.8 and 3.0, then an assigned score of 3 is attributed (Jacxsens et al., 2010b; Luning et al., 2011a). Analysed companies with similar score for each indicator were counted (frequency counting) to get insight into the similarities in the level of design and operation of core FSMS (control and assurance) activities and risk-level of the context wherein the systems operate.

11-11-2015

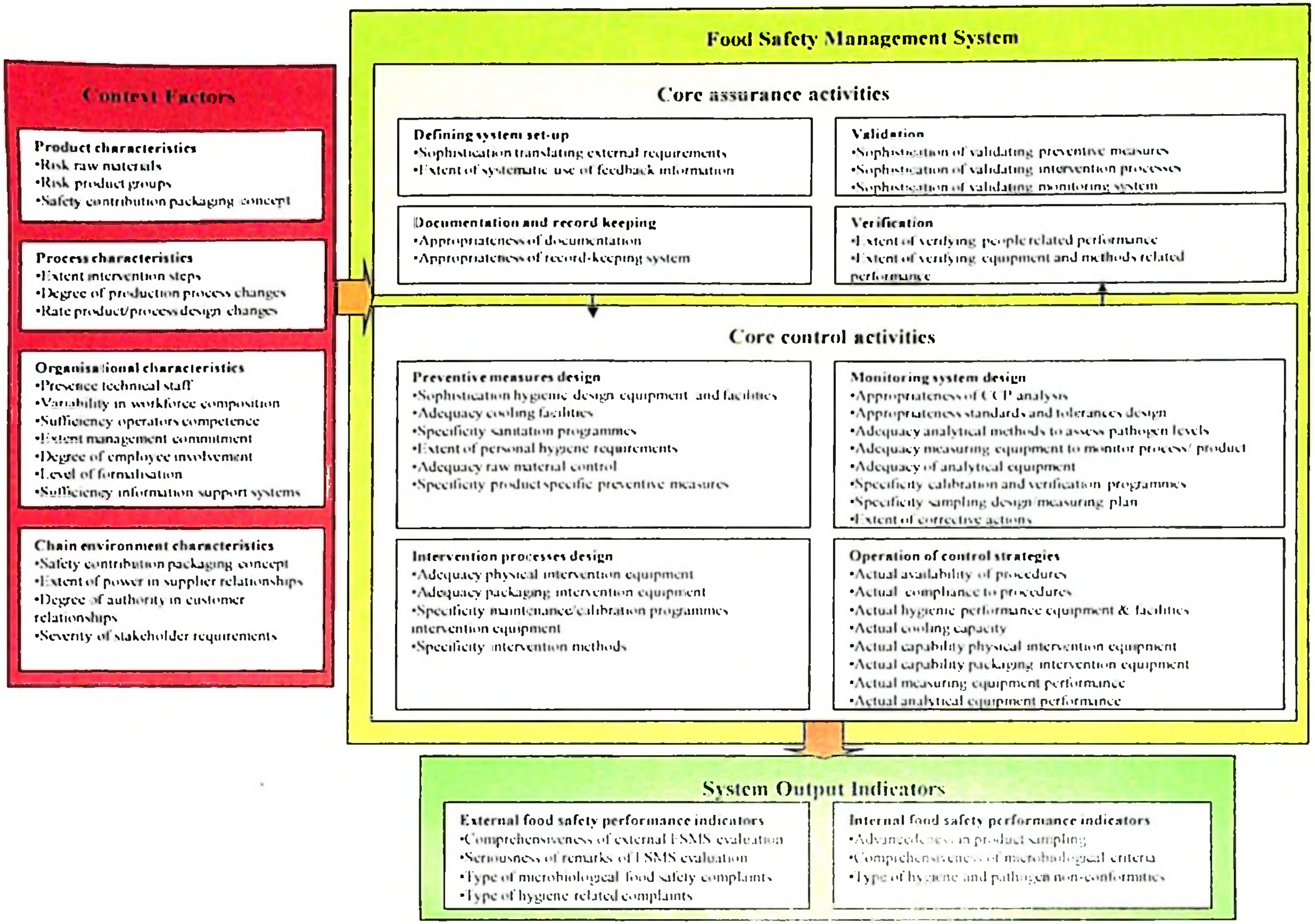


Figure 1.3. Food safety management system diagnostic instrument (Luning et al., 2011b)

1.5.2. *Microbial assessment scheme*

Microbial Assessment Scheme (MAS) is a procedure that defines the identification of critical sampling locations (CSL); selection of microbiological parameters, sampling frequency, sampling and analytical methods; and data analysis and interpretation (Jacxsens et al., 2009b). Critical sampling locations are defined as locations where microbial sampling provides information about the performance of core control strategies as addressed in the FSMS diagnostic instrument (Jacxsens et al., 2009b). Loss of control at these locations will lead to unacceptable food safety problems due to contamination, growth and or survival of micro-organisms (Jacxsens et al., 2009b). Examples of critical sampling locations are products (raw materials, intermediate, and final products), food contact surfaces (tables and containers) and hands/gloves of the personnel. The MAS provides an overall insight into the microbiological performance of an FSMS using restricted number of samples through selection of CSLs and microbiological parameters. Microbiological parameters included indicators of food safety (pathogens i.e. *Salmonella* spp., *L. monocytogenes* and *V. cholerae*), faecal hygiene (*E. coli*), personal hygiene (*S. aureus*) and overall hygiene (*Enterobacteriaceae* and total viable counts) and needs to be adapted according to specific activity of the company. Normally, MAS is conducted three times in three consecutive months and three times in a production day (start, mid and end of the production) to get an idea of distribution of microbial contamination (Jacxsens et al., 2009b). The legal criteria and guidelines used to interpret microbiological results in dairy and fish products are indicated in Table 1.3 and Table 1.4, respectively.

From the MAS results microbial safety level profiles are calculated, indicating which micro-organisms and to what extent contribute to microbial food safety of a particular company. Three levels can be classified for microbial safety; level 3 corresponds to a good result (legal criteria or guidelines are respected, no improvements needed, the current level of FSMS is high enough to control the hazard). Level 2 represents a medium result (legal criteria or guidelines are exceeded, improvements need to be made on a single control activity), whereas level 1 refers to low result (legal criteria/guidelines are exceeded, improvements need to be made on multiple control activities). The basic assumption of the MAS is that low numbers of micro-organisms and small variations in microbial counts indicate an effective FSMS (Jacxsens et al., 2009b). Table 1.5 gives an overview of various studies where MAS has been applied to analyse microbiological performance of FSMS in the food industry. Both tools, the FSMS-DI and MAS have been applied in this work (Chapter 2-6).

Table 1.3. Microbiological specifications of milk and milk products, food contact surfaces, and hands of the personnel

Microorganisms	Maximum limit (CFU)			
Raw milk	**Tanzanian Standards**[a]	**East African Standards**[b]	**EU Regulations**[c]	**Ghent University guidelines**[d]
Total viable count	Grade I (<2x10^5), II (m= 2x10^5; M=1x10^6), III (m=1x10^6; M=2X10^6)/mL	Grade I (<2x10^5), II (m= 2x10^5; M=1x10^6), III (m=1x10^6; M=2X10^6)/mL	-	
Coliforms	Very good (m=0, M =10^3) and good (m=1x10^3; M=5x10^4)/mL	Very good (m=0, M =10^3); good (m=1x10^3; M=5x10^4)/mL	-	-
E. coli[e]	-	-	-	-
S. aureus[e]	-	-	-	-
Salmonella spp.[e]	-	-	-	-
Pasteurised milk	**Pasteurised milk**	**Pasteurised milk**[f]	**Pasteurised milk**[e]	**Pasteurised dairy products**
Total viable counts	30,000/mL	<3 x10^4/mL	-	m= 1x10^3; M=5x10^4/mL
Coliforms	10/mL	1x10^1/mL	-	
E. coli	Absent in 1 mL	Absent in 1mL	-	
Enterobacteriaceae			1x10^1/mL	m= <1; M=5/mL
S. aureus[e]	-			
Salmonella spp.	-	Absent in 25g	-	Absent in 25g
Listeria monocytogenes	-	Absent in 25g	-	Absent in 25g
Fermented/cultured milk		**Fermented milk**[g]		
Total viable counts	-		-	-
Coliforms	Absent in 1 mL			
E. coli	Absent in 1 mL	Absent in 1mL	-	-
Enterobacteriaceae	-	-	-	m= 10^1; M=10^2
S. aureus[e]	<10^2/mL			
Salmonella spp.	Absent in 25 mL	Absent in 25g	-	Absent in 25g
Listeria monocytogenes	-	Absent in 25g	-	Absent in 25g
Food contact surfaces (working tables/trays)				
Total viable counts				**
E. coli	-	-	-	**
Enterobacteriaceae	-	-	-	**
Salmonella spp.				Absent in tested area (25 cm^2)
Listeria monocytogenes				Absent in tested area (25 cm^2)
Hands of the personnel				
E. coli	-	-	-	-
Enterobacteriaceae	-	-	-	-
S. aureus	-	-	-	<10CFU/mL (Quantification limit)

**Microbiological level is same as product handled under that critical sampling location, [a](Tanzania Standard, 2009b, a, 2013); [b](East African Community, 2006a), [c](European Union, 2004a), [d](Sampers et al., 2010), [e](European Union, 2004a), [f](East African Community, 2006b), [g](East African Community, 2006c)

Table 1.4. Microbiological specifications of fish products, food contact surfaces, and hands of the personnel

Microorganisms	Maximum limit (CFU)			
	Tanzanian Standards[a]	East African Standards[b]	USFDA[d]	Ghent University guidelines[e]
Fresh fin fish				
Total viable counts	$m = 10^6$ CFU/g, $M = 10^7$ CFU/g	$M = 10^6$ CFU/g	-	-
E. coli	$m = 5$ CFU/g, $M = 10^2$ CFU/g	$M = 10^1$ CFU/g	-	-
Enterobacteriaceae	-	$M = 10^2$ CFU/g	-	-
L. monocytogenes	-	-	Absent in 25g	-
Salmonella spp.	Absent/g	Absent in 25g	Absent in 25g	-
V. cholerae	-	Absent in 1g	Absent in 25g	-
Frozen fin fish[b] or fillets[f]				
Total viable counts	$m = 10^6$ CFU/g, $M = 10^7$ CFU/g	$M = 10^6$ CFU/g	-	-
E. coli	$m = 5$ CFU/g /g, $M = 10^2$ CFU/g	$M = 10^1$ CFU/g	-	-
Enterobacteriaceae		$M = 10^2$ CFU/g	-	-
L. monocytogenes		-	-	-
Salmonella spp.	Absent	Absent in 25g	-	-
V. cholerae		Absent in 1g	-	-
Food contact surfaces (working tables)				
Total viable counts	-	-	-	**
E. coli	-	-	-	**
Enterobacteriaceae	-	-	-	**
L. monocytogenes	-	-	-	Absent in the tested area
Salmonella spp.	-	-	-	Absent in the tested area
V. cholerae	-	-	-	Absent in the tested area
Hands of the personnel				
E. coli	-	-	-	**
Enterobacteriaceae	-	-	-	**
S. aureus	-	-	-	Below limit (10 CFU/25 cm^2) of quantification

[a](Tanzania Standard, 1988). [b](East African Community, 2010a). [c](European Union, 2005). [d](U.S. Food and Drug Administration, 2009). [e](Sampers et al., 2010). [f](East African Community, 2010b)

** Same as product handled in the respective area

Table 1.5. Overview of previous studies applied the FSMS-DI and MAS to analyse performance of FSMS in the food industry

Study area	Country	Major outcome	Reference
Meat Products			
Animal processing industry	Europe	Most participating companies had adequately adapted their FSMS to the riskiness of their context characteristics resulting in good system output. Only a small group have overall basic systems and operate in a moderate or moderate to high risk context, which was reflected in lower system output scores small and medium enterprises had advanced systems, and achieve a good system output. However, their typical organisational characteristics like less resources, more restricted formalisation, limited information systems, but more stable workforce, might require more tailored support from government and/or branch organisations to develop towards advanced systems.	(Luning et al., 2015)
Lamb chain (slaughterhouse, processing plant, butcheries)	Spain	The slaughterhouses, processing plants and butcher shops had basic-average FSMS operating in moderate-risk context, which was not enough to obtain a good system output. Suggestions for improvements towards higher activity levels or lower risk levels in context characteristics (organisation and chain-environment characteristics) were given for each actor.	(Osés et al., 2012)
Meat (beef, pork and poultry)	Spain	Large beef meat processor showed too high TVC but the high FSMS activity scores indicated that this problem could be only solved by supplier measures. Likewise, medium-sized poultry meat processor showed a clear dependency on suppliers. However, actual microbiological assessment revealed a broader contamination problem, and additional measures to improve, amongst others, sanitation program, compliance to procedures, personal hygienic requirements were proposed. Although, no pathogens found, the (small) lamb meat processor showed various contamination problems corresponding with various low FSMS activity levels and high-risk context. The combined diagnosis provided clear directions for improvement towards more advanced FSMS activity levels or to reduce risk levels in context.	(Luning et al., 2011a)
Fish products			
Fish	Vietnam	Poor microbiological safety and quality of the products due to high contamination levels throughout the process. *Escherichia coli, S. aureus*, and *V. cholerae* were found on hands of operators (at packaging area). Presence of *L. monocytogenes* (in 1/9 samples) and *V. cholerae* (4/9) on the final products indicated inadequate hygiene practices.	(Tong Thi et al., 2014)
Fish	Kenya	Microbiological assessment showed that final fish products from 67% (6 of 9) of the companies were within the legally accepted microbiological limits. *Salmonella* spp. were absent in all CSLs. Hands or gloves of workers from the majority of companies were highly contaminated with *S. aureus* at levels above the recommended limits. Large-sized companies performed better in *Enterobacteriaceae, E. coli,* and *S. aureus* than medium- and small-sized ones in a majority of the CSLs, including receipt of raw fish material, heading and gutting, and the condition of the fish processing tables and facilities before cleaning and sanitation. Fish products of 33% (3 of 9) of the companies and handling surfaces of 22% (2 of 9) of the companies showed	(Onjong et al., 2014b)

		high variability in *Enterobacteriaceae* counts. Likewise, high variability in TVC and *Enterobacteriaceae* was noted on fish products and handling surfaces	
Fish	Vietnam	Lactic acid bacteria found in 9/54 product samples with six samples exceeding the limit. Mesophilic bacteria exceeded tolerance level in 5 enumerations. *Listeria monocytogenes* and *Vibrio parahaemolyticus* were below the detection limit throughout the study, indicating a very good situation.	(Noseda et al., 2013)
Dairy products			
Dairy processing companies	Rwanda	The quality of raw milk was satisfactory for the majority of samples, but 5.2% contained *Salmonella* spp. At the processing level, the total mesophilic count and coliforms indicated ineffective heat treatment during pasteurisation or post-pasteurisation contamination. Increasing bacterial counts were observed along the retail chain and could be attributed to insufficient temperature control during storage. Milk and dairy products sold in milk shops were of poor and variable microbiological quality in comparison with the pasteurised milk sold in supermarkets. The microbiological load and pathogen prevalence in cheese were unacceptably high.	(Kamana et al., 2014)
Dairy processing companies	Kenya	Three dairies (two large-scale and one medium scale) achieved the maximum profile scores of 18 for environmental samples and 15 for the end product. *Escherichia coli* was detected on food contact surfaces (in three small-scale dairies) and in final product (2/3 small dairies), an indication of cross-contamination. Most operations in small-scale dairies were manual, with minimal system documentation and poor hygienic practices such as hand washing and cleaning and disinfection procedures. Dairies implementing HACCP or ISO 22000 had maximum profile scores and safer products	(Opiyo et al., 2013)
Dairy processing companies	Japan	Dairy companies with national HACCP approval had higher system output as they have advanced FSMS operating under less risky context. All companies scored high level on technology-dependent activities (i.e. preventive measures and intervention processes), but less in managerial activities as monitoring and typical quality assurance activities like validation and verification of the FSMS	(Sampers et al., 2012)
Fruits and vegetables			
Primary production of lettuce	Brazil	All three surveyed organic lettuce farms operate in a moderate to high risk level with regards to product and process characteristics. The indicators of organization and chain characteristics indicated moderate to high risk level (use of historical knowledge and high turnover of employees). The design of control activities was at a basic level (use historical or common knowledge), whereas operation of core control activities and assurance activities are not inexistence/applied.	(de Quadros Rodrigues et al., 2014)
Fresh produce	Kenya	Majority of the processors (≥7) operate under medium-risk level in most (74%) of the indicators of context riskiness. For product characteristics, 7/13 processors had high-risk raw materials due to high susceptibility to microbial contamination. Even though majority of the companies had 6/29 control activities at advanced level, 48% at an average level and 24% control activities not applied. Also, majority of companies have 89% of the assurance activities at average level. Performance of FSMS of 53% and 37% of the processors were at basic and advanced level, respectively. All the processors had advanced scores for monitoring of pesticide residues but five lacked sampling and subsequent criteria for microbial analysis. The performance of FSMS activities	(Sawe et al., 2014)

		was basic-average level for 77% of the companies while operating under moderate context riskiness resulting in moderate system output.	
Various food products			
Food processing companies	Belgium	Ninety percentages of 82 food processing companies analysed were certified for a voluntary standard like BRC or IFS prior to or next to the Belgian self checking system (SCS) certification (50%). Although five clusters could be identified among the 82 participating companies in the performance profiles of their FSMS and system output, overall no significant difference could be identified between SCS certified and non-certified food processing companies. However, SCS certified companies indicated advanced assurance activities (i.e. validation and verification of the FSMS). No significant differences were found according to company size, but depending on the sector more robust FSMS could be identified (e.g. animal products processing sector). It was indicated that a certification system based on audits is an appropriate approach in pro-actively governing food safety and supporting the implementation of control and assurance activities at advanced level, hence increasing the robustness of the FSMS as a basis for good system output.	(Jacxsens et al., 2015)
Food service/hospitality sector			
Food service establishments (FSE)	Spain	Hierarchical cluster analysis revealed four clusters of FSE differing in organisational characteristics and FSMS activity levels. The largest cluster composed of all small restaurants, showed lowest FSMS performance levels and limited organisational support, due to lack of safety expertise/support, limited training, restricted employee involvement, and no formalisation. In general, they did not use sector guidelines or any expert knowledge to design their FSMS. However, some crucial control measures (like cooling and cooking) performed at an average level; they use professional equipment with known capability with only sometimes unstable performance. Only a small cluster of FSE provided supportive organisational conditions and their systems perform at an average to advanced level. They invested in best available equipment, some tested and adapted to their circumstances, and acquired expertise support to design and independently evaluate their system.	(Luning et al., 2013)

CHAPTER 2

Food safety management systems performance in African food processing companies: a review of deficiencies and possible improvement strategies

Redrafted from

Jamal B. Kussaga, Liesbeth Jacxsens, Bendantunguka P.M. Tiisekwa, and Pieternel A. Luning (2014). Food safety management systems performance in African food processing companies: a review of deficiencies and possible improvement strategies. Journal of the Science of Food and Agriculture, 94(11):2154-2169.

Chapter 2. Food safety management systems performance in African food processing companies: a review of deficiencies and possible improvement strategies

2.1 Abstract

This study seeks to provide insight into current deficiencies in FSMS in African food processing companies and to identify possible strategies for improvement so as to contribute to African countries' efforts to provide safe food to both local and international markets. This study found that most of the reviewed studies shown that African food products had high microbiological and chemical contamination levels exceeding the set (legal) limits. This study identified various deficiencies at government, sector/branch, retail, and company levels which affect performance of FSMS in Africa. For instance, very few companies (except exporting and large-scale companies) have implemented HACCP and ISO 22000:2005. Various measures were proposed to be taken at government (like construction of risk-based legislative frameworks, strengthening of food safety authorities, recommend use of ISO 22000:2005, and consumers' food safety training), branch/sector (like sector-specific guidelines, third-party certification), retail (develop stringent certification standards, impose product specifications), and company levels (improving hygiene, strict raw material control, production process efficacy, enhancing monitoring systems, assurance activities, supportive administrative structures). By working on those four levels, FSMS of African food companies could be better designed and tailored towards their production processes and specific needs to ensure food safety.

2.2. Introduction

Recent global food crises have increased attention to food safety in the food value chain (Henson and Jaffee, 2007). Food companies and agribusinesses have put considerable efforts into implementing and improving FSMS, since the Codex Alimentarius hygiene code of practice has become the worldwide reference (Codex Alimentarius Commission, 2003). However, food products are sourced from all over the world, transported over long distances, produced under different cultivation practices and climatic conditions, and are manufactured using various processing techniques creating more possibilities for incidences of food safety hazards (Henson and Jaffee, 2007; Jacxsens et al., 2010a; Tirado et al., 2010) like *E. coli* O104:H4 in sprouted seeds in 2011 (Buchholz et al., 2011), rift valley fever in meat in 2007 (Breiman, 2008), melamine contamination in infant milk in 2007 (Gossner et al., 2009) and aflatoxins in maize in 2004 (Probst et al., 2007).

In Africa, food processing companies experience an increase in export of high-value agricultural food products (including fish and horticultural products) (Henson et al., 2005; Okello et al., 2007). For example, during 1990-2007 export of fruits and vegetables from sub-Saharan Africa to Europe increased by more than two-folds (Golub and McManus, 2008; Henson et al., 2011). However, uncontrolled use of agro-chemicals and climatic conditions increased the risk of food safety hazards in Africa (Bempah et al., 2011). Nowadays, African food companies put more efforts into designing and upgrading their FSMS in response to demands of importing countries (Henson et al., 2005; Bagumire et al., 2009b) and to a lesser extent of local markets (Reardon et al., 2003; Weatherspoon and Reardon, 2003). African governments are currently upgrading their legislation and national food control systems to guarantee safety of their food products (Nguz, 2007; Bagumire et al., 2009b; Neeliah et al., 2009). However, they still experience food export rejections due to poor microbiological (such as *Salmonella* spp.) quality of their products (Chapter 1). Moreover, at the local level, food borne diseases such as diarrhoea, cholera, salmonellosis, typhoid, and mycotoxicoses are rising (WHO, 2007). This implies that the FSMS of food processing companies in Africa are not yet effective (Chapter 1).

The objective of this review was therefore, to gain insight into the current deficiencies in FSMS in African food processing companies and to identify possible strategies for improvement to enable African countries to provide safe food to both local and export markets. Studies on microbiological and chemical safety of African food products, performance of current FSMS in food companies in Africa, and hurdles of context characteristics wherein the FSMS operate were reviewed. This chapter is organised into six major sections which systematically reviewed literature (i) to identify microbiological and chemical hazards in food products; (ii) based on the structure of the FSMS-DI to identify the status of FSMS in food processing companies in Africa; (iii) on hurdles to implement FSMS and safe food production in Africa; and (iv) performance of FSMS of export and local market oriented companies. It also proposed (v) potential improvement strategies towards effective FSMS, and (vi) briefly discussed the global trend in the application of QA standards and guidelines to improve FSMS.

2.3. Microbiological and chemical safety of African food products

Tables 2.1-2.3 list the microbiological and chemical food safety hazards of African food products reported in the last 12 years (from 2000-2011). Various search engines including ScienceDirect, Ingentaconnect, Emerald, and Wiley Interscience were accessed through Global Online Research in Agriculture (AGORA) to search for peer reviewed articles. In addition, PubMed, Google Scholar and Bing were used to search for peer reviewed articles and grey literature. The combinations of keywords used include: 'microbiological quality + African food products'; 'microbiological hazards + African food products', 'chemical hazards + African food products'. Forty relevant publications were selected. Of the total (40) reported cases of microbial contamination, 33 (83%) exceeded the limits, and 35 (81%) of 43 cases of chemical contamination were beyond the national, USFDA, EU, or CAC maximum residual limits (MRLs). This indicates that African products like fruits and vegetables, fish, dairy items, meat, poultry, and cereal do face problems in meeting national/international microbiological and chemical standards. In **fruits and vegetable products**, microbiological hazards including toxigenic moulds and bacterial pathogens were demonstrated in 6 studies (Table 2.1). Also, parasites and protozoa were reported. Major chemical hazards observed in 7 studies on fruits and vegetable products were mycotoxins, pesticide residues, and heavy metals (Table 2.1).

Table 2.1. Microbiological and chemical hazards detected in fruits and vegetable products manufactured in Africa as reported in scientific publications from 2000-2011.

Hazard	Detected hazard(s)	Food type(s)	Country and references
Microbiological (n[1]=6)	Aspergillus and Penicillium	Fruits (apples, strawberries)	Egypt (Aziz and Moussa, 2002)
	Aspergillus niger, A. ochraceous, and *A. flavus*	Tomato	Nigeria (Muhammad et al., 2004)
	A. flavus, A. niger, Penicillium citrinum and *Fusarium verticilliodes*	Dried vegetables (Okra, tomato)	Benin, Mali, and Togo (Hell et al., 2009)
	Total Aerobic Counts (TAC) (7.0 Log CFU/g), coliforms (7.7), *E. coli* (3.0), *Enterobacteriaceae* (9.8), yeasts, and moulds (6.0). Pathogens include *L. monocytogenes*, *Salmonella* spp. and *S. aureus*	Fresh-cut organic vegetables	Zambia (Nguz et al., 2005)
	Escherichia coli, S. aureus, Klebsiella pneumoniae, and *Candida* spp.	Fruit juices (mango orange)	Libya (Ghenghesh et al., 2005)
	Staphylococcus species (20 CFU/g) and fungal exceeded producers limit (10 CFU/g) in raisins and Apricot products (1000 CFU/g). Salmonella and thermoduric organisms detected in prunes.	Dried fruits (raisins, prunes, apricots)	SA (Witthuhn et al., 2005)
	Escherichia coli O157:H7	Vegetables (cabbage, carrots)	SA (Abong'o and Momba, 2008)
Protozoa (n=1)	Helminth (including *Ascaris* spp. and *Taenia or Echinococcus* spp.) and cysts of *Giardia* spp.	Vegetable salads (cucumber, lettuce)	Libya (Abougrain et al., 2010)
Chemical (n=8)	Aflatoxin B_1 (AFB_1) and AFB_2 (3.2 μg/kg in hot chilli; 6.0 μg/kg in okra)	Okra and hot chilli	Benin, Mali, Togo (Hell et al., 2009)
	Patulin beyond South African legal limit, 50 ng/mL	Apple juice	SA (Katerere et al., 2007)
	Malathion exceeded the MRL (0.1 mg/kg)	Tomatoes and pepper	Ghana (Darko and Akoto, 2008)
	Pesticides including organophosphorus, organonitrogen, and pyrethroids, exceeded MRLs	Vegetables (pepper, green beans)	Egypt (Dogheim et al., 2002)
	Lead (0.01-0.87 mg/kg), Cd (0.01-0.15 mg/kg), Cu (0.83-18.3mg/kg), and Zn (1.36-20.9 mg/kg)	Fruits and vegetables	Egypt (Radwan and Salama, 2006)
	Lead (6.35-20.85 mg/kg) and estimated daily intakes (1.11-2.02 x10^{-2} mg/kg bw) exceeded recommended levels (0.3mg/kg) for green leafy vegetables and FAO/WHO limits of 3-4 x10^{-3} mg/kg bw.	Vegetables (bitter leaf, pumpkin)	Nigeria (Adekunle et al., 2009)
	Lead, cadmium, copper, zinc, cobalt, and nickel	Fruits and vegetables	Nigeria (Sobukola et al., 2010)

[1] Number of articles cited per hazard category; SA: South Africa

With regards to **fish and meat products**, two studies found microbiological hazards, like *Salmonella* spp., *L. monocytogenes*, and *V. cholerae* in fish and fishery products (Table 2.2). Other studies detected pesticide residues like lindane and Dichlorodiphenyltrichloroethane (DDT) (4 studies) and biochemical histamine (1 study) in fishery products. Moreover, 14 studies reported microbiological hazards (such as *Salmonella* spp., *Bacillus cereus*, *L. monocytogenes*, and *Campylobacter* spp.) and 2 other studies noted pesticide residues in meat and poultry products (Table 2.2).

Table 2.2. Microbiological and chemical hazards detected in fish and meat products manufactured in Africa as reported in scientific publications from 2000-2011.

Hazard category	Detected hazard(s)	Food type(s)	Country and references
Fish and fishery products			
Microbiological (n^1=2)	*Staphylococcus aureus*, *L. monocytogenes*, and *V. cholerae*.	Seafood	Nigeria (Falana et al., 2005)
	Salmonella spp.	Fish products	Uganda (Edward, 2004)
Chemical (n=6)	Histamine exceeded the South African legal limit (50ppm): fish meal (76 ppm), smoked snoek (>50 ppm) and dried tuna (8000 ppm).	Seafood	SA (Auerswald et al., 2006)
	Lindane and α-endosulfan below the FAO, U.S. FDA, Australian, and German MRLs	Nile perch and tilapia	Uganda (Kasozi et al., 2006)
	Fenitrothion, DDT, and endosulfan below their respective MRLs	Nile tilapia and perch fillets	Tanzania (Henry and Kishimba, 2006)
	DDE (*p,p'*-1,1-dichloro-2,2-bis-(4-chlorophenyl)ethylene) and DDT (*p,p'*-1,1,1-trichloro-2,2-bis-(4-chlorophenyl)ethane)	Fish	Ghana (Darko et al., 2008)
	Lead, DDE, DDT and endosulfan sulphate were below the U.S. FDA action levels and EU MRLs	Aquaculture	Uganda (Bagumire et al., 2009b)
Meat products			
Microbiological (n=14)	*Salmonella* spp.	Minced meat, burgers and sausages	Botswana (Mrema et al., 2006)
	E. coli O157:H7	Meat cubes, minced meat, and sausages	Botswana (Magwira et al., 2005)
	Salmonella spp., *L. monocytogenes*, and *Campylobacter* spp.	Chicken carcasses	SA (Van Nierop et al., 2005)
	E. coli 0157 (64/180 meat products) and *E. coli* 0157:H7 (5/64 products)	Biltong, minced meat, and polony	SA (Abong'o and Momba, 2009)
	E. coli	Ground beef, turkey, and sausage	Morocco (Badri et al., 2009)
	E. coli, *S. aureus*, and *E. coli* O157:H7	Raw and cooked beef burgers	Libya(Elshrek et al., 2008)
	Bacillus cereus, *S. aureus*, *Pseudomonas* spp., *E. coli*, TAC and *Enterobacteriaceae* exceeded legal limits in meat. Also, *Salmonella* spp. and *L. monocytogenes* detected	Fresh red meat	SA (Nel et al., 2004)
	Salmonella spp. (101/126 samples from abattoir, and 174/199 from retailers))	Meat	Senegal (Stevens et al., 2006)
	Salmonella spp. (23/160 minced beef, 12/85)	Meat products	Ethiopia (Ejeta et al.,

	mutton, and 9/55 pork samples)		2004)
	Salmonella spp.	Meat	Ethiopia (Molla et al., 2003)
	Campylobacter coli, C. jejuni, E. coli, and *Salmonella* spp.	Chickens	Cameroon (Nzouankeu et al., 2010)
	Salmonella spp.	Beef	Nigeria (Orji et al., 2005)
	Escherichia coli O157:H7	Minced beef boerewors	SA (Charimba et al., 2012)
		Biltong	SA (Keshia and Denise, 2010)
Chemical (n=2)	Oxytetracycline above the WHO/FAO MRLs for muscle (200 µg/kg), liver (600 µg/kg), and kidney (1200 µg/kg).	Beef, kidneys, and livers	Nigeria (Olatoye and Ehinmowo, 2011)
	Tetracycline (524-1,046 µg/kg) above Kenyan limit.	Beef, kidneys, and livers	Kenya (Muriuki et al., 2001)

[1] Number of articles cited per hazard category; SA: South Africa

For the **dairy products**, microbiological hazards such as *Salmonella* spp., *S. aureus*, and *E. coli* were reported in 10 studies, whereas 7 studies found chemical hazards like mycotoxins and pesticide residues (Table 2.3). The main route of mycotoxin contaminations in milk and dairy products is animal feed (Coffey et al., 2009).

Table 2.3. Microbiological and chemical hazards detected in dairy products manufactured in Africa as reported in scientific publications from 2000-2011.

Hazard	Detected hazard(s)	Food type(s)	Country and references
Microbiological (n[1]= 10)	*Enterobacteriaceae, E. coli, Salmonella* spp., *K. pneumoniae*, and *E. sakazakii*	Yoghurt and cheese	Ethiopia (Yilma et al., 2007)
	Enterobacteriaceae, TAC, *S. aureus, E. coli, B. cereus*, Enterococcus, yeasts, and moulds	Raw milk	Mali (Bonfoh et al., 2006)
	More than 6 Log CFU/mL of TAC, *E. coli, B. cereus, S. aureus, S. agalactiae, Enterobacter aerogenes*, and *Enterococcus faecalis*.	Raw milk	Tanzania (Kivaria et al., 2006)
	Escherichia coli (including ETEC) and *S. aureus* up 7.8 log CFU/mL.	Pasteurised and fermented milk	Zimbabwe (Gran et al., 2003)
	Lactobacillus, Streptococcus, Enterococcus, Enterobacteria, *Salmonella* spp., Shigella, and moulds.	Fermented milk	Burkina Faso (Savadogo et al., 2004)
	Escherichia coli in 81% of NSM samples (31) and in all (70) CM samples, with 39% and 47% of respective samples containing more than 1000 CFU/mL.	Fermented milk	Zimbabwe (Gran et al., 2002)
	Proteolytic-psychrotrophs, *Corynebacterium pseudodiphtheriticum* and *Bacillus brevis*	Raw and pasteurised milk	Botswana (Aaku et al., 2004)
	Coliforms, yeasts, and moulds	Yoghurt	Uganda (Mukisa and Kyoshabire, 2010)
	TAC, coliforms, *C. burnetii*, coagulase-positive Staphylococci and *Salmonella johannesburg* beyond Senegalese official standards	Raw, pasteurised, and fermented milk	Senegal (Breurec et al., 2010)

	Coliforms, coagulase-positive *Staphylococci* spp., *Listeria* spp., H_2S-reducing *Clostridia* spp., *B. cereus*	Raw and fermented milk	Guinea, Gambia, and Senegal (Hempen et al., 2004)
Chemical (n=7)	Aflatoxins in raw milk (6.3 µg/kg), cheeses (10 µg/kg), and milk powders (15 µg/kg) surpassed the EU/CAC permissible levels of 0.05 µg/kg (products for adults) or 0.025 µg/kg (infant formula)	Raw milk, cheeses, and milk powders	Egypt (Abbas, 2005)
	Aflatoxins in milk (4.0 µgL^{-1}) and ice cream (2.23 µgL^{-1}) exceeded the EU/CAC limits of 0.05 µg/kg (products for adults) or 0.025 µg/kg (infant formulae)	Milk and ice cream	Nigeria (Atanda et al., 2007)
	DDT in cheese (14.02-298.57 µg/kg), fresh milk (12.53 µg/kg) and yoghurt (4.09-8.96 µg/kg), and endosulfan in fresh milk (0.60 µg/kg), yoghurt (0.05-0.06 µg/kg), and cheese (2.70-4.25 µg/kg), lower than WHO limits.	Raw milk, yoghurt, and cheese,	Ghana (Darko and Acquaah, 2008)
	Antimicrobial residues in milk.	Raw milk	Tanzania (Kivaria et al., 2006; Kurwijila et al., 2006a)
	Antimicrobial residues belonging to b-lactams, tetracyclines, aminoglycosides, macrolides, and sulfonamides families.	Raw and pasteurised milk	Kenya (Kang'ethe et al., 2005)
	Aflatoxin M_1 (0.22-6.90 µg/L).	Raw milk	Sudan (Elzupir and Elhussein, 2010)
	Penicillin (229/1109 samples: 165/229 contained penicillin G-type, with 118/165 exceeding the EU MRL, 4 µg/kg)	Raw milk	Kenya (Shitandi and Sternesjö, 2001)

[1] Number of articles cited per hazard category

With respect to **cereal and derived products**, microbiological hazards were observed in 8 studies, whereas mycotoxins were reported in 19 studies (Table 2.4). Nevertheless, the food safety problems reported from Africa can be considered as the tip of an iceberg since many cases go unreported due to lack of good monitoring and surveillance or outbreak reporting systems (FAO/WHO, 2005; Todd, 2006). Most food products from reviewed reports may be unsatisfactory or may not meet local and export markets' food safety requirements.

Table 2.4. Microbiological and chemical hazards detected in cereal products manufactured in Africa as reported in scientific publications from 2000-2011.

Hazard	Detected hazard(s)	Food type(s)	Country and references
Microbiological (n[1]=8)	Fumonisins producing fungi	Maize, wheat	Uganda (Kaaya and Kyamuhangire, 2006), Nigeria (Bankole et al., 2003), SA (Mashinini and Dutton, 2006), others (Bankole et al., 2006)
	Zearalenone (ZEA) producing fungi	Corn, barley, rice sorghum, wheat, oats and millet	North Africa (Zinedine et al., 2007b)
	Aspergillus spp., *Penicillium* spp. and *F. verticillioides*.	Maize	Ghana (Kpodo et al., 2000), Benin (Fandohan et al., 2005),
	Toxigenic fungi including Aspergillus, Fusarium, Penicillium and Rhizopus	Maize, sorghum malt, wort and beer	Botswana (Nkwe et al., 2005), Uganda (Kaaya and Kyamuhangire, 2006), and Cameroon (Tagne et al., 2003; Njobeh et al., 2009)
Chemical (n=19)	Ochratoxin A (OTA) up to 1.08 µg/kg; Fumonisin B_1 (FB_1) (up to 5960 µg/kg) and ZEA (17 µg/kg)	Corn, wheat, and barley	Morocco (Zinedine et al., 2006)
	OTA (3.5 ± 5.3 ng/g), aflatoxins (12.9 ng/g) and AFB_1 (7.9 ng/g), ZEA (10.4 ng/g).	Wheat, barley, corn, sorghum	Tunisia (Ghali et al., 2008)
	Deoxynivalenol (DON) exceeded EU limit of 1.75 µg/g	Durum wheat	Tunisia (Bensassi et al., 2010)
	OTA exceeding EU limit (5µg/kg)	Wheat, barley, sorghum	Tunisia (Zaied et al., 2009)
	Mycotoxins (0-712 mg/kg)	Sorghum	Nigeria (Makun et al., 2009)
	AFB_1 (0.13-37.42 µg/kg) exceeded EU (5µg/kg) and 2 Algerian (10 µg/kg) limits	Wheat and wheat products	Algeria (Riba et al., 2010)
	Ergosterol (0.1-24.2 µg/g), ZEA (2-13 µg/kg) and Tricothecenes (4-280 µg/kg)	Stored maize	Nigeria (Bankole et al., 2010)
	Aflatoxins beyond Kenyan legal limit (20 ppb)	Maize	Kenya (Lewis et al., 2005)
	Aflatoxins (up to 11.2 µg/kg)	Corn flour	Morocco (Zinedine et al., 2007b)
	OTA exceeded EU limit in rice (5 µg/kg), cereal products (3 µg/kg)	Rice and bread	Morocco (Zinedine et al., 2007a; Zinedine et al., 2007c)
	Enitins (37.5-688 mg/kg), fusaproliferin (<7.4 mg/kg), and beauvericin (<10.6 mg/kg)	Breakfast and infant cereals	Morocco (Mahnine et al., 2011)
	Aflatoxins in Benin (24-117.5 ng/g), Ghana (0.4-490.6 ng/g), and Togo (0.7-108.8 ng/g)	Maize	Benin, Ghana, and Togo (James et al., 2007)
	Fumonisins(70-52670 µg/kg)	Maize	Ghana (Kpodo et al., 2000)
	Fumonisins (11,048 µg/kg) and aflatoxins (158 µg/kg) exceeded respective Tanzania MRLs 1000 µg/kg and the 10 µg/kg in maize	Home stored maize	Tanzania (Kimanya et al., 2008)
	Fumonisins (6.1-12 mg/kg).	Maize	Benin (Fandohan et al., 2005)
	Aflatoxins in malt (408± 68 mg/kg) and beer (22.32 mg/l) exceeded the CAC MRL in ready-to-eat products (10 mg/kg)	Sorghum malt and opaque beer (*thobwa*)	Malawi (Matumba et al., 2011)
	FB_1 (47-1316 µg/kg) in malt, and ZEA in malt (2213 µg/kg) and beer (20 µg/kg)	Sorghum malt, wort, and beer	Botswana (Nkwe et al., 2005)
	Aflatoxin (12.8-30.2 ppb) exceeded the U.S.FDA/WHO limit (20ppb) in maize	Maize	Uganda (Kaaya and Kyamuhangire, 2006)

[1] Number of articles cited per hazard category; SA: South Africa

2.4 Deficiencies in performance of FSMS of African food processing companies

Tables 2.5-2.7 show major deficiencies and shortcomings in core control (Table 2.5) and assurance (Table 2.6) activities as well as system output indicators (Table 2.7) as reported in studies (from 2000-2011) on FSMS performance in Africa. Similar search engines as indicated in (section 2.3) were applied in the literature search. The combinations of keywords used include: 'food safety management systems + African food processing plants'; 'HACCP assessment + African food processing plants'. A total of one hundred relevant studies on FSMS in Africa reported serious deficiencies in the systems. Control activities addressed in this study include the design of preventive measures, intervention processes, and monitoring systems, according to the structure given in Figure 1.4 (Chapter 1). For the **preventive measures**, several studies (43 studies, Table 2.5) found that the dairy industries in Zimbabwe, Tanzania, and Mali use commonly outdated and poorly designed equipment, and also lack proper cooling facilities (Gran et al., 2002; Kurwijila and Boki, 2003; Millogo et al., 2010). Smaller companies that serve domestic markets, in particular, use locally fabricated equipment (Aworh, 2008; Obadina et al., 2008) which is not hygienically designed (Gran et al., 2002). Inadequate raw material control was also reported for the meat sector in South Africa (Nel et al., 2004) and the dairy sectors in Uganda (Faye and Loiseau, 2002) and Burkina Faso (Millogo et al., 2008). In addition, inadequate sanitation programmes and restricted personal hygiene were observed with meat (Botswana) (Mrema et al., 2006), dairy (Burkina Faso, Uganda, and Zimbabwe) (Gran et al., 2003; Millogo et al., 2010; Mukisa and Kyoshabire, 2010) and cassava processing companies (Ghana) (Obadina et al., 2010). Moreover, dairy companies in Ethiopia (Yilma et al., 2007) and Zimbabwe (Gran et al., 2003) and meat shops in Nigeria (Adegoke et al., 2008) used contaminated water due to lack of access to potable water.

With respect to **intervention processes** (20 studies, Table 2.5; processes aimed at reducing microbial contamination to acceptable levels) such as pasteurization, fermentation, and drying, studies showed inadequate and uncontrolled processes (Gran et al., 2002; Aaku et al., 2004; Breurec et al., 2010). For example, spontaneous and uncontrolled fermentation of animal proteins (milk and fish), cereal (sorghum, maize and millet) and vegetable (cowpea leaves) and starchy root crops (cassava) is a common practice for the manufacture of various traditional fermented products (Mugula et al., 2003; Tsegaye and Ashenafi, 2005; Hellström et al., 2010; Franz et al., 2014). Moreover, high microbiological counts (including *Pseudomonas* spp., total aerobic counts, and coliforms) were found in commercially pasteurised milk in Botswana (Aaku et al., 2004), Senegal (Breurec et al., 2010), and Ethiopia(Mirkena, 2010). Excessive counts of coliforms (3.44 log CFU/mL), yeast (3.11 log CFU/mL), and moulds (4.16 log CFU/mL) have been reported in yoghurt in Uganda (Elshrek et al., 2008). In addition, several fungal isolates (from 18 in tomato to 218 in baobab leaves) including aflatoxin producing strains were recovered in dried vegetables in Benin, Mali, Togo, and West Africa (Hell et al., 2009), and 11.9%, 9.9%, 5.4%, and 3.2% of samples of cooked spiced-beef burgers in Libya were contaminated with *E. coli, Aeromonas* spp., *E. coli* O157:H7, and *S. aureus*, respectively (Elshrek et al., 2008).

Typical **monitoring system** design (13 studies, Table 2.5) issues refer to CCP assessment, setting standards and tolerances/limits of process parameters and pathogen levels, analytical equipment, sampling plans, and corrective actions. For the domestic sectors, CCP assessment is not common because hazard analysis of CCP is not mandatory (FAO/WHO, 2005; Ramnauth et al., 2008; Sarter et al., 2010); hence, most companies have neither implemented HACCP nor any prerequisite programmes (PRPs) yet. Besides, a few companies (mainly large size and exporting) have implemented ISO 22000:2005. The export market requirements have made application of HACCP (and to some extent ISO 22000:2005) a common phenomenon in sectors for export like fish and meat (Jaffee et al., 2005; World Bank, 2005). However, poor adoption and application of HACCP by fish establishments in Benin (Food and Veterinary Office, 2009) and improperly defined CCPs by the South African meat processing companies (Food and Veterinary Office, 2011b) are still observed. Standards and tolerances are often not specified for the domestic sectors (FAO/WHO, 2005). Madagascar (Sarter et al., 2010), Tanzania (Musonda and Mbowe, 2002; FAO/WHO, 2005), and Nigeria (Okoli et al., 2005) lack accredited laboratories for chemical and/or microbial analyses. Furthermore, company-specific product sampling plans are often lacking. Therefore, fish companies like those in Tanzania, use sampling plans developed by food control authorities (Food and Veterinary Office, 2011c).

Table 2.5. Overview of design and operation of control activities of food safety management systems in African food processing companies as reported in scientific publications from 2000-2011

	Problems observed	Sector
Control activities related to prevention measures (like hygienic design, raw material control, water quality, personal hygiene requirements, cooling facilities, sanitation programs) (43 studies reported deficiencies in preventive measures)	Non hygienic designed equipment and facilities like inadequate plant layout (n^1=7)	Dairy (Gran et al., 2002; Gran et al., 2003; Sarter et al., 2010), fish (Edward, 2004; Sarter et al., 2010), fruits and vegetables (Sarter et al., 2010), meat (Okoli et al., 2005; Sarter et al., 2010), cassava (Obadina et al., 2010) and various sectors (Ruteri and Xu, 2009)
	Lack of cooling facilities (no stable electricity and cooling systems); use of domestic refrigerators (n=11)	Dairy (Gran et al., 2002; Bonfoh et al., 2003; Millogo et al., 2008; Millogo et al., 2010), meat (Okoli et al., 2005), fish (Daby and Sigurlinnason, 2003; Mbarki et al., 2008), and various food sectors (Henry and Picha, 2000; Ruteri and Xu, 2009).
	No adequate raw material control (n=3)	Meat (Nel et al., 2004), dairy (Faye and Loiseau, 2002), and various food sectors

		(Hanak et al., 2000).
	Lack of access to potable water (use untreated water from open streams and wells; microbiologically or chemically contaminated) and lack of processing water quality control (n=11)	Dairy (Gran et al., 2002; Yilma et al., 2007; Sarter et al., 2010; Mhone et al., 2011), fish (Daby and Sigurlinnason, 2003; Sarter et al., 2010), meat (Sarter et al., 2010), cassava (Obadina et al., 2010), cereal (Amoa-Awua et al., 2007), fruits and vegetables (Henson et al., 2011), and various food sectors (Weatherspoon and Reardon, 2003; Nguz, 2007)
	Poor personal hygiene (workers observed to wipe their faces by bare hands during processing and do not wash hands when switching from dirty to clean areas, no strict personal hygiene requirements, common facilities) (n=6)	Dairy (Gran et al., 2002; Gran et al., 2003; Mhone et al., 2011), cassava (Obadina et al., 2008), meat (Shale et al., 2005), and fish (Edward, 2004).
	Poor sanitation programs (proper detergents and disinfectants not used; mixing dirty and clean equipment); no pest control programmes and proper waste management systems (n=5)	Dairy (Gran et al., 2002; Gran et al., 2003; Elshrek et al., 2008; Millogo et al., 2010) and fish (Daby and Sigurlinnason, 2003)
Control activities related to intervention processes (like capability intervention equipment, maintenance programme, effectiveness intervention methods, packaging interventions) (20 studies reported deficiencies in intervention processes)	Poor physical intervention processes like pasteurisation, sterilisation, and drying (n=7)	Dairy (Faye and Loiseau, 2002; Gran et al., 2002; Gran et al., 2003; Aaku et al., 2004; Yilma et al., 2007; Breurec et al., 2010) and yam (Mestres et al., 2004)
	No/simple packaging (n=2)	Various food products including dairy and meat (FAO/WHO, 2004; Jaffee and Henson, 2005)
	Inadequate intervention methods like fermentation (spontaneous and uncontrolled) (n=4)	Dairy (Gran et al., 2002; Gran et al., 2003) and various fermented products (Holzapfel, 2002; Motarjemi, 2002)
	No/poor maintenance programmes (n=7)	Dairy (Gran et al., 2002; Gran et al., 2003; Mhone et al., 2011), fish (Edward, 2004), cereal products (Aworh, 2008), cassava (Sanni et al., 2007), and various sectors (Keller, 2004)
Control activities related to monitoring systems (like, CCP assessment, setting standards and tolerances, analytical equipment, samplings plans, corrective actions) (13 studies observed deficiencies	No hazard analysis and/or proper assessment of CCP; no HACCP (except for exporting sectors like fish and beef) (n=3)	Fish (Daby and Sigurlinnason, 2003; Ramnauth et al., 2008) and various products (Zinedine and Mañes, 2009)
	Standards and tolerances not specified (n=1)	Various sectors (Keller, 2004)
	No/very few accredited laboratories (no sampling plans) (n=6)	Fish (Musonda and Mbowe, 2002; Bagumire et al., 2009a), meat (Okoli et al., 2005), and various products (FAO/WHO, 2004, 2005; Sarter et al., 2010)

in monitoring system)	Limited/lack of analytical equipment (no accredited laboratories) (n=2)	Fish (Ouaouich, 2007) and various products (FAO/WHO, 2004)
	No/corrective actions do not include products involved in the deviations (n=1)	Various sectors (Keller, 2004)

[1] Number of articles cited per analysed indicator of core control activities

Major deficiencies in core **assurance activities** of African companies (7 studies, Table 2.6) include lack of validation of preventive measures (like cooling, cleaning, and sanitation), intervention processes (cooking, drying, and fermentation), and monitoring systems, and verification of personnel, equipment, and methods-related performance (Jackson, 2006; FAO/WHO, 2007). Reports about food companies in Mauritius (Ramnauth et al., 2008), Tanzania (Musonda and Mbowe, 2002; Food and Veterinary Office, 2011c), and Ghana (Amoa-Awua et al., 2007) indicated inadequate documentation and record-keeping systems.

Table 2.6. Overview of the set-up of assurance activities of food safety management systems in African food processing companies as reported in scientific publications from 2000-2011

	Problems observed	Sector
Assurance activities related to validation of control measures (4 studies reported deficiencies in validation	Lack of scientific information to underpin validation activities (n[1]=2)	Various food products (Jaffee and Henson, 2005; Ouaouich, 2007)
	Absence of validation of cooling facilities, pasteurization, sterilization, water and air quality, sanitation procedures (cleaning and disinfection) (n=2)	Various products (Jaffee et al., 2005; World Bank, 2005)
Assurance activities related to verification of control measures (4 studies reported deficiencies in verification)	No verification of people compliance to procedures, intervention equipment and methods. No hygienic performance tests (n=4)	Fish (Ouaouich, 2007) and various sectors (Jackson, 2006; Neeliah and Goburdhun, 2007; Neeliah et al., 2009)
Assurance activities related to documentation and record-keeping (3 studies reported deficiencies in documentation)	No/inadequate documentation and record-keeping system (n=3)	Fish (Ramnauth et al., 2008), cereal products (Amoa-Awua et al., 2007) and various sectors (McSwane and Linton, 2000)

[1] Number of cited articles per analysed indicator of core assurance activities

The typical **system output** indicators included external and internal evaluation of FSMS (13 studies, Table 2.7). Table 2.7 indicates that, with the exception of exporting sectors, domestic market sectors experience inadequate internal and external evaluation of FSMS. Domestic market sectors, particularly the smaller companies, receive inspection only from the federal/national agencies, which in most cases lack adequate qualified personnel (Neeliah et al., 2009; Sarter et al., 2010). Yet, serious remarks on the performance of FSMS are common (Food and Veterinary Office, 2007, 2009, 2011c). Internal evaluation is rarely conducted due to lack of expertise in the majority of micro- and small-scale companies (Sarter et al., 2010). Microbiological sampling and analysis are conducted by a country's National Food Safety Authorities (FSA), which have competent personnel and use internationally-acknowledged standards (Oloo, 2010; Food and Veterinary Office, 2011c). With regard to export-oriented sectors like fish and meat, some companies experience serious remarks on their systems (Food and Veterinary Office, 2007, 2009, 2011b) and receive both microbial food safety and hygiene-related complaints by customers (Rapid Alert System for Food and Feed, 2009). Hygiene and pathogen nonconformities are occasionally reported. The above studies indicated numerous deficiencies in control and assurance activities, and food safety performance, in general.

Table 2.7. Overview of the level of system output indicators in African food processing companies as reported in scientific publications from 2000-2011

	Problems observed	Sector
System output indicators related to external FSMS evaluation (11 studies reported deficiencies in internal evaluation of FSMS)	Domestic market sectors experience mainly regulatory audits of their FSMS/no audits (n[1]=2)	Dairy (Agenbag and Lues, 2009) and various products (Sarter et al., 2010)
	Major remarks on various aspects of FSMS (n=3)	Fish (Henson and Mitullah, 2004; Food and Veterinary Office, 2007, 2011c)
	Microbial food safety complaints for export and/or no records for domestic sectors (n=5)	Fish (Bagumire et al., 2009a; Rapid Alert System for Food and Feed, 2009; Food and Veterinary Office, 2011c; Rapid Alert System for Food and Feed, 2012) and vegetables (Okello et al., 2007)
	Hygiene-related complaints were occasionally reported in export and domestic market sectors (n=1)	Fish (Food and Veterinary Office, 2011c)
System output indicators related to internal FSMS evaluation (2 studies reported deficiencies in external evaluation of FSMS)	Domestic market sectors experience ad-hoc sampling, mainly on final products done by regulatory authority for product certification purposes (n=2)	Dairy (Agenbag and Lues, 2009) and various products (World Bank, 2005)

[1] Number of cited articles per analysed indicator of system output

2.5. Performance of FSMS in domestic and export oriented food processing companies in Africa

Studies comparing exporting (mainly medium and large companies) and domestic (commonly small enterprises) market chains in Africa found obvious differences in performance of FSMS (Ababouch et al., 2005; Jaffee et al., 2005). Exporting sectors like fish have relatively advanced FSMS compared to typical domestic market sectors like dairy (Jaffee et al., 2005; Ababouch, 2006) (Chapter 1). This is partly due to stringent food safety requirements set by the export market demanding food exporting companies to develop FSMS and redesign their buildings and equipment equivalent to the importing countries' standards (Henson and Mitullah, 2004; Neeliah et al., 2011). Proliferation and increased stringency in food safety and agricultural standards is a basis for the competitive repositioning and enhanced export performance of developing countries (Jaffee and Henson, 2004). Food exporting sectors like fish in Tanzania, Kenya, Uganda, Mauritius, and Senegal, meat in South Africa, Botswana, and Namibia, and fruits and vegetables in Kenya, Ghana, South Africa, and Egypt would not risk losing the lucrative export markets, thus, they have heavily invested to improve their food safety performance and meet the export market requirements (Henson et al., 2000; Jaffee and Masakure, 2005; Fold and Gough, 2008; Bagumire et al., 2010; Henson et al., 2011). For instance, the fishery sectors in Kenya, Tanzania, and Uganda have invested in cold stores on landing beaches, provision of ice to fishers, and purchase of refrigerated trucks to transport fish (Henson et al., 2000; Thorpe and Bennett, 2004). In addition, traceability systems were implemented for meat in Namibia and Botswana (Germain, 2005), horticulture in Kenya and Ghana, and fish sectors (Ababouch, 2007) to meet the export market requirements (Ouma, 2010). Moreover, the exporting sectors have validated PRPs and HACCP plans (Henson and Mitullah, 2004; World Bank, 2005; Henson and Jaffee, 2007). Likewise, sanitation programmes, standards, and tolerances are specified and in-house laboratories have been established (Henson and Mitullah, 2004; Ababouch et al., 2005). Furthermore, exporting countries to the EU are obliged to designate a competent authority to oversee and control food manufacturing companies engaged in export (European Union, 2002). Such competent authorities have been formed and inspection systems were improved in many African exporting countries including Uganda, Tanzania, Kenya, Mauritius, Mozambique, and Ghana (Abila, 2003; Bagumire et al., 2009a; Neeliah et al., 2011). For fisheries, the competent authorities are designated in the ministries responsible for fisheries (Chapter 1). The competent authorities are also subjects to the EU inspection. The competent authorities conduct periodic inspections, analyse fish samples, and validate HACCP plans and quality manuals for the exporting companies (Neeliah et al., 2011). Furthermore, food inspections carried out by the Food and Veterinary Office (FVO) in African fish (like Benin, Cameroon, Ghana, Tanzania, Kenya, Ivory Coast, Mauritius, and Senegal) and meat exporting countries (such as Botswana, Namibia, and South Africa) from 1998 to 2011 found various non-conformances in the official control systems and food establishments like lack of clearly written guidelines and procedures, insufficient recording and documentation, structure (no separation between clean and dirty areas), maintenance, pest control, and poor hygiene at the establishments, vessels, and landing sites (Food and Veterinary Office, 2011a; Neeliah et al., 2011).

The domestic market is characterized by inadequate regulatory and market incentives for food safety (World Bank, 2005; Francesconi et al., 2010). The enforcement of food laws and regulations to domestic market processing sectors is inadequate (Chapter 1). Yet, majority of the companies for the domestic market are micro- and small-scale companies, without state-of-art facilities and well-trained personnel (Chapter 1). Most African countries do not have consumer groups to pressurise food companies adopt best practices to improve food safety. As opposed to food export sectors with well established competent authorities, domestic market sectors across Africa lack well established competent authorities to monitor food companies and stakeholders in the respective food chains (Unnevehr, 2015).

2.6. Hurdles due to context characteristics

The performance of FSMS is not only affected by the design and operation of core control and assurance activities in the system itself, but also by the hurdles in the context wherein it operates (Chapter 1). This study divides hurdles due to context into four different levels including the government, sector/branch, business, and company.

2.6.1. Hurdles at government level

Despite the fact that some African countries like Kenya, South Africa, and Cameroon have national food safety policies, the food safety concerns are not adequately addressed (Table 2.8). For example, the **food laws and regulations** of most African countries including Tanzania, Ghana, Malawi (FAO/WHO, 2005, 2007), Madagascar (Sarter et al., 2010), Benin, Mali, and Togo (Hell et al., 2009), Kenya (Oloo, 2010), and Mauritius (Neeliah and Goburdhun, 2007) are not yet in line with CAC requirements and are neither adequately enforced nor providing clear mandate to responsible authorities to prevent food safety problems. Various studies have also indicated inadequacies in their food control systems, resulting into importation and manufacture of substandard products. For instance, Kenya, Tanzania, and Uganda seem to have 2 food safety control systems, an advanced one and a weak/neglected system. The advanced food safety control systems ensure compliance with standards of the export market, whereas the weak, neglected, or nonexistent food safety control systems deal with the domestic food supply (World Bank, 2005; Food and Agriculture Organisation, 2007; Henson, 2007). In addition, existence of multiple agencies in food control (including Algeria, Botswana, Mozambique, Ghana, Uganda, and Zambia), which commonly lack proper coordination and limited laboratory capacities (like funding, personnel, and equipment) contribute to poor food safety performance (FAO/WHO, 2005). Food standards authorities in some countries like Gabon, Mozambique, Swaziland, and Lesotho are neither well defined nor adequately engaged in setting-up the food standards (FAO/WHO, 2005). Moreover, a sound scientific risk assessment is lacking in majority of countries. They lack expertise and fail to collect toxicological as well as exposure assessment data to carry-out risk assessments (FAO/WHO, 2005). Few African countries have established inspection policy and procedures for export and products intended for the domestic market as the case in Algeria, Burkina Faso, Ghana Sierra Leone, and Zambia (FAO/WHO, 2005). The national food inspection services often lack support, trained workforce, and perform multiple tasks (Chapter 1). Besides, inspection services are located in urban areas while rural and remote areas are experiencing little or do not receive any control (FAO/WHO, 2005). With exception to a few countries like Botswana and South Africa, the majority lack accreditation bodies and/or certification facilities at national levels resulting into high certification costs (Jaffee and Henson, 2004), hindering adoption and implementation of certifiable QA standards. Majority of African countries lack constant supply of electricity and potable water as well as poor waste management adversely impacting the food safety performance (FAO/WHO, 2003). Despite several countries having created consumer organisations and consumer protection policies like in Benin, Nigeria, South Africa, and Kenya (Oloo, 2010), they are not yet effective.

2.6.2. Hurdles at sector/branch level

Sector or branch organisations are essential to ensure food safety performance. For instance, exporting sectors including fish and horticulture have established sector organisations at the national and regional levels (Chapter 1), which have promoted manufacture of high-quality fish and horticultural products in Africa. Examples of such organisations at the regional levels are the Lake Victoria Fisheries Organisation (LVFO) (LVFO, 2012) and Horticultural Council of Africa (HCA) (FPEAK (http://www.fpeak.org/hca.html)). At the national levels, associations in the fishery sector include the Kenya Fish Processors and Exporters Association (AFIPEK), Uganda Fish Processors and Exporters Association (UFPEA), and Tanzania Industrial Fishing and Processors Association (TIFPA) (Henson and Mitullah, 2004). Examples of associations in the horticultural sector include the Tanzania Horticulture Association (TAHA), Vegetable Producers and Exporters Association of Ghana (VEPEAG), Ethiopian Horticulture Producer and Exporters Association (EHPEA), Zambian Export Growers Association (ZEGA), and Fresh Produce Exporters Association of Kenya, FPEAK (http://www.fpeak.org/hca.html). These are among the most successful and active associations that have made export of non-traditional products from African countries possible through the manufacture of high-quality products that meet international market requirements (English et al., 2004). For instance, AFIPEK published a GMP Code for the handling and processing of fish and fishery products (Henson and Mitullah, 2004) and FPEAK developed a QA scheme for horticultural production, the Kenya-Good Agricultural Practice (Kenya-GAP) (FPEAK, 2007; Henson, 2008).

Furthermore, the dairy sector has established associations at regional and national levels. Dairy associations at regional levels include the Eastern and Southern Dairy Association (ESADA) and Eastern Africa Dairy Development Board (www.dairyafrica.com). At country levels dairy boards/authorities have been established, for example, Tanzania, South Africa, Kenya, Rwanda, Uganda, and Swaziland (Moll et al., 2007; Kurwijila and Bennett, 2011). However, other food sectors for domestic markets lack well established organisations to monitor product quality and safety in most African countries. They lack specific guidelines, traceability systems, risk-based quality control programmes, and independent audits (FAO/WHO, 2005; World Bank, 2005). As a result, few food processing companies for the domestic market have implemented PRPs, HACCP, and certifiable QA standards (World Bank, 2005; Food and Agriculture Organisation, 2007; Sarter et al., 2010), which influence the design and performance of FSMS. Lack of proactive players (producers and processors) in some sectors could be a major hurdle towards the establishment of sector specific organisations. This could be partly attributed to inadequate market/retail food safety demands.

2.6.3. Hurdles at market/retail level

Compared to developed countries in Europe and the U.S.A, supermarket is a relatively new phenomenon in the majority of African countries (Reardon et al., 2003; Reardon et al., 2005; Francesconi et al., 2010). The spreading of supermarkets in Africa started in the last decade (Reardon et al., 2005). Multinational retailers like the Carrefour, Woolworths, Tesco, SPAR, and Wal-Mart have opened branches in Africa. Moreover, supermarket chains within Africa including the Shoprite, Uchumi, Metro, and Pick 'n Pay have opened branches in several African countries (Weatherspoon and Reardon, 2003). However, the share of supermarkets in Africa is still very small, often less than 10% (Reardon et al., 2005; Neven and Reardon, 2004) with exception to a few countries including South Africa and Kenya having 55% (Reardon et al., 2003) and 20-30% (Neven and Reardon, 2004), respectively. The rise of supermarkets is associated with industrialisation of food processing practices (Francesconi et al., 2010) and supports food safety performance through use of certification standards (like the British Retail Consortium, International food Standards, Global G.A.P.), retailer-specific standards, and production requirements (Emongor and Kirsten, 2009). A limited growth of supermarkets is noticed in countries like Tanzania, Burkina Faso, Malawi, and Ethiopia, which have very few supermarkets located in the urban areas (Francesconi et al., 2010; Nishiura, 2010; Neven and Reardon, 2004). This implies that food producers and processors receive restricted **market pressure**; limiting the adoption of private certification standards by the food manufacturing sectors (Reardon et al., 2005) and improvement of FSMS.

2.6.4. Hurdles at company level

Supportive **organizational conditions** (such as high workforce quality, supportive administrative structures, and specific information systems) facilitate decision-making in the FSMS, whereas restricted or lack of organisational conditions creates ambiguity and uncertainties in the decision-making, which affect performance of FSMS activities (Luning et al., 2011b). Table 2.8 shows that food processing companies in Africa (20 studies) face hurdles due to inadequate workforce quality and insufficient administrative structures and lack information systems to support decision-making. For instance, some studies reported lack of well-trained technical personnel (as in Tanzania and Morocco) (Benkerroum and Tamime, 2004; Ruteri and Xu, 2009), restricted operators' competence (fish companies in Mauritius) (Ramnauth et al., 2008), too few/simple procedures (Uganda), and basic information systems (Madagascar) (Sarter et al., 2010). With exception of few food companies in Africa, the majority lack in-house laboratories and expertise to conduct microbiological and/or chemical analyses. Thus, they exclusively depend on national food control authorities' laboratories. However, studies indicated inadequacies of these laboratories such as lack of proper equipment and often under-staffing (analysts and inspectors) to effectively perform the required analyses and to monitor the food industry (Jaffee et al., 2005; Bagumire et al., 2009a; Food and Veterinary Office, 2009).

Chain environmental characteristics can put demands on the FSMS as high dependency on other chain actors creates vulnerable decision-making situations, which increase the chance of poor food safety (Luning et al., 2011b). Table 2.8 also shows that the majority of food companies in Africa have high dependency on other chain actors. For instance, some food companies in Kenya, Tanzania, and Uganda have no influence on their suppliers; they can neither set specifications nor audit suppliers' FSMS (Dolan and Humphrey, 2004; Okello et al., 2007). Lack of supplier specifications leads to unpredictable safety levels of incoming raw materials and puts demands on the FSMS. Food companies, particularly those for export, lack authority in their customer relationships. Exporting sectors like fishery in Mauritius and Uganda (Edward, 2004; Ramnauth et al., 2008), horticulture in Kenya (Jaffee and Masakure, 2005; Ouma, 2010), and meat in Botswana (Ransom, 2011) experience third party certifications and specific customer demands. Moreover, these sectors are confronted with conflicting stakeholders' requirements (such as kosher standards, eco-labelling, and halal certification) which put high demands on their systems.

In general, it indicates that African countries have different levels in FSMS performance and context riskiness. Some countries have good performing FSMS in few sectors, particularly, the exporting, while others are still at the basic level. The observed deficiencies in FSMS of food processing companies in Africa, high-risk in context characteristics, and chemical and microbiological hazards in the products call for urgent intervention to safeguard the health of local consumers and for the products to penetrate the export market.

Table 2.8. Context factors influencing FSMS performance in African food processing companies as reported in scientific publications from 2000-2011

	Problems observed	Sector/ product
Organisational characteristics (like technological staff, operator competences, stability workforce, formalization, information systems) (20 studies)	Lack of skilled personnel; do not understand principles of hygiene and good manufacturing practices (n[1]=10)	Fish (Daby and Sigurlinnason, 2003; Ramnauth et al., 2008; Bagumire et al., 2009b), dairy (Benkerroum and Tamime, 2004) cereal (Amoa-Awua et al., 2007), cassava (Obadina et al., 2010), and various sectors (Nguz, 2007; Ruteri and Xu, 2009; Oloo, 2010)
	Lack of technical expertise and restricted competence (n=5)	Dairy(Elshrek et al., 2008), fish (Ramnauth et al., 2008) and various sectors (FAO/WHO, 2005; Ouaouich, 2007; Oloo, 2010)
	Lack of management commitment (n=1)	Various sectors (FAO/WHO, 2005)
	Procedures not available/barely developed (n=1)	Cereal (Aworh, 2008)
	Poor communication (no adequate and reliable information) (n=3)	Various sectors (Nguz, 2007; Neeliah et al., 2009; Sarter et al., 2010)
Chain environment characteristics (like, power in supplier and customer relationships, strictness of QA requirements, legislative infrastructure) (20 studies)	Lack of supplier specifications (n=4)	Fish (Johnson, 2010), vegetables (Dolan and Humphrey, 2004; Okello et al., 2007) and other products (Weatherspoon and Reardon, 2003)
	Lack of authority in customer relationships (international customers demand third party certification; preferences for product characteristics) (n=5)	Meat (Cabrera et al., 2010; Ransom, 2011), fruits and vegetables (Okello and Swinton, 2007), and various sectors (Weatherspoon and Reardon, 2003; FAO/WHO, 2005)
	Absence of food safety awareness by local customers; restricted/no food safety policies or consumer organisation groups. HACCP and GMP not mandatory with the exception of exporting sectors (n=5)	Meat (Cabrera et al., 2010), fish (Ramnauth et al., 2008; Bagumire et al., 2009b), and various sectors (FAO/WHO, 2005; Neeliah et al., 2009)
	Inadequate and outdated food laws (as 12/53 countries have adequate food laws) (n=6)	Fish (Bagumire et al., 2009a), cereals (Zinedine and Mañes, 2009), and various products (Hanak et al., 2000; Neeliah and Goburdhun, 2007; Neeliah et al., 2009; Sarter et al., 2010)

[1] Number of articles cited per analysed context factor

2.7. Possible improvement strategies towards effective food safety management systems in Africa

This review indicates that African food industry is characterised by high risk-conditions in context (like poor workforce quality, lack of administrative structures, and restricted support from the government), serious shortcomings in FSMS (unhygienic design of equipment and facilities, lack of validation and verification), and many problems with product safety for export markets (for example fish and meat) and local markets (dairy and cereal). The combination of the high-risk context situations due to vulnerable chain characteristics including restricted government support and limited supportive conditions in food organisations, and the basic or sometimes even absent performance levels of crucial control and assurance activities, imply a high-risk on safety issues. Interventions are therefore needed in the context to reduce riskiness and in the FSMS to develop towards more advanced levels (Luning et al., 2011a). Moreover, in this review, the interventions to reduce context riskiness are discussed at various levels including the government, branch/sector, retail, and company (Figure 2.1).

2.7.1. Proposed measures at the governmental level

First, the government could **develop or strengthen the national food safety policies and legislation**. Food safety policies provide the basis for the establishment of risk-based food safety legal frameworks and acceptable level of food safety objectives based upon risk assessment (FAO/WHO, 2005; Bagumire et al., 2009a). Food legislation defines the minimum expected standard within which the food industry has to operate (Neeliah and Goburdhun, 2007). It facilitates the adoption of best practices and HACCP principles in the food supply chain in line with CAC (Bagumire et al., 2009a; Al-Kandari and Jukes, 2011). It must clearly state the rights of consumers to safe and wholesome foods and the responsibility of producers and processors to provide safe and wholesome foods (FAO/WHO, 2003) and recommend application of preventive control measures (Mutukumira and Jukes, 2003). A legal sound framework is a critical driver for the development and implementation of FSMS in the food industry (Yapp and Fairman, 2006). However, proper enforcement mechanisms (effective food control infrastructure and adequate capacity) are required to ensure that food companies comply with the food law (FAO/WHO, 2003, 2005). There is a need for African country governments to harmonise their food laws, which are currently fragmented, for effective food control (FAO/WHO, 2004, 2005). Second, **governments could review the organisation of food safety control authorities** (FSAs) and strengthen their capacities to effectively enforce food laws and regulations by investing in staff training, facilities (buildings, equipment, and analytical capabilities) (FAO/WHO, 2003, 2005; Neeliah and Goburdhun, 2007; Bagumire et al., 2009a; Al-Kandari and Jukes, 2011), and by providing legal powers (Sarter et al., 2010). The mandates of agencies involved in food control could be clearly and unambiguously stated, and operational collaboration and coordination established to enhance their effectiveness (FAO/WHO, 2003; Neeliah and Goburdhun, 2007; Neeliah et al., 2009; Sarter et al., 2010). The FSAs could establish HACCP-based control/inspection systems, provide infrastructure for uniform application of HACCP, and conduct validation and verification (FAO/WHO, 2003; Neeliah and Goburdhun, 2007; Al-Kandari and Jukes, 2011). Risk-based inspection, monitoring, and surveillance by the food control authority ensure compliance and give feedback on the FSMS performance (Ababouch, 2000). The FSAs can support micro- and small-scale enterprises to develop, validate, and verify HACCP plans. Audits, validation, and verification of HACCP plans by the FSAs will provide an independent judgment on their systems (Jacxsens et al., 2010b). The FSAs can further support FSMS performance by developing product sampling plans and analytical methods to ensure that the FSMS act in compliance with inter/national standards. Micro and small-scale companies often lack sufficient technical expertise to develop HACCP and sampling plans, conduct microbiological analysis, and interpret the results (Taylor and Kane, 2005). Therefore, adequate laboratory testing services to assess quality and safety of the food supply is essential for an effective food control system (Neeliah et al., 2009).Third, the governments may initiate and facilitate **formation of accreditation bodies** at national levels to reduce certification costs and facilitate the certification process (Jaffee and Henson, 2004; FAO/WHO, 2005, 2007). Fourth, **African governments may support FSMS performance of food companies by ensuring a constant supply of electricity and potable water, and proper waste management** (Sarter et al., 2010). Therefore, enabling environments need to be created for the food companies to adopt the best practices and achieve food safety. Actions that will enable implementation of existing QA standards and guidelines, food laws and regulations to improve food safety performance could be supported by the government.

Fourth, African countries' governments have to include **food safety education in their secondary school curricula and vocational training programmes**. Besides, at the university levels, food safety courses need to be strengthened and recommended to students pursuing biological sciences and related fields. Since, food safety knowledge increases with age; youngest consumers require additional education on food safety (Sanlier, 2009). This would increase food safety awareness and engage students/children in more protective behaviours. However, food safety education is essential for all consumers and food handlers, including managers and staff working in the food companies to improve their food safety behaviour (Sanlier, 2009). Governments have to provide information to consumers about how to avoid food safety risks. Therefore, African governments need to develop national policies regarding food safety education to be given to consumers and stakeholders in the food value chains.

2.7.2. Proposed measures at the sector/branch level

First, the available **sector organisations could be strengthened** and for the sectors without formal organisations could **develop respective organisations** at national and regional levels. Second, the sector organisations could develop **control guides** for their specific sectors. These guides could include sector-specific HACCP guidelines, GMP/GHP codes, and auditable standards (Figure 2.1). Sector guidelines are more flexible than regulatory ones, and they are often developed by people who well understand the problems of implementing best practices in the commercial sector (Lawley, 2010). Third, the sector organisations may recommend the use of **traceability systems and auditable risk-based quality assurance programmes** including ISO 22000:2005. They may perform an independent audit of FSMS of respective food companies and provide information on changes in regulatory and sector requirements. Fourth, the sector organisations could be involved in national standard setting committees and **provision of services like legal assistance and technical backup** for the food companies (Neeliah et al., 2009). Food processing sectors particularly those dealing with the domestic market, may learn through the experience of export sectors like fish and horticulture to strengthen or develop associations that will monitor and guide food companies to improve their food safety performance and promote international trade.

2.7.3. Proposed interventions at the market/retail level

The Business (wholesalers and retailers) in most African countries could first, ensure supply of good-quality and safe products by imposing **third party certification standards** (like BRC and ISO 22000:2005) and specific requirements to their suppliers. They may adopt private certification standards operating in developed countries like Europe, Northern America, and Japan or develop own standards/specific requirements (Figure 2.1). Second, multinational supermarket chains and those within Africa could open more branches in more African countries; the local retailers may use the experience to improve their food safety performance. The high food safety demands imposed by retailers provide an incentive for food companies to adopt the best practices and certification standards (Weatherspoon and Reardon, 2003) and develop physical and human capital in order to raise their **technical competencies** (Fulponi, 2006). Third, retailers may pay **price-premiums** to high-quality food products supplied to promote food safety performance of their suppliers. Fourth, the market/retail could **support** food companies, particularly the micro- and small-scale through provision of expertise in implementing their demands and QA standards and guidelines, validation (preventive measures, intervention and monitoring systems) and independent audit of their FSMS.

2.7.4. Proposed interventions at the company level

At the company level, concise roadmap may be needed to step-wise progress towards more advanced systems. A step-wise approach to implement interventions at the company level would provide more time for food companies, the majority of which are micro- and small-scale companies, to mobilise resources. First, food companies, particularly micro- and small-companies, should be open to **technological innovations** like hygienic design of buildings and equipment, develop/improve available sanitation programmes, and personal hygiene restrictions. The non hygienic designed equipment (like pasteurisers/sterilisers, dryers, packaging equipment, and containers/tanks) and buildings (layout, floor, and walls) could be modified to ensure food safety. Specific sanitation programmes for processing and cleaning equipment, production zones, lavatories, and the surroundings could be developed. Moreover, there is a need for food companies to implement strict hygiene requirements for personnel and visitors. For example, ensuring that personnel put on clean protective clothing, suitable footwear and hair coverings and wash or disinfect their hands after visiting the toilets and before handling products are some of the interventions. These measures are related to the design of preventive strategies to avoid product contamination during processing.

Second, the companies should ensure strict **control of raw materials** through proper monitoring of the delivery chain, adequate control at receipt, sampling design and measuring plans, and supplier specifications.

Third, food companies should **improve their production processes** (for example, adequacy of intervention systems such as pasteurisation, sterilisation, fermentation and adequacy of cooling capacity and equipment maintenance). Use proper and validated intervention equipment for pasteurisation, cooking or drying to ensure adequate intervention processes. Moreover, food companies may use right starter cultures and incubation time-temperature conditions for adequate fermentation processes.
Fourth, food companies could develop **monitoring systems** including follow up of the CCP, define limits and tolerances, establish corrective actions, and calibration programmes.

Fifth, food companies could develop **food safety assurance activities** such as validation, verification, documentation, and record keeping systems. Procedures on how such core assurance activities are organized and executed in the company have to be developed. For instance, what processes/equipment need to be validated/verified, when (how often), and who is responsible (such as internal personnel or consultants/experts). Assurance activities control the FSMS and provide evidence and confidence to stakeholders about meeting the safety requirements (Luning et al., 2009).

Sixth, food companies could create **supportive administrative structures** (like enhancing management commitment, formalisation, and information systems) to reduce context riskiness and improve food safety performance. In addition, food companies may develop standard operating procedures for all activities (including storage, processing, transport, waste management, pest control, cleaning and disinfection, recall, and finance) and conduct formal meetings (with minutes well written) to support decision-making towards food safety. Moreover, food companies could develop strict supplier specifications and set specific requirements on product use by major customers, which may include distribution and storage conditions to prevent unpredictable use of the products by customers.

Seventh, **training of personnel** including managerial staff on food safety and hygiene could enhance their commitment to food safety. The companies should introduce continuous on-job food safety/hygiene training and refresher courses for their staff. Frequent changes in food safety demands accompanied by the occurrence of food safety hazards and emerging pathogens require appropriate knowledge to implement the requirements and control the food safety hazards. Not only, food safety training enables food handlers to make safe and informed decisions about food safety (Seaman, 2010) but also, supports managers to assess food safety risks and assign appropriate hygiene training for their staff (Egan et al., 2007). Thus, food safety performance depends on the knowledge level of the operators/food handlers (Seaman and Eves, 2006; Sanlier, 2009; Luning et al., 2011b).These 7 steps can be considered as a step-wise methodology to work in and set-up or improve a FSMS.

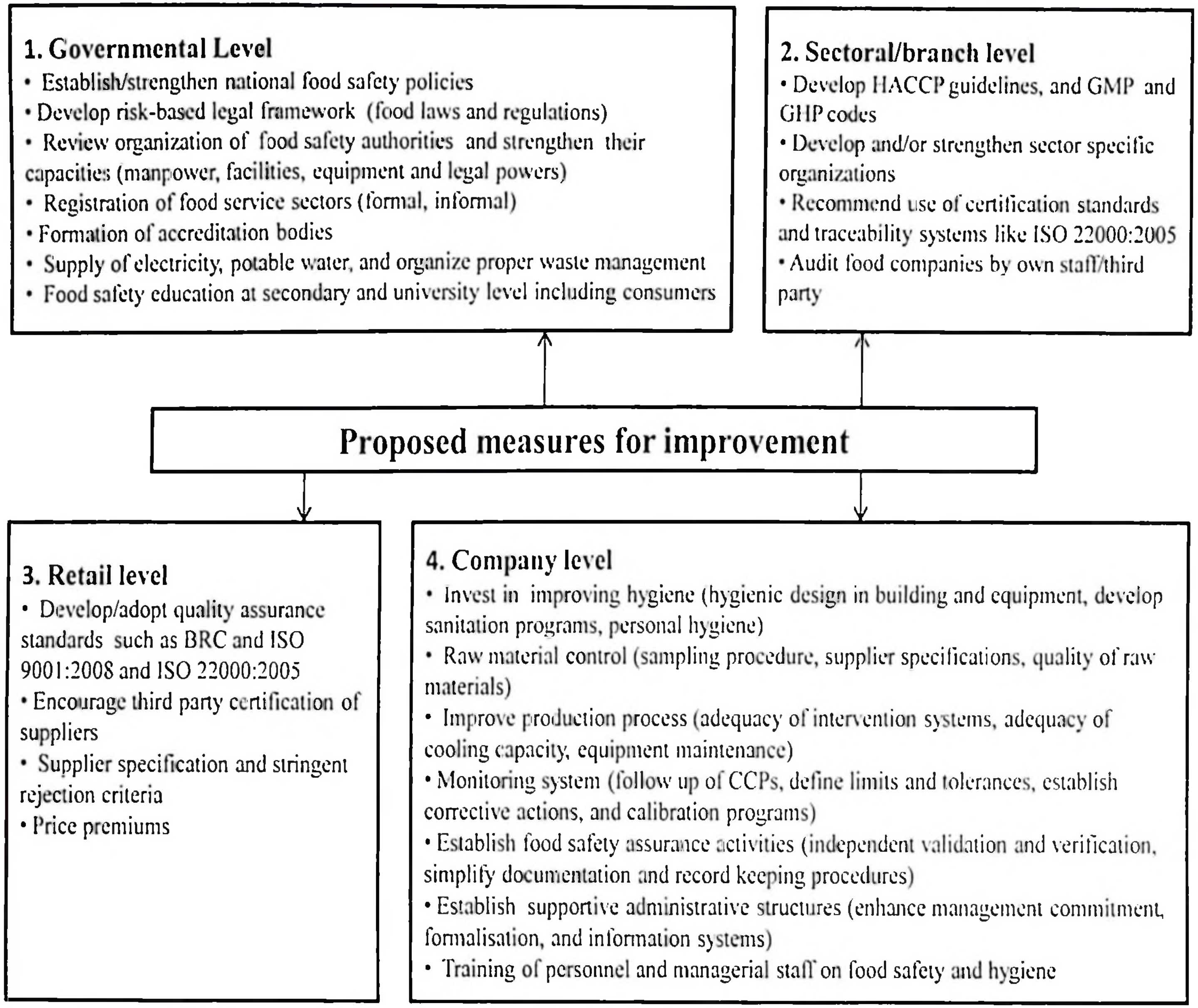


Figure 2.1. Proposed measures towards advanced FSMS in African food processing companies

2.8. Global trend in the application of food safety standards and guidelines to improve FSMS

There is a wide range of QA standards and guidelines in the agri-food chain. These include among others the pre-requisite programmes, HACCP, ISO 9001:2008, ISO 22000:2005, British Retail Consortium, Global Good Agricultural Practices, International Featured Standards and Safe Quality Food Standard (Jacxsens et al., 2011a). These standards and guidelines offer potential benefits to control food safety and/or food quality (Jacxsens et al., 2011a). HACCP was originally considered applicable to the food industry; however, introduction of ISO 22000:2005 has extended the use of HACCP principles to the primary production (Bagumire et al., 2009b). Hence, ISO 22000:2005 is currently perceived as global standard. Since food products are sourced from all over the world, it could be accepted as a universal food safety standard (Arvanitoyannis, 2009). Besides, ISO 22000:2005 is an auditable standard and valuable marketing or promotional tool (Mamalis et al., 2009). It also incorporates legal and regulatory requirements and harmonizes quality management and HACCP principles. For instance, in Greece, ISO 22000 replaces HACCP in the organic food sector (Bilalis et al., 2009). At the end of December 2012, 23,231 certificates of ISO 22000:2005 have been issued in 142 countries and economies, recording a 20% annual growth (ISO, 2012). Africa is in the fourth place of ISO 22000:2005 adoption with 797 certificates, far behind East Asia and Pacific (10922 certificates), Europe (8426 certificates), and Central and South Asia (1524 certificates) (ISO, 2012). However, in terms of per capita consumption, Africa (797 certificates/26 countries = 31 certificates/country) becomes the second from the last followed by Middle East (656/13 = 51), North America (321/3 = 107), Central and South Asia (1524/10 = 153), Europe (8426/46 = 183), East Asia and Pacific (10922/22 = 497) (ISO, 2012). ISO 22000 assigns responsibility to the top management of the company and requires effective communication (both internal and external) and formation of the food safety policy with measurable objectives; this ensures commitment of the top management to food safety. It makes use of operational pre-requisite programs which significantly reduce number of CCPs as compared to HACCP (Varzakas and Arvanitoyannis, 2008; Arvanitoyannis and Varzakas, 2009). It can be implemented by all types of organisations in the food supply chain, from feed and primary production to retail and food service outlets and other organisations indirectly involved in the food chain. Moreover, similar motivating factors for the adoption and implementation of HACCP and ISO 9001 standard could be applicable to ISO 22000:2005 because it incorporates HACCP and quality management system principles. Therefore, in the future ISO 22000:2005 could be a successor of HACCP (Arvanitoyannis, 2009; Bilalis et al., 2009).

2.9. New developments of African FSMS: Analysis of literature from 2011-2015

Recent studies have reported microbial and chemical contaminations in various products across the African continent. A study in Rwandan dairy industry found *Salmonella* spp. in raw milk, high TVC and coliforms in pasteurised milk and cheese (Kamana et al., 2014) . Another study in Cameroon found TVC beyond the legal requirements (<6.3 Log CFU/mL) and coliforms (>5.0 Log CFU/mL) in raw milk. Pasteurised milk contained high TVC (>3 Log CFU/mL for TVC), and mozzarella cheese had high counts of coliforms (≥ 2.7 Log CFU/g) and *E. coli* (>3Log CFU/g) (Belli et al., 2013). Higher levels of TVC beyond the national standards were reported in raw milk (36/109 samples) and pasteurised milk (12/41 samples) in Tanzania (Schoder et al., 2013). Also, foodborne pathogens such as *E. coli* O157:H7 and *Salmonella* spp. were isolated from raw milk but were not detected in heat-treated or fermented products (Schoder et al., 2013). However, coliforms were detected in heat-treated and fermented dairy products (Schoder et al., 2013).

Aspergillus flavus was found in smoked-dried fish in Nigeria (Ikutegbe and Sikoki, 2014), maize grain intended for human consumption from 18 sub-Saharan African countries (Probst et al., 2014), stored maize in Lesotho (Mohale et al., 2013), maize and rice in Egypt (Madbouly et al., 2012) and cassava products in Benin (Adjovi et al., 2014), peanuts and peanut butter in Zimbabwe (Mupunga et al., 2014).

Higher levels of aflatoxins were found in peanut butter (ranging from 6.1 to 247 ng/g) and peanut (ranging from 6.6 to 622 ng/g) with aflatoxin B1 being the most prevalent (ranging from 3.7 to 191 ng/g) (Mupunga et al., 2014). Aflatoxin M1 (AFM1) beyond EU limits (50ng/L) were detected in raw milk from Nigeria (ranging from 9.0 to 456.0 ng/L) (Oluwafemi et al., 2014), Morocco (10-100ng/L) (El Marnissi et al., 2012), Tunisia (13,600 ± 1,400 ng/L) (Abbès et al., 2012), South Africa (20-1500 ng/L) (Dutton et al., 2012). In addition, AFMI beyond EU limits (50 ng/L) was also found in raw milk and imported powdered milk in Sudan (Ali et al., 2014) and processed milk in South Africa (Dutton et al., 2012). Furthermore, higher levels of aflatoxin B1 were detected in sorghum and sorghum products in Sudan (Elbashir and Ali, 2014), peanuts in Kinshasa (DRC) and Pretoria (South Africa) (Kamika and Takoy, 2011). Furthermore, various products from agrarian households in Cameroon were contaminated with mycotoxins including maize which were contaminated with fumonisins (20-5412 μg/kg), aflatoxin B1 (6-645 μg/kg), roquefortine C (1-181 μg/kg), and deoxynivalenol (27-3842 μg/kg); peanut contained aflatoxin B1 (6-125 μg/kg) and ochratoxin A (0.3-12 μg/kg), whereas cassava products had aflatoxin B1 (6-194 μg/kg) and penicillic acid (25-184 μg/kg) (Ediage et al., 2014). Higher levels of aflatoxins (ranging from 14-1041 μg/kg) and fumonisins (178.5-218.5μg/kg) were reported in groundnut-, groundnut/maize- and maize-based snacks in Nigeria (Kayode et al., 2013). Aflatoxin B1 (20 mg/kg), fumonisin B1 (2-796μg/kg), moniliformin (5-1,205 μg/kg) were detected in village stored maize in

Lesotho (Mohale et al., 2013). Also, high levels of fumonisin B1 (up to average of 35.98mg/kg) and B2 (up to average of 14.14 mg/kg) were detected in harvested maize from Transkei in South Africa (Shephard et al., 2013). Also, fumonisin B1 were found in maize (101-53,863 μg/kg) and porridge (0.2-20 μg/kg) consumed by rural population of Limpopo province in South Africa (Phoku et al., 2012), maize from Mozambique (869 μg/kg) and Burkina Faso (269 μg/kg) (Warth et al., 2012), and maize (33 μg/kg) and rice (1014 μg/kg) in Egypt (Madbouly et al., 2012). Aflatoxin B1 was quantified in maize (up to 69.9 μg/kg) and groundnuts (up to 10.5 μg/kg) from Burkina Faso and Mozambique and in Egyptian maize (9.75 μg/kg) and rice (5.15 μg/kg) (Madbouly et al., 2012). Recently, highly pathogenic H5N1 avian influenza in fowls have been reported in some African countries including Nigeria and Egypt (Fasina et al., 2015). Also, norovirus were reported (100-1,000 RNA copies/g) in shellfish particularly, the clams and oysters in Morocco (Benabbes et al., 2013) and fresh produce including green onion, watercress, radish leek and lettuce in Egypt (El-Senousy et al., 2013).

Moreover, recent studies in food safety and hygiene in Ghana found that food handlers were below standard; they had low level of education and limited use of FSMS especially in locally owned businesses across the country (Ababio and Adi, 2012; Feglo and Sakyi, 2012; Ababio and Lovatt, 2015). Inadequate heating processes were reported in dairy industry in Tanzania (Schoder et al., 2013), Rwanda (Kamana et al., 2012), Cameroon (Belli et al., 2012). Insufficient temperature control during storage and along the dairy products supply chain are reported in Rwanda (Kamana et al., 2014) and Tanzania (Schoder et al., 2013).

Therefore, with the additional insights in more recent literature on the status of food safety in Africa, our study still necessitates the elucidation of potential improvements for the dairy and fish sector in Tanzania.

2.10. Conclusions

This study has demonstrated that African food production sectors are characterised by poor microbiological and chemical safety products. Most food products from the reviewed reports were contaminated with micro-organisms (including pathogens) above the set limits and chemical contaminants (including pesticides and mycotoxins) beyond the set MRLs. Hence, both export and domestic markets are subjects to unsafe food products. The FSMS of African food companies have major deficiencies in their control (due to inadequate preventive measures, intervention and monitoring systems) and assurance (lack of validation and verification, and inadequate documentation and record keeping system) activities. With exception to export, domestic oriented companies receive inadequate internal and external evaluation of their FSMS. Consequently, export oriented companies had advanced FSMS compared to domestic market oriented companies. African food companies experience various hurdles (at government, sector, business, and company levels) to design and operate their FSMS and ensure supply of safe products for both export and local markets. Therefore, improvement strategies at four different levels were proposed to address the identified hurdles to ensure effective FSMS in African food industry.

African countries governments need to develop legal frameworks, food safety authorities to perform inspections and product controls; branch organisations to set up common knowledge; and market (retailers) to force their suppliers towards a higher level of FSMS by proposing specifications and certification schemes. Although most African countries have promulgated food laws and regulations, these are not yet adequate and law enforcement has not been effective, particularly for the domestic market sectors. The existence of food laws in these countries is however, an indication of willingness and desire by African countries to improve FSMS. Therefore, proposed measures for improvement at the governmental level should be taken first, followed by initiatives at the sector and business levels to support interventions at the company levels.

CHAPTER 3

Current microbiological performance of Food Safety Management Systems of Dairy Processing Companies in Tanzania

Redrafted from

Jamal B. Kussaga, Pieternel A. Luning, Bendantunguka P.M. Tiisekwa and Liesbeth Jacxsens (2015). Current performance of food safety management systems of dairy processing companies in Tanzania. International Journal of Dairy Technology, DOI: 10.1111/1471-0307.1218.

Chapter 3. Current microbiological performance of food safety management systems of dairy processing companies in Tanzania

3.1. Abstract

A FSMS-DI was applied in 22 dairy processing companies in Tanzania to analyse the set-up and operation of core control and assurance activities and the safety output of the system in view of riskiness characteristics of the systems' context. Three clusters of companies were identified differing in levels of set-up and operation of the FSMS activities and system output, but all operated in a similar moderate-risk context. Assessment of products, environmental and hand samples in one of the companies, using indicator micro-organisms for respectively faecal (*E. coli*), personal hygiene (*S. aureus*), and pathogens (*L. monocytogenes*) contamination, indicated a poor to moderate food safety level as several samples exceeded the set limits. A two stages intervention approach was proposed to enable commitment and sustainable improvement on the longer term.

3.2. Introduction

Tanzania produces a significant quantity of milk, 1.85 billion litres annually (Chapter 1). The milk marketing chain in Tanzania involves informal (80-90% of total milk) and formal (10-20% of total milk) markets as discussed in Chapter 1 (section 1.2.2). Although, Tanzania has high potential for East African Common Market (EACM), the performance of FSMS is not yet adequate (Kivaria et al., 2006; Swai and Schoonman, 2011) as was discussed in Chapter 1 and Chapter 2. Milk adulteration and spoilage, microbial and chemical contamination are common problems (Lore et al., 2005; Kivaria et al., 2006; Swai and Schoonman, 2011). Locally manufactured dairy products such as pasteurised milk, UHT milk, cultured milk, yoghurt, cheese, ghee, and ice cream are characterised by poor and inconsistent quality (Lore et al., 2005; Kurwijila et al., 2006a; Swai and Schoonman, 2011). Moreover, they commonly do not meet quality and safety requirements of local, regional, and international export markets (Omore and Kaitibe, 2007; Kurwijila and Bennett, 2011).

Therefore, this study was conducted to gain insight into the system output in view of the status of core control and assurance activities of implemented FSMS and the context wherein the systems operate in order to identify the opportunities for improvement of the current FSMS in the Tanzanian dairy industry.

3.3. Materials and methods

3.3.1. Characteristics of dairy processing companies involved in this study

Tanzania has about 74 dairy processing companies. This study analysed 22 companies out of a total of 25 companies visited in ten regions of mainland Tanzania. Three companies were left out the study because they were too small without defined processing lines. The companies studied included 6 large-scale (daily capacity of >10,000 L), 1 medium-scale (daily capacity of 5,001-10,000 L), 5 small-scale (daily capacity 1001-5000 L), and 10 micro-scale (daily capacity of ≤1,000 L) (Table 3.2). These companies produced pasteurised and UHT milk, cultured milk, plain and flavoured yoghurt, cheese, and ghee. The FSMS-DI was used to analyse the FSMS of 22 companies. In addition, MAS was applied in one large-scale company as an indication of the actual microbiological system output of the dairy sector. This company was among the intermediate performers and was the closest (300 Km) company to the analytical laboratory. Although this company was small, it had an integrated automated system (plate heat exchanger for pasteurisation and packaging) and used cleaning in place (CIP) system. It manufactured various products including cultured milk (80%), yoghurt (15%), fresh pasteurised milk (2%), UHT milk (2%), and ghee (1%). The cultured-milk production was selected for actual microbiological analysis, because at the time of sampling only two products were produced, cultured and UHT milk. Compared to UHT, cultured milk was regarded as high-risk product because it undergoes pasteurisation and fermentation which only reduces vegetative cells but not inactivating spores. Present micro-organisms could grow when the favourable conditions are met. Figure 3.1 shows the flow diagram for production of cultured-milk and the critical sampling locations.

3.3.2. Diagnosis of the design and set-up of FSMS activities, system output and context riskiness

The FSMS-DI as explained in section 1.5.1 (Chapter 1) was used to diagnose the context riskiness (part 1), level of design and operation of FSMS activities (part 2 and 3), the system output (part 4). The assessment was conducted with the personnel responsible for quality and/or management of the company, which took approximately 2-3h. The mean scores were calculated and transformed to assigned scores as indicated in section 1.5.1 (Chapter 1).

3.3.3. Microbiological assessment

A microbial assessment scheme (MAS) as discussed in Chapter 1 (section 1.5.2) was also used to analyse the actual microbiological output of FSMS of dairy processing companies. The step-wise protocol of the MAS was followed and adapted for the dairy processing companies as described below.

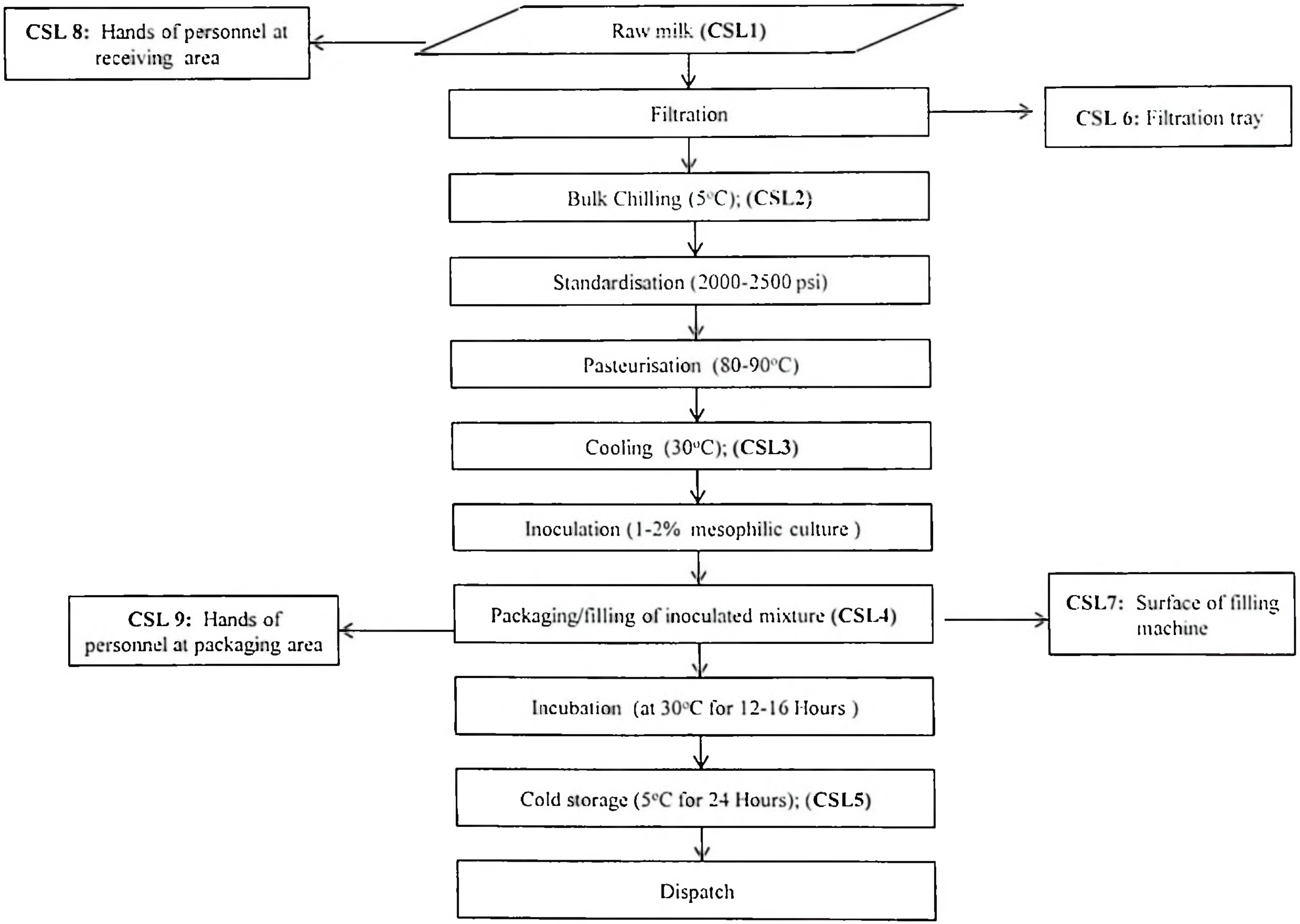


Fig. 3.1. Process flow diagram of cultured milk indicating the critical sampling locations

3.3.3.1 Selection of critical sampling location (CSL)

Nine CSLs were selected (Table 3.1, Fig. 3.1) including the raw materials, the raw milk (CSL1), bulk-chilled raw milk (CSL2), pasteurised milk (CSL3), packaged cultured milk mixture (inoculated pasteurised milk) (CSL4), and cultured milk (CSL5). Environmental samples were taken from food contact surfaces including filtration tray (CSL6) and filling machine (CSL7), and hands of operators at receiving (CSL8) and packaging sections (CSL9).

Table 3.1. Detailed MAS for the dairy processing company producing cultured milk

CSL	Microbiological parameter	Frequency	Sampling method
CSL 1: Raw milk at receiving	Total viable count; *Enterobacteriaceae*; *E. coli*; *S. aureus* ; *Salmonella* spp.; *L monocytogenes*	3 times (1 sample per sampling day)	20 mL of raw milk (ISO, 2008b)
CSL 2: Bulk chilled raw milk	Total viable count; *Enterobacteriaceae*; *E. coli*; *S. aureus* ; *Salmonella* spp.; *L. monocytogenes*	3 times (1 sample per sampling day)	20 mL raw milk (ISO, 2008b)
CSL 3: Pasteurised milk (cooled to 20-22°C)	- Total viable count; *Enterobacteriaceae*; *E. coli*; *S. aureus* ; *Salmonella* spp.; *L. monocytogenes*	3 times (1 sample per sampling day)	20 mL pasteurised milk (ISO, 2008b)
CSL 4: Packed cultured-milk mixture before fermentation (20-22°C)	- Total viable count; *Enterobacteriaceae*; *E. coli*; *S. aureus* ; *Salmonella* spp.; *L. monocytogenes*	3 times (1 sample per sampling day)	20 mL cultured milk mixture (ISO, 2008b)
CSL 5: Final packaged cultured milk (fermented)	Total viable count; *Enterobacteriaceae*; *E. coli*; *S. aureus* ; *Salmonella* spp., *L. monocytogenes*	3 times (1 sample per sampling day)	20 mL cultured milk (ISO, 2008b)
CSL 6 and 7: Filtration tray and surface of filling machine	Total viable count; *Enterobacteriaceae*; *E. coli*; *S. aureus* ; *Salmonella* spp., *L. monocytogenes*	3 times (3 samples per sampling day at start, middle, and end of production)	Surface swabbing 25 cm^2 on filling machine (ISO, 2004)
CSL 8 and 9: Hands of personnel at receiving and packaging areas	*E. coli*; *Enterobacteriaceae*; *S aureus*	3 times (3 samples per sampling day at start, middle, and end of production)	Surface swabbing 25 cm^2 of personnel hands (ISO, 2004)

3.3.3.2. Selection of microbiological parameters

Six parameters including indicators of food safety (*L. monocytogenes* and *Salmonella* spp.), faecal hygiene (*E. coli*), personal hygiene (*S. aureus*) and general process hygiene (*Enterobacteriaceae* and Total Viable Count, TVC) were selected (Jacxsens et al., 2009b).

3.3.3.3. Sampling frequency

Products were sampled once per sampling day, whereas food contact surfaces and operators' hands sampled three times; start, middle and end of production day. A total of 117 [((3 samples x 5 (CSLS1-5) x 3 (1 sampling/month in 3 months)) + (3 samples x 2 (CSL 6-7) x 3 times of sampling/day x 3 (1 sampling/month in 3 months)) + (1 sample x 2 (CSL8-9) x 3 times of sampling/day x 3 (1 sampling/month in 3 months))] analytical samples were taken over the three months.

3.3.3.4. Selection of sampling and analytical methods

A 300 mL sample of raw and bulk pasteurised milk and 500 mL packets of in-process and final products were sampled and transported to the accredited National Fish Quality Control Laboratory (NFQCL) for microbial analysis. Horizontal methods for sampling techniques using cotton swabs on surfaces in food industry (ISO 18593:2004) were used to sample food contact surfaces and hands of operators (ISO, 2004). Sterile template was used to delineate 25 cm^2; similar template was sanitised in 70% alcohol and used to delineate areas for the subsequent sampling. After sampling, cotton swabs were put back into their respective tubes and product samples were stored and transported (at ≤4°C) in a cool box containing ice packs to the laboratory for microbial analysis. Analytical samples were prepared according to ISO 6887-1:1999 and ISO 6887-5:2010 (ISO, 1999, 2010). For detection (absence/presence) tests, 25 mL samples of products and 5 mL of cotton swab samples from food contact surfaces were used for laboratory analysis. Enumeration of TVC, *Enterobacteriaceae*, *E. coli*, *S. aureus* and *L. monocytogenes* were respectively carried out by ISO 4833:2003, ISO 21528-2:2004, ISO 16649-2:2001, ISO 6888-1:1999/Amd.1:2003 and ISO 11290-2:1998 standards. Detection of *Salmonella* spp., and *L. monocytogenes* performed according to ISO 6579:2002 and ISO 11290-1:1996/Amd.1:2004 standards, respectively.

3.3.3.5. Results interpretation

The criteria used to judge the results are indicated in Table 1.3 (section 1.5.2, Chapter 1). Since dairy sector is domestic market oriented; Tanzania Standards, TZS 165:2003, TZS 629:2009, and TZS 251:2009 were mainly used to interpret microbiological results. However, Tanzania standards have no legal limits for pathogens; thus, East African Standards, EAS 67, EAS 33, and EAS 69 were also used to compliment the Tanzanian standard (Table 1.3). For food contact surfaces and hands of the personnel, microbiological guidelines developed by the Laboratory of Food Safety and Preservation, Ghent University (Sampers et al., 2010) were used.

3.3.4. Statistical analysis

Data processing was carried out by using Microsoft Excel. For statistical analysis, hierarchical cluster analysis SPSS (Version 16.0 for Windows, SPSS Inc., Chicago, IL, USA) with the furthest neighbour method and squared Euclidean distance were applied. Then, Kruskal Wallis Non parametric H test was used to determine the significant difference among the clusters. However, it is not possible to establish within the clusters, which cluster differs from the other. Therefore, a post-hoc test (i.e. Mann-Whitney U test) was applied for the clusters that indicated significant difference in particular indicators to determine which of the clusters are significant different. The statistical significant was established at $P<0.05$ for the Kruskal Wallis H test and $P< 0.017$ for the Mann-Whitney U test.

3.4. Results and discussion

3.4.1. Overall system output, performance levels of FSMS activities, and context riskiness

The concept behind the FSMS-DI is that companies operating in a high-risk context require a more advanced FSMS to realise a good system output, whereas in a lower-risk context more simple systems could be sufficient (Luning et al., 2011a). Hierarchical cluster analysis produced three clusters; IA, IB and II composed of 10, 5, and 7 companies, respectively (Fig.3.2). These clusters differed in various aspects as indicated in Table 3.2. Companies in each cluster have the same level of the context riskiness, design and operation of FSMS activities, and system output. Companies in clusters IA and II operated in moderate-risk contexts, while those in cluster IB operated in a rather high-risk context (Table 3.3). However, companies in cluster IA had more advanced FSMS in place (Table 3.4) and better system output than those in clusters IB and II (Table 3.5). This is because cluster IA contained companies ranging from micro- (<10 employees) to large-scaled, with hygienically designed equipment and facilities, well trained personnel, and organised supply chain as compared to cluster IB (containing micro-, small-, and large-scale) and cluster II (composed of micro- and small-scale companies, Table 3.2).

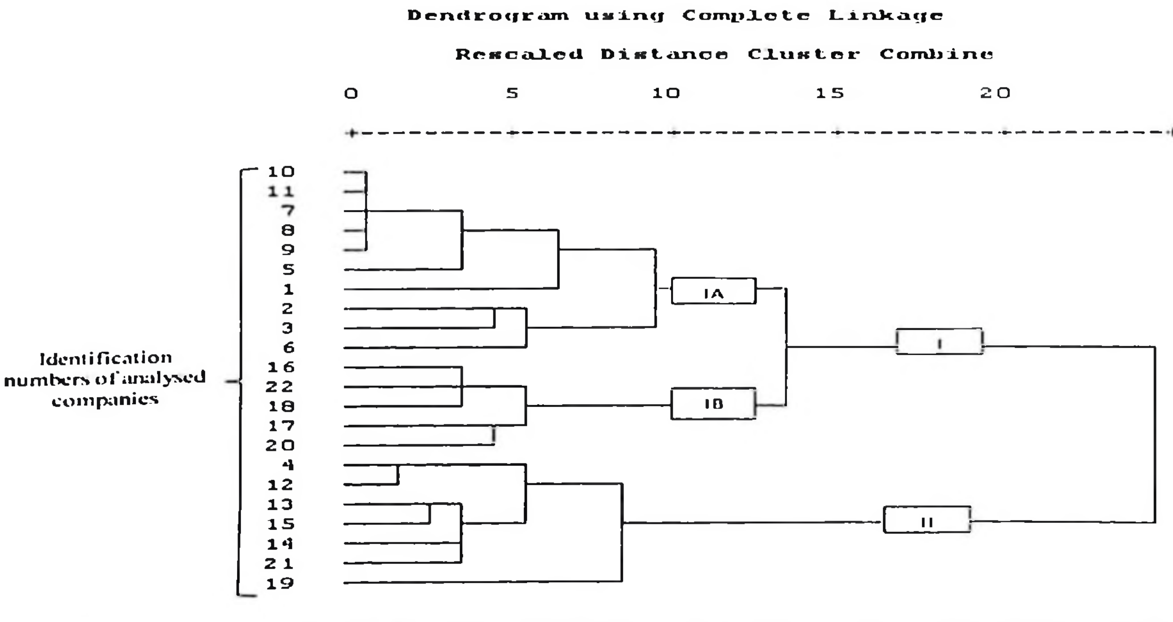


Figure 3.2.A dendrogram showing the clusters obtained by hierarchical cluster analysis of the combined data set of context riskiness, level of control and assurance activities and system output.

Table 3.2. Characteristics of identified clusters of dairy processing companies

Characteristics	Cluster IA	Cluster IB	Cluster II
Size (installed processing capacity, number of employees)	Micro-scale: 5 companies with installed capacity 500-1000 L, <5 employees. Medium-scale: 1 company with installed capacity of 5,000 L; 50-99 employees Large-scale: 4 companies with installed capacity of 12,000-120,000 L; >100 employees	Micro-scale: 1 company with installed capacity of 1000 L; <5 employees Small- scale: 2 companies with installed capacity of 3500-4000L; 5-49 employees Large-scale: 2 companies each with installed capacity of 15,000 L	Micro-scale: 4 companies each with installed capacity of 1000 L; , <5 employees Small-scale: 3 companies with installed capacity of 1200-3000L; 5-49 employees
QA standards or guidelines implemented	PRPs (GHP and GMP)	PRPs (partly)	PRPs (partly)
QA standards certified	None	None	None
QA manager	Micro- (yes), medium- (yes), Large-scale (1 no, 3 yes).	Micro-(no), small (no), and large scale (yes)	Micro-(no) and small-scale (1 no, 1 yes)
QA department	Micro- (yes), medium- (yes), Large-scale (1 no, 3 yes)	Micro-(0), small (0), and large scale (2)	Micro-(no) and small-scale (1 no, 1 yes)
People working in the QA department	Micro- (1), medium- (7), Large-scale (0-4).	Micro-(0), small (0), and large scale (2)	Micro-(0) and small-scale (0-1)
Quality of the workforce	Educated and well trained personnel (from Tanzania and Kenya)	Many are on-the-job trained	On-the-job trained

3.4.2. Diagnosis of context riskiness

Dairy companies in all the clusters had moderate-risk product and process characteristics (Table 3.3). They dealt with high-risk raw materials, the raw milk (median and mean scores 3) and had restricted intervention steps (median and mean scores 2) and low rate in production process changes (median score 1-2; mean score1.4-1.6). The majority used pasteurisation and fermentation processes, which could only eliminate vegetative cells but not spores, and had relatively stable product assortment as no packaging/product modifications in the last 2-3 years. The significant difference (*P<0.017*) was observed in the degree of production process changes (Table 3.3). Companies in cluster IA indicated low-moderate risk (median score 1; mean score 1.7) while those in cluster II showed moderate-high risk (median score 3; mean score 2.7) due to high rate in production process changes during a production day.

Table 3.3. Frequency and statistical analysis of individual scores of indicators to assess the risk level of context factors in each cluster of dairy companies

Indicators to assess level of riskiness of context factors	Frequency of individual score of all 22 companies[1]			Median scores and associated mean scores (in brackets) of the three clusters (IA, IB, & II)[2]			P-value of post hoc (Mann-Whitney U) test between groups[3]		
Risk level of context factors	**1**	**2**	**3**	**IA(10)**	**IB(5)**	**II(7)**	**IA:IB**	**IA:II**	**IB:II**
Product and process characteristics									
Risk raw materials	0	0	22	3.0 (3)	3.0 (3)	3.0 (3)	-[4]	-	-
Risk product group(s)	0	17	5	2.0 (2.4)	2.0 (2)	2.0 (2.2)	-	-	-
Safety contribution packaging concept	1	14	7	2.5 (2.5)	2.0 (2)	2.0 (2.1)	-	-	-
Extent intervention steps	0	22	0	2.0 (2.0)	2.0 (2.0)	2.0 (2.0)			
Degree production process changes	5	10	7	**2.0 (1.7)**^{a}	**2.0 (2.0)**^{a}	**3.0 (2.7)**^{b}	0.375	**0.006**	0.067
Rate product or process design changes	14	5	3	1.0 (1.4)	2.0 (1.6)	1 (1.6)	-	-	-
Organisation characteristics									
Presence of technological staff	0	10	12	**2.0 (2.1)**^{a}	**3.0 (2.8)**^{b}	**3.0 (3.0)**^{b}	**0.009**	**0.000**	0.237
Variability workforce composition	16	6	0	**1.0 (1)**^{a}	**1.0 (1.4)**^{a}	**2.0 (1.6)**^{b}	0.038	**0.008**	0.575
Sufficiency operator competences	1	14	7	**2.0 (2.0)**^{a}	**2.0 (2.2)**^{a}	**3.0 (2.7)**^{b}	0.430	**0.011**	0.093
Extent of management commitment	0	10	12	**2.0 (2.3)**^{a}	**2.0 (2.4)**^{a}	**3.0 (3.0)**^{b}	0.708	**0.005**	0.023
Degree of employee involvement	3	16	3	2.0 (2.1)	2.0 (2)	2.0 (1.9)	-	-	-
Level of formalisation	6	7	9	**1.0 (1.5)**^{b}	**2.0 (2.4)**^{b}	**3.0 (2.9)**^{a}	0.030	**0.002**	0.113
Sufficiency supporting information systems	5	7	10	**1.0 (1.6)**^{a}	**2.0 (2.4)**^{a}	**3.0 (3.0)**^{b}	0.047	**0.001**	0.023
Chain characteristics									
Safety contribution in chain position	0	0	22	3.0 (3.0)	3.0 (3.0)	3.0 (3.0)	-	-	-
Power in supplier relationships	11	9	2	**1.0 (1.3)**^{a}	**1.0 (1.4)**^{a}	**2.0 (2.1)**^{b}	0.708	**0.016**	0.076
Authority in customer relationships	4	15	3	2.0 (1.8)	2.0 (1.8)	2.0 (2.3)	-	-	-
Severity of stakeholder requirements	22	0	0	1.0 (1.0)	1.0 (1.0)	1.0 (1.0)	-	-	-
Context riskiness (overall score)				**1.9** (1.9)^{a}	**2.1** (2.1)^{ab}	**2.3 (2.3)**^{b}	*0.077*	***0.004***	*0.017*

[1] Number of companies in each score indicating the risk-level of the context; level 1 (low-risk), level 2 (moderate-risk), level 3 (high-risk)
[2] Bolded median scores within the same row indicate significant difference at *P <0.05* among the clusters (Kruskal Wallis H Test)
[3] Bolded P-values indicate significant difference (*P<0.017*) between the clusters (Mann-Whitney U test)
[4] Post hoc tests were not performed for median scores which did not indicate significant difference with Kruskal Wallis H test.

For organisational characteristics, there were no significant differences ($P>0.05$) in dairy companies in all clusters with regards to degree of employee involvement. It shows restricted involvement of employees (median and mean scores 2) in design and modification of FSMS though they were stimulated to provide ideas. The significant difference ($P<0.05$) among the companies in the clusters was observed in technological staff, workforce composition, operators competence, management commitment, formalisation and information systems. However, post hoc test revealed significant difference ($P<0.017$) of the mentioned indicators for organisational characteristics of companies between clusters IA and II (Table 3.3). Companies in cluster IA had stable workforce composition (median and mean scores 1), high level in formalisation and sufficient information systems (median score 1; mean score1.6), whereas those in clusters IB (median score 2, mean score 2.4) and II (median and mean scores 3) lacked technological staff, management commitment, formalisation and information systems. This situation contributes to poor decision-making on the FSMS and could result into inadequate system output. Similar studies in Kenya reported poor technical competence of operators of dairy processing plants (Opiyo et al., 2013). Such deficiencies are regarded as amongst the barriers to adoption of best practices (Demirbas, 2007; Karaman et al., 2012), and could result into poor operation of core control strategies (Luning et al., 2011a; Sampers et al., 2012).

For the chain-environment characteristics, for all clusters, except one indicator, power in supplier relationships ($P<0.05$), there were no significant difference for other indicators. All clusters scored 3 in safety contribution in chain position because dairy companies manufactured ready-to-eat (RTE) products. Moreover, all clusters scored 1 with regards to strictness in stakeholders' requirements as dairy companies received general legislative requirements and inadequate market demands. As a consequence, none of the companies had implemented QA standards or guidelines including HACCP principles. In addition, dairy companies in all clusters revealed restricted authority in customers' relationships (median and mean scores 2, Table 3.3). Restricted authority in customers' relationships means less influence on product use by customers, which may result in more unpredictable use that may negatively impact safety at consumption (Luning et al., 2011b). Although some dairy companies could discuss the product use by major customers, they could not influence customers' systems. Post hoc test revealed significant difference ($P<0.017$) with regards to power in supplier relationships between cluster IA and II. Cluster IA (median score 1; mean score 1.3) and IB (median score 1; mean score 1.4) had low-restricted dependency on company suppliers than cluster II (median score 2; mean score 2.1) because as compared to dairy companies in cluster IA and IB, those in cluster II could put specific requirements on quality systems of their major suppliers. Previous studies in Kenya observed that small-scale milk suppliers lack ability to maintain regularity, supply large quantities, and consistently meet the set standards (Omore and Kaitibe, 2007). Moreover, studies in Tanzania observed that farmers and milk traders, who are the major suppliers, adulterate milk with water (Kurwijila and Boki, 2003; Swai and Schoonman, 2011). Thus, restricted power in supplier relationships due to inadequate specifications may lead to receipt of variable and inferior quality raw materials. Likewise, restricted authority on customers' relationships could lead to inadequate handling of dairy products along the distribution chain; leading to product spoilage and pathogen growth (Anderson et al., 2011). Poor product handling and inadequate chilled storage (use of domestic refrigerators, overloading) cause product spoilage (NIRAS, 2010). Also, inadequate stakeholders' requirements (like legal, sectoral and market demands) contribute to poor adoption of good practices and improvement of FSMS by dairy companies (Demirbas, 2007). In general, dairy companies have to adapt their FSMS to at least an average level in order to effectively deal with the current moderate-risk context observed in this study.

3.4.3. Diagnosis of performance of FSMS activities

3.4.3.1. Design of preventive control measures

All clusters indicated significant difference ($P<0.05$) in all indicators of design of preventive measures (Table 3.4). Likewise, Mann-Whitney U test between clusters IA and II revealed significant differences ($P<0.017$) in all indicators of preventive measures design, except one indicator, hygienic design of equipment and facilities. On contrary to the above, post hoc test between cluster IA and cluster IB, and between clusters IB and II did not show any significant different ($P>0.017$) in all indicators of preventive measures design. Cluster IA had dairy companies with advanced (median scores 2-3; mean scores 2.2-3.0) preventive measures design as compared to companies in clusters IB and II, which have majority of indicators at basic-average level (median score 1-2; mean score 0.3-2.0). Dairy companies in cluster IB and II had mean scores ranging from 0.3-1.6 in sanitation programmes, personal hygiene requirements and product specific measures. In addition, cluster II companies indicated basic (mean score 1-1.7) hygienic design of equipment and cooling facilities as they used domestic refrigerators (Table 3.4). It was further observed that milk suppliers used plastic containers (which was previously used to package cooking oil) to store and transport raw milk. Such containers have areas which are difficult to clean; they could easily get scratched and hinder effective cleaning (Gran et al., 2002). Moreover, pests (like flies, cockroaches, and rats), dirty and broken floors, walls, and ceilings were observed in the production areas. Crevices on floors and walls could serve as sites for pathogen growth (Costa Dias et al., 2012), which could result into cross contamination. Studies in dairy industries in other African countries have also observed deficiencies in the design and/or layout of equipment and facilities (Gran et al., 2002), sanitation programmes (Gran et al., 2002; Gran et al., 2003; Aaku et al., 2004; Bonfoh et al., 2006), personal hygiene (Bonfoh et al., 2006), and inadequate cold storage (Kamana et al., 2014). For example, workers in dairy plants in Zimbabwe did not wash their hands when switching from dirty to clean processes (Gran et al., 2002; Mhone et al., 2011).

3.4.3.2. Design intervention processes

All indicators of design of intervention processes with exception to adequacy of intervention methods were significantly different ($P<0.05$) among dairy companies in all clusters (Table 3.4). All clusters indicated dairy companies with restricted intervention methods (median scores 1-3; mean scores 1.8-2.0) because the potential reduction level of pathogens and microorganisms of the applied method i.e. pasteurisation and/or fermentation was not known. Post hoc tests illustrated that clusters IA and IB differed ($P<0.017$) in all other three indicators of intervention system design, whereas companies in cluster IA and IB differed significantly ($P<0.017$) in adequacy of packaging intervention equipment and maintenance and calibration programmes (Table 3.4). As compared to clusters IB and II which indicated basic level; companies in cluster IA revealed an advanced design in intervention processes. Basic level (mean score 0.3-1.2) indicates that dairy companies used general intervention equipment (not product specific), whose process capability is not known. The maintenance and calibration programmes for intervention equipment (i.e., batch pasteurisers and simple filling machine) were initiated by problems and not documented. Likewise, previous studies in dairy sectors identified simple processing equipment in Zimbabwe (Gran et al., 2002) and Kenya (Opiyo et al., 2013), lack of maintenance and calibration programmes in Zimbabwe (Gran et al., 2002; Gran et al., 2003; Mhone et al., 2011), inappropriate packaging equipment in Eastern and Southern Africa (Land O'Lakes, 2007), and inadequate heat treatment/pasteurisation of milk in Rwanda (Kamana et al., 2014).

3.4.3.3. Monitoring system design

All clusters differed significantly ($P<0.05$) in 4 of 7 indicators of monitoring system with exception to three indicators including CCP/CP analysis, analytical methods and calibration and verification programme. All clusters indicated low (median and mean scores 0), basic (median and mean score 1), and average-advanced level (median score 3; mean score 2.4-2.6) in CCP/CP analysis, calibration programmes, and analytical methods, respectively (Table 3.4). The analytical methods revealed average-advanced level because all companies conducted microbial analysis at the accredited laboratories of Tanzania Bureau of Standards (TBS) and Tanzania Food and Drugs Authority (TFDA). However, microbiological analysis was conducted for product certification purposes. Low level (score 0) shows that CCP/CP analysis is not performed (Table 3.4); eventually, none of the dairy companies had fully operational PRPs or implemented any of the HACCP principles or other QA standards. Post hoc test indicated significant difference (*P<0.017*) in all other four indicators of monitoring system design between clusters IA and II, whereas three indicators differed significantly between cluster IA and cluster IB (Table 3.4). Cluster IA companies have indicated significantly (*P<0.017*) high level (median scores 2.5-3.0; mean scores 2.3-2.5) compared to companies in clusters IB and II in adequacy of measuring equipment (median scores 1-2; mean score 1.4-1.6) and extent of corrective actions (median score 0-1.0; mean score 0.3-1.0). This shows that companies in clusters IB and II did not have standardised measuring equipment and corrective actions were based on company knowledge. Moreover, dairy companies in cluster II have not yet specified (median and mean score 0) the sampling plans and limits and tolerances. Small-scale dairy establishments are reported to have inadequate technical experience and resources to apply HACCP and good practices (Demirbaş et al., 2006; Karipidis et al., 2009; Karaman, 2012; Opiyo et al., 2013).

3.4.3.4. Actual operation of control strategies

All clusters differed significantly (*P<0.05*) in 4 of 7 indicators of operation of control strategies (Table 3.4). All clusters had companies with basic procedures (i.e. procedures are commonly paper based, partly available at location, difficult to understand by users and are not kept up-to-date) and sometimes contamination occurs due to inappropriate equipment or facilities (mean score 2). However, all companies had stable measuring equipment (e.g. thermometers and lactometers) and analytical equipment (i.e. microbiological/chemical analyses conducted at the accredited laboratories of the food control authorities). Post hoc analysis between cluster IA and II companies observed significant difference (*P<0.017*) in the level of compliance with procedures, actual cooling capacity, and capability of physical and packaging intervention equipment (Table 3.4). Compared to clusters IB and II, companies in cluster IA indicated advanced level in compliance to procedures, actual cooling capacity, and packaging intervention equipment. For cluster II companies, operators executed tasks based on own insights, and regularly experienced unexpected contaminations due to non-hygienic equipment, and unstable performance of equipment and cooling facilities. Also, studies performed in dairy sectors in Kenya and Tanzania reported lack of procedures (Opiyo et al., 2013) and inadequate packaging equipment (Kurwijila and Boki, 2003; Anonymous, 2007).

Table 3.4. Frequency and statistical analysis of individual scores of indicators to assess the performance level of food safety management system activities in each cluster of dairy processing companies

Indicators to assess performance level of FSMS activities	Frequency of individual scores of all 22 companies[1]				Median and associated mean sores (in brackets) of the three clusters (IA, IB, & II)[2]			P-values for post hoc (Mann-Whitney U) test[3]		
Performance level of FSMS activities	0	1	2	3	IA(10)	IB(5)	II(7)	IA:IB	IA:II	IB:II
Design of preventive measures										
Sophistication hygienic design equipment and facilities	0	2	17	3	2.0 (2.3)	2.0 (2.0)	2.0 (1.7)	0.186	0.033	0.210
Adequacy of cooling facilities	2	2	5	13	**3.0 (3.0)**	**3.0 (2.6)**	**1.0 (1.1)**	**0.038**	**0.000**	**0.014**
Specificity sanitation programme	6	2	12	2	**2.0 (2.2)**	**2.0 (1.6)**	**0.0 (0.3)**	0.114	**0.000**	0.021
Extent personal hygiene requirements	0	11	5	6	**2.5 (2.4)**	**1.0 (1.6)**	**1.0 (1.0)**	0.090	**0.001**	0.081
Adequacy raw material control	0	1	15	6	**3.0 (2.6)**	**2.0 (2.0)**	**2.0 (1.9)**	0.031	**0.010**	0.398
Specificity product specific preventive measures	5	5	6	6	**2.5 (2.5)**	**1.0 (1.4)**	**0.0 (0.4)**	0.049	**0.000**	0.096
Design intervention processes										
Adequacy physical intervention equipment	0	8	4	10	**3.0 (2.8)**	**2.0 (2.0)**	**1.0 (1.1)**	0.078	**0.000**	0.080
Adequacy packaging intervention equipment	5	5	8	4	**2.0 (2.4)**	**0.0 (0.4)**	**1.0 (1.0)**	**0.001**	**0.003**	0.188
Specificity maintenance/calibration programmes	1	10	8	3	**2.0 (2.2)**	**1.0 (1.2)**	**1.0 (1.0)**	**0.012**	**0.003**	0.054
Adequacy intervention method	1	1	20	0	**2.0 (1.8)**	**2.0 (1.8)**	**2.0 (2.0)**	-[4]	-	-
Design monitoring system										
Appropriateness CCP analysis	21	1	0	0	0.0 (0)	0.0 (0.2)	0.0 (0)	-	-	-
Appropriateness limits and tolerances	8	1	7	6	**3.0 (2.6)**	**2.0 (1.4)**	**0.0 (0)**	**0.011**	**0.00**	**0.006**
Adequacy analytical methods	2	2	1	17	3.0 (2.4)	3.0 (2.6)	3.0 (2.6)	-	-	-
Adequacy measuring equipment	0	6	11	5	**2.5 (2.5)**	**2.0 (1.6)**	**1.0 (1.4)**	**0.017**	**0.004**	0.575
Specificity calibration/verification programme	5	16	1	0	1.0 (1.0)	1.0 (0.8)	1.0 (0.6)	-	-	-
Specificity sampling design and measuring plan	11	8	2	1	**1.0 (1.2)**	**0.0 (0.6)**	**0.0 (0)**	0.158	**0.001**	0.086
Extent corrective actions	5	10	1	6	**3.0 (2.3)**	**1.0 (1.0)**	**0.0 (0.3)**	**0.016**	**0.001**	0.018
Actual operation control strategies										
Actual availability of procedures	5	7	10	0	2.0 (1.6)	1.0 (1.2)	0.0 (0.7)	-	-	-
Compliance to procedures	5	6	5	6	**3.0 (2.3)**	**1.0 (1.4)**	**0.0 (0.6)**	0.061	**0.006**	0.069
Hygienic performance equipment and facilities	1	0	21	0	2.0 (2)	2.0 (2)	2.0 (1.7)	-	-	-
Actual cooling capacity	4	1	5	12	**3.0 (2.7)**	**3.0 (3)**	**0.0 (0.7)**	**0.186**	**0.001**	**0.003**
Capability physical intervention equipment	0	4	14	4	**2.0 (2.2)**	**2.0 (2.4)**	**1.0 (1.4)**	0.425	**0.008**	0.021
Capability packaging intervention equipment	9	0	5	8	**3.0 (2.7)**	**0.0 (0)**	**0.0 (1.0)**	**0.001**	**0.007**	0.109

Measuring equipment performance	0	1	1	20	3.0 (2.7)	3.0 (3.0)	3.0 (3.0)	-	-	-
Analytical equipment performance	2	1	1	18	3.0 (2.4)	3.0 (3)	3.0 (2.6)	-	-	-
Assurance activities										
Sophistication translating external requirements	2	7	6	7	3.0 (2.5)	**2.0 (1.5)**	**1.0 (0.9)**	0.112	**0.002**	0.066
Extent of systematic use of feedback information	1	9	5	7	**2.5 (2.3)**	**2.0 (2.2)**	**1.0 (0.9)**	0.791	**0.002**	**0.008**
Sophistication validating preventive measures	8	8	6	0	**2.0 (1.6)**	**1.0 (0.9)**	**0.0 (0)**	0.019	**0.000**	**0.006**
Sophistication validating intervention processes	7	7	8	0	**2.0 (1.7)**	**1.0 (1.2)**	**0.0 (0)**	0.077	**0.000**	**0.001**
Sophistication validating monitoring systems	12	3	7	0	**2.0 (1.6)**	**0.0 (0.2)**	**0.0 (0)**	**0.005**	**0.001**	0.237
Extent verifying people related performance	6	9	2	5	**2.5 (2.2)**	**1.0 (0.8)**	**0.0 (0.3)**	**0.012**	**0.001**	0.093
Extent verifying equipment and methods performance	5	10	6	1	**2.0 (1.7)**	**1.0 (1.4)**	**0.0 (1.0)**	**0.016**	**0.001**	0.018
Appropriateness documentation	0	13	9	0	**2.0 (1.7)**	**1.0 (1.4)**	**1.0 (1.0)**	0.280	**0.005**	0.079
Appropriateness record keeping	0	11	11	0	**2.0 (1.9)**	**1.0 (1.4)**	**1.0 (1.0)**	0.046	**0.000**	0.079
FSMS performance					**2.3 (2.2)**[a]	**1.5 (1.5)**	**1.0 (1.0)**	**0.002**	**0.001**	**0.015**

[1] Number of companies in each score indicating performance level of FSMS activities: level 0 (not applied i.e. low level), level 1 (basic level), level 2 (average level), level 3 (advanced level)
[2] Bolded median scores within the same row indicate significant difference at *P <0 05* among the clusters (Kruskal Wallis H Test)
[3] Bolded P-values indicate significant difference (*P<0 017*) between the clusters (Mann-Whitney U test)
[4] Post hoc tests were not performed for median scores which did not indicate significant difference with Kruskal Wallis H test

3.4.3.5 *Assurance activities*

All clusters indicated significant difference (*P<0.05*) in all indicators of core assurance activities (Table 3.4). Post hoc test between clusters IA and II revealed significant differences (*P<0.017*) in all indicators of assurance activities. Three indicators of assurance activities (i.e. feedback information, validation of preventive measures and intervention processes) indicated significant difference (*P<0.017*) between clusters IB and II companies. The set-up of assurance activities was at average (cluster IA) and basic (cluster IB) levels. Dairy companies in cluster II did not carry out validation of the design of preventive measures, intervention, and monitoring systems, while the rest of activities were at basic level. Basic level corresponds to aspects like problem driven/reactive (for translation of stakeholders demands), not structured and ad-hoc (for documentation and record-keeping system) and not independent (for verification activities) (Table 3.4). Since most dairy companies in Tanzania were micro-enterprises, inadequate human and financial resources, could significantly contribute to such poor set-up of assurance activities. Likewise, a study in Kenya (Opiyo et al., 2013) and South Africa (von Holy, 2005) observed poor documentation and record-keeping systems in dairy companies. Also, lack of validation and verification was mentioned as common problems in south African dairy companies (von Holy, 2005).

3.4.4. Diagnosis of system output by diagnostic instrument and microbiological assessment

All clusters differed significantly (*P<0.05*) in one indicator of system output, the evaluation of FSMS. Cluster IA had companies with moderate level in indicators of system output, whereas those in clusters IB and II revealed low level (Table 3.5). Post hoc test revealed significant difference (*P<0.017*) in system output between clusters IA and II. Dairy processing companies in cluster IA had significantly (*P<0.017*) comprehensive FSMS evaluation (median score 3; mean score 2.4) than ones in clusters IB and II (median score 1; mean score 1.4/0.9, Table 3.5). While only federal food control agencies evaluated the FSMS of companies in clusters IB and II; those in cluster IA involved other accredited third parties. Although, food control agencies are expected to intensively assess the FSMS, Tanzanian food control agencies focus mainly on premise inspection and registration, GMP and GHP audits. Therefore, involvement of accredited third parties (i.e., private audits) in FSMS audits could enable intensive assessment of FSMS (Jacxsens et al., 2010b) and provide an independent judgment on the performance of current systems (Hatanaka et al., 2005; Herath and Henson, 2006). In our study, the majority of dairy companies experienced a few microbiological food safety- and hygiene-related complaints by customers, but none of them had systematic complaints registration in place (Table 3.5). It can be concluded that there is limited information to the companies to gain insights in the actual performance of their own systems.

Table 3.5. Frequency and statistical analysis of individual scores of indicators to assess level of system output in each cluster of dairy companies

Indicators to assess level of system output	Frequency of individual scores of all 22 companies[1]				Median and mean scores (between brackets) of the three clusters (IA, IB, & II)[2]			P-values for post hoc (Mann-Whitney U) test[3]		
Level of system output	**0**	**1**	**2**	**3**	**IA(10)**	**IB(5)**	**II(7)**	**IA:IB**	**IA:II**	**IB:II**
FSMS evaluation	1	13	0	8	**3.0 (2.4)**	**1.0 (1.4)**	**1.0 (0.9)**	0.077	**0.004**	0.170
Seriousness of remarks of FSMS evaluation	1	5	14	2	2.0 (2)	2.0 (1.8)	2.0 (1.4)	-[4]	-	-
Microbiological food safety complaints by customers	0	0	14	8	2.0 (2.3)	3.0 (2.6)	2.0 (2.3)	-	-	-
Hygiene related complaints by customers	0	0	8	14	3.0 (2.8)	2.0 (2.4)	3.0 (2.6)	-	-	-
Product sampling to confirm microbiological performance	1	20	0	1	1.0 (1.2)	1.0 (1)	1.0 (0.9)	-	-	-
Judgment criteria	1	10	3	8	1.0 (2.2)	1.0 (1.8)	1.0 (1.3)	-	-	-
Hygiene and pathogen non-conformities	0	2	19	1	2.0 (1.9)	2.0 (2)	2.0 (2)	-	-	-
System output					**2.3 (2.1)**	**1.7 (1.8)**	**1.6 (1.6)**	0.144	**0.007**	0.283

[1] Number of companies indicating levels of system output: level 0 (no indication of system output), level 1 (poor system output), level 2 (moderate system output), level 3 (good system output)
[2] Bolded median scores within the same row indicate significant difference at $P < 0.05$ among the clusters (Kruskal Wallis H Test)
[3] Bolded P-values indicate significant difference ($P<0.017$) between the clusters (Mann-Whitney U test)
[4] Post hoc tests were not performed for median scores which did not indicate significant difference with Kruskal Wallis H test

To get a deeper insight into the type of food safety/hygiene issues, additional microbiological assessment was conducted in one company belonging to cluster IB. According to the FSMS-DI, dairy companies in cluster IB were not performing so well. Therefore, microbiological sampling would give an indication about the type of problems that could be expected in the companies having more simple systems compared to their context riskiness. In addition, this company was closer to the analytical laboratory as other companies were more than 500 kilometres away. Microbial sampling was conducted in cultured milk because it was the major product processed (contributing to 80% of total production). The MAS (Table 3.6) illustrates that all samples of raw milk (3/3) from a single supplier and bulk chilled raw milk, pooled from various suppliers (3/3) had TVC beyond the Tanzania's, EAC, and EU legal limits. *Escherichia coli* in raw milk exceeded the European Union standards (3 Log CFU/mL). Although Tanzanian, East African and European Union standards did not set limits for *Enterobacteriaceae* in raw milk, they were excessively quantified (7.7 Log CFU/mL). Moreover, pathogens including *Salmonella* spp. and *L. monocytogenes* were found in raw milk (Table 3.6). Since raw milk from healthy animals has low TVCs (probably <2,000 CFU/mL), the very high TVCs, *E. coli*, *Enterobacteriaceae* and the pathogen levels found in raw milk are indicative of either poor hygiene during and post milking and/or poor animal health status. It was however, observed that majority of suppliers were small-scale traders without refrigeration or proper storage containers. Majority of these suppliers used plastic containers which were not hygienically designed; such containers were previously used to pack cooking oil. Lack of good agricultural and animal feeding practices, inadequate general hygiene of milking personnel and equipment, and inappropriate milking methods could result into unacceptable levels of microbial (pathogen) contamination during primary production (Codex Alimentarius Commission, 2004). However, though undesirable and extreme levels of indicator micro-organisms and pathogens are reported (Table 3.6), proper pasteurisation will ensure that the levels of indicator microorganisms and pathogens are reduced to safe levels.

The in-process products including pasteurised milk and cultured-milk mixture before fermentation (i.e., inoculated-pasteurised milk) had higher levels of *Enterobacteriaceae* beyond the European Union standards and Ghent University's guidelines (Table 1.3, Chapter 1). Also, both in-process products were contaminated with *L. monocytogenes*. The presence of *L. monocytogenes* and high levels of *Enterobacteriaceae* found in the pasteurised milk and the inoculated-pasteurised milk are all indicative of possible post heat-treatment contamination due to biofilms formation on equipment and pipe-fittings, poor heat treatment, inadequate cleaning and sanitisation of plant and equipment, poor personnel hygiene, environmental contamination or combination of these could be the cause (Kamana et al., 2014). The analysed company (and most of the companies visited) did not conduct phosphatase tests to check the effectiveness of heat-treatment of the milk. Inadequate intervention strategies (like pasteurisation/sterilisation) and sanitation programmes could contribute to microbiological problems in the dairy industry (Gran et al., 2002; Codex Alimentarius Commission, 2004; Karaman et al., 2012).

Furthermore, the final products, the cultured milk, had higher levels of *E. coli* and *Enterobacteriaceae* beyond the legal limits (Table 3.6). Although no *Salmonella* spp. detected, *L. monocytogenes* were detected and quantified in the cultured milk. Likewise, recovery of faecal and general hygiene indicators beyond the legal limits and presence of pathogens illustrate post heat-treatment contamination, inadequate pasteurisation/fermentation, poor personal hygiene and sanitation. Since *E. coli* were below the quantification limit in pasteurised milk, excessive counts on culture milk mixture, final product and surface of filling machine indicate possibility of cross contamination due to inadequate cleaning procedures, starter culture or from the biofilms that could have been formed on the equipment. Particularly, *L. monocytogenes* and *E. coli* can form biofilms in poorly designed and cleaned equipment, which subsequently contaminate products (Salo et al., 2006; Carpentier and Cerf, 2011; Doijad et al., 2011).

The food contact surfaces including filtration trays of raw milk at receiving area and surfaces of the filling machine were heavily contaminated with hygiene indicator microorganisms and pathogens (Table 3.6). Filtration trays had high level of TVCs (beyond Tanzanian standards), *E. coli* and *S. aureus* (beyond the levels in raw milk), and were contaminated with pathogens like *L. monocytogenes*. High levels of microbiological contamination of filtration trays indicate cross contamination from raw milk, inadequate sanitation of equipment and poor personal hygiene. In addition, surfaces of the filling machine were heavily contaminated with TVCs, *E. coli* and *L. monocytogenes* (Table 3.6). It could further indicate cross contamination from spillage of inoculated-pasteurised milk (which is also contaminated with such microorganisms) during packaging and poor sanitation of the filling machine.

Moreover, hands of the personnel at receiving section had *S. aureus* beyond the set guidelines. At filling section, all indicator microorganisms analysed were below the quantification limit (Table 3.6). Quantification of *S. aureus* on hands of the personnel could be due to cross contamination from raw milk or poor personal hygiene. During sampling, it was observed that personnel did not strictly follow hygienic principles; they occasionally wash their hands without soap or disinfectants. Besides, there were no specific hygienic instructions for the employees. The actual microbial assessment revealed slightly lower (score 1-2) system output (Table 3.6) than one obtained from the FSMS-DI (score 2, Table 3.5). In general, it shows that the judgment of the system output by indicators provide a first indication of actual microbiological output of the system (Jacxsens et al., 2010). The low score for the actual system output reveals also that intervention measures for improvement are necessary to guarantee supply of quality and safe products for the domestic market.

Table 3.6. Microbiological assessment results for dairy processing company indicating critical sampling locations, number of samples exceeded and analysed parameters

Critical sampling location (CSL)	Indicator microorganisms (A/P or log CFU/g or log CFU/25 cm²)					
	Food safety (A/P)		Faecal hygiene*	Personal hygiene*	General process hygiene*	
Microbiological parameters analysed	LIST[a]	SALM[b]	ECOL[c]	STAP[e]	ENTE[d]	TVC[f]
1. Raw milk	**P[g](2/3)**	**P (2/3)**	<1-4.3 (1/3)	<2-2.5[j]	<1-7.7 (2/3)	**6.5–9.5 (3/3)**
2. Bulk chilled raw milk	**P (1/3)**	A[h]	<1 -4.5 (1/3)	<2-3.0	**5.5-6.8 (3/3)**	**7.0-8.4 (3/3)**
3. Pasteurised milk (bulk)	**P (1/3)[i]**	A	<1	<2	<1-1.4	1.5-3.8
4. Packaged cultured milk mixture (before fermentation)	**P (1/2)**	A	<1-4.0 (1/2)	<2	**1.7-2.1 (2/2)**	4.1–5.9
5. Cultured milk (final product)	**P (1/3)**	A	<1-4.4 (2/3)	<2	**2.4-4.3 (3/3)**	7.7-8.3
6. Filtration tray receiving area	**P (3/9)**	A	<1-4.9 (1/9)	<1-2.9 (1/9)	<1-3.1	**5.5-6.9 (9/9)**
7. Filling machine at packaging	**P (1/9)**	A	<1-4.1 (1/9)	<2	<1	4.0-6.3 (1/9)
8. Operator's hands (receiving area)	-	-	<1-4.1	< 1-2.3 (2/9)	<1-2.6	-
9. Operator's hands packaging area	-	-	<1	<1	<1	-
Samples (Absent or <1)	21/31	29/31	30/47	39/47	27/47	0/47
Samples (Present or exceeding legal limits)	10/31	2/31	3/47	4/47	10/47	-
FS performance score	1	2	2	2	2	1
Overall score FS	**10/18 (Assigned score 1-2)**					

[a] *Listeria monocytogenes*; [b] *Salmonella* spp.; [c] *Escherichia coli*; [d] *Enterobacteriaceae*; [e] *Staphylococcus aureus*; [f] Total viable count; [g] Present (with bolded letters/numbers); [h] Absent; [i] number of samples exceeding the limit within a particular CSL (with bolded numbers); [j] lowest and highest CFU counted in all three visits within a specific CSL.

*the results are expressed in log CFU/mL for products and log CFU/25 cm² for contact surfaces (filtration tray, filling machine) and hands of personnel. Bolded numbers indicate samples exceeded legal limits or guidelines. Tanzania standards were used to interpret microbiological results in raw milk (TVC), pasteurised milk (TVC, *E. coli* and *Salmonella* spp.) and cultured milk (*S. aureus*, *E. coli* and *Salmonella* spp.); East African standards for *L. monocytogenes* in pasteurised, cultured milk mixture and final products, European Union standards for *Enterobacteriaceae* in pasteurised milk (Table 1.3). Ghent University guidelines used for *Enterobacteriaceae*, *Salmonella* spp. and *L. monocytogenes* on food contact surfaces and *S. aureus* on hands of the personnel (See Table 1.3).

3.4.5. Proposed interventions for improvement of current FSMS to more effective FSMS

Current FSMS in micro- and small-scale dairy processing companies perform at a basic level whereas they operate in moderate to high-risk context, which increases the chance on unpredictable and uncontrollable system outcomes, which was also demonstrated by microbiological sampling. Therefore, intervention measures to improve performance levels of FSMS activities and reduce the level of context riskiness are needed for all clusters. In Fig. 3.3 a two-stage intervention approach is proposed to create commitment and achieve a sustainable improvement on the longer term. The intervention measures for improvement are systematically proposed on (a) design of core control activities, (b) establishment of context requirements, (c) operation of control strategies, and (d) set-up of assurance activities. The intervention measures are suggested to be implemented into two stages using the above sequence: in the first stages (i.e. stage I) they could be implemented in the short-term while those in the second stages (i.e. stage II) could be implemented in the longer-term.

For the control strategies, in the first stage dairy companies in all clusters could improve sanitation programmes (develop complete sanitation programmes). In clusters IB and II, dairy companies could also use proper cleaning/disinfection materials (the instruction for use could be derived from suppliers/label), intensify personal hygiene requirements (medical check-up, clothing and body cleanliness and strict control of raw milk at receipt (e.g. acidity test, colour, smell and mastitis). Dairy companies could use the available sampling plans and microbiological criteria developed by the sector (e.g. Tanzania Dairy Board), government (i.e. TZS 626:2009, TZS 251:2009 and TZS 1625:2013) (United Republic of Tanzania, 1981a, b) or CAC to be able to verify their status of raw materials and final products. Dairy companies in clusters IB and II could also depend on the support from the equipment suppliers to develop maintenance plans and calibration programmes of their equipment. Also, they could use general hygiene codes for the sector (as described by TBS) and/ or legal requirements to specify standards and tolerances, describe corrective actions, and develop sampling design and measuring plans for microbiological assessment. Furthermore, companies in clusters IB and II could develop paper-based procedures, ensure their availability at location, and intensify personnel supervision to ensure compliance with procedures. For the assurance activities, dairy companies in clusters IB and II could use the national food control agencies to inspect and audit employees on GHP and systematically perform full documentation and registration of product and process data in separate systems. They could also perform independent validation of preventive measures, intervention processes and monitoring system by using internal staff. To reduce the level of context riskiness, in the first stage, dairy companies from all clusters could change employee recruitment criteria (education level and experience) and perform internal training plans change supplier agreements (delivery conditions, and apply available sectoral/legal standards for the raw milk).

A. Design preventive measures, intervention and monitoring systems:

Stage I

- Improve sanitation programmes (complete, cleaning materials or agents, instructions for use from the label) (Clusters IA, IB & II)
- Enhance requirements on personal hygiene (training and routine medical check-up) (IB & II)
- Strict control of raw milk (sectoral/legal microbiological criteria) (IB & II)
- Specific equipment maintenance and calibration programmes (supplier advises) (IB &II)
- Use available sectoral sampling design and measuring plans (IB & II)
- Use sectoral/legal guidelines to develop standards and tolerances (IB &II)
- Develop corrective measures based on sectoral hygiene codes (IB & II)

Stage II

- Invest in hygienic design of buildings (plant layout, washing facilities) and equipment (automatic pasteurisers, packaging/filling machines, cooling facilities (ALL clusters)
- Use of Lactoperoxidase System in storage and transport of raw milk (II)
- Develop specific sampling design and measuring plans (IA)
- Follow-up of CCPs/CPs (implement HACCP principles; ALL clusters)
- Complete and equipment/section-differentiated sanitation programmes (IA)
- Develop standards and tolerances adapted for company specific production situation (Cluster IA)
- Develop differentiated corrective measures based on systematic causal analysis (IA)

C. Improvement of operation of implemented control strategies:

Stage I

- Improve availability of procedures (ALL clusters)
- Intensify personnel supervision to ensure procedures compliance (ALL clusters)

Stage II

- Follow up of interventions (packaging, pasteurisation; ALL clusters)
- Follow up of cooling activities (ALL clusters)

D. Setting-up assurance activities:

Stage I

- Independent audits of employees on GHPs by the national food safety control agency (ALL clusters)
- Full documentation and registration of product and process data in separate systems (IB &II)
- Validation of preventive measures, intervention and monitoring systems (IB & II)

Stage II

- Independent validation of preventive measures, intervention and monitoring systems by accredited third parties (ALL clusters)
- Independent verification of people and equipment related performance by accredited third parties (ALL clusters)
- Establish integrated system of documentation and registration of product and process data (online/digital) (ALL clusters)

B. Establish context requirements:

Stage I

- Change recruitment criteria of staff i.e. strict requirements on education and experience (ALL clusters)
- Training operators and management in good practices e.g. GMP/GHP (ALL clusters)
- Change supply agreements like delivery time, quality and microbiological specifications (ALL clusters)

Stage II

- Develop standard operating procedures (SOPs) for all activities (certain degree of formalisation for ALL clusters)
- Develop quality information systems (Clusters IB &II)
- Establish milk delivery control system on farm, processing and distribution (ALL clusters)
- Setting specific requirements for transport and storage of product (ALL clusters)
- Provide refrigerators to retailers to ensure cold chain and expand product marketing (Cluster IA)

Figure 3.3. Proposed intervention measures and stages for improvement of FSMS of dairy processing companies in Tanzania

In the second stage (Fig.3.3.), dairy companies could focus on more demanding (in terms of time, financial and human resources) interventions. For the control activities all clusters could invest in hygienic design of equipment (automated pasteurisers, sterilisers, and packaging) and facilities (i.e. use industrial cooling facilities, building design and layout) and implement HACCP principles. Machines and other equipment (milk collection cans, filtration trays, cooling tanks) should be hygienically designed (i.e. prevent cracks, crevices, rough welds and dead ends) to ensure effective cleaning and disinfection and to prevent formation of biofilms and fouling (Codex Alimentarius Commission, 2004, 2007). The companies could use stainless steel equipment including milk collection containers. Companies in clusters IB and II could use the experience of cluster IA companies in hygienic design of equipment and facilities. Moreover, companies in cluster II could use the Lactoperoxidase system in storage and transport of raw milk as they do not have operational cold chain in place. However, the dairy companies need to set-up raw milk collection centres with trained personnel to apply the right dosage of thiocyanate (NaSCN) and hydrogen peroxide (sodium percarbonate) and ensure hygienic principles at the centre for a desired effect. More specific interventions for cluster IA companies in this stage include developing specific and differentiated procedures for sanitation and production process; sampling design and measuring plans based on the statistical analysis of pathogen distribution in company specific production situation; and differentiated corrective measures based on systematic causal analysis; . Moreover, companies in cluster IA could adapt the standards and tolerances to the company specific production circumstances.

For the assurance activities, companies in all clusters could use national food control authorities to audit their operators on GHPs; use independent expert for validation of preventive measures, intervention and monitoring systems and verification of people and equipment related performance. Use of accredited third parties will result into comprehensive and independent judgment on the set-up and execution of such assurance activities (Luning et al., 2009). Moreover, they may establish comprehensive and integrated documentation and record-keeping system which is easily retrievable (online/inline) for all staff to facilitate decision making on the FSMS.

With regards to context riskiness, dairy companies in all clusters could establish information systems, milk delivery control system (identify suppliers/farmers, establish milk collection centres installed with cooling facilities, and provide refrigerated trucks to transport raw milk and milk products). Moreover, dairy companies could provide refrigerators to retailers to guarantee the cold chain, which could also create more marketing opportunities (Chapter 2). In general, the strengths of companies in cluster IA are in hygienic design of equipment and facilities, cooling facilities, personal hygiene, raw material control, physical and packaging intervention, standards and tolerances, corrective actions, compliance to procedures, formalisation, and set-up of assurance activities could be used by companies in clusters IB and II to improve their FSMS.

3.5. Conclusions

Majority of the dairy companies in clusters IB and II are micro and small-scale, without hygienically designed equipment and facilities and none have implemented any QA standards and guidelines. The FSMS of dairy companies in all clusters differ in the levels of the setup and operation of core control and assurance activities and in the system output and risk-level of context. Cluster II companies were expected to have more advanced FSMS because they operate in moderate-high risk context. However, companies in cluster II are the least in the design and operation of FSMS as compared to ones in other clusters which operate in moderate risk context. Cluster IA contained the best performing dairy companies whose majority were previously owned by Tanzania Dairy Ltd (TDL). These companies have hygienically designed equipment (integrated or automated system using CIP) and facilities (building layout, cooling facilities), trained personnel (sourced locally and from Kenya) and formalisation (procedures), information system, set up of assurance activities and evaluation of the FSMS. Most of the companies in this group have collection centres with installed cooling facilities and have cold trucks to collect raw milk (and distribute final products), with well organised distribution chain. They have well organized raw material supply chain. Cluster IB contained mostly small- and large-scale companies which are intermediate performers, these companies have inadequately designed facilities and less trained personnel; however, some have collection centres and cold trucks for milk collection. Cluster II consists of mainly micro- and small-scale companies with non-hygienically designed equipment and facilities, most of these companies use batch processes. These are the companies with less trained personnel and less organised raw material supply chain. However, size of the company is not an indication of good performance as even micro-scale companies analysed in this study are among the best performers. Therefore, dairy processing companies in Tanzania could learn among themselves. Particularly, companies in cluster IA could be a role model of those in clusters IB and II to improve their FSMS. The micro-and small-scale companies in clusters IB and II and large-scale companies in cluster IB could learn from their counterparts in cluster IA on how to improve their FSMS. The proposed measures for improvement in this study could be used as in-puts for development of generic roadmap for improvement of FSMS in Tanzanian food industry.

CHAPTER 4

Challenges in performance of HACCP-based food safety management systems implemented in fish processing companies in Tanzania

Redrafted from

Jamal B. Kussaga, Pieternel A. Luning, Bendantunguka P.M. Tiisekwa, Liesbeth Jacxsens (2014). Challenges in performance of food safety management systems: a case of fish processing companies in Tanzania. Journal of Food Protection, 77(4), 621–630.

Chapter 4. Challenges in performance of HACCP-based food safety management systems implemented in fish processing companies in Tanzania

4.1. Abstract

This study aimed at giving insight in the system output in view of the current design and operation of core control and assurance activities and context riskiness of these systems in order to identify the opportunities for improvement of the HACCP-based FSMS. A FSMS-diagnostic instrument was applied to assess the performance levels of FSMS activities in view of context riskiness and system output in 14 fish processing companies in Tanzania. Two clusters (cluster I and II) with average FSMS (level 2) operating under moderate-risk context (score 2) but with different system output levels were identified. Cluster I indicated relatively better system output (mean score 2.8) than cluster II (mean score 2.3). It shows that fish companies especially in cluster II need further improvement of their FSMS to higher levels and reduce the context riskiness to assure better system output (level 3). Among the measures to improve FSMS activity levels include hygienic design, strict raw material control, developing specific sanitation procedures and sampling design and measuring plans, proper follow-up of critical control point analysis, and independent validation of preventive measures, and establishing comprehensive documentation and record-keeping system. The risk-level of the context could be reduced through automation of production processes (like filleting, packaging, and sanitation) to restrict people's interference, recruitment of permanent high-skilled technological staff, and developing specific information on proper storage and distribution conditions and use of the products by customers. However, such intervention measures for improvement could be taken in phases, starting with less expensive ones (like sanitation procedures) that can be implemented in the short-term to more expensive interventions (setting-up assurance activities) to be adopted in the long-term. These measures are essential for fish processing companies to move towards FSMS that are more effective.

4.2. Introduction

Fish industry is the leading food exporting industry in Tanzania. Fish export is among the major sources of foreign exchange in Tanzania (United Republic of Tanzania, 2013). Fish products are however, associated with various food safety hazards including chemical (like antibiotics, pesticides, and dynamite) and biological (microbiological and parasites) which require strict control and monitoring along the fish value chain as was addressed in Chapter 1 and Chapter 2. Moreover, the importing countries have adopted most comprehensive food safety control systems, with most stringent food legislation and regulation

(Ponte, 2007; Bagumire et al., 2009a). This poses a significant challenge to fish exporting companies to meet the export market demands, given the operating regulatory and economic situations in the fish exporting developing countries like Tanzania (Musonda and Mbowe, 2002; Kadigi et al., 2007).

Access to food export markets largely depends on the capacity of food companies to upgrade their levels of conformity with export market requirements (Kadigi et al., 2007). Compliance with agricultural health and food safety standards of importing countries require specific actions and efforts by individual producers and processors to implement the requirements into their QMS, of which food safety management is a specific component. However, lack of insight in the performance of implemented FSMS of fish processing companies impedes such efforts. The objective of this study was to get insight into the system output in view of the current performance of core FSMS (control and assurance) activities and context riskiness of these systems to identify opportunities for improvement in implemented systems in Tanzanian fish industry.

4.3. Materials and methods

4.3.1. Characteristics of participating fish processing companies

The FSMS-DI (as discussed in Chapter 1, section 1.5.2) was applied to assess the current FSMS of 14 establishments including 1 small-scale, 1 medium-scale and 12 large-scale companies (Table 4.1). These establishments were certified by the European Union to export fish and fishery products to the Union. They all used Codex Alimentarius PRPs and HACCP guidelines to design their FSMS, which comply with EU Regulation 852/2004 (European Union, 2004b) and EU Regulation 853/2004 (European Union, 2004a) requirements. In addition to these guidelines, for their system design 3 companies used the QA standard ISO 9001 (ISO, 2008a), 9 used ISO 22000 (4 of them were certified) (ISO, 2005), and 7 companies used BRC standard (5 of them were certified, Table 4.1) (The British Retail Consortium, 2015).

4.3.2. Diagnosis of performance level of food safety management system activities, system output, and context riskiness

The FSMS-DI was used to diagnose performance of core control and assurance activities in fish companies. The FSMS-DI used in this study is clearly described in section 1.5.1 (Chapter 1). The FSMS diagnosis involved an in-depth face-to-face interview with the responsible QA personnel accompanied with document analysis and onsite visits to the production floor to confirm the assessment (2-3 h).

Table 4.1 Characteristics of the identified clusters

Characteristics	Cluster I	Cluster II
Size of the company (number of employees, installed processing capacity/day)	Small (1 company with 28 personnel and <5 tons installed capacity) and large-scale companies (10 companies with 131->300 employees and 70-150 tons installed capacity)	Medium (1 company with 84 personnel, 6 tons installed capacity) and large-scale (2 companies with 100-249 personnel and 70-140 tons installed capacity)
QA standards/guidelines implemented	Small-scale: GMP, GHP and HACCP Large-scale: GMP, GHP, HACCP, ISO 22000, ISO 9001 and BRC	Medium scale: GMP, GHP and HACCP Large-scale: GMP, GHP, HACCP, ISO 22000, ISO 9001 and BRC
QA standards certified	ISO 22000 and BRC in 4 companies	ISO 22000 and BRC in 1 company
QA manager	Yes	Yes
QA department	Yes	Yes
People working in the QA department	Small-scale: 4 personnel Large-scale: 5-25 personnel	Medium-scale: 6 personnel Large-scale: 11-30 personnel
Quality of the workforce	Well trained personnel sourced from within and outside (Kenya and India)	Well trained personnel sourced from within and outside (Kenya and India)

4.3.3. Data analysis

The FSMS diagnosis resulted into a list of 58 scores for each fish processing company analysed. Overall mean scores were calculated and transformed to assigned overall scores to obtain a first indication about; the set-up and operation of FSMS, system output, and context riskiness were calculated as described in section 1.5.1 (Chapter 1).

4.3.4. Statistical analysis

A hierarchical cluster analysis SPSS (Version 16.0 for Windows, SPSS Inc., Chicago, IL, USA) with the furthest neighbour method and squared Euclidean distance were applied to get an insight in the differences in context riskiness, FSMS performance, and system output between the companies. Then statistical analysis by use of Mann-Whitney U test was performed to compare the mean scores of indicators of system output, FSMS activities, and context riskiness between the clusters. The statistical significance was established at $P<0.05$ level. Hierarchical cluster analysis is suitable to group cases into homogeneous sub-groups based on measured characteristics.

4.4. Results and discussion

4.4.1. Overall context riskiness, performance of FSMS activities and system output

Hierarchical cluster analysis produced two clusters, cluster I and II, which contained eleven and three fish processing companies, respectively (Fig. 4.1). Cluster I companies had better system output (overall mean score 2.8) than ones in cluster II, which had moderate-good (overall mean score 2.3) (Table 4.3). Cluster I comprised of one small- and ten large-scale companies, whereas cluster II contained one medium- and two large-scale companies (Table 4.1). However, both clusters had an average FSMS (overall mean score 2, Table 4.2) operating under medium-risk context (overall mean score 2, Table 4.4). Thus, according to the basic principle of FSMS-DI, a good system output (score 3) was anticipated for both clusters; which has been also reflected in the FSMS-DI (score 2-3/3). Nevertheless, an in-depth analysis of the FSMS activities, system output, and context riskiness are imperative to identify the opportunities for improvement of current FSMS in fish processing companies.

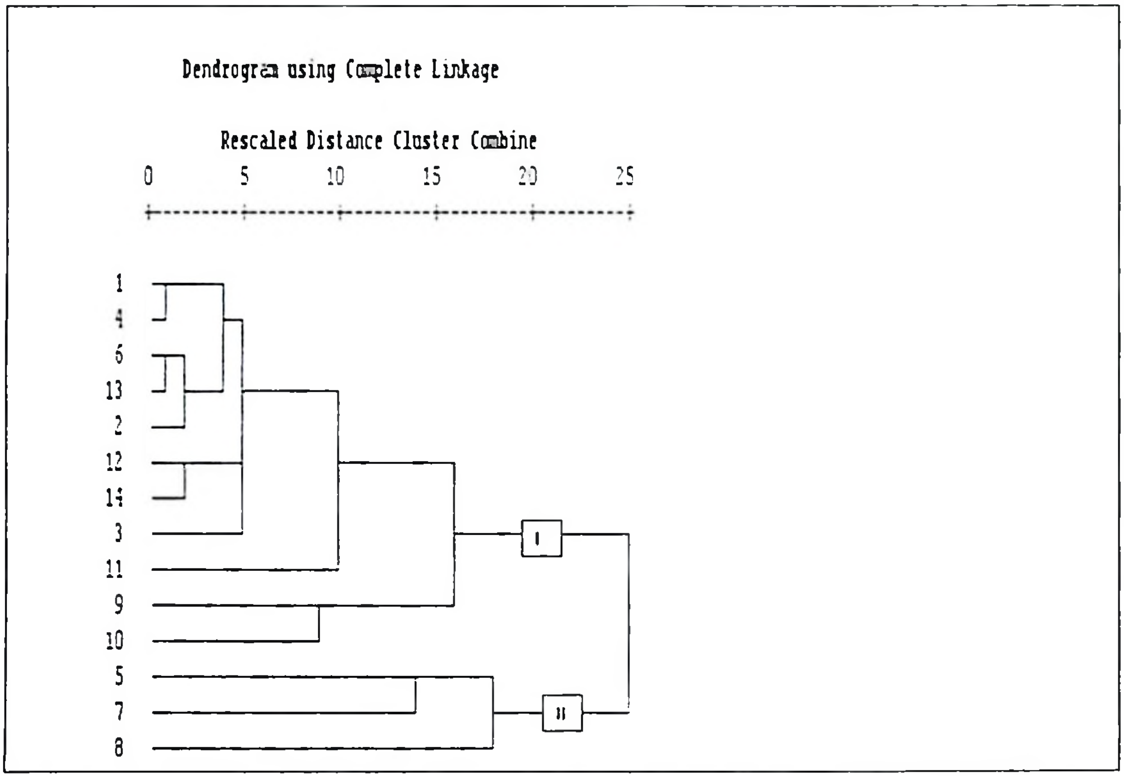


Figure 4.1. A dendrogram showing the clusters obtained by hierarchical cluster analysis using risk scores of context factor, performance scores of control and assurance activities and system output indicators (I represents 'cluster I' and the associated numbers indicate list of companies; II represents 'cluster II' and associated numbers indicate list of companies)

4.4.2. Diagnosis of the level of design and operation of food safety management system activities

In general, both clusters had FSMS activities performing at an average level (Table 4.2). However, the clusters scored 2-3 or 3 (advanced level) in several control (14/25) and assurance (3/9) activities (Table 4.2). All analysed fish companies manufactured fresh and raw frozen fish products, hence no (median and mean score 0) physical intervention equipment (equipment which apply physical processes like heating and drying) and intervention methods (like fermentation) are applied to inactivate or eliminate microorganisms to acceptable levels. Furthermore, the sampling design and measuring plans were based on the fishery sector guidelines, not tested in company specific situation (median and mean scores 2.0). In addition, the procedures, which were mostly paper based, were partly available in location and kept up-to-date in ad-hoc basis (median and mean score 2.0). The EU inspectors in 2011 in Tanzanian fish industry found that some fish companies lacked procedures or instructions on how to use chlorine test kits and proper product storage in the cold store (Food and Veterinary Office, 2011c). Procedures guide workers through their production and sanitation activities, preventing poor decision-making (Luning and Marcelis, 2007; Ball et al., 2009).

For preventive measures design, a significant difference (*$P<0.05$*) between clusters was only observed in specificity of sanitation programmes. Cluster I companies have significantly more advanced sanitation programmes (median score 3; mean score 2.9) than cluster II companies (median score 2; mean score 2.3). However, not statistically significant, cluster II companies indicated average level (median and mean scores 2) in hygienic design of equipment and facilities, and raw material control (Table 4.2), which respectively shows that critical equipment like cooling facilities comply with specific hygiene requirements (but not tested in the company production situation) and the major quality checks on raw materials were mainly on size and sensory attributes. The EU mission in Tanzania in 2006, reported inadequacies in the design of facilities, absence of hand-washing basins, and appropriate soap in some of the inspected fish companies (Food and Veterinary Office, 2007, 2011c). A study in Nigerian seafood processing plants also observed use of inappropriate equipment and cooling facilities (Okonko et al., 2009). Non hygienically designed equipment and facilities are implicated with microbiological cross contamination in the fish industry (Guobjoernsdottir et al., 2005; Shikongo-Nambabi et al., 2011). This present study observed that some of the analysed companies have installed bells, which ring every thirty minutes to remind personnel to wash and disinfect their hands (including processing equipment like knives) in a chlorine dip (5ppm). Since they dip clean hands, the level of chlorine would eliminate most of the residual pathogens on hands. Fish companies are, however, required to comply with the EU demands. Otherwise, a section supervisor reminds workers at a certain determined time interval to wash their hands and processing equipment. Periodic washing and sanitisation of equipment prevent accumulation of dirt and microorganisms on the equipment, tables, and hands of the personnel, which could contaminate the products. Furthermore, every section had specific cleanliness personnel, who regularly performed cleaning.

For intervention processes design, a significant difference (*$P<0.05$*) between the clusters was observed in adequacy of packaging intervention equipment and specificity of maintenance programmes (Table 4.2). Cluster I companies had basic (median score 0; mean score 0.4) packaging intervention equipment and advanced (median score 3; mean score 2.7) maintenance and calibration programmes. Cluster I companies packaged their products in Styrofoam and waxed boxes with plastic linings to prevent microbiological contamination. However, these packaging methods could not reduce or inactivate microorganisms including pathogens. Whereas cluster II companies used dedicated packaging intervention equipment (like vacuum packaging) for the fish industry; the packaging conditions and equipment specifically designed and tested for company production circumstances (median score 3; mean score 2.7). Moreover, cluster II companies had basic maintenance and calibration programmes (median score 1; mean score 1.3), denoting that maintenance/calibration initiated by problems, no clear instructions about frequency, and not well documented. This is in alignment with EU audit reports which revealed poor maintenance of processing floor (Food and Veterinary Office, 2007), and damaged doors of cold stores, broken ceiling of salt store, and rusted ice machine and knife sharpeners (Food and Veterinary Office, 2011c) in Tanzanian fish exporting companies.

For monitoring system design, a significant difference ($P<0.05$) was observed in adequacy of measuring equipment (Table 4.2). Cluster I companies had relatively advanced performance (median score 3.0; mean score 2.7) in measuring equipment than cluster II, which portrayed an average level (median and mean score 2.0). The rest of indicators of monitoring system design indicated advanced level (median score 3; mean score 2.3-3.0) for both clusters indicating that they are based on scientific evidence, have been tested and adapted for the company specific production situation. For the actual operation of core control strategies, the difference ($P<0.05$) between clusters was observed in capability of packaging intervention equipment. Cluster I companies indicated basic level (median score 0; mean score 0.6) due to unstable packaging processes, major variations, and lack of control charts, while those in cluster II showed a relatively advanced level (median score 3.0; mean score 2.7) as they had stable packaging processes with minor variations and used control charts though not systematically interpreted. Similarly, poor packaging processes of seafood were observed in Nigerian companies (Okonko et al., 2009).

For assurance activities, the significant differences ($P<0.05$) between the clusters were noted in translating external requirements into internal FSMS requirements and validation of intervention systems (Table 4.2). Cluster I companies indicated a relatively advanced level (median score 3; mean score 2.6) than companies in cluster II which had basic level (median and mean score 1) in translation of external requirements into internal FSMS requirements. This respectively demonstrates that fish companies in cluster I were more proactive in translating external requirements than those in cluster II, which were more reactive. Previous studies narrated that fish companies in Tanzania translate external requirements into their systems as a response to food safety problems or as demanded by the export market and competent authority (Frohberg et al., 2006; Food and Veterinary Office, 2011c). In general, fish exporters and local authorities have adopted a reactive strategy towards SPS compliance (Neeliah et al., 2011; Neeliah et al., 2012). For instance, fish companies in African countries including Mauritius have adopted private QA standards like BRC to meet demands of their customers (Neeliah et al., 2012). Similarly, fish exporting companies in Tanzania have extensively implemented HACCP (Henson and Mitullah, 2004; Thorpe and Bennett, 2004; Johnson, 2010).

Moreover, 9/10 companies in cluster I did not apply intervention processes, thus, no validation of intervention systems (median and mean score 0). In contrast, all companies in cluster II used vacuum packaging equipment; the effectiveness was independently validated based on expert's opinion on regular basis and after system modification (median score 3; mean score 2.7). Though not statistically significant (*P =0.256*), cluster I companies indicated a relatively advanced level (median score 3; mean score 2.6) in validation of preventive measures than those in cluster II (median score 2; mean score 1.7, Table 4.2). This implies that validation of preventive measures in cluster II companies was based on historical knowledge and judged by own staff working in the system, whereas in cluster I companies, it was carried-out systematically by independent experts using scientific knowledge, on regular basis. A scientific evidence-based, systematic, and independent validation of effectiveness of preventive measures will result in an effective FSMS (Luning et al., 2009). In addition, fish companies had structured and partly automated documentation, however, access to external sources was not formalised. Besides, verification of procedures and compliance were based on independent analysis of procedures and records on a regular basis. A study in the USA found that 35% of respondents have never carried-out validation of their control systems in their plants (Ilyukhin et al., 2001). Furthermore, previous studies observed poor documentation and record-keeping system in fish processing plants in Tanzania (Food and Veterinary Office, 2007, 2011c) and aquaculture farms in Uganda (Bagumire et al., 2010).

Table 4.2. Frequency analysis of individual scores and statistical analysis of scores of indicators of FSMS activities in each cluster of fish processing companies

Indicators of FSMS activities	Frequency of individual scores of all 14 companies[a]				Median and associated mean (in brackets) scores of the two clusters[b]		Mann-Whitney U test
	0	1	2	3	I(11)	II(3)	P-value[c]
Design preventive measures							
Sophistication of hygienic design	0	0	11	3	2.0 (2.3)	2.0 (2.0)	0.325
Adequacy cooling facilities	0	0	1	13	3.0 (3.0)	3.0 (2.7)	0.056
Specificity sanitation programme	0	0	3	11	**3.0 (2.9)[c]**	**2.0 (2.3)**	**0.038**
Extent of personal hygiene requirements	0	0	4	10	3.0 (2.6)	3.0 (3.0)	0.234
Sophistication of raw material control	0	0	8	6	3.0 (2.6)	2.0 (2.0)	0.103
Adequacy product specific preventive measures	0	0	2	12	3.0 (2.9)	3.0 (2.7)	0.305
Design intervention processes							
Adequacy physical intervention equipment	14	0	0	0	0.0 (0)	0.0 (0)	1.000
Adequacy packaging intervention equipment	9	0	3	2	**0.0 (0.4)**	**3.0 (2.7)**	**0.005**
Specificity maintenance programme	0	2	4	8	**3.0 (2.7)**	**1.0 (1.3)**	**0.009**
Adequacy intervention method	13	0	0	1	0.0 (0)	0.0 (1.0)	0.056
Design monitoring system							
Appropriateness of CCP analysis	0	1	7	6	2.0 (2.4)	3.0 (2.3)	0.794
Appropriateness of limits and tolerances	0	0	4	10	3.0 (2.7)	3.0 (2.7)	0.843
Adequacy of analytical methods	0	0	4	10	3.0 (2.7)	3.0 (2.7)	0.843
Adequacy of measuring equipment	0	0	6	8	**3.0 (2.7)**	**2.0 (2.0)**	**0.030**
Specificity calibration programme	0	0	2	12	3.0 (2.9)	3.0 (2.7)	0.305
Specificity of sampling design and measuring plan	0	1	11	2	2.0 (2.1)	2.0 (2.0)	0.745
Extent of corrective actions	0	0	2	12	3.0 (2.8)	3.0 (3.0)	0.445
Actual operation control strategies							
Actual availability of procedures	0	0	12	2	2.0 (2.2)	2.0 (2.0)	0.442
Compliance to procedures	0	0	7	7	2.0 (2.5)	3.0 (2.7)	0.530
Hygienic performance equipment and facilities	0	0	4	10	3.0 (2.7)	3.0 (2.7)	0.843
Actual cooling capacity	0	0	1	13	3.0 (3.0)	2.0 (2.7)	0.056
Capability physical intervention equipment	14	0	0	0	0.0 (0)	0.0 (0)	1.000
Capability packaging intervention equipment	9	0	1	4	**0.0 (0.6)**	**3.0 (2.7)**	**0.021**
Measuring equipment performance	0	0	1	13	3.0 (2.9)	3.0 (3.0)	0.602
Analytical equipment performance	0	0	0	14	3.0 (3.0)	3.0 (3.0)	1.000
Assurance activities							
Sophistication translating external requirements	0	3	5	6	**3.0 (2.6)**	**1.0 (1.0)**	**0.006**
Extent of systematic use of feedback information	0	0	2	12	3.0 (2.9)	3.0 (2.7)	0.305
Sophistication validating preventive measures	1	1	4	8	3.0 (2.6)	2.0 (1.7)	0.256
Sophistication validating intervention systems	10	1	1	2	**0.0 (0)**	**3.0 (2.7)**	**0.001**
Sophistication validating monitoring systems	1	0	5	8	3.0 (2.0)	2.0 (1.7)	0.215
Extent verifying people-related performance	0	1	8	5	2.0 (2.0)	3.0 (2.7)	0.215
Extent verifying equipment and methods performance	0	1	5	8	3.0 (2.6)	2.0(2.3)	0.478
Appropriateness documentation	0	0	7	7	2.0 (2.5)	3.0 (2.7)	0.530
Appropriateness record-keeping	0	0	10	4	2.0 (2.4)	2.0 (2.0)	0.234
Overall FSMS performance					*2.1 (2.1)*	*2.1 (2.1)*	*0.697*

[a] Number of companies in each score indicating performance level of FSMS activities: 0, not applied; 1, basic; 2, average; 3, advanced.

[b] P-value for Mann Whitney U test to compare the median scores between the clusters

[c] Bolded median and mean scores indicate significant differences ($P<0.05$) between the clusters

4.4.3. Diagnosis of system output

Table 4.3 illustrates that companies in cluster II and I respectively indicated moderate-good (mean score 2.3) and good (mean score 2.8) system output. Both clusters indicated a comprehensive external and internal FSMS output assessment. Several accredited third parties including the TFDA, TBS, EU, and auditors for specific QA standards (like BRC and ISO 22000) inspect fish companies. A significant difference ($P<0.05$) between the clusters was observed in 1 indicator of external FSMS output, the microbiological food safety complaints by customers. While cluster I companies had never received microbiological food safety complaints (median and mean scores 3), cluster II companies received and recorded various complaints. Though no significant difference ($P>0.05$) in indicators of internal FSMS performance, companies in cluster II used legal (like Tanzania and the EU) microbiological criteria and specifications from external parties (like customers and sector organisations) to judge their microbiological results (median and mean scores 2). Cluster I companies applied additional specifications established in their internal guidelines (median and mean scores 3). Applying more criteria to interpret microbiological results gives a more accurate indication of the microbiological output of the FSMS (Jacxsens et al., 2010b).

Table 4.3. Frequency analysis of individual scores and statistical analysis of scores of indicators of food safety performance in each cluster of fish processing companies

Indicators of system output	Frequency of individual scores of all 14 companies [a]				Median and associated mean scores (in brackets) of the two clusters [b]		Mann-Whitney U Test
	0	1	2	3	I(11)	II(3)	P-value [c]
External system output assessment							
Food safety management system evaluation	0	3	0	11	3.0 (2.6)	3.0 (2.3)	0.585
Seriousness of remarks of FSMS evaluation	0	0	4	10	3.0 (2.7)	3.0 (2.7)	0.843
Microbiological food safety complaints by customers	1	0	2	11	**3.0 (2.9)**	**2.0 (1.7)**	**0.030**
Hygiene-related complaints by customers	1	0	3	10	3.0 (2.7)	3.0 (2.0)	0.623
Internal system output							
Product sampling to confirm microbiological performance	0	0	2	12	3.0 (2.9)	3.0 (2.7)	0.305
Judgment criteria	0	1	3	10	3.0 (2.8)	2.0 (2.0)	0.077
Hygiene and pathogen non-conformities	0	0	5	9	3.0 (2.6)	3.0 (2.3)	0.925
Overall system output					*2.9* (2.8)	*2.8* (2.3)	*0.128*

[a] Number of companies in each score indicating system output: 0, no indication; 1, poor; 2, moderate; 3, high.
[b] Bolded median scores indicate significant differences ($P<0.05$) between the clusters
[c] P-value for Mann-Whiney U test to compare the median scores of system output between the clusters

4.4.4. Diagnosis of riskiness of FSMS context

Table 4.4 shows that there was no significant difference ($P>0.05$) between the clusters in the overall context riskiness as all companies were operating in moderate-risk context (overall mean score 2). Generally, most companies indicated high-risk level (median and mean scores 3) in raw materials (14/14), extent of intervention steps (13/14), and final product groups (9/14). This implies that raw materials, the fresh fish, were associated with high initial microbiological levels (including pathogens) and required special storage conditions (like chilling/icing to <4°C), final product groups had high water activity and production process did not involve intervention steps to reduce microbiological contamination to acceptable levels. Previous studies found that fish from tropical waters had high microbiological counts on their skins and gills (10^3-10^6 CFU/cm^2) compared to coldwater fish (10^2-10^4 CFU/cm^2) (International Commission on Microbiological Specifications for Foods, 2002; Noseda et al., 2013). Moreover, pH (7.0) and water activity (0.98) of fish meat provide optimum conditions for bacterial growth (Noseda et al., 2013).

For organisational characteristics (Table 4.4), the level of formalisation (the degree to which organisation's procedures, rules, personnel requirements, and information systems are written down and enforced) in cluster I companies was significantly ($P<0.05$) higher (median score 1; mean score 1.2) than those in cluster II (mean and median scores 2). While cluster I companies had procedures for every activity, those in cluster II had procedures restricted (limited) to crucial processes typically related to the FSMS. However, fish companies in both clusters indicated relatively low-risk (median score 1-2; mean score 1.3-2.0) organisational characteristics, which correspond to supportive conditions for decision-making in safety tasks. This shows that fish companies had sufficient operators' competence, high management commitment, and well established information systems to support decisions in the FSMS. To the contrary, previous studies reported lack of knowledge and skills in Nigerian seafood processors (Okonko et al., 2008; Okonko et al., 2009) and workers in Ugandan aquaculture farms (Bagumire et al., 2010). In addition, studies in Belgian poultry (Sampers et al., 2010), Japanese dairy (Sampers et al., 2012), and Spanish meat (Osés et al., 2012) processing plants observed inadequate information systems. Likewise, poor operators' competence, and restricted employee involvement and workforce composition have been reported in a Vietnamese fish company (Noseda et al., 2013). Workforce-composition refers to typical variation of composition of people involved in a respective representative production unit or company (Luning et al., 2011b).

Table 4.4. Frequency analysis of individual scores and statistical analysis of scores of indicators of context factors in each cluster of fish processing companies

Indicators of context factor	Frequency of individual scores of all 14 companies [a]			Median and mean (in brackets) scores of the two clusters [b]		Mann-Whitney U test
	1	2	3	I(11)	II(3)	P-value [c]
Product and process characteristics						
Risk of raw materials	0	0	14	3.0 (3.0)	3.0 (3.0)	1.00
Risk of product group(s)	0	5	9	3.0 (2.6)	3.0 (2.7)	0.925
Safety contribution of packaging concept	0	13	1	2.0 (2.0)	2.0 (2.3)	0.056
Extent of intervention steps	0	1	13	3.0 (2.9)	3.0 (3.0)	0.602
Degree of production process changes	1	7	6	2.0 (2.3)	3.0 (2.7)	0.338
Rate product/process design changes	9	4	1	1.0 (1.6)	1.0 (1.0)	0.167
Organisation characteristics						
Presence of technological staff	6	8	0	2.0 (1.6)	1.0 (1.3)	0.365
Variability of workforce composition	5	8	1	2.0 (1.7)	2.0 (1.7)	0.929
Sufficiency of operator's competences	8	6	0	1.0 (1.5)	1.0 (1.3)	0.717
Extent of management commitment	11	3	0	1.0 (1.2)	1.0 (1.3)	0.585
Degree of employee involvement	5	7	2	2.0 (1.8)	2.0 (1.7)	0.798
Level of formalisation	10	3	1	1.0 (1.2)	2.0 (2.0)	0.077
Sufficiency of information system	10	4	0	1.0 (1.3)	1.0 (1.3)	0.843
Chain characteristics						
Safety contribution in chain position	2	11	1	2.0 (1.8)	2.0 (2.3)	0.103
Power in supplier relationships	13	1	0	1.0 (1.0)	1.0 (1.3)	0.056
Authority in customer relationships	5	8	1	2.0 (1.7)	1.0 (1.7)	0.658
Severity of stakeholder requirements	1	9	4	2.0 (2.3)	2.0 (2.0)	0.407
Overall context riskiness				*1.8* (1.9)	*1.8* (1.9)	*0.815*

[a] Number of companies in each score indicating risk level of context: 1, low; 2, medium; 3, high.
[b] Median scores of each indicator for each cluster
[c] P-value for Mann-Whitney U test to compare the mean scores of context riskiness between the clusters

For chain characteristics (which represent safety contribution in chain position, extent of power in supplier relationship, degree of authority in customer relationship, and severity of stakeholder requirements), there were no a significant difference ($P>0.05$) between clusters in indicator scores (Table 4.4). Majority of fish companies (13/14) in both clusters indicated low-risk (mean score 1) with regards to supplier relationships because they developed product specifications and audited FSMS of their suppliers. Some companies provided supplier guarantee, advice and training in good handling practices. In addition, both clusters revealed relatively high authority in customer relationships (median score 1-2; mean score 1.7). Hence, fish companies could discuss with major customers (not final consumers) on product use and could influence their quality management systems/FSMS (Table 4.4). This shows less dependence on chain actors, which support decision-making process (Luning et al., 2011b). A recent study in Vietnamese fish industry observed that fish companies had restricted influence on their export customers (Noseda et al., 2013). Cluster I encountered severe stakeholders' requirements (like government, retailers, and consumers) as apart from legislative, they had to meet additional demands (such as BRC and Eco-labels) which could be similar or different (median score 2; mean score 2.3). Although cluster II companies received strict demands, they were similar for all stakeholders (median and mean scores 2). Likewise, a Vietnamese fish company had to meet additional QA requirements, which were different from each customer (Noseda et al., 2013). Serving different export markets may cause food companies to maintain several HACCP plans even though they deal with one process and product (Panisello and Quantick, 2001; Jaffee and Henson, 2004; Cormier et al., 2007). This situation could result into several critical control points, which complicates CCP monitoring activities resulting into ineffective HACCP plans.

4.5. Intervention measures for improvement of current FSMS of fish companies

Fish companies need to improve their FSMS to high level and reduce the context riskiness to assure good system output. The intervention measures are recommended to be taken in phases, starting with less expensive ones that can be implemented in the short term to more expensive interventions to be adopted in the long term (Fig.4.2). Fish companies could start by improving the design of preventive measures, intervention processes, and monitoring systems; followed by establishing context requirements; then improving operation of control strategies; and setting-up the assurance activities.

In the first phase for the design of control activities, the fish companies in cluster II could develop specific maintenance/calibration programmes of intervention equipment and perform strict control of raw materials (pesticides, microbiological and organoleptic tests). Moreover, companies in both clusters need to develop specific sanitation procedures (such as equipment, production zones, cooling facilities, and toilets), sampling design and measuring plans based on the statistical analysis of pathogen distribution in their production processes and ensure availability of procedures (digitalised/online) at location. Periodic evaluation of microbiological quality of raw materials from all suppliers is essential to establish the sources of raw materials with high microbial hazards but also to identify microbiological performance of suppliers. Different level of control could be practiced for different suppliers to reduce risk of accepting poor quality raw materials.

For assurance activities, companies in clusters II and I could utilise food control authorities (National Fish Quality Control Laboratory (NFQCL), TBS, and TFDA) to conduct validation of preventive measures and monitoring system and verification of people related performance, respectively (Fig. 4.2). With regards to context characteristics, the risk-levels could be lowered in the first phase for companies in both clusters by training of employees and recruiting trained and skilled personnel on permanent basis and developing specific information on the storage, distribution and use of product by major customers (Fig.

4.2). Inadequate handling (like time-temperature abuse, cross contamination) of fish products along the supply chain may contribute to proliferation of spoilage and pathogenic microorganisms (Shikongo-Nambabi et al., 2011; Domenech et al., 2012). Specific measure for cluster II companies is to change supplier specifications like microbiological criteria, chemical, and time of delivery. These are critical measures for all fish processing companies, because there are no intervention strategies applied to reduce or eliminate microorganisms to acceptable levels (Luning et al., 2011a).

In the second phase, for the control activities, fish companies in both clusters could target on the modification of equipment (use of stainless steel, automation) and buildings (layout, exhaust fans, and air conditions, repair of walls and floors) and implementation of HACCP/CCP analysis. Another specific intervention measure for companies in cluster I could be improving the capability of packaging intervention equipment, particularly, vacuum packaging. For assurance activities, fish companies in both clusters are required to establish robust record keeping system and use independent experts to validate preventive measures and monitoring system and verification of people related performance (Fig. 4.2). Robust system of record-keeping will demonstrate whether procedures are precisely and consistently followed; it is also vital for verification and certification (Codex Alimentarius Commission, 2003; European Union, 2004b; FAO/WHO, 2009), as well as traceability purposes (Nkondola et al., 2006; Mgonja et al., 2013). For the context, companies in both clusters could automate their production processes like filleting, skinning, packaging, and cleaning and sanitation to reduce people interference and risk of microbiological contamination.

In general, this study revealed important learning opportunities for the companies in the different clusters as each cluster excels in alternating aspects. For instance, cluster I companies perform better than the ones in cluster II in specific sanitation programmes, cluster II companies perform better than those in cluster I in packaging intervention equipment. Moreover, cluster I companies are more advanced than the ones in cluster II in adequacy of measuring equipment, while cluster II companies are more advanced than those in cluster I in capability of packaging intervention (i.e. use vacuum packaging). Fish companies in cluster I are more advanced than the ones in cluster II in translation of external requirements into internal FSMS requirements. Therefore, strength of companies in one cluster over the other could be used as a lesson towards improvement. Particularly, cluster II in packaging equipment could be a lesson towards implementation of recommendations for companies in other clusters. The next chapter (i.e. Chapter 5) uses FSMS diagnosis data of one large-scale company from cluster I and performs actual microbiological assessment to give more insight in the actual microbiological output of FSMS and deviations of microbiological data in the company.

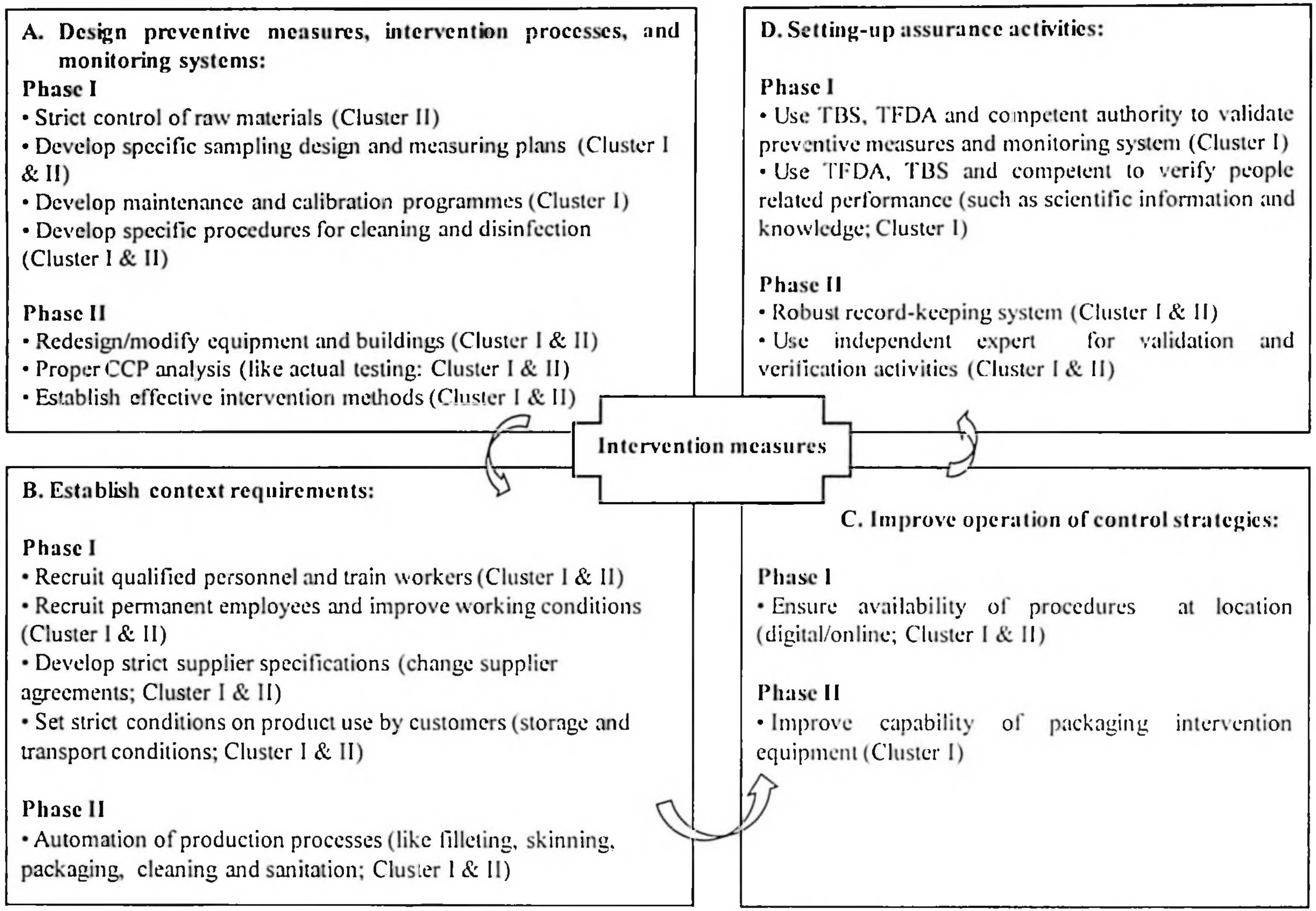


Figure 4.2. Proposed intervention measures for improvement of FSMS of fish processing companies

CHAPTER 5

Microbiological performance of a HACCP-based food safety management system of a Tanzanian fish exporting company

Redrafted from

Kussaga, J.B., Luning, P.A., Tiisekwa, B.P.M., and Jacxsens, L. (Submitted). Microbiological performance of a HACCP-based food safety management system of fish exporting company. Journal of Aquatic Food Product Technology.

Chapter 5. Microbiological performance of a HACCP-based food safety management system of a Tanzanian fish exporting company

5.1. Abstract

This study aimed at giving insight into microbiological safety output of a HACCP-based FSMS of one of Tanzanian Nile perch exporting company by using a combined assessment, FSMS-DI and actual microbiological assessment. The FSMS diagnosis data of one company from Chapter 4 were used as a case study to determine the actual microbiological output of current FSMS in the fishery sector. The FSMS diagnosis indicated FSMS activities at an average level which operate in moderate-risk context level but with good system output. Likewise, microbiological assessment revealed a better system output with respect to pathogens and indicators of faecal hygiene (*E. coli*) as none of them were detected in any critical sampling location throughout the study. Although indicators of general process hygiene (*Enterobacteriaceae* and TVC) exceeded regulatory limits and guidelines in raw materials and food contact materials, whereas *S. aureus* on operator's hands were beyond the general microbiological guidelines in the fish industry. Higher levels of general process hygiene and personal hygiene indicators call for improvement on hygienic design, specific production and sanitation procedures, independent validation, process automation, and change in personnel recruitment criteria.

5.2. Introduction

Tanzania exports 45,550 tons of ornamental fish and 41,291 tons of fisheries products, which worth US$ 159.1 million (United Republic of Tanzania, 2013). Being the largest food exporting sector, it provides substantial employment, income, and foreign exchange contributing to the economic development of the nation (Chapter 1). Fish importing countries like the EU, U.S.A and Japan have set stringent requirements along the fish market chain (Onjong et al., 2014a). Consequently, exporting countries including Tanzania have taken various initiatives at various levels to translate the requirements into their production systems (Bolwig et al., 2013). At the company level, various QA standards (ISO 22000, BRC, and ISO 9001) and guidelines (HACCP, GMP, and GHP) have been translated into their respective FSMS (Chapter 4). At the sectoral level, sector organisations like Tanzania Industrial Fish Processors Association (TIFPA) exercised the due diligence in fish safety and QA systems to ensure the quality and safety of export products (www.tifpa.org, accessed on 25th August 2014). At the government level, various regulations were promulgated, the competent authority was designated, workers trained, inspection system improved and landing sites (i.e., supplied with potable water, toilets, fenced and paved) were built (Kussaga et al., 2014b). Also, at the East African regional level, there was harmonisation of food safety regulations and procedures through the Lake Victoria Fisheries Organisation, LVFO (Bolwig et al., 2013)

However, despite such efforts, fish companies are still experiencing notifications and border rejections of their products (Rapid Alert System for Food and Feed, 2009; Kussaga et al., 2014b; Rapid Alert System for Food and Feed, 2014). The major reasons behind such notifications and rejections are filthy, microbiological (like *Salmonella* spp. and *V. cholerae*) and chemical contaminations (pesticides and illegal fishing by using chemical poisons like dynamite) (Rapid Alert System for Food and Feed, 2009, 2014). Although Chapter 4 identified various inadequacies in the design (hygienic design of equipment and facilities, sampling design and measuring plan, sanitation programmes) and operation (procedures and capability of physical packaging equipment) of core FSMS control activities and set-up of core assurance activities like validation and record keeping system, typical microbiological assessment to determine the actual microbiological output of the system was not performed. Therefore, this study aims at getting an understanding of the typical causes of insufficient microbiological performance of a HACCP-based FSMS of a Nile perch exporting company in order to propose intervention measures for improvement towards an effective system. It involved a combined assessment of the design and operation of the FSMS activities by using FSMS-diagnosis data of one large-scale company from Chapter 4 and performing actual microbiological assessment in the frozen fillet processing line of this company as a case study. This will give insights in the deviations of FSMS diagnosis to the actual microbiological assessment.

5.3. Materials and methods

5.3.1. Characteristics of the company

This company was selected because it is among the intermediate performers and agreed for the microbiological assessment to be conducted. Other companies would not allow for actual microbiological assessment to be conducted. It is a large-scale company with a total of 150 employees with a capacity of processing 120 metric tons/day (however, currently it processes less than 30 metric tons per day due to limited availability of Nile perch). It has also a big QA department with 10 personnel and a QA manager. It has implemented PRPs, HACCP, and ISO 22000; however, it was not ISO 22000 certified. This company has been approved for export to the European Union after being audited by the national competent authority (i.e. Department of Fisheries, Ministry of Livestock and Fisheries Development) to determine if the hygiene requirements are in compliance with the EU demands (i.e. Commission Regulation (EU) 852/2004, EU 853/2004, and EU 2073/2005). Its major products are fresh chilled and frozen Nile perch fillets for the export market. The processing line for the frozen Nile perch fillets (Figure

5.1) was selected for microbiological assessment because at the time of sampling it was the only product being processed.

5.3.2. Diagnosis of food safety management systems performance

Data of one company from Chapter 4 was used as a case study in this chapter.

5.3.3 Microbiological food safety output diagnosis

The principles of the MAS protocol as clearly described in section 1.5.2 (Chapter 1) were used to determine the actual microbiological output of an implemented FSMS. Microbiological analysis was conducted at an accredited NFQCL of the Department of Fisheries, Ministry of Livestock and Fisheries Development in Mwanza, Tanzania, which is the competent authority. The next sections clearly indicate the MAS procedure (Table 5.1).

5.3.3.1. Selection of critical sampling locations

In this study, 12 CSLs were selected (Figure 5.1, Table 5.1) including the raw materials, the whole fresh fish before offloading from the collection trucks (CSL1), washed whole fresh fish in 5ppm chlorine water (CSL2), trimmed fresh fillets before washing with 0.5ppm chlorine water (CSL3), and trimmed fresh fillets dipped in 0.5ppm chlorine water (CSL4). Other CSLs were bagged fresh fillets before plate freezing (CSL 5) and final packaged plate-frozen fillets (CSL6), tables at receiving (CSL7), tables at trimming (CSL8), and tables at packaging (CSL9), operators' hands at receiving (CSL10) and trimming (CSL11), and operator's hand gloves at packaging (CSL12) areas. Sterile dry enviro-sponges (abrasive) made in USA, 3M St. Paul were used to sample 50 cm^2 on the products, whereas cotton swabs were used to sample 25 cm^2 of food contact materials (filtration tray and surface of filling machine) and hands of the personnel.

Table 5.1. Detailed microbial assessment scheme of a frozen Nile Perch fillets processing line

Critical sampling location	Microbiological parameter	Sampling method
CSL1: Raw fish (in trucks at point of receipt)	Total viable counts (TVC), *Enterobacteriaceae*, *E. coli*, *V. cholerae*, *Salmonella* spp., and *L. monocytogenes*	3 samples (1sample/sampling day) by abrasive swabbing on 50 cm^2 of fish skin
CSL2: Raw fish after dipping in 5ppm chlorine water	TVC, *Enterobacteriaceae*, *E. coli*, *V. cholerae*, *Salmonella* spp., and *L. monocytogenes*	3 samples (1sample/sampling day) by abrasive swabbing on 50 cm^2 of fish skin after disinfection
CSL3: Trimmed fish fillet	TVC, *Enterobacteriaceae*, *E. coli*, *V. cholerae*, *Salmonella* spp., and *L. monocytogenes*	3 samples (1sample/day) by abrasive swabbing on 50 cm^2 of fillet after trimming
CSL4: Trimmed fillet after dipping in 0.5ppm chlorine water	TVC, *Enterobacteriaceae*, *E. coli*, *V. cholerae*, *Salmonella* spp., and *L. monocytogenes*	3 samples (1sample/day) by swabbing on 50 cm^2 of disinfected fillet
CSL5: Bagged fresh fillet before freezing	TVC, *Enterobacteriaceae*, *E. coli*, *V. cholerae*, *Salmonella* spp., and *L. monocytogenes*	3 samples (1sample/day) by abrasive swabbing on 50 cm^2 of bagged fresh fish fillet
CSL6: Final packaged fillet after freezing	TVC, *Enterobacteriaceae*, *E. coli*, *V. cholerae*, *Salmonella* spp., and *L. monocytogenes*	3 samples (1sample/day) by abrasive swabbing on 50 cm^2 of frozen fillet
CSL7-9: Working tables (receiving, trimming and packaging)	TVC, *Enterobacteriaceae*, *E. coli*, *V. cholerae*, *Salmonella* spp., and *L. monocytogenes*	9 samples (3 samples x 3 times/day) by cotton swabs on 25 cm^2 of the table, ISO 18593:2004 (ISO, 2004)
CSL 10-12: Hands of operators (receiving, trimming and packaging)	*E. coli*, *Enterobacteriaceae*, and *S. aureus*	9 samples (3 samples x 3 times/day) by cotton swabs on 25 cm^2 of personnel hands/gloves, ISO 18593:2004 (ISO, 2004)

5.3.3.2. Selection of microbiological parameters

Seven microbiological parameters including indicators of food safety (*L. monocytogenes*, *V. cholerae* and *Salmonella* spp.), faecal hygiene (*E. coli*), personal hygiene (*S. aureus*), and general process hygiene (*Enterobacteriaceae* and TVC) were selected.

5.3.3.3. Sampling frequency

Samples were taken three times in three consecutive months (October 2010 to February 2011). Products were sampled once per sampling day, whereas food contact surfaces and hands of the personnel were sampled three times i.e. start, middle and end of production day (Table 5.1). A total of 214 samples [(4 samples x 6 (CSL 1-6) x 3 (1 sampling/month in 3 months) + 4 samples x 3 (CSL 7-9) x 3 times of sampling/day x 3 (1 sampling/month in 3 months)) + (1 sample x 3 (CSL 10-12) x 3 times of sampling/day x 3 (1 sampling/month in 3 months))] were taken over the three months period.

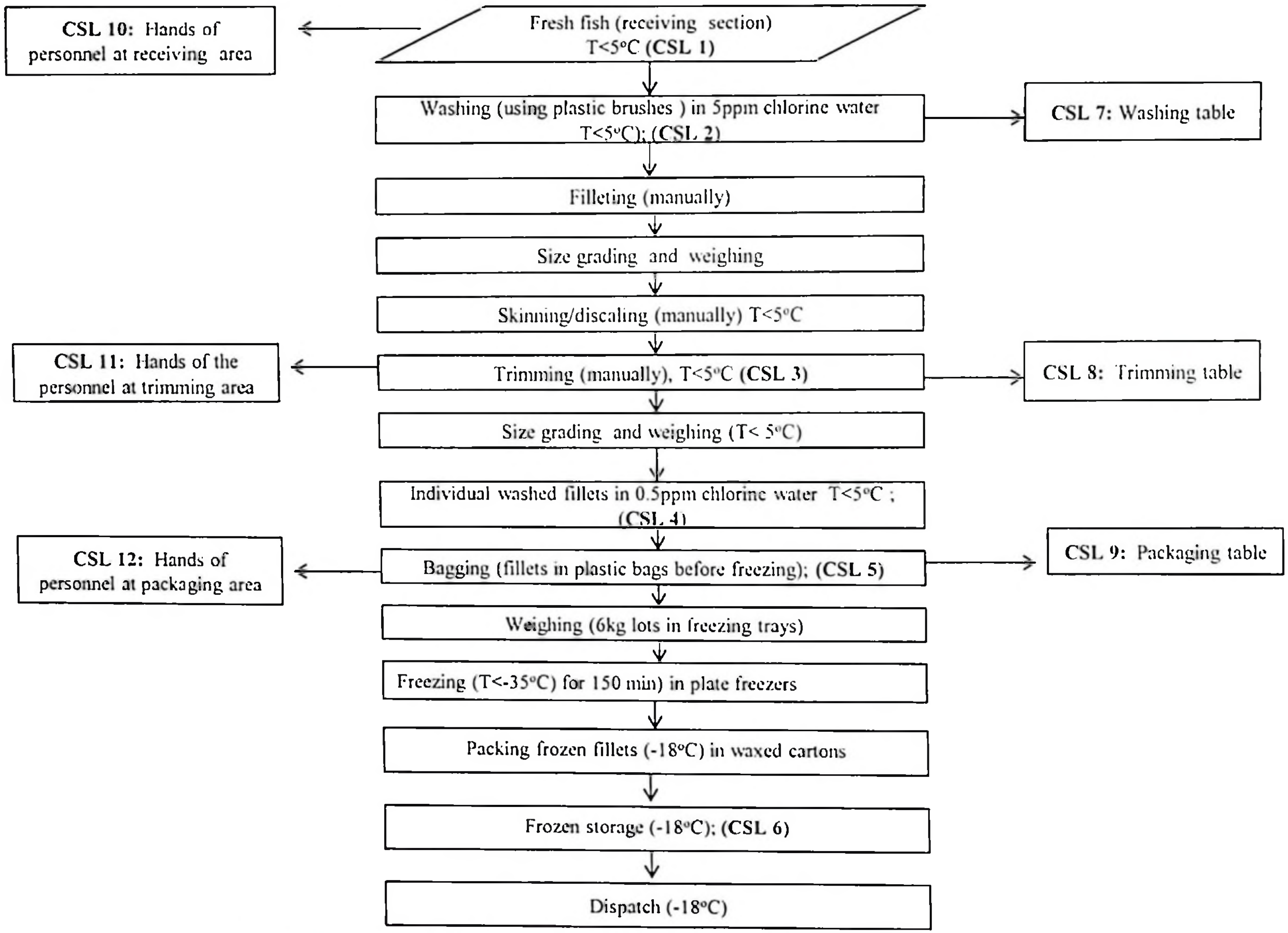


Figure 5.1. Process flow diagram of frozen Nile perch fillets indicating the critical sampling locations

5.3.3.4. Selection of sampling and analytical methods

Sampling and laboratory analysis were conducted according to classical ISO and U.S. Food and Drug Administration-Bacteriological Analytical Manual (FDA-BAM) methods. In this study, non-destructive sampling technique was used for products, food contact surfaces and hands of the personnel. On each product, a sterile template was used to delineate 50 cm^2 and sterile pre-moistened dry-sponge (3M, St. Paul, Minnesota, USA) in the respective dilution medium (as each parameter uses a specific medium) was used to sample vertically, horizontally, and diagonally in the delineated area. Swabbing using abrasive sponges is regarded as the best alternative to destructive/excision sampling (Pearce and Bolton, 2005; Lindblad, 2007). The muscle of a healthy fish is considered sterile (Apun et al., 1999); the micro-organisms on the surface of fish fillets are a result of cross contamination from personnel, processing water and equipment, and/ or food contact surfaces. Thus, swabbing by abrasive sponges would give an indication of the level of process hygiene and preventive measures of the company. In low contaminated products, abrasive sponge is superior (in recovering micro-organisms) to dry/wet swab and excision, and it is recommended when contamination levels are not known (Tenhagen et al., 2011). For the food contact surfaces and hands/gloves of the personnel, ISO 18593:2004 (horizontal methods for sampling techniques using cotton swabs on surfaces in food industry) was applied (ISO, 2004). Similarly, a sterile template was used to delineate 25 cm^2 on working tables whereas pre-moistened cotton swab with respective medium for the specific microbiological parameter was used to sample the delineated area. After sampling, enviro-sponges and cotton swabs were put back into their respective stomacher bags and tubes containing the media. Samples were stored and transported (at $\leq 4^{\circ}C$) in a cool box containing ice packs to the laboratory for microbial analysis. At the laboratory ISO 6887-3:2003 standard was used to prepare analytical samples. For detection (absence/presence) tests, 100 mL samples (abrasive sponges for the products) and 5 mL samples (cotton swab for food contact surfaces) were used for laboratory analysis. Enumeration of TVC, *Enterobacteriaceae*, *E. coli*, *S. aureus* and *L. monocytogenes* were respectively carried out by ISO 4833:2003, ISO 21528-2:2004, ISO 16649-2:2001, ISO 6888-1:1999/Amd.1:2003 and ISO 11290-2:1998 standards. Detection of *Salmonella* spp., *L. monocytogenes*, and *V. cholerae* performed according to ISO 6579:2002, ISO 11290-1:1996/Amd.1:2004 and BAM: 1995 standards, respectively.

5.3.4. Data analysis and interpretation

The actual microbiological assessment and FSMS-diagnosis data were analysed by using Microsoft Office Excel 2007. Microbiological results were interpreted according to the criteria described in European Union, Tanzanian and East African standards and guidelines developed by Ghent University (Table 1.4, Chapter 1). With regards to FSMS diagnosis data, the spider web diagrams were developed by using Microsoft Office Excel 2007 to indicate the risk level of the indicators of context factors and performance levels of the FSMS activities and system output. Then the mean and assigned scores for each core control and assurance activity and context factor were calculated as indicated in section 1.5.1 (Chapter 1): they are also indicated on the spider web diagrams. For comparison purposes, the means and assigned scores of all fish companies (adopted from Chapter 4) are also indicated in the spider web diagrams (broken line boxes in Figures 5.2 and 5.3).

5.4. Results and discussion

5.4.1. Diagnosis of food safety management systems

Figures 5.2-5.4 illustrate the results of FSMS diagnosis. More coloured spider webs indicate that the indicators of FSMS activities and system output are elaborated at high level or there is high-risk level of the context. This study revealed an average-advanced FSMS (overall score 2-3), which operates in a medium-risk context (overall score 2) with a subsequent better system output (overall score 3). Likewise, a recent study covering all fish processing companies in Tanzania revealed an average FSMS (score 2) operating in moderate-risk context (score 2) but with relatively good system output, score 2-3 (Kussaga et al., 2014b). Although, the FSMS-diagnosis results indicated a better system output, the actual microbial assessment (score 2-3) revealed some inadequacies in the system with regards to indicators of general process hygiene (*Enterobacteriaceae* and TVC), personal hygiene (*S. aureus*) (Figure 5.4, 5.5). However, the current FSMS is effective to pathogens including *L. monocytogenes*, *V. cholerae* and *Salmonella* spp., as none of the pathogens was detected throughout the study. Thus, with regards to pathogens, the current FSMS does not require any further improvement (Jacxsens et al., 2009b).

5.4.1.1. Diagnosis of the risk level of context characteristics

In overall, the FSMS operates in a moderate-risk context (score 2). For product and process characteristics, the company dealt with high-risk raw materials (such as fresh raw fish) and final product groups (like fresh chilled/frozen fillets) which both require special storage conditions to prevent proliferation of micro-organisms including pathogens (score 3, Figure 5.2A). Both raw materials and final product groups are perishables (Jensen et al., 2010). Like other types of fish, Nile perch fish and fresh fillets have high water activity (0.98) and neutral pH, making them good media for microbiological growth (Erkan and Özden, 2008). Moreover, the production process is characterised by small batches with clear interference with people (due to low level of automation in filleting, skinning, and cleaning and disinfection). Besides, the production process has no intervention steps to reduce pathogens to acceptable levels. Under this context situation, it shows that this company is highly dependent on suppliers to ensure quality and safety of its products. Although the company is actively developing supplier specifications, it should also ensure that the preventive control strategies in the FSMS are at an advanced level.

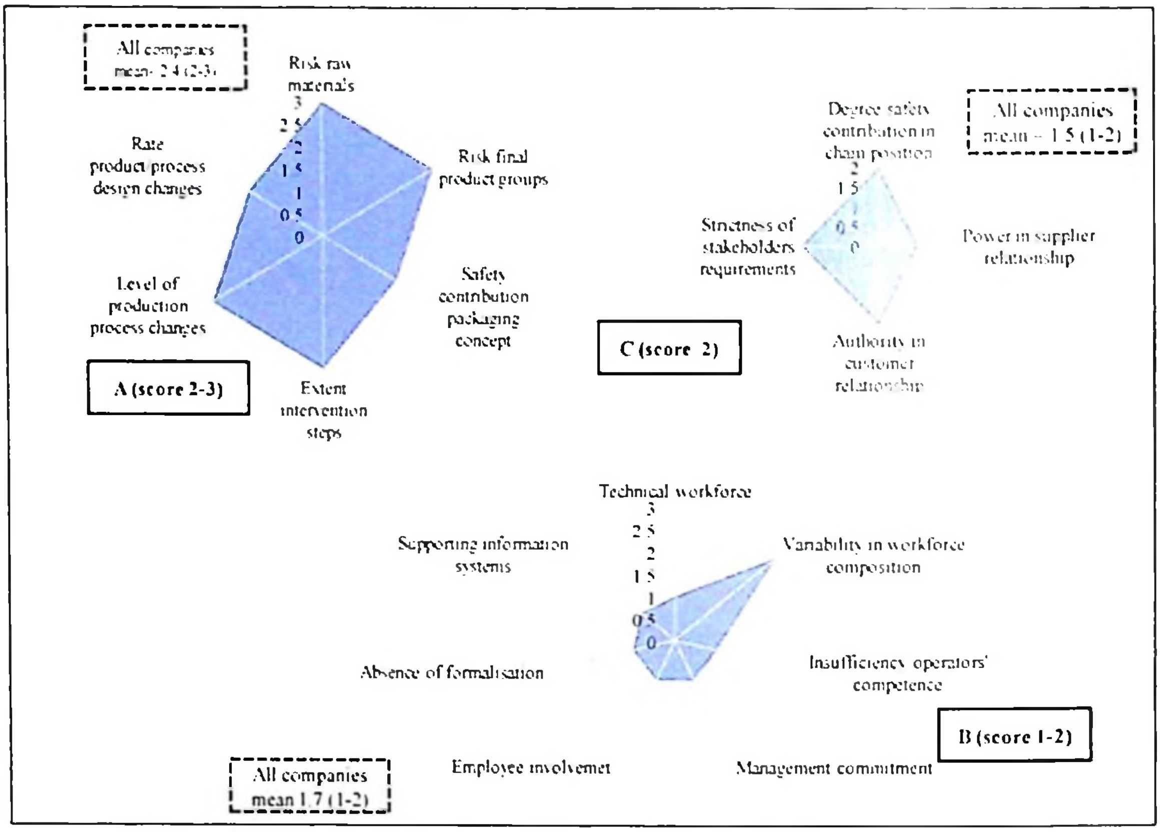


Figure 5.2. Levels of context riskiness (A) product and process characteristics, (B) organizational characteristics, (C) chain environment characteristics (numbers in brackets indicate associated mean scores); broken boxes indicate the overall mean and assigned mean scores adapted from Chapter 4

With regards to organisational characteristics, all indicators scored 1 (low-risk level) except degree of variability in workforce composition, which scored 3 (high-risk level, Figure 5.2B). These administrative conditions support appropriate decision-making in the FSMS due to availability of competent technical staff (trained and experienced), management commitment (food safety/quality policy, food safety team, and financial support), high formalisation (procedures for every activity or operation) and availability of supporting information systems. However, high-turnover of employees and temporary operators throughout the year increase the chances of poor execution of food safety tasks due to continuous loss of company specific experience/skills. Recent studies observed that majority of fish companies in Tanzania (8/14) (Kussaga et al., 2014b) and Kenya (7/9) (Onjong et al., 2014a) had moderate turnover of employees. High variability in workforce composition is also reported in a Vietnamese Pangasius processing company (Tong Thi et al., 2014). As an intervention strategy, the company has to recruit permanent staff and review its remuneration packages and working conditions to enable workers to stay longer. Remuneration packages (like salaries/wages) and working conditions could either motivate workers to perform well and stay longer or frustrate them to quit the job (Mullins, 2007).

For the chain environment characteristics, this company produced fresh chilled or frozen fillets which require further cooking at the final consumer; thus, it contributes to the final safety through prevention of contamination and growth of pathogens (score 2). With regards to supplier and customer relationships, the company is explicitly involved in the development of product specifications and audit suppliers QMS (score1). However, it has restricted authority in customers' relationships (as it could only discuss the product use by major customers but has no influence on their systems), and has to meet additional but similar QA requirements from stakeholders like eco-labelling, BRC, HACCP, and traceability (score 2, Figure 5.2C). Lack of influence on QMS/FSMS of major customers could result into unpredictable use and handling of the products (e.g., temperature abuse, unhygienic handling) compromising safety of the products.

5.4.1.2. Diagnosis of performance levels of core control activities

All indicators of preventive measures design scored 3 (advanced level) with exception to hygienic design of equipment and facilities, which scored level 2 (Figure 5.3A). This illustrates that critical equipment like cooling facilities comply with specific hygiene requirements (but not tested in the company specific production situation). Cooling facilities are very critical for food processing companies that do not apply intervention strategies (like heating, fermentation and drying); therefore, their performance need to be tested (Luning et al., 2008). Although offsite assessment revealed that other preventive measures were at advanced level, onsite visit showed that motors of the conveyor belts were not properly cleaned, flaking out of the wall paints, and condensation from ceiling board, which could serve as potential sources of microbiological proliferation and contamination. In principle, it is required that any equipment in the processing area is included in the cleaning schedule. Moreover, all indicators of intervention processes scored 0 (were not included in calculating the overall FSMS score), because this company manufactured fresh and frozen fish products which do not apply physical intervention processes (like heating) and intervention methods (like fermentation) to reduce microbiological hazards to an acceptable level. Since no intervention processes were applied, the preventive strategies need to be at an advanced level to prevent cross contamination and growth of available micro-organisms (Luning et al., 2011a).

With exception to appropriateness of CCP/CP analysis and specificity of sampling design (for microbiological assessment) and measuring plan (scored level 2), the rest of the indicators of monitoring system design (corrective actions, standards and tolerances, adequacy of analytical methods and measuring equipment, and calibration program) scored level 3 (Figure 5.3B). Analysis of pathogens (like *Salmonella* spp. and *V. cholerae*) and chemical contaminants (pesticides including

DDT) is performed by several accredited laboratories including the laboratory of the competent authority, the NFQCL, TBS, and Chemiphar laboratory in Uganda (for heavy metals like lead and mercury). The measuring equipment to monitor process/product status like thermometers were in-line (automated) for the chillers, plate freezers, and cold room, where the temperature measurements or variations could be easily seen and temperature records are retrievable. The company has a specific program for calibration and maintenance of thermometers. Normally thermometers are checked on daily basis to ensure proper freezing of fish products. For audit purposes, calibration and maintenance records are kept up-to-date. In addition, the food control authorities like TBS conduct calibration of measuring equipment (however, periodically). Moreover, the competent authority inspects fish companies on regular basis. A similar study in a *Pangasianodon hypophthalmus* processing company found that sampling design and measuring plan was at an average level (Noseda et al., 2013). Since analysis of CCP/CPs is done based on expert knowledge without actual testing, the company analysed in this study, could use additional scientific knowledge and experimental tests under the company production circumstances. In addition, the sampling design and measuring plan have to be typified by analysis of pathogen distribution in own food production process.

For operation of control strategies (assigned score 2, Figure 5.3C), actual process capability of intervention and packaging equipment scored level 0. This is because the company produced fresh and frozen products, so no any physical intervention equipment used. Besides, the packaging concept was not aimed to control or reduce microbial contamination. Fish products were wrapped in plastic bags and packaged in Styrofoam and waxed-box cartons with plastic bag linings to protect from contaminants (like dirt) and exclude oxygen to prevent oxidation. Moreover, actual availability of procedures, compliance to procedures and hygienic performance of equipment and facilities scored level 2 (Figure 5.3C). This shows that procedures were available at location though mostly paper-based and kept up-to-date on ad-hoc basis, tasks were executed based on habits and operators regularly controlled on compliance, and unexpected contamination problems occur due to inappropriate equipment and/ or facilities. However, the company had stable cooling capacity and measuring equipment (level 3). The major measuring equipment used were thermometers and *p*H meters. In addition, the actual performance of analytical equipment scored level 3 because microbiological and chemical analyses were conducted at accredited laboratories of the competent authority for fish products (NFQCL) and national food control agencies (TBS and TFDA). Besides, the company had its own laboratory to conduct basic microbiological analysis (like *Enterobacteriaceae*, *E. coli*, and TVC) with exception to pathogens (*Salmonella* spp. and *V. cholerae*) and chemical contaminants (i.e., dioxins and heavy metals like lead and mercury), which are analysed either within (NFQCL, TBS, and TFDA) or outside the country like Chemiphar (U) Ltd in Uganda (especially for heavy metals). Apart from monitoring of chlorine level in processing water (i.e. the company has its own water treatment section), other chemical tests (heavy metals) are conducted for monitoring purposes as requested by the competent authority.

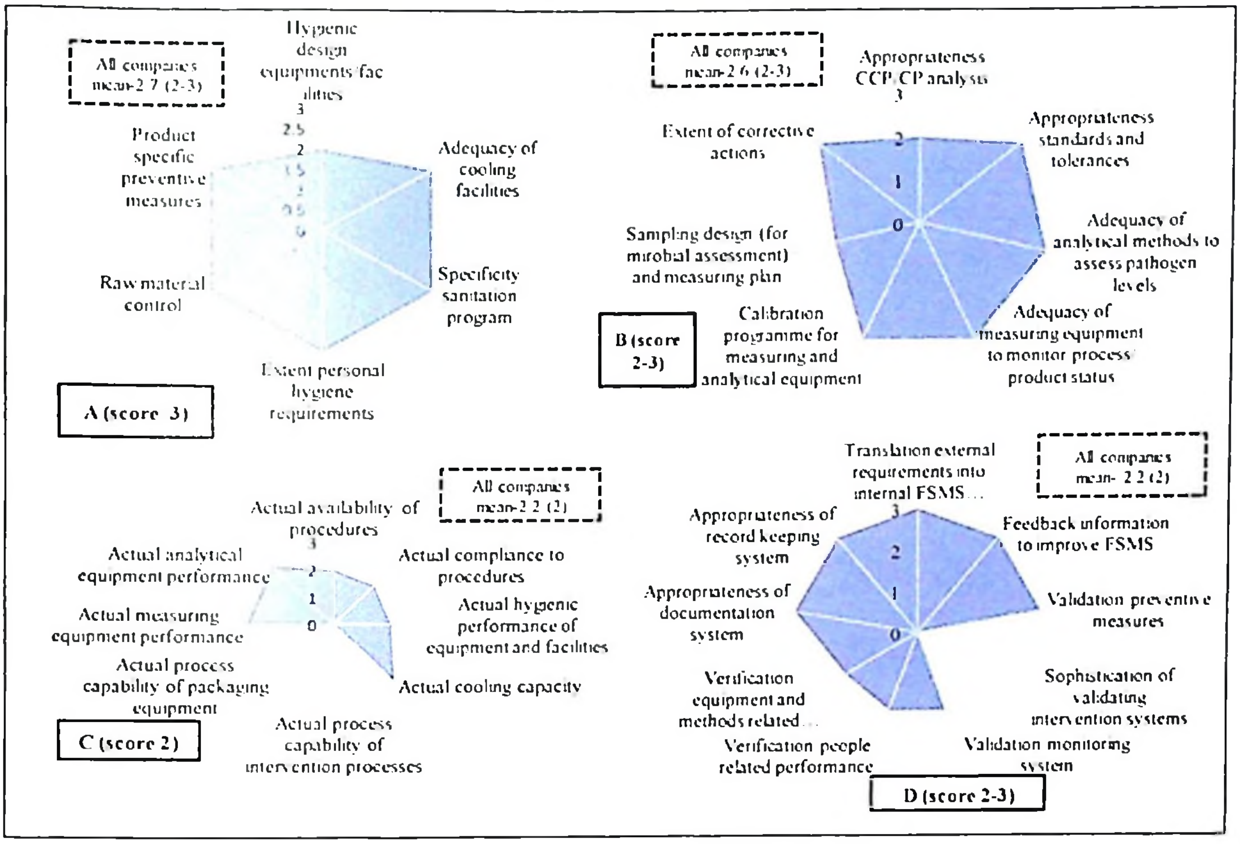


Figure 5.3. Levels of FSMS activities: (A) preventive measures; (B) monitoring system design; (C) operation of core safety control strategies; (D) assurance activities (numbers in brackets indicate associated mean scores); broken boxes indicate the overall mean and assigned mean scores adapted from Chapter 4

5.4.1.3. Diagnosis of performance levels of core assurance activities

Five out of nine indicators of core assurance activities scored level 3 (Figure 5.3D). The company scored 0 in validation of intervention systems because no intervention processes were applied. Moreover, it scored level 2 in validation of monitoring system and verification of people- and equipment and methods-related performance. This shows that, however, validation of monitoring system was conducted on regular basis by external expert: it was based on comparison with regulatory documents without experimental trials. Likewise, it confirms that verification activities were conducted on regular basis by independent internal staff by analysing procedures, records and calibration activities. Therefore, this company could develop interventions towards advanced activity levels like scientific based and independent validation of monitoring systems and verification of people- and equipment and methods- related performance. However, as found in the national-wide study (Kussaga et al., 2014b), the company proactively translated the external assurance requirements like new legislation (e.g., the EU) and evaluated on its own the critical production circumstances.

5.4.1.4. Diagnosis of system output by the FSMS-DI

All system output indicators scored level 3 indicating good system output (assigned score 3, Figure 5.4). Similarly, a national-wide study revealed a relatively good system output with most indicators scoring level 3 (Kussaga et al., 2014b). Based on the self assessment, this fish company has comprehensive internal and external FSMS output assessment. The FSMS is audited by several accredited third parties including private and governmental (national food control agencies and the competent authority) audits, no major and/or minor remarks on the FSMS, and no customers' microbiological food safety and hygiene related complaints. Besides, the company had structured sampling for both the products and environment, and used combination of legal requirements/criteria and specifications by external parties and company established specifications to judge the microbiological results. Moreover, it had no non-conformities regarding microbiological food safety or hygiene indicators. Fish companies in Tanzania are inspected by the national food safety control authorities and audited by accredited third parties; the majority had specific sampling plans and none experienced microbiological food safety or hygiene non-conformities (Kussaga et al., 2014b). The actual microbiological assessment of products, food contact surfaces, and hands/gloves of the personnel were performed to confirm the results of FSMS-diagnosis.

5.4.2. Diagnosis of actual microbiological output of the system

The actual microbiological assessment indicated a moderate-good (score 2-3) system output (Table 5.3, Figures 5.4 and 5.5), which is relatively lower than the one obtained through the FSMS-DI diagnosis (score 3, Figure 5.4). Similar to actual microbiological assessment, a Tanzanian fish industry-wide study indicated an overall moderate-good system output, score 2-3 (Kussaga et al., 2014b). This illustrates that although the FSMS-diagnosis revealed advanced activity levels, they are not sufficient to control certain microbiological parameters or deal with the current context risk-level. On the other hand, it reveals an overestimation of the level of design and operation of core control and assurance activities by the company during the self-assessment as it is opposed to the actual microbiological assessment. However, indicators of food safety (*Salmonella* spp., *L. monocytogenes*, and *V. cholerae*) and faecal hygiene (*E. coli*) were respectively below the detection levels (absence in 50 cm^2 for food products or 25 cm^2 for food contact surfaces) and quantification limit (<1 CFU in 50/25 cm^2) throughout the study (assigned score 3, Table 5.3). This indicates that the implemented FSMS activities are sufficient to control such microbiological parameters. This is also in agreement with the FSMS-diagnosis, which indicated an average-advanced FSMS (score 2-3) operating under moderate-risk context (score 2). Taking into account that no intervention processes applied, the preventive measures which were the most important control strategies for this company were also at an advanced level (score 3, Figure 5.3A).

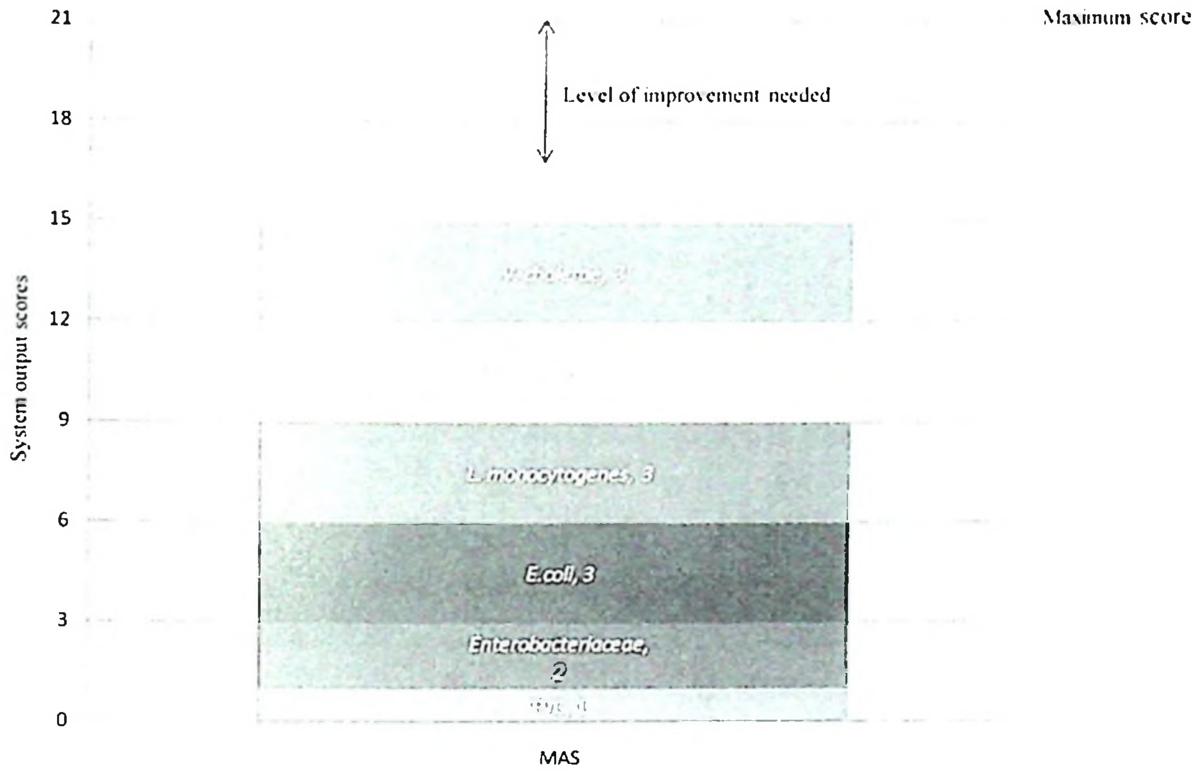


Figure 5.4. Levels of system output by actual microbiological assessment (associated numbers are the scores for each parameter)

On the contrary, *Enterobacteriaceae* were assigned overall score 2 (moderate system output) because were found on tables at trimming (3 out of 9 samples) and packaging (2/9) areas, and hands of personnel at trimming (3/9) and packaging (5/9) sections above the levels in the products handled at the respective areas (Table 5.3, Figure 5.5). The FSMS-diagnosis has also shown restricted use of procedures (which were commonly paper based and not systematically kept up-to-date) as tasks execution was based on habits, and unexpected contamination occasionally occurs due to inappropriate equipment and facilities like flaking out of wall-paints (Figure 5.3C). Recent studies in fish processing companies in Vietnam (Tong Thi et al., 2014) and Kenya (Onjong et al., 2014b) observed high variability of *Enterobacteriaceae* on food contact surfaces and hands of the personnel as well as fish products. According to literature, possible causes of *Enterobacteriaceae* contamination are inadequate procedures of slaughter, handling, packaging, and storage (Boari et al., 2008; Okonko et al., 2008; Okonko et al., 2009) and ineffective cleaning of food contact surfaces like tables and equipment (Bagge-Ravn et al., 2003). Likewise, water and ice (Okonko et al., 2009; Shikongo-Nambabi et al., 2010; Mohamed et al., 2011), personnel (Mohamed et al., 2011), and reduced chlorine concentration of the dip after intensive use (Shikongo-Nambabi et al., 2011) or microbial build-up after an extensive use of the dip could be possible causes of contamination. *Staphylococcus aureus* scored level 2 because were observed on hands of personnel at receiving (4/9 samples), trimming (2/9) and packaging (1/9, Table 5.3, Figure 5.5) above the microbiological guidelines in the fish industry (Table 5.2), indicating inadequate personal hygiene. Also, FSMS diagnosis revealed high turnover of employees and execution of tasks were based on habits, indicating that good manufacturing and hygienic practices (like personal hygiene, hand washing, use of aprons/hair covers) were not exactly followed. Previous studies reported *S. aureus* on workers hands and fishery products (Simon and Sanjeev, 2007; Mohamed et al., 2011; Onjong et al., 2014b; Tong Thi et al., 2014). Food handlers are also known to be potential sources of staphylococcal food contamination (Okonko et al., 2009; Adedeji and Ibrahim, 2011; Mohamed et al., 2011).

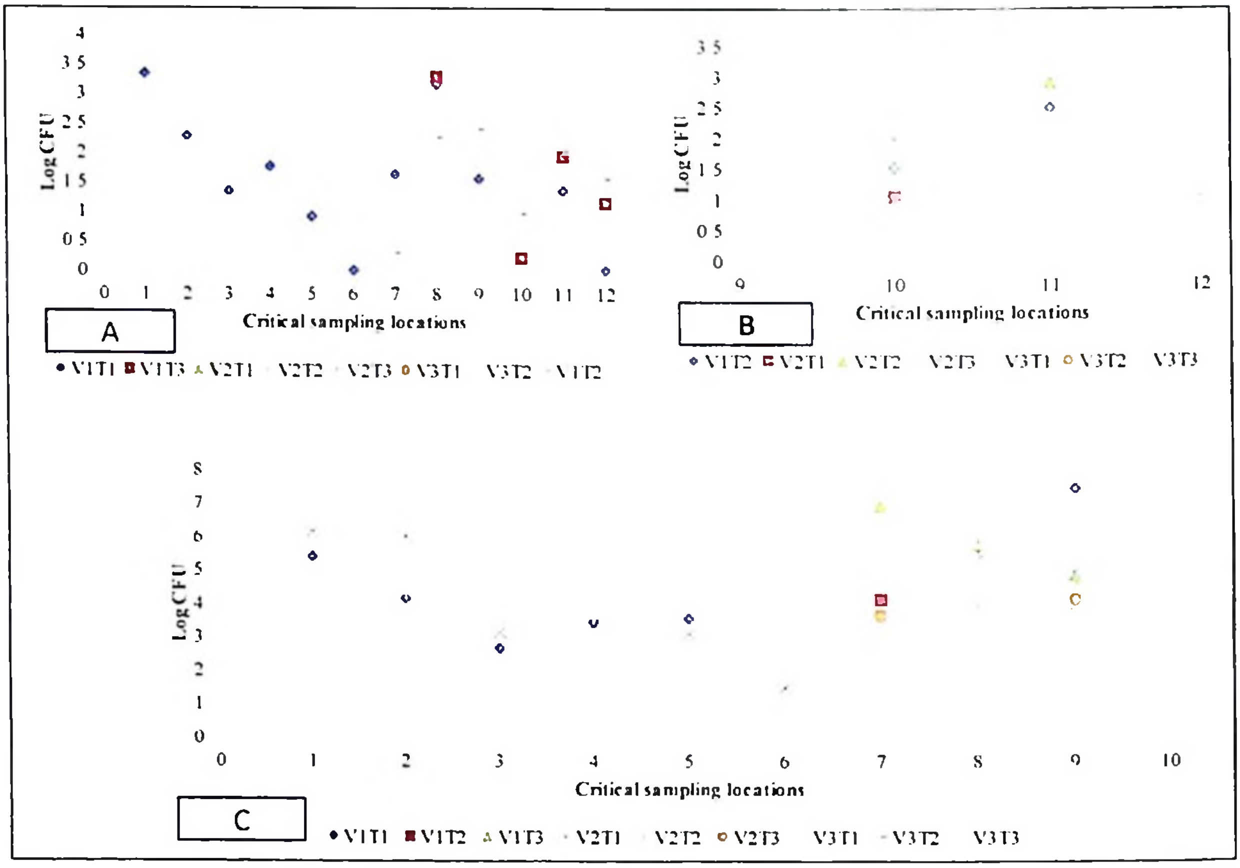


Figure 5.5. Distribution of (A) *Enterobacteriaceae*, (B) *S. aureus*, and (C) Total viable counts in all critical sampling locations along the frozen Nile Perch processing line. The results are expressed in Log CFU/25 cm^2 for contact surfaces and Log CFU/50 cm^2 for products (V1T1- V3T3 (indicate number of visits and times of sampling, e.g. V1T1-visit1 Time1 sampling, V1T2-Visit1 Time2, V1T3-Visit2 Time3, V2T1-Visit2 Time1, V2T2-Viisit2 Time2, V2T3,-Visit2 Time3, V3T1-Visit3 Time1, V3T3,-Visit3 Time2, 3T3- Visit3 Time3 sampling)

Total viable counts exceeded the limits in raw materials (1/3 samples) and tables at trimming (7/9) and packaging (7/9) sections. The huge variations in TVC was noted in products (2.4-7.5 log CFU/cm^2) and working tables (<1-7.5 log CFU/cm^2) (assigned score 1, Table 5.3, Figure 5.5). However, high prevalence of TVC on working tables suggests that besides the raw materials, other likely sources of contamination could be personnel and inadequately cleaned tables. Although water could be another route of contamination, the possibility of contamination through processing water is minimal as the company routinely monitors microbiological quality and chlorine level in the water.

Besides, the company has its own source of water and treatment is done and monitored by the company. Though the company dealt with high-risk raw materials (which could be contaminated from the source and along the chain, and require special storage conditions, Figure 5.2A), there were no intervention processes applied (as the 5ppm concentration of chlorine could not reduce microbiological levels to an acceptable level). This chlorine concentration (5 mg/L) is also far below the EU levels of chlorine (250 mg/L in form of chloride) required in drinking water (European Union Commission, 1998). Furthermore, the company had restricted hygienic design of equipment and facilities and no independent verification of equipment/methods and people related performance. According to literature, skin or fillet of freshly caught fish may contain microbial load ranging from 2-6 log CFU/cm^2 (Olafsdóttir et al., 1997). The bacterial loading on freshly caught fish reflects the environment from which it was caught, rather than the fish species (Al-Harbi and Uddin, 2005). Also, other studies noticed TVC beyond the set standards in raw fish (Okonko et al., 2009; Shikongo-Nambabi et al., 2010; Onjong et al., 2014b), fresh fish-fillets (Chytiri et al., 2004; Onjong et al., 2014b), working tables (Okonko et al., 2009; Onjong et al., 2014b) and hands of the personnel (Okonko et al., 2009). Thus, raw materials, food contact surfaces, and hands of personnel could be the sources of TVC (Chytiri et al., 2004; Shikongo-Nambabi et al., 2010; Shikongo-Nambabi et al., 2011). Furthermore, this company (including other Tanzanian fish exporting companies) occasionally receives notifications and border rejections of their products due to failures to meet microbiological standards of the export market (Food and Veterinary Office, 2007; Kadigi et al., 2007; Rapid Alert System for Food and Feed, 2009; Day et al., 2012a; Kussaga et al., 2014b; Rapid Alert System for Food and Feed, 2014). This illustrates that suggested improvement measures are necessary to control further food safety problems.

Table 5.2. Detailed MAS results indicating microbial parameters analysed at each CSL, frequency of detection/quantification, and assigned and overall system output scores

Critical sampling location (CSL)	Detection of food safety indicators			Quantification of indicators of hygiene (CFU/50 or 25 cm^2)**			
	Absent (A)/Present (P) in 50 or 25 cm^2			Faecal Hygiene	Personal hygiene	Overall process hygiene	
	LIST[a]	SALM[b]	VIBRIO[c]	ECOL[d]	STAP[f]	ENTE[e]	TVC[g]
1. Raw fish (before washing)	A	A	A	<1	NA	<1-3.3	5.4-7.5 (1/3)[h]
2. Washed raw fish	A	A	A	<1	NA	<1-2.3	4.1-6.0[i]
3. Trimmed fillets	A	A	A	<1	NA	<1-1.3	2.7-4.3
4. Washed fillet	A	A	A	<1	NA	<1-1.7	3.4-3.6
5. Bagged fillet	A	A	A	<1	NA	<1	3.1-4.0
6. Packaged frozen fillet	A	A	A	<1		<1	<1-4.1
7. Tables at receiving section	A	A	A	<1	NA	<1-1.6	<1-6.9
8. Tables at trimming section	A	A	A	< 1	NA	**<1-3.3 (3/9)**	**<1-5.8 (7/9)**
9. Tables at packaging section	A	A	A	<1	NA	**<1-2.4 (2/9)**	**<1-7.5 (7/9)**
10. Operator's hands- receiving section	NA	NA	NA	<1	**<2 -2.9(4/9)**	<1-1.0	NA
11. Operator's hands- trimming section	NA	NA	NA	<1	**< 2-2.9 (2/9)**	**<1-2.3 (3/9)**	NA
12. Operator's gloves- packaging section	NA	NA	NA	< 1	<2	**< 1-1.6 (5/9)**	NA
Total samples not detected with pathogens or microorganisms below or within the legal limits	45/45	45/45	45/45	72/72	20/27	59/72	26/45
Total samples detected with pathogens or microorganisms exceeding the legal limits	0/45	0/45	0/45	0/72	7/27	13/72	19/45
System output assigned score	3	3	3	3	2	2	1
Overall system output score					17/21 (score 2-3)		

[a] *L. monocytogenes;* [b] *Salmonella* spp.; [c] *V. Cholerae;* [d] *E. coli;* [e] *Enterobacteriaceae,* [f] *S. aureus;* [g] Total viable counts; [h] number of samples exceeding the limit in all samples analysed within a particular CSL; [i] lowest and highest CFU counted in all three visits within a specific CSL; NA - not applicable; ** The results are expressed in log CFU/50 cm^2 for products and log CFU/25cm^2 for contact surfaces (filtration tray, filling machine) and hands of personnel. Bolded numbers indicate samples that exceeded legal limits or guidelines. Tanzania standards were used to interpret results for TVC and *E. coli* in raw fish and frozen fillets; East African standards for *L. monocytogenes, Salmonella* spp., *E. coli* and *Enterobacteriaceae* in frozen fish fillets, European Union for *Salmonella* spp., *V. cholerae* and *L. monocytogenes* in raw fish; Ghent University guidelines for *Enterobacteriaceae, Salmonella* spp. *V. cholerae*, and *L. monocytogenes* on food contact surfaces and *S. aureus* on hands of the personnel (See Table 1.4).

5.5. Conclusions

The actual microbiological assessment indicated slightly low system output as compared to the FSMS diagnosis. This shows that the design and operation of FSMS activities were not sufficient enough to deal with the level of context riskiness. In addition, actual microbiological assessment found variable and high counts of TVC in raw materials, final products and food contact surfaces as well as *Enterobacteriaceae* in food contact surfaces. Currently, there are no EU requirements set for such parameters, providing an opportunity for this Nile perch processing company to continue exporting to the EU as pathogen levels are within the EU standards. However, higher levels of *Enterobacteriaceae* indicate possibilities of health issues as these are regarded as indicators of process hygiene, inadequate processing and post processing contamination. If there is poor process hygiene there is a chance of introducing pathogens to the process, or when the heating process was inadequate survival of pathogens is likely. Some members of the family *Enterobacteriaceae* (e.g. *Shigella* spp.) are also responsible for causing foodborne diseases. Therefore, fish companies are required to improve the level of the design and operation of the FSMS activities and reduce the level of context riskiness to guarantee good system output.

CHAPTER 6

Performance of food safety management systems in food processing sectors for export and domestic markets: a comparative study

Redrafted from

Jamal B. Kussaga, Pieternel A. Luning, Liesbeth Jacxsens, Bendantunguka P.M. Tiisekwa (2013). Diagnosis of food safety management systems performance in food processing sectors for export and domestic markets. African Journal of Food Science and Technology, 4(10): 240-250

Chapter 6. Performance of food safety management systems in food processing sectors for export and domestic markets: a comparative study

6.1. Abstract

This study provides the comparison of the performance of current FSMS implemented in food processing companies oriented for export (fish) and domestic markets (dairy). The FSMS-diagnosis results from Chapter 3 (dairy sector) and Chapter 4 (fishery sector) were evaluated to identify possible causes in the differences in performance of FSMS between the two sectors. It was revealed that fish companies had average FSMS and moderate to good system output, while dairy companies indicated basic FSMS with poor system output. However, the FSMS of both sectors operated in moderate-risk context. Both sectors need specific measures to improve the design and operation of core FSMS (control and assurance) activities and reduce the risk-level of the context to guarantee good system output. The measures to reduce the level of context riskiness include putting high and specific requirements on operators' competence level, describing all activities in standard operating procedures, and setting requirements on product use by major customers. The measures to enhance FSMS performance include use of industrial cooling facilities, hygienic design, strict raw material control, specific sanitation programmes, and analysis of critical control point. Dairy companies need to set-up assurance activities including validation, verification, documentation, and record-keeping system. However, enabling regulatory environment is essential for the food industry, particularly the domestic market sectors, to improve FSMS and guarantee food safety.

6.2. Introduction

Current food safety problems in the agri-food chain imply that performance of FSMS is not yet satisfactory. Food imports from developing countries are subjects to stringent sanitary and phytosanitary (SPS) measures and heavy scrutiny at the point of receipt of the importing countries (Henson and Jaffee, 2007; Ouaouich, 2007). Besides compliance at the national levels by developing modern food control systems and designating competent authorities to oversee, inspect, and audit food exporting companies; individual companies should also have hygienically designed equipment and facilities, improved processes, and risk-based FSMS (Jaffee et al., 2005). Exporting sectors including fish have implemented various export market demands to improve their system output and access the export market (World Bank, 2005; Kadigi et al., 2007). However, exported products including fish, meat, fruits, and vegetables are still rejected over time (Jaffee et al., 2005; World Bank, 2005; Rapid Alert System for Food and Feed, 2009), which signifies that despite the efforts to improve FSMS, their systems' outputs are not yet sufficient.

Although at local levels there is a considerable increase in demands for quality and safe food supplies partly due to affluent population and improved living standards (Weatherspoon and Reardon, 2003; Francesconi et al., 2010; Nishiura, 2010), the performance of FSMS in sectors targeting the domestic market is still inadequate (Kivaria et al., 2006; Molins and Masaga, 2006; Swai and Schoonman, 2011). Food processing companies including dairy, often fail to meet quality and/or safety demands of local niche markets like the supermarkets, hotels, and restaurants. The problem is further amplified by the co-existence of formal and informal (traditional) food supply systems, and availability of two food control systems; an advanced one for the export market, and a weak or nonexistent system for the domestic food supply (World Bank, 2005; Food and Agriculture Organisation, 2007). While quality and safety of food products for the export market are guaranteed, those targeted for the domestic market are not adequately controlled (Chapter 1, 2). This could result into manufacture of inferior/variable quality products for the local market. Therefore, the purpose of this study is to compare the performance of implemented FSMS in food processing sectors for export (for this case fish) and domestic market (dairy) in order to get deeper insights into the possible causes of the differences in performance of FSMS between the two sectors and propose measures for improvement to guarantee quality and safety of food supplies for the local market.

6.3. Materials and methods

6.3.1 Diagnosis of food safety management systems

Food safety management diagnosis results from Chapter 3 (dairy sector) and Chapter 4 (fish sector) were used in this chapter.

6.3.2. Data processing and analysis

The mean scores of indicators of context riskiness, FSMS activities, and system output were calculated as described in section 1.5.1 (Chapter 1). The statistical analysis involved Statistical Package for Social Sciences (SPSS) version 16.0 for Windows (SPSS Inc., Chicago, IL, USA). Mann-Whitney U test was performed to compare the design and operation of FSMS activities, context riskiness, and system output between dairy (domestic market oriented) and fish (export market oriented) processing companies. The statistical significance was established at $P<0.05$.

6.4. Results and discussion

6.4.1. Overall context riskiness, food safety management systems and system output

In general, each sector operated in moderate-risk context (Table 6.1). The significant difference ($P<0.05$) was observed in FSMS activity levels; fish companies had an average level (overall mean score 2.1) while dairy companies showed a basic to average level (overall mean score 1.7). The level of design and operation of FSMS in dairy companies is insufficient to deal with the moderate-risk context to ensure good system output. Consequently, dairy companies indicated moderate system output (overall mean score 1.9), while fish companies had moderate to good system output (overall mean score 2.7, Table 6.3). However, the majority of dairy companies were micro- and small-scale enterprises lacking hygienically designed equipment and facilities and quality workforce or expertise (Table 3.2, Chapter 3).

6.4.2. Context factors influencing performance of food safety management systems

For the product and process characteristics, 3 of 6 indicators were significant different (*P<0.05*) between fish and dairy processing companies (Table 6.1). Fish companies had relatively high-risk product groups (median score 3; mean score 2.6) than dairy (median score 2; mean score 2.2). However, all companies dealt with high-risk raw materials, the raw milk and fish (median and mean scores 3), which require special storage conditions to prevent growth and multiplication of present micro-organisms. Fish companies produced fresh and frozen fish fillets, whereas dairy companies manufactured cheese, UHT, and pasteurised milk, which are all ready-to-eat (RTE) products. In addition, fish companies had no intervention processes (median score 2; mean score 2.9); while dairy companies had restricted processes (median and mean scores 2). With the exception of UHT milk, other dairy products were pasteurised and/or fermented to eliminate or inactivate vegetative cells, but not spores. Compared to dairy (median score 2; mean score 2.1), fish companies indicated medium to high-risk level (median score 2; mean score 2.4) in product/process design changes due to frequent changes in product-package (Table 6.1). Lack or restricted use of intervention processes reveals strong dependency of food companies on their suppliers to ensure safety of the products. Thus, strict control of raw materials and re-evaluation of supplier agreements/specifications and FSMS of suppliers are necessary for both sectors to assure quality/safety of raw materials (Luning et al., 2009).

For organisational characteristics, all indicators except one, the workforce composition, were significant different (*P<0.05*) between the two sectors (Table 6.1). Dairy companies have shown non-supportive organisational conditions (mean score 2.3-2.6) to decision-making due to lack of technical workforce, management commitment, and specific requirements on competence level of operators. Half of the analysed dairy companies lacked personnel with knowledge on food safety, food technology, and/or food science. Besides, there were no official quality/safety team, formalised meetings, and dedicated budgets for food safety. Moreover, there were no specific requirements on competence and experience of operators. This condition contributes to poor system output of implemented systems. In contrast, fish companies indicated supportive organisational conditions (mean score 1.2-1.6) due to availability of operational food safety team with formalised meetings and budget, standard operating procedures, quality information systems accessible to all operators, and strict requirements on operators' competence and experience (Table 6.1). Compared to sectors for the domestic market, exporting sectors operate in more advanced food control systems (Jaffee et al., 2005; Food and Agriculture Organisation, 2007). Majority of dairy companies were micro- and small-scale with limited financial and human resources to create supportive organisational conditions (Table 3.2, Chapter 3). In comparison to large-scale processors, micro- and small-scale food processors in Tanzania operate in an informal sector and use poor technology and low-skilled personnel (Ruteri and Xu, 2009). Moreover, a study in Turkish dairy industry observed that small-scale companies lacked sufficient technical expertise in food safety (Demirbaş et al., 2006; Demirbas and Karagozlu, 2008). Therefore, dairy companies should create supportive organisational conditions like recruiting skilled and experienced personnel, developing specific information systems, and training of operators and management on food safety to respectively enhance their competences and commitment. Effective implementation of QA standards and guidelines require full commitment and involvement of management and the workforce (Panisello and Quantick, 2001; Wilcock et al., 2011). Management commitment means that the personnel will get required materials and support to develop and implement QA programmes (Wilcock et al., 2011). Lack of dedicated food safety budget result into specific and serious barriers for implementation of QA standards/guidelines like HACCP (von Holy, 2004). Moreover, adequate food safety training of employees could positively improve food safety and prevent foodborne diseases (Rowell et al., 2013).

With regards to chain-environment characteristics, significant differences ($P<0.05$) were observed in safety contribution in chain position and severity of stakeholders' requirements (Table 6.1). In comparison to fish, dairy companies were at more critical chain position as they manufactured RTE products that require pathogen reduction to acceptable levels and strict storage and/or distribution conditions to prevent microbial growth and (cross) contamination. Moreover, dairy companies basically meet local legislative requirements (median and mean scores 1), which in most cases are not strictly enforced. Besides local legislative requirements, fish companies have to meet additional and sometimes conflicting requirements from various chain stakeholders (Table 6.1). Serving different markets with conflicting customers' food safety demands puts more pressure on the system (Luning et al., 2011b). Besides, Tanzanian export sectors have well-established private organisations (like LVFO, TAHA, and TIFPA) to oversee quality and safety of the products in the respective sectors, sectors for the domestic market entirely rely on government agencies that are characterised by inadequate human and financial resources required to monitor and control the whole food supply chain. Particularly, fish companies are export oriented, serving several international markets with different legislative and customers' demands. They have implemented various QA standards with different certification requirements like the BRC and ISO 9001:2008 (Ababouch et al., 2005). Degree of involvement in international markets influences the adoption of PRPs and QA standards/guidelines in the food industry (Holleran et al., 1999; Bai et al., 2007; Jacxsens et al., 2011a). For instance, in India, food exporting companies are more aware of the regulatory requirements to implement HACCP than ones serving the domestic market (Jayasuriya et al., 2006). Moreover, Chinese food enterprises have implemented HACCP in order to access overseas markets (Bai et al., 2007).

On contrary, dairy sector serves exclusively for the domestic market which has inadequate enforcement of food legislation and regulations accompanied by poor business and customers' food safety demands. Subsequently, none of the dairy companies have implemented any QA standards/guidelines (Kurwijila and Boki, 2003; Molins and Masaga, 2006; Food and Agriculture Organisation, 2007). The country policy, regulatory environment, and business demands provide incentives for food companies to adopt QA standards and guidelines as well as other customer/business specific requirements (Holleran et al., 1999). Regulatory and market-based incentives were the major motives behind HACCP adoption in British and Canadian food industries (Henson et al., 1999; Jayasinghe-Mudalige and Henson, 2007). Nonetheless, poor hygienic practices, outdated legislation, ineffective food control systems, and inadequate market demands could be the key factors perpetuating poor food safety performance in sectors serving the local markets in Africa (Henson et al., 2005; World Bank, 2005; Abegaz, 2010; Oloo, 2010). Tanzania in particular, lacks regulation prohibiting sale of unprocessed milk; as a result 80-90% of households in Dar es Salaam still buy unprocessed milk from street vendors or via home delivery (Anonymous, 2006). Therefore, similar regulatory conditions operating for the export sector could be applied to dairy to facilitate the adoption of PRPs and QA standards/guidelines and improve system output. Furthermore, consumer awareness on food safety should be enhanced through training and information campaigns, which will ultimately put more pressure on the entire food industry to improve food safety.

Table 6.1. Frequency and statistical analysis of individual scores of indicators for context factors of fish and dairy companies

Context factors	Number of fish companies per score[a]			Number of dairy companies per score[a]			Median scores and associated mean scores (in brackets) of indicators of fish and dairy companies[b]		P-value for Mann-Whitney U test
Risk level of context	**1**	**2**	**3**	**1**	**2**	**3**	Fish	Dairy	
Product characteristics									
Risk of raw materials	0	0	14	0	0	22	3.0 (3.0)	3.0 (3.0)	1.00
Risk of final product groups	0	5	9	0	17	5	**3.0 (2.6)**	**2.0 (2.2)**	**0.014**
Safety contribution packaging concept	0	13	1	1	14	7	2.0 (2.3)	2.0 (2.3)	0.175
Process characteristics									
Extent of intervention steps	0	1	13	0	22	0	2.0 (2.9)	2.0 (2.0)	0.099
Level of production process changes	1	7	6	5	10	7	**1.0 (2.4)**	**2.0 (2.1)**	**0.011**
Rate product/process design changes	9	4	1	14	5	3	**1.0 (1.5)**	**2.42 (1.5)**	**0.000**
Organisational characteristics									
Lack of technical workforce	6	8	0	0	10	12	**2.0 (1.6)**	**3.0 (2.6)**	**0.000**
Degree of variability in workforce composition	5	8	1	16	6	0	1.0 (1.8)	1.0 (1.3)	0.340
Insufficiency operators' competence	8	6	0	1	14	7	**1.0 (1.4)**	**2.0 (2.6)**	**0.000**
Lack of management commitment	11	3	0	0	10	12	**1.0 (1.2)**	**2.0 (1.3)**	**0.002**
Deficiency of employee involvement	5	7	2	3	16	3	**1.0 (1.8)**	**2.0 (2.3)**	**0.002**
Absence of formalisation	10	3	1	6	7	9	**1.0 (1.4)**	**2.0 (2.6)**	**0.003**
Insufficiency supporting information systems	10	4	0	5	7	10	**2.0 (1.4)**	**1.43 (2.0)**	**0.008**
Chain environment characteristics									
Degree safety contribution in chain position	2	11	1	0	0	22	**2.0 (1.9)**	**3.0 (3.0)**	**0.000**
Lack of power in supplier relationships	13	1	0	11	9	2	**1.0 (1.1)**	**1.5 (1.6)**	**0.009**
Lack of authority in customer relationships	5	8	1	4	15	3	2.0 (1.7)	2.0 (2.0)	0.192
Strictness of stakeholders requirements	1	9	4	22	0	0	**1.75 (2.2)**	**1.0 (1.0)**	**0.000**
Context riskiness							**1.8 (1.9)**	**2.1 (2.1)**	**0.000**

[a] Number of companies in each risk level of context: 1: low, 2: medium, and 3: high
[b] Bolded median scores are significant different ($P<0.05$) between fish and dairy sectors
[c] P-value for Mann-Whitney U test to compare the median scores of context riskiness between fish and dairy processing companies

6.4.3. Diagnosis of the design and operation of core control activities

For control activities, with the exception of hygienic design and raw material control, the rest of indicators of preventive measures differed significantly (*P<0.05*) between the two sectors (Table 6.2). In overall, fish companies had relatively advanced preventive measures design (median score 3; mean score 2.3-2.9) than dairy companies (median score 1.5-2.0; mean score 1.5-2.3). Fish companies had cooling facilities, sanitation programmes, personal hygiene requirements, and product specific preventive measures at advanced level (median score 3; mean score 2.7-2.9). Their cooling facilities were specifically modified for their specific production conditions. The cleaning agents (detergents and disinfectants) were modified and tested on their effectiveness for the fish processing sector. Moreover, fish companies had high and specific requirements for personal clothing handling (washing, drying, and storage), personal care and health, and tailored facilities (toilets, washing basins, and changing rooms) to support personal hygiene. Fish companies had product specific preventive measures which were tested for specific production circumstances. On contrary, 11 of 22 dairy companies applied basic (score 1) personal hygiene requirements (standard requirements on clothing and personal care, common washing facilities, and no specific hygiene instructions) and several had no (score 0) sanitation programmes (6) and product specific preventive measures (5, Table 6.2). For instance, some dairy companies had toilets located several metres away from the processing buildings, without water or hand washing facilities. This could result into cross contamination and poor microbiological safety. Studies in Zimbabwe (Gran et al., 2003), Burkina Faso (Millogo et al., 2010), and Turkey (Karaman et al., 2012) also observed that dairy companies lacked hygienically designed equipment and facilities (like building layout and cooling facilities) and had inadequate sanitation programmes and personal hygiene requirements. Moreover, several nonconformities in structure and design, and hygiene and cleaning were observed in ice-cream and cheese processing companies in Spain (Domenech et al., 2013). Dairy companies should re-design their facilities and equipment, develop specific sanitation programmes (for equipment, processing zones, toilets, surrounding environment), introduce strict personal hygiene requirements (including clothing and body cleanliness), and raw material control. Besides organoleptic tests (colour and smell) and acidity test (alcohol test and clot on boiling), other specific rapid tests like mastitis and antimicrobial residues in milk could be also conducted. Severity of checks could depend on suppliers' previous performance; supplier with history of poor quality could either experience more severe checks or excluded altogether. Moreover, dairy companies could change the current supplier agreements and specifications.

All indicators of the design of intervention processes (with the exception of packaging intervention) were significantly different (*P<0.05*) between the two sectors (Table 6.2). Fish companies did not apply physical interventions (like drying and heating/cooking) and intervention methods (as fermentation), while dairy applied intervention processes (pasteurisation, sterilisation and fermentation) to eliminate or reduce microorganisms to acceptable levels. Although the intervention methods applied in dairy companies were supported by scientific information and expert knowledge, their effectiveness were not yet tested. Fish companies had relatively advanced (median score 3; mean score 2.4) maintenance and calibration programmes (specifically designed for the production process) than dairy companies (median score 1.5; mean score 1.6) as they were initiated by problems and not documented. Previous studies in the dairy industry have also reported inadequate intervention processes like pasteurisation (Aaku et al., 2004; Belli et al., 2013) and maintenance and calibration programmes of the intervention equipment (Gran et al., 2002; Gran et al., 2003; Mhone et al., 2011). Since, no intervention processes were applied in fish companies, preventive strategies like cooling and raw material control should be at advanced levels to guarantee food safety. In addition, dedicated packaging interventions for the fishery sector could be adopted. The dairy companies should use automated filling and packaging-intervention equipment (to prevent people interferences), and develop specific equipment maintenance programmes to ensure stable performance.

Except one indicator (the analytical methods) of monitoring system design, both sectors differed significantly ($P<0.05$) in 6 indicators (Table 6.2). Fish companies had advanced (median score 2.0; mean score 2.4) analysis of critical control point (CCP)/control point (CP) because the allocation were executed by own and expert knowledge according to Codex Alimentarius Commission (CAC) guidelines, and the CCPs were tested for the production circumstances. None of the dairy companies have implemented HACCP; hence CCP/CPs were not analysed. Fish companies had relatively advanced level (median score 3.0; mean score 2.6-2.7) in standard and tolerances specification (scientifically supported and adapted for production circumstances) and measuring equipment (automated and tested for the production process). Moreover, calibration programmes were specifically designed/adapted for the production condition; and corrective actions were based on causal analysis of own product and process deviations and were specifically differentiated (Table 6.2). Similarly, EU inspectors found that fish companies have implemented quality and food safety requirements equivalent to the EU demands and are licensed for export (Food and Veterinary Office, 2011c). Furthermore, fish companies are regulated by the competent authority, the Department of Fisheries, Ministry of Fisheries and Livestock Development, which has adequately defined the sampling plan for the fishery sector. Therefore, fish companies use this sampling plan to ensure compliance (Food and Veterinary Office, 2011c). In addition, the fish industry in Tanzania experiences periodic EU audits, in which individual fish companies and the competent authority are inspected (Frohberg et al., 2006; Henson, 2008).

Inadequate stakeholders' demand could be among the impediments for adoption of best practices and HACCP in the dairy industry (Weatherspoon and Reardon, 2003; Henson, 2008). Studies in food industries in Poland and Canada found that export-oriented companies have greater possibilities to implement PRPs, QA standards/guideline and legal requirements than ones serving the respective domestic markets (Konecka-Matyjek et al., 2005; Herath et al., 2007). Moreover, export sectors receive significant investments in food safety infrastructure and skills development than sectors serving the domestic market (Schillhorn van Veen, 2005). Compliance of enterprises that are more domestic oriented would exclusively depend on the country's food regulations (Mensah and Julien, 2011) and domestic market demands (Reardon et al., 2003; Weatherspoon and Reardon, 2003). Hence, dairy companies could develop specific equipment maintenance and calibration programmes (indicating frequency, equipment, and responsible person). Small- and micro-scale enterprises may basically implement the PRPs, whereas medium- and large-scale companies could further include HACCP to design their FSMS. Since, majority of the analysed dairy companies were micro-scale, use of regulatory microbiological sampling design and measuring plans would be sufficient. Food control authorities are however, recommended to increase their sampling frequency and ensure that all companies are timely audited.

With regards to operation of control strategies, the significant difference ($P<0.05$) was observed in 5 of 7 activities (Table 6.2). In contrast to dairy, fish companies have indicated relatively advanced level (median and mean scores 2.5-3.0) in compliance to procedures, actual hygienic performance of equipment and facilities, and cooling capacity. This respectively shows that operators were aware of the existence and content of procedures and consciously follow them, hygienic performance tests conducted regularly, and performance of cooling facilities was stable. Dairy companies had basic (mean score 1.2) procedures which were often paper based. Besides, fish companies had no intervention processes (median and mean scores 0), while dairy companies had intervention processes (including pasteurisation and fermentation), which could only eliminate vegetative cells but not spores (median and mean scores 2). The majority of dairy companies were micro-enterprises often using non-hygienically designed equipment and buildings, simple technology (such as batch pasteurisation and fermentation, manual packet filling and sealing), and inadequate procedures (like mere instructions) (Jaffee et al., 2005; Kurwijila and Bennett, 2011). Thus dairy companies should invest in equipment (like purchase of automatic pasteurisers and filling equipment) and buildings, and develop standard operating procedures for production and sanitation.

Table 6.2. Frequency and statistical analysis of individual scores of indicators for FSMS activities of fish and dairy processing companies

Core control activities	Number of fish companies per score[a]				Number of dairy companies per score[a]				Median and mean (in brackets) scores[b]		P-value for Mann-Whitney U test[c]
FSMS activity levels	0	1	2	3	0	1	2	3	Fish	Dairy	
Design preventive measures											
Sophistication hygienic design equipment/facilities	0	0	11	3	0	2	17	3	2.0 (2.2)	2.0 (2.1)	0.303
Adequacy of cooling facilities	0	0	1	13	2	2	5	13	3.0[b] (2.9)	3.0 (2.3)	0.026
Specificity of sanitation programmes	0	0	3	11	6	2	12	2	3.0 (2.8)	2.0 (1.5)	0.000
Extent of personal hygiene requirements	0	0	4	10	0	11	5	6	3.0 (2.7)	1.5 (1.8)	0.002
Adequacy raw material control	0	0	8	6	0	1	15	6	2.0 (2.4)	2.0 (2.2)	0.278
Specificity of product specific preventive measures	0	0	2	12	5	5	6	6	3.0 (2.9)	2.0 (1.6)	0.000
Design intervention processes											
Adequacy of intervention equipment	14	0	0	0	0	8	4	10	0.0 (0)	2.0 (2.1)	0.000
Packaging intervention equipment	9	0	3	2	5	5	8	4	0.0 (0.9)	2.0 (1.5)	0.092
Maintenance and calibration programme for equipment	0	2	4	8	1	10	8	3	3.0 (2.4)	1.5 (1.6)	0.005
Effectiveness intervention methods	13	0	0	1	1	1	20	0	0.0 (0.2)	2.0 (1.9)	0.000
Design monitoring system											
Appropriateness CCP/CP analysis	0	1	7	6	21	1	0	0	2.0 (2.4)	0.0 (0.1)	0.000
Standards and tolerances design	0	0	4	10	8	1	7	6	3.0 (2.7)	2.0 (1.5)	0.003
Analytical methods to assess pathogen levels	0	0	4	10	2	2	1	17	3.0 (2.7)	3.0 (2.5)	0.966
Measuring equipment to monitor process/ product status	0	0	6	8	0	6	11	5	3.0 (2.6)	2.0 (2.0)	0.012
Calibration programme for measuring and analytical equipment	0	0	2	12	5	16	1	0	3.0 (2.9)	1.0 (0.8)	0.000
Sampling design (for microbial assessment) and measuring plan	0	1	11	2	11	8	2	1	2.0 (2.1)	0.5 (0.7)	0.000
Extent of corrective actions	0	0	2	12	5	10	1	6	3.0 (2.9)	1.0 (1.4)	0.000
Operation control strategies											
Actual availability of procedures	0	0	12	2	5	7	10	0	2.0 (2.1)	1.0 (1.2)	0.000
Actual compliance to procedures	0	0	7	7	5	6	5	6	2.5 (2.5)	1.5 (1.6)	0.012
Actual hygienic performance of equipment and facilities	0	0	4	10	1	0	21	0	3.0 (2.7)	2.0 (1.9)	0.000
Actual cooling capacity	0	0	1	13	4	1	5	12	3.0 (2.9)	3.0 (2.1)	0.014
Actual process capability of intervention processes	14	0	0	0	0	4	14	4	0.0 (1.0)	2.0 (2.0)	0.000
Actual process capability of packaging equipment	9	0	1	4	9	0	5	8	0.0 (1.0)	2.0 (1.6)	0.286
Actual measuring equipment performance	0	0	1	13	0	1	1	20	3.0 (2.9)	3.0 (2.9)	0.813

Actual analytical equipment performance	0	0	0	14	2	1	1	18	3.0 (3.0)	3.0 (2.6)	0.096
Core assurance activities											
Translating of stakeholder requirements into own FSMS	0	3	5	6	2	7	6	7	2.0 (2.2)	2.0 (1.8)	0.253
Systematic use of feedback information to modify FSMS	0	0	2	12	1	9	5	7	**3.0 (2.9)**	**2.0 (1.8)**	**0.001**
Validation of preventive measures	1	1	4	8	8	8	6	0	**3.0 (2.4)**	**1.0 (0.9)**	**0.000**
Validation of intervention systems	10	1	1	2	7	7	8	0	0.0 (0.6)	1.0 (1.1)	0.105
Validation of monitoring system	1	0	5	8	12	3	7	0	**3.0 (2.4)**	**0.0 (0.8)**	**0.000**
Verification of people-related performance	0	1	8	5	6	9	2	5	**2.0 (2.3)**	**1.0 (1.3)**	**0.006**
Verification of equipment- and methods- related performance	0	1	5	8	5	10	6	1	**3.0 (2.5)**	**1.0 (1.1)**	**0.000**
Documentation system	0	0	7	7	0	13	9	0	**2.5 (2.5)**	**1.0 (1.4)**	**0.000**
Record-keeping system	0	0	10	4	0	11	11	0	**2.0 (2.3)**	**1.5 (1.5)**	**0.000**
FSMS performance									*2.1* (2.1)	*1.7* (1.7)	***0.019***

[a] Number of fish and dairy companies per each activity levels (0: not applicable, 1: basic level, 2: average level, 3: advanced level)
[b] Bolded median scores are significant different (*P<0.05*) between the fish and dairy sectors
[c] P-value for Mann-Whitney U test to compare the median scores of context riskiness between fish and dairy processing companies

6.4.5. Diagnosis of the set-up of core assurance activities

Moreover, Table 6.2 shows that 8 of 9 indicators of assurance activities differed significantly between the two sectors (*P<0.05*). In general, fish companies had significantly advanced level (mean score 2.2-3.0) in the set-up of assurance activities (*P<0.05*) than dairy companies, which were at basic level (mean score 0.8-1.8). The majority of dairy companies did not conduct (median and mean scores 0) validation of monitoring systems and preventive measures as well as verification of people- and equipment-related performance. Lack of such crucial core assurance activities means that the effectiveness and execution of the FSMS is not evaluated (Luning et al., 2009). A study in Japanese dairy companies observed that smaller companies without HACCP approval did not conduct validation and verification activities (Sampers et al., 2012). Though in this study, few dairy companies had conducted validation and verification activities, they were not independent or scientifically supported. Such activities were carried out by own people working in the system (often lacking proper knowledge and expertise) and not documented. Validation and verification by external experts provide independent opinions on the performance of the system (Luning et al., 2009). Likewise, a study in the UK food industry found that most companies developed and implemented FSMS by their own employees (Mensah and Julien, 2011). Moreover, in this study, the majority of dairy companies lacked structured documentation and systematic registration of record-keeping data. Previous studies also observed lack of proper documentation and record-keeping system in micro- and small-scale enterprises (Taylor and Kane, 2005; Karipidis et al., 2009; Karaman, 2012). In addition, a study in Spanish food industry found that HACCP plans lacked documented hazard analysis (Ramírez Vela and Martín Fernández, 2003). Therefore, dairy companies need to establish assurance activities like using personnel from the food control authority, research institutions or universities for validation and verification purposes. Moreover, they could develop comprehensive documentation and record-keeping procedures. Given the financial and human capabilities of micro-enterprises, very small dairy companies could however, use simple documentation and record-keeping systems, which could be often paper-based.

6.4.6. System output diagnosis

Although two indicators (microbial food safety and hygiene-related complaints) did not show any statistical significant difference (*P>0.05*), the rest of indicators were significantly different (*P<0.05*) between the two sectors (Table 6.3). Compared to dairy companies, fish companies revealed relatively advanced level (mean scores 2.6-2.9) in the external and internal evaluation of FSMS. The FSMS of fish processing companies were evaluated by several accredited third-parties including the competent authority, EU, and independent third party auditors for the BRC and ISO standards. Nonetheless, no major remarks on the FSMS performance, indicating better system output.

Table 6.3. Frequency and statistical analysis of individual scores of indicators for system output of fish and dairy processing companies

System output	Number of fish companies per score[a]				Number of dairy companies per score[a]				Median and mean (in brackets) scores[b]		P-value for Mann-Whitney U test[c]
System output levels	0	1	2	3	0	1	2	3	Fish	Dairy	
External FSMS performance assessment											
FSMS evaluation	0	3	0	11	1	13	0	8	3.0[b] (2.6)	1.0 (1.7)	0.014
Seriousness of remarks of the FSMS evaluation	0	0	4	10	1	5	14	2	3.0 (2.7)	2.0 (1.8)	0.000
Microbiological food safety complaints by customers	1	0	2	11	0	0	14	8	3.0 (2.6)	2.0 (2.4)	0.031
Hygiene-related complaints by customers	1	0	3	10	0	0	8	14	3.0 (2.6)	3.0 (2.6)	0.752
Internal FSMS performance assessment											
Product sampling to confirm microbiological performance	0	0	2	12	1	20	0	1	3.0 (2.9)	1.0 (1.1)	0.000
Judgment criteria	0	1	3	10	1	10	3	8	3.0 (2.6)	1.5 (1.8)	0.014
Hygiene and pathogen nonconformities	0	0	5	9	0	2	19	1	3.0 (2.6)	2.0 (2.0)	0.000
System output									2.8 (2.7)	1.9 (1.9)	0.000

[a] Number of fish and dairy companies in each level of indicators of system output (0: no indication, 1: poor, 2: moderate, 3: good system output)
[b] Bolded median scores are significant different ($P<0.05$) between the fish and dairy sectors
[c] P-value for Mann-Whitney U test to compare the median scores of context riskiness between fish and dairy processing companies

In comparison to dairy, fish companies had structured sampling plans in raw materials, final products and environment, and use various criteria (like CAC, EU, and TBS) to interpret microbiological results. This could have been partly contributed by strict export market demands imposed on fish companies (Herath et al., 2007) as compared to inadequate domestic market pressure on dairy companies. Dairy companies may use sampling designs and measuring plans developed by the food control authorities (like TBS and TFDA) or develop their own. Moreover, complaints registration procedures need to be developed and implemented. Food control authorities need to intensify their inspections to dairy companies and ensure that their recommendations for improvement are meticulously implemented.

6.5. Conclusions

Although both sectors operated in moderate-risk context, fish companies, the exporting sector, had average FSMS and relatively good system output compared to the dairy companies, the sector for the domestic market. All fish companies have implemented PRPs and HACCP, and the majority are BRC, ISO 9001, and ISO 22000 certified. However, each sector would require specific intervention measures for improvement on their FSMS and lowering the risk-level of the context. Specific areas for improvement of FSMS of fish companies are the design of preventive measures (like hygienic design of equipment and facilities i.e. buildings) and monitoring system (developing specific sampling design and measuring plans) as there were no physical intervention processes. For the dairy companies, the major focus could be on the preventive measures (like development of specific sanitation programmes, strict personal hygiene requirements, and raw material control), intervention processes (use of automatic pasteurisation and packaging equipment), monitoring system (CCP/CP analysis, specific sampling design and measuring plan, develop standards and tolerances, and corrective actions) and establishing assurance activities (set-up system requirements, independent validation and verification, and comprehensive documentation and record-keeping system) and intensifying their food safety performance assessments.

For the context characteristics, fish and dairy companies could create supportive organisational conditions (like developing information systems, improving quality of the workforce, and enhancing management commitment) to decision making and set-up product-use requirements to prevent unpredictable use by the customers. For both sectors effective control measures are required to mitigate the risk of raw materials. Since, there are no intervention processes applied in the fishery sector, strict raw material control programme from fishing to the company premises and specific sampling design and measuring plans have to be established. With regards to dairy sector, in addition to the described control measures in the fishery sector (i.e., raw material control with regards to chemical contaminants and sampling and measuring plans), effective physical intervention processes (pasteurisation and fermentation) are recommended to mitigate the risks in raw milk. However, government support in terms of expertise and resources would be required to enable micro-and small-scale companies, particularly the dairy establishments, to adopt good practices and QA standards and guidelines. Strengthen dairy organisations through information, education, and communication campaigns to create food safety awareness to consumers that could put more pressure to food companies to improve their systems' output. In general, market orientation, stakeholders' demands (legislation, sectoral/branch, market/retail, and customers), organisation of the raw material supply chain, size of the companies, audits/inspection, and innovativeness of the studied companies are the possible causes of the observed differences in the design and operation of FSMS between the two sectors. Therefore, dairy companies could use the experience of fish processing companies to improve the design and operation of core control and assurance activities and system output in order to manufacture food products that meet domestic and export markets' requirements. However, similar level of enforcement of food laws and regulations, and other supply chain requirements applied in the export sector should be used by the sectors serving the domestic market to improve the design and operation of FSMS and guarantee supply of quality and safe products.

CHAPTER 7

General discussion, conclusions and future perspectives

Chapter 7: General discussion, conclusions and future perspectives

7.1. Introduction

Export oriented companies in Tanzania are improving their FSMS, but still experience microbiological and chemical food safety problems (Ababouch et al., 2005; Ababouch, 2006; Onjong et al., 2014b). At local level, food companies continue to experience an increase in the number of cases of foodborne disease outbreaks (TFDA, 2011). Moreover, food safety awareness by the public and market (supermarkets and hotels) has increased the demand for quality and safe products in Africa (Jabbar et al., 2010). This poses a significant challenge to food processing companies to develop more effective FSMS that will reduce incidences of food safety hazards in the agri-food chain. This study attempted to get insight in the FSMS situation in Tanzanian food industries and to develop measures to be undertaken to improve effectiveness of current FSMS in order to ensure supply of safe food for both domestic and export markets. The overall objective was to gain an understanding on the underlying factors causing insufficient performance of food safety management systems in fish (export oriented) and dairy (domestic market oriented) processing companies in Tanzania in order to develop a roadmap for improvement of these systems.

This chapter discusses the findings on the literature review (Chapter 1 and Chapter 2) and empirical studies on the actual performance of FSMS of domestic (dairy, Chapter 3) and export-oriented (fish, Chapter 4, 5) processing companies in Tanzania. Also, it discusses the results of the comparative study (Chapter 6) to identify possible causes of the differences in FSMS performance of domestic (dairy) and export (fish) market oriented companies. Furthermore, a generic roadmap to support improvement of FSMS of Tanzanian food industries is described. Finally the usefulness of the diagnostic tools is discussed as well as the significance and limitations of this research including suggestions for further research.

7.2. Major research findings

Chapter 1 provides an overview of characteristics of food production sectors and Tanzania legal framework for food safety. The cited literature concludes that the food manufacturing sector in Tanzania is largely agro-based composed of mainly micro- and small-scale (97%) companies with very few large-scale. The micro-and small-scale companies (often for the domestic market) operate in an informal sector (without proper regulation) and use labour intensive and poor technologies. The food distribution chain involves various players often lacking reliable electricity, good infrastructure (roads/railways), and proper knowledge on good handling and distribution practices. In comparison to the export sectors, the domestic market producing sectors operate in an inadequately regulated environment. Tanzania has no effective legal framework for food safety as there is not yet national food safety policy. Moreover, there are several food laws and regulations and institutions involved in enforcement without effective harmonisation and coordination of regulatory activities. This does not only result in higher costs but also duplication of efforts.

Chapter 2 describes the deficiencies in performance and possible improvement strategies of FSMS in African food processing companies. The study reviewed studies on microbiological and chemical hazards in African food products, deficiencies of FSMS in African food companies, and hurdles due to context characteristics. It was concluded that most food products from reviewed reports may not meet local and export market food safety requirements. The FSMS from reviewed studies indicated inadequate design and operation of core control and assurance activities. However, as compared to domestic market oriented companies, export oriented companies had advanced FSMS. Moreover, African companies experience hurdles to improve their FSMS at various levels including government (due to poor legal framework for food safety), sector associations (due to lack of sector associations for the domestic sector), market/retail (insufficient food safety demands from the market due to small market share 10%), and company (inadequate workforce quality, basic information systems, inadequate procedures, dependency on other chain actors, conflicting stakeholders requirements). Improvement measures were proposed at four different levels including government (developing legal frameworks, food safety authorities to perform inspections and product controls); sector/branch (support food companies adopting best practices, inspection, and translating legal and market demands), market/retail (market/retailers to force their suppliers towards a higher level of FSMS by proposing specifications and certification schemes) and company level (hygienic design of equipment and facilities, specific sanitation programmes, raw material control, process automation, implement ISO 22000/HACCP and PRPs, specify standards, tolerances and corrective measures, perform validation and verification, improve documentation and record keeping, and perform product sampling).

Therefore, this study (Chapter 1, 2) underpinned the need to perform status assessment of current FSMS of food processing companies in Tanzania. The actual assessment of FSMS in dairy (Chapter 3) and fish (Chapter 4, 5) processing companies showed differences in the set-up and operation of their core control and assurance activities, the system output and context riskiness. Hierarchical cluster analysis resulted in two clusters in fish (with similar level of set-up and operation of FSMS activities and context riskiness but differing in system output, Chapter 4) and three clusters in dairy companies (differing in level of design and operation of FSMS activities, context riskiness and system output, Chapter 3). Cluster IA contained the best performing dairy companies (which have hygienically designed equipment and facilities, qualified personnel, formalisation and well organised raw material and finished products supply chains) as compared to clusters IB and II. Cluster IB composed of intermediate performing companies with inadequately designed facilities and trained personnel; some have collection centres and cold trucks for milk collection. Cluster II contained the poor performers (micro- and small-scale companies) with non-hygienically designed equipment and facilities, most of these companies use batch processes (Chapter 3). The number of clusters reflected the size-range of the companies analysed. Dairy companies ranged from micro- to large-scale companies, while large-scale companies dominated the fish sector. Overall, the fish companies operate in a moderate risk context and have average level FSMS, and a moderate to good system output. On the contrary, the dairy companies operate in a moderate- to high-risk context and have basic to average level FSMS and poor to moderate system output.

All the investigated fish processing companies used Codex Alimentarius Commission's PRPs (GHP and GMP) and HACCP principles to design their FSMS (Chapter 4, 5). The majority of companies have an **average level FSMS** typified by standard equipment (knives, vacuum packaging machine, heat exchangers) and facilities (building layout, freezers and cold rooms), which comply with hygienic requirements but they were not tested nor modified for the company specific production circumstances. Data also revealed that they had no insight in actual hygienic performance of their equipment and facilities. All fish companies had procedures (for cleaning, personal hygiene, maintenance and calibration of equipment and CCP procedures) at location, but they were paper based and not regularly up-dated. With respect to **assurance**, they conducted independent validation of preventive measures and the monitoring systems, and people and equipment verification is done by the competent authority, the European Commission Food and Veterinary Organisation, and third party auditors for certification purposes. The lack of intervention processes revealed the dependence of fish companies on their raw material suppliers to ensure safety of their final products. The **organisational context** was typified by sufficient workforce quality, high level of formalisation, and clear commitment expressed by a dedicated food safety budget. The **supply chain is characterised** by having influence on supplier specifications, clear enforcement of food laws and regulations, and defined customer demands. Although strict food safety regulations and customer demands put more pressure on the system (Luning et al., 2011b), they also enable food companies to improve their systems to meet the demands.

In contrast, most dairy companies (Chapter 3) have **basic operating FSMS**; they use basic equipment (plastic containers, batch pasteurisers) and have simple or limited facilities (no hand washing facilities, basic plant layout). Very few companies used PRPs to design their FSMS and none have applied HACCP principles. Operators execute tasks based on their own insights due to lack of procedures to perform core control tasks like sanitation. Most companies lack aseptic packaging of heat treated milk, which increases the chance on post processing contamination (Grimaud et al., 2007). The actual microbiological assessments of samples of food products, food contact surfaces and hands of the personnel analysed for dairy companies, indeed showed samples with exceeding limits for hygiene and pathogen indicators, which confirmed poor system output probably caused by their high-risk context combined with the basic level FSMS (Chapter 3). The set-up of **assurance activities** is at basic level because it is conducted by own people (often not well educated/experienced), so no independency was guaranteed. Apart from inspection by the food control authorities, dairy companies rarely receive independent inspections/audits. Therefore, the performance of FSMS is rarely externally evaluated, which likely contributed to the basic system design and poor system output (Jacxsens et al., 2010b). The **organisation context** of the dairy companies is typified by restricted formalisation and information systems, absence of food safety responsible/team, no resources allocated for FSMS activities, and employees with low competence level. The **supply chain environment** is characterised by poor enforcement of food laws and regulations, restricted influence on supplier specifications and customers' demands and limited QA requirements.

Dairy and fish companies differ considerably in their **market orientation**. The dairy companies produce for local markets whereas the fish companies produce mainly for export markets. Export oriented companies are subject to various customers and strict regulatory requirements from both within and outside (export market) the country (Kirezieva et al., 2015). Export oriented companies commonly receive multiple inspections and audits from accredited third parties, indicating that their FSMS are independently evaluated (Kussaga et al., 2013). Independent validation (preventive measures and monitoring systems) and verification (people, equipment and methods related performance) contribute to effective FSMS (Luning et al., 2009). Dairy companies receive inspections of their FSMS from food control agencies, Tanzania Food and Drugs Authority (TFDA) and Tanzania Bureau of Standards (TBS), which have limited inspection plans and expertise (United Republic of Tanzania, 2014). The absence of third and second party audits seems to have a negative impact on the design and operation of FSMS of companies as well (Opiyo et al., 2013; Kirezieva et al., 2015).

Furthermore, the export-oriented fish companies have a more organised raw material supply chain than local oriented companies. For example, raw materials (fresh fish) suppliers (specific companies' agents, specifications) are provided with flaked ice, containers and sometimes fishing equipment to ensure quality and safety of their supplies (Kussaga et al., 2014b). There are specialised refrigerated trucks to transport raw materials from landing sites to the companies' premises and the cold chain is observed for the finished products (Chapter 1, 4). This has been possible through defined customers' requirements and effective enforcement of food laws and regulations by the competent authority, the Fisheries Department under the Ministry of Livestock and Fisheries Development (Kadigi et al., 2007; Kussaga et al., 2014a; Kussaga et al., 2014b). However, food quality/safety culture of the export oriented companies could be also one of the reasons for such achievement as opposed to the majority of local market oriented companies.

Companies with a good food safety/quality culture will undertake various initiatives like adoption of best practices and third party auditing to improve their FSMS (Hayburn, 2014).

On the contrary, the dairy companies, the micro-enterprises in particular, purchase raw materials (raw milk) from various suppliers including specialised company agents and hawkers. Use of hawkers indicates that dairy companies have no control over the primary producers. This demands strict control at reception to ensure (microbiological) quality raw materials (Grimaud et al., 2007). However, the majority of dairy companies have restricted control (based on legislative and sectoral guidelines) of raw materials at receipt (Kussaga et al., 2015). In addition, the raw material suppliers for micro- and- small scale dairy companies lack special milk storage containers, milk collection centres lack cooling tanks and there are no special refrigerated trucks to transport milk from the source to the companies' premises (Chapter 3). Limited power supply in remote areas where milk is being sourced could be the bottleneck to the establishment of milk cooling centres/installing cooling facilities at milk collection points (Grimaud et al., 2007). Transporting raw milk by bicycle/motor cycles or vans in plastic containers under ambient conditions could compromise the quality and safety of raw milk (Grimaud et al., 2007; RLDC, 2009). Therefore, raw milk of poor (microbiological) quality could access dairy companies because of these inadequate operational conditions (Codex Alimentarius Commission, 2004).

To conclude, lack of strict stakeholders (government, customers (wholesalers and retailers), consumer and consumers' organisations) food safety requirements affects the adoption of best practices and QA standards and guidelines in the design of FSMS (Codron et al., 2014; Unnevehr, 2015). In absence of market and consumer pressure, the government is expected to intervene to regulate food safety (Unnevehr and Hirschhorn, 2001). Strict food safety regulations put more pressure on the system (Luning et al., 2011b), however, they could catalyse food safety improvement (Maertens and Swinnen, 2009) and export performance (Masakure et al., 2009). Furthermore, consumers and consumer associations complement the efforts of food control agencies in encouraging the food industry to provide safe products (FAO/WHO, 2005). Although food companies for export market have relatively advanced design and operation of FSMS compared to the domestic oriented companies, specific intervention measures for improvement are necessary for both sectors (Chapter 6). The presumable causes of the differences in the design of FSMS between dairy and fish companies are market orientation, stakeholder's demands (legislation, sector, market/retail and consumer organisations), and organisation of the raw material supply chain, size of the companies, audits/inspection, and innovativeness of the companies. Dairy companies particularly, those from clusters IB and II, are recommended to use the experience of fish processing companies or best performing dairy companies (i.e. from cluster IA) to improve the design and operation of their FSMS. However, similar level of enforcement of food laws and regulations, and other supply chain requirements applied in the export sector should be used to sectors serving the domestic market to improve the design and operation of FSMS and guarantee supply of quality and safe products.

7.3. Roadmap for improvement of current FSMS towards more effective systems

The empirical studies observed that the current design and operation of core control and assurance activities of FSMS of fish (Chapter 4, 5) and dairy (Chapter 3) processing companies are not yet adequate to deal with the context riskiness. Similarly, the literature review (Chapter 2) showed that the performance of FSMS in other African food industries are also not yet adequate to ensure safe products for both domestic and export markets (Kussaga et al., 2014a). Also when the comparison is made between local oriented companies and export focused companies, still improvements are necessary on the tailoring and adapting for fit-for-purpose FSMS (Chapter 6). As a result, improvement strategies were proposed at four levels including government, market/retail, sector/branch and company (Kussaga et al., 2014a). However, these measures are general and cannot directly facilitate the improvement process in companies. It is recognized that changes in companies need to be facilitated in steps (Scott et al., 2009). Changes would require capital investment, resource allocation, and organisational commitment (Scott et al., 2009); hence, should be formalised into the company's planning and operational practices. Therefore, this study developed a roadmap for improvement to guide companies in systematically mapping the problem situation, analysing the problem and redesigning the system. This roadmap proposes short to long-term solutions which could be gradually adopted by the food companies to improve their systems. It shows tools and methods that could be used to collect information for a particular food safety problem (Table 7.1), tools and methods to analyse the collected information (Table 7.2), and tools and methods that could be used to redesign (develop and implement solutions, Table 7.3). This roadmap could facilitate food companies in Tanzania to identify the problems in their FSMS, analyse the problems and develop and implement possible solutions to guarantee food safety for both domestic and export markets. This will result into gradual improvement of the system output of food companies; therefore, the proposed roadmap for improvement could be used as continuous improvement programme by the food processing companies in Tanzania.

7.3.1. The design of the roadmap for improvement

The roadmap design is based on two concepts: the concept of food quality relationship model and that of the improvement cycle. The food quality relationship model describes food quality as a function of food behaviour and human behaviour. Food behaviour is dependent on dynamic product properties (food dynamics) and the applied technological conditions to stabilise the properties. Human behaviour is dependent on the dynamic individual decision-making of employees (human dynamics) and the applied administrative conditions to direct this behaviour (e.g. setting procedures and working practices in place) (Luning and Marcelis, 2006, 2007; Luning and Marcelis, 2009a). The concept of the improvement cycle (Figure 7.1) involves (1) mapping the problem area (i.e., collecting information and documentation), (2) analysing the problem area (i.e., identification of causes and effects), and (3) redesigning (i.e., development and implementation of solutions) (Stevenson, 2006). The improvement process is a gradual, step-by-step on-going process. Depending on the initial situation, improvements could vary from simple measures to reduce variation in products on the short-term, to changes in the infrastructure on the long-term (Luning et al., 2010; Jacxsens et al., 2011b). Three levels of increasing improvement efforts were defined based on the food quality relationship model (Figure 7.1); 1) changes in product and people behaviour, 2) changes in technological process conditions and administrative conditions, and 3) changes in the technological infrastructure and organisational arrangements (Luning and Marcelis, 2009b; Luning et al., 2010). After each improvement cycle, the new situation should be reassessed in order to judge the effect of the improvement (Luning et al., 2010). A structured and integrated continuous improvement program provides opportunities for both incremental continuous improvement (smaller, gradual improvements) and radical process redesign (major overhaul, rapid improvements) (Scott et al., 2009). However, for sustainability, smaller and gradual improvements are recommended.

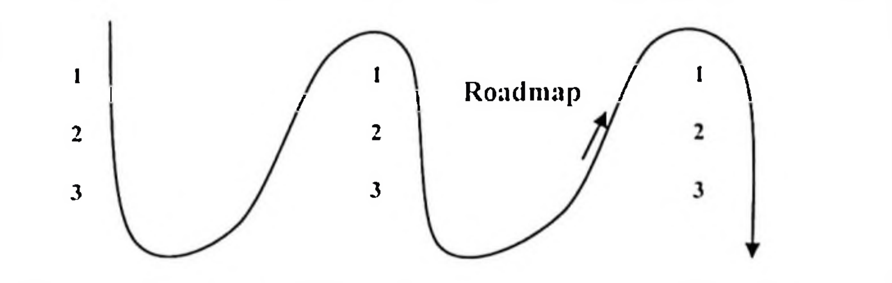
Improvement cycle/ steps	Level of improvement efforts		
	1. Change product and people behaviour	2. Change technological process and administrative conditions	3. Change technological infrastructure and organisational arrangements
1. Map the problem situation 2. Analyse the problem 3. Redesign			

Figure7.1. Development stages of the roadmap for improvement of FSMS (PathogenCombat, 2008)

Step 1. Mapping the problem situation: information gathering (data collection and literature)

The initial stage in the improvement cycle is mapping the problem situation, which involves information gathering and documentation. The company has to identify personnel responsible for information collection, particularly, the food safety/HACCP team or personnel responsible for quality assurance (i.e. QA manager). Information gathering can be based on **data collection** from the actual situation of the company (customer complaints, inspection reports, product rejection rates, microbiological results) on the one hand, and on the other hand information from **literature** (scientific, grey literature, sector guidelines and standards) or **technical information** of equipment/products delivered by suppliers, **international reports** (RASFF, EFSA, FAO, WHO), **national reports** (surveillance and monitoring reports) as well as **national food safety legislation** (Van Boxstael et al., 2013). The FSMS-DI and MAS diagnosis have been used in this study as tools to evaluate the current status of FSMS activities and to map risk factors in the context (Kussaga et al., 2014b, 2015). Based on those findings, needs for improvement could be identified for the Tanzanian case of fish and dairy processing companies as an example. The general suggestions for these case studies for improvement in FSMS are related to **technological/infrastructural changes** (i.e., hygienic facilities/design, production process, validation, verification of control measures), **managerial changes** (people/organisation i.e. quality of the workforce, management commitment, formalisation, information systems, documentation and record keeping system). In the **context risk**, the focus could be towards reduction of the risk level of the chain characteristics (i.e. legal and policy framework, customers' food safety awareness, and stakeholders' requirements). However, for the scope of this study, the proposed roadmap will not include aspects of the chain characteristics, as these are beyond a company's' control. Table 7.1 provides an overview of potential tools (such as MAS, FSMS-DI, checklists, and inspection/audit tools) and methods (like interview, survey, microbiological analysis and observation) to perform the information collection step (i.e. problem mapping) at each level of improvement efforts as defined in Figure 7.1. The information on the products, processes, people and organisation is systematically collected in order to propose suggestions for improvement of the FSMS (control and assurance) activities. For the assurance activities the information on validation (preventive measures, intervention and monitoring systems) and verification (people, equipment and methods related performance) was collected. Validation is defined as obtaining evidence that a control measure or combination of control measures, if properly implemented, is capable of controlling the hazard to a specified outcome (Codex Alimentarius Commission, 2003). Verification is the application of methods, procedures, tests and other evaluations, in addition to monitoring, to determine whether a control measure is or has been operating as intended (Codex Alimentarius Commission, 2003).

Table 7.1. Problem mapping- tools and methods to collect information from food processing companies

Levels of improvement efforts		
Level 1. changes in product characteristics and people behaviour	**Level 2.** changes in technological process conditions and administrative conditions	**Level 3.** changes in the technological infrastructure and organisational arrangements
	Actual performance in the company	
Product status • Collect* information about rejections, complaints, microbial load in products and % realised inspections to get insight in *product hygiene/safety* (analysing *customer complaints* and inspection *records; RASFF* for export products, microbial analysis (adapt MAS protocol) to determine microbial load)	*Production process* • Collect information about the actual process and packaging parameters (monitoring data), the sanitation program specifications, the actual hygiene performance of equipment and utensils (by microbial analysis i.e. adapt MAS protocol; FSMS-DI)	*Technological infrastructure* • Collect information about the hygienic specification of equipment and facility design (by analysing technical information of equipment) • Collect information on maintenance and equipment breakdown time and situations (analysing equipment maintenance records)
People behaviour • Collect information about hand hygiene and observe actual hygienic behaviour to get insight in personal hygiene performance (by hand swabs/Rodac plates and microbial analysis i.e. MAS protocol, behaviour observation and checklists)	*Administrative conditions* • Collect information on presence and completeness of procedures, instructions, pictograms, registration of data of monitoring, documentation system (interview by using FSMS-DI, checklist, and observation)	*Organisational arrangements* • Collect information about the assignment of tasks, responsibilities and authorities of all hygiene related tasks (by inventory of assigned tasks, responsibilities and authorities, interview, FSMS-DI)
	Validation (setting requirements)	
Product status • Collect information on microbiological testing of products to validate product such as packaging conditions and shelf life period (by microbial analysis; accelerated shelf life testing)	*Production process* • Collect information from HACCP plan i.e. what are the current process specifications as defined in the HACCP plan (by checklist) • Validation information like CCP analysis, standards and tolerances, corrective actions of various control measures and intervention equipment (e.g. pasteuriser, steriliser, and packaging machines) and methods (fermentation, disinfection, pasteurisation, sterilisation) (by analysing validation records; European Union Commission Food and Veterinary Organisation's (FVO) inspection reports, checklists)	*Technological infrastructure* • Collect information on how validation of hygienic equipment and facilities design are validated and collect those validation results (analysis of internal and external validation reports)

People behaviour • Collect data available in the company on setting requirements to the people on hygienic working (e.g. use of gloves or not based on which decision, frequency of change of clothes, application of mouth mask or not) (by checklists and/or survey questionnaire)	*Administrative conditions* • Collect data on how decisions are made on data registration (responsibility, mode, frequency) and on record keeping (paper, computer, centralised/separate system) (by checklists and interview) • How is the information flow e.g. from suppliers or customers towards the production requirements organised (interview suppliers, customers, personnel)	*Organisational arrangements* • Collect information on how assignment of tasks, responsibilities and authorities have been decided in the companies (by inventory of tasks and responsibilities) • How the organogram historically has grown (analyse the current organogram and compare with the previous; interview)
	Verification (checking how set requirements are fulfilled and followed)	
Product status • Verification information on sampling plan: how is the sampling plan built up, which criteria are considered, frequency of sampling, are all product included? (during internal audit)	*Production process* • Verification/audit information on adequacy of preventive measures (hygienic design and cooling facilities) intervention equipment (pasteurisers, sterilisers, packaging equipment), intervention methods (fermentation, disinfection) and analytical equipment (by verification or audit; FVO audit reports)	*Technological infrastructure.* • Verification/audit information on hygienic specification of equipment and facility design by trend analysis of hygiene performance of the environment (e.g. *L. monocytogenes* check in processing environment, mould formation on walls and equipment), and trend analysis on maintenance/equipment breakdown time and situations (when and why breakdowns happened?) (audit/verification reports; equipment maintenance records)
People behaviour • Check compliance to procedures and people behaviour in the company (by internal auditing, observation, group discussion, interview and checklists). • Use competence standards and assessment framework (behaviour event interviewing and psychometric testing) to assess the competence of personnel	*Administrative conditions* • Collect data on verification of documentation and registrations: how is it checked that registration are complete, signature of responsible personnel, completeness (checklist, verification records)	*Organisational arrangements* • Collect information whether the organisation of the company and separation of duties are clear. No problems in communication, replacements of persons in case of illness, and up-take of responsibilities. This can be collected during internal auditing processes

*Food safety/HACCP team or identified personnel are responsible with collection of information during this problem mapping step

For example, dairy companies in cluster II (Chapter 3) should first identify responsible personnel for collection of the information on the identified problems. As these companies have no operational food safety/HACCP team in place, they could therefore, establish the food safety/HACCP team which will be responsible for food safety issues in their respective companies. As for personal hygiene (which was at basic level), the food safety teams of dairy companies in cluster II could use MAS protocol (by performing hand swabs), interview (using FSMS-DI or checklists) and personal observation (personal behaviour and practices, hand washing) as tools to collect information at improvement effort level 1 (i.e., change in people behaviour). At improvement effort level 2 (change in administrative conditions), the information on presence and completeness of sanitation (cleaning and disinfection) procedures could be also collected by interview (checklists and FSMS-DI). At improvement effort level 3 (change in organisational arrangements), dairy companies (from cluster II) could perform an inventory of the assignment of tasks, responsibilities and authorities of hygiene related tasks (Table 7.1).

Step 2. Analysing the identified problems

After data collection to map the problem, a next step in the roadmap for improvement has to be taken (Figure 7.1), namely, analysing the problem area (i.e., identification of causes and effects). The food safety/HACCP team or the person identified by the company is responsible for the data analysis step. This step proposes the methods and tools that could be used to analyse and interpret the collected information. Several methods (like basic statistics, statistical process control, benchmarking, interview, content analysis) and tools (such as audit tools, basic statistic tools, record management tool, and protocols for validation and verification) have been proposed to analyse and interpret the collected information at each level of improvement effort (Table 7.2). Although validation and verification protocols could not directly support analysis of causes and effects, they could be used to interpret the collected information. Proposed methods and tools take into account the managerial as well as technological aspects. Table 7.2 provides an overview of potential tools and methods which can be applied on the different levels of improvement efforts to establish the cause-effect relationship.

For instance, with regards to personal hygiene, the food safety team of dairy companies in cluster II could use basic statistical tools (e.g. cluster analysis, analysis of variance) to analyse information collected on personal hygiene (microbiological results and interview) from problem mapping (Table 7.1). At improvement effort level 2 (administrative conditions), the food safety/HACCP teams could perform content analysis of sanitation procedures to assess quality/content of sanitation procedures. Moreover, at improvement effort level 3 (organisational arrangements) relevant statistical methods (descriptive statistics) could be used to analyse the inventory results on how the sanitation tasks, responsibilities and authorities are assigned in Cluster II dairy processing companies (Table 7.2).

Table 7.2. Tools and methods to analyse and interpret collected information in fish and dairy processing companies in Tanzania

Levels of improvement efforts		
Level 1. Tools and methods to analyse collected information on product characteristics and people behaviour	**Level 2.** Tools and methods to analyse information on technological process and administrative conditions	**Level 3.** Tools and methods to analyse information on technological infrastructure and organisational arrangement
	Actual performance in the company	
Product status	*Production process*	*Technological infrastructure*
• Analyse* the collected information on product rejections, realised inspections and microbiological status of the products (by relevant basic/descriptive statistics methods	• Analyse the collected information on production process (process capability, effectiveness of vacuum packaging machine, out of control situations), microbiological status of equipment and utensils to assess effectiveness of sanitation programs by statistical methods	• Benchmarking to compare own physical infrastructure (equipment, building layout, toilets and hand washing basins, and cooling facilities) with best-practice companies in order to identify weak points (determine functions to benchmark i.e. infrastructure, identify key performance indicators to measure, identify best-in-class companies, measure the performance of the best-in-class companies and compare the results to own company performance, define and take actions) • Analyse the collected information on the causes of equipment breakdown and system downtime (assess maintenance reports and technical information)
People behaviour	*Administrative conditions*	*Organisational arrangements*
• Analyse the collected information on hand hygiene (microbiological results) and personal behaviour and practices by relevant statistical tests (Non-parametric tests like Kruskal Wallis)	• Content analysis of procedures, documentation and registration system (to check completeness, accuracy, and usability) • Analyse collected information on availability of procedures, documentation and registration system by relevant statistical methods	• Analyse the collected information on tasks, responsibilities (obligation to perform assigned tasks) and authorities (right to act/make decision) given to operators including cleanliness personnel by relevant statistical methods • Benchmarking to compare own organisational infrastructure or practices with best-practice companies in order to identify weak points
	Validation (setting requirements)	
Product status	*Production process*	*Technological infrastructure*
• Analyse the collected information on microbiological quality, packaging (vacuum) conditions, and shelf life of the products by relevant statistical methods	• Analysis of collected information to assess variability in the process (information on validation of CCP analysis, standards and tolerances, corrective actions, control measures, intervention equipment, and methods) by relevant statistical methods	• Analyse validation results (compare current with previous results by statistical methods e.g. T-tests or ANOVA) • Content analysis of the current validation protocol/methods • Computerised system to record validation results (necessary for comparison purposes and audits)

People behaviour	*Administrative conditions*	*Organisational arrangements*
• Analyse the data collected (through observation or interviews) about personal hygiene requirements (gloves/mask, frequency of change of gloves/mask, hand washing and disinfection, switching from one production zone to another) by relevant statistics i.e. non parametric tests	• Content analysis of described tasks and responsibilities with regards to registration and record keeping system (completeness, accuracy, responsible) • Statistical analysis to assess the variability in data registration and record keeping systems and the information flow • Use record management assessment/audit tool (ISO 15489-1: 2001) to audit/analyse the record keeping systems	• Content analysis of description of tasks and responsibilities of personnel, authority to take action in case things go wrong • Content analysis of the organogram (compare the current against the previous) and quality policy and objectives
	Verification (checking how set requirements are fulfilled and followed)	
Product status	*Production process*	*Technological infrastructure*
• Content analysis of the sampling plan (criteria, scope, frequency, responsible personnel)	• Review of audit and verification reports of preventive measures (equipment and building design, performance of cooling facilities), intervention equipment (effectiveness of pasteurisation/sterilisation and packaging i.e. vacuum/aseptic) and methods (microbiological quality of fermented products, effectiveness of cleaning and disinfection by residue and microbial analysis) • Statistical analysis (e.g. non-parametric tests) of collected information on verification and make comparison between companies and sectors (or between different production units)	• Trend analysis/estimation of audit data (hygienic performance tests on contact surfaces and environment) • Equipment breakdown analysis (causes of equipment breakdown, maintenance records, frequency)
People behaviour	*Administrative conditions*	*Organisational arrangements*
• Analyse collected information on personal hygiene, competence and compliance to procedures by relevant statistical methods	• Content analysis of verification/audit protocol for documentation and registration (responsible personnel, completeness, criteria) • Compare companies verification protocol with available protocols in literature by statistical methods (t-test or ANOVA)	• Content analysis on the organisational structure of the company (specialisation, formalisation, and level of delegation of work/tasks) • Analyse the gaps in communication and company information sharing policy

*Food safety/HACCP team or identified personnel will be responsible with analysis of the collected information

Step 3. Redesigning-improvement options

This step stipulates the improvement options that could be adopted to improve the current situation. It is the stage at which solutions are developed and implemented (Jacxsens et al., 2011b). Table 7.3 provides suggestions for the tools (hygienic design, warning systems) and methods (total productive maintenance, changing inspection frequency, change sanitation programmes, change validation and verification protocols, change organisational responsibilities, change maintenance and calibration programmes and intensify supervision) that could be adopted to redesign/improve the current situation. The food safety/HACCP team or identified personnel are responsible to spearhead the solution development and implementation stage. At each level of improvement efforts the improvement options are proposed. Fish and dairy processing companies could use the proposed roadmap to improve their current FSMS. However, the proposed roadmap is not food-company specific; dairy and fish processing companies have to identify their particular problems and select from Table 7.1 for the tools and methods used in problem mapping and Table 7.2 for tools and methods used to analyse and interpret the collected information. In Table 7.3 tools and methods to change the current situation are shown. Furthermore, dairy and fish processing companies could select specific intervention measures for improvement (solutions) for the identified problems in their FSMS from Table 7.3. Since, it is a generic roadmap various food processing sectors could use it to derive their sector/company specific improvement measures towards more effective systems.

For example, with regards to personal hygiene, the improvement options for the dairy companies in cluster II could include training of personnel (on food safety and hygiene) and strict personal supervision to ensure compliance to sanitation procedures (at improvement effort level 1); change of sanitation procedures and instructions (at level 2) and change of organisational structure like redefining roles, responsibilities and authorities of staff on hygiene related tasks (at level 3, Table 7.3). Since implementation of the proposed measures at each level require financial and human resources, dairy companies from cluster II (which are mainly micro-and small-scale-companies, Chapter 3) could start with level one improvement efforts, then progressively move to the next levels. This will give time for the companies to mobilise resources to ensure commitment and sustainable improvement.

Table 7.3. **Redesign –tools and methods that could be applied to change the current situation to improve FSMS of fish and dairy processing companies in Tanzania**

Levels of improvement efforts*		
Level 1. Tools and methods to change product characteristics and people behaviour	**Level 2.** Tools and methods to change technological process and administrative conditions	**Level 3.** Tools and methods to change technological infrastructure and organisational arrangements
	Actual performance in the company	
Product status • Apply 100% inspection or acceptance (statistical-based) sampling plans for raw materials (raw milk and fish), in-process (pasteurised milk, fillets) and final products (packaged cultured milk and frozen fillets) • Remove non-complying products/batches (spoiled, undersize/weight for fish, under filled for milk)	*Production process* • Change product process and storage/distribution conditions (like temperature) and parameter values • Change equipment maintenance and calibration programmes (increase the frequency and scope, indicate responsible personnel) • Conduct hygiene performance tests on equipment and facilities (include walls, air conditions and fans; increase frequency and microbiological parameters like *Listeria monocytogenes)* • Use statistical process control and process control charts (e.g. Shewart chart) to monitor the production process	*Technological infrastructure* • Redesign or use semi/full automated processing equipment (pasteuriser, steriliser, skinning, filleting, and packaging) and cooling facilities (with automatic temperature recording/data logging devices and warning systems) • Use hygienic principles to design/change buildings (define high and low care zones) and washing facilities (toilets, changing rooms, and hand washing basins) • Replace plastic containers with stainless steel containers • Implement total productive maintenance (equipment improvements, preventive maintenance and management) to prevent equipment breakdowns and associated losses like downtime, speed losses and product defects
People behaviour • Intensify personnel supervision to ensure compliance to procedures or instructions (e.g. raw material sampling; personal hygiene, cleaning and disinfection) • Training of personnel on hygiene and food safety	*Administrative conditions* • Change procedures and instructions (for production and sanitation) and their principles for control and monitoring • Change or use good documentation and record keeping practices (use web-based and automated reporting system)	*Organisational arrangements* • Change the organisational structure (re-define the roles and responsibilities of staff including cleaning personnel and describe their authority in action and decision making)
	Validation (setting requirements)	
Product status • Change internal validation of products (define interval, products and parameters	*Production process* • Use available validation protocols like Codex (CAC/ GL 69-2008), scientific studies, regulatory/guidance documents	*Technological infrastructure* • Develop company specific validation protocol for sanitation, intervention and monitoring systems

to validate)	for the sector to validate preventive measures (cleaning and disinfection), intervention equipment (pasteuriser, steriliser and vacuum packaging) and methods (fermentation), and monitoring systems (monitoring of CCP, standards and tolerances, corrective actions, control measures).	• Perform experimental tests to validate (internal) products (challenge tests, accelerated shelf life testing) and effectiveness of cleaning and disinfection (residue and microbial contaminants in final rinse and surface swabs)
People behaviour • Intensify personal hygiene requirements (jewellery, hands, beards/hairs, clothing, hand washing, practices/habits like no picking from the nose or eating during production)	*Administrative conditions* • Change procedures and rules on data registration and record keeping (indicating methods, responsible person and duration of records keeping) • Change audit protocol/procedures (use accredited experts for audit purposes) • Develop/change information flow procedures or rules (type of information like quality and safety, responsible, means of transfer, processing and feedback).	*Organisational arrangements* • Change organisational structure (re-define tasks, responsibilities and authorities of personnel)
	Verification (checking how set requirements are fulfilled and followed)	
Product status • Change product sampling protocol (use 100% or acceptance sampling plans for the raw materials)	*Production process* • Use accredited experts and/or personnel from food control and competent authorities to audit preventive measures (equipment and building design, performance of cooling facilities), intervention equipment (effectiveness of pasteurisation/sterilisation and packaging i.e. vacuum/aseptic) and methods (microbial quality of fermented products, effectiveness of cleaning and disinfection)	*Technological infrastructure* • Use hygienically designed equipment (pasteurisers, sterilisers, blast and plate freezers) and facilities (building layout and structure, cooling)
People behaviour • Intensify supervision to ensure personnel comply with audit/verification requirements • Training of staff on food safety and hygiene (use competency-based training)	*Administrative conditions* • Change/develop verification plan and audit protocols (define scope, methods, criteria, frequency and type - external by accredited experts/food control authorities personnel or internal) • Develop registration and records management plans • Change or develop staff training plans (on-the-job training and refresher courses)	*Organisational arrangements* • Change organisational structure (division of tasks, responsibilities and authorities) • Change/develop communication policy (indicating how information is shared within the company) • Develop rules and procedures of handling and replacing a patient/injured personnel • Apply information and communication technology principles

*Food safety/HACCP team or identified personnel will be responsible with monitoring the implementation of suggested measures/solutions

7.4. Possible measures at government and sector levels

Fish and dairy processing companies operate in a chain; therefore, they need support from various chain actors including the raw material suppliers, government and sector/branch organisations to complete the implementation of the suggested intervention measures. **Government is expected to support** the food industry by developing risk-based legal framework for food safety, enacting and enforcing food laws and regulations, and setting-up food standards (Chapter 2). Enabling environment in terms of policy, legislation, and enforcement of food laws and regulations is required for all players along the food chain to adhere and comply with the law. Food laws and regulations prohibiting sale of raw milk and transport of raw milk under ambient and unhygienic conditions would significantly reduce the amount of raw milk sold via the informal market and reduce milk spoilage and food safety hazards. Also, food control authorities should routinely conduct inspection and audit of food companies. Government support through food safety training/education at all levels and facilitating formation of consumer organisations is also necessary to create food safety awareness and external pressure to food processing sectors. Training of food processing technicians would support the food industry to readily get qualified food technologists at low cost instead of recruiting staff from abroad. Thus, vocational training centres and universities should be facilitated to introduce certificate and diploma level courses in food science, food hygiene and microbiology, food technology, food chemistry, and food safety (Chapter 2).

Although **raw material** could be the major source of food safety problems in the food processing companies, a big proportion (90%) of raw milk goes through the informal milk marketing channel (direct sale of raw milk to milk vending points, households, restaurants or consumed on farm) without good hygienic conditions, cold storage and any form of processing, which expose consumers to various food safety hazards. Therefore, government support (through training of farmers to improve their skills on hygienic milk production and best animal husbandry, supply of electricity, infrastructure development and strengthening extension services; and campaigns on how to treat and handle milk at household level) is also needed to ensure quality and safety of raw materials along the milk chain. In addition, consumer food safety education is recommended to create awareness. The actors in this informal market could be trained in good handling and hygienic practices to reduce exposure of consumers to food safety hazards. Although Tanzania has various food laws and regulations, food companies, particularly, the micro-scale, operate in less regulated market and there is no control of the primary producers. Most farmers use their own experience and/or could partly seek advice from non-experienced and inadequately trained operators of agro-vet shops on how to treat their animals; and often drugs withdraw periods are not always respected. Moreover, farmers are not aware of GAP and GHP; combination of these factors increases the prevalence of health hazards in the milk supply chain.

The **food control authorities** particularly, Tanzania Food and Drugs Authority (TFDA) could support food companies through audit/inspection of the premises and provide technical advises on hygienic design of equipment (use of food grade materials, smooth surfaces and no dead ends) and buildings (layout, zoning, hand washing and toilets) and implementation of best practices (GMP and GHP) and QA standards (ISO 22000 and BRC) and guidelines (HACCP). Likewise, Tanzania Bureau of Standards (TBS) could provide technical advises to food companies, training on quality and safety assurance, reduce product certification costs, routine calibration of measuring equipment including thermometers, weighing balances and lactometers. Also, consumer education will create food safety awareness that will in turn pressurise food companies to improve their FSMS. Besides, national food standards (i.e. microbiological specifications of all products) have to be readily available (online) for all food processors and routine inspection and continuous monitoring of the food industry are necessary for compliance. It could also develop general product sampling plans that will be used by all food processing sectors. In addition, proper control of packaging materials and ingredients (which are mostly imported) would ensure manufacture of quality and safe products. Since, food processing companies are located countrywide; more TBS and TFDA offices need to be established at least in each zone and later on in every region for effective monitoring of the food industry and provision of the technical support. This will reduce costs to food processing companies in accessing services of the food control authorities. Majority of food processing companies lack expertise and resources to hire accredited experts for validation (e.g., preventive measures, intervention and monitoring systems) and verification (e.g. people, methods and equipment related performance) activities, thus, food control authorities could support food companies in such core assurance activities.

The roles of **national product boards** like Tanzania Dairy Board (TDB), Tanzania Meat Board and Cereal and other Produce Board are to regulate dairy, meat and cereal industries, respectively. These are supposed to be the competent authorities for their respective sectors. Tanzania Dairy Board may support the dairy industry through regular inspection, verification, validation, and technical backstopping (identify appropriate technology and consultation) for the dairy companies. It could assist dairy companies to translate regulatory as well as customers' requirements into their FSMS. The dairy and meat boards (both under the Livestock Department, Ministry of Livestock and Fisheries Development) could use the experience of the competent authority for the fisheries sector (Fisheries Department, Ministry of Livestock and Fisheries Development) to improve the current situation. The competent authority for fisheries strictly regulate the fish industry (through inspection, training of fishermen and processors, certification for export, validation (CCPs) and verification activities), which have enabled export of fish and fish products. Therefore, TDB could also perform inspection, training (farmers and milk processors) and certification of dairy processing companies.

The **local government authorities** have day-to-day interactions with food companies; they should conduct routine hygiene inspection of the food companies as well as primary producers (livestock keepers) in their areas of jurisdiction. Moreover, they could support food companies through provision of potable water and develop infrastructure (like designating special industrial sites with proper roads and waste disposal, i.e. both liquid and solid wastes). These would complement the efforts by the national food control authorities, which have limited personnel and resources to cover the whole country.

The **sector/branch organisations** can complement the governmental support for food companies to improve their FSMS through recommendation of certification standards (like ISO 22000 or BRC) and performing audit/inspections (Chapter 2). Sector associations like Tanzania Milk Producers Association (TAMPRODA) could support dairy processing companies through production of quality raw materials (the raw milk) and ensuring stable supply of raw milk to processing companies. Training of farmers on good animal husbandry and best practices would improve milk production and quality. Moreover, the sector organisation could lobby the government to improve genetic potential of cow to improve milk production and for a favourable dairy business environment. Some companies have already established good relationships with farmers through contract farming and formation of primary societies as the case with Tanga Fresh Ltd and others, such as ASAS Dairies Ltd, have own farms. Formation of primary societies could facilitate establishment and management of milk collection centres at the primary production level. Combination of these aspects would reduce quality problems of raw milk and increase availability of milk to dairy processing companies (reducing milk going through the informal channels). In addition, Tanzania Milk Processors Association (TAMPA) could support dairy companies through application of sector guidelines to improve quality and safety of dairy products. It could be used to provide technical and legal assistance (i.e. technical backup) to its members and the entire dairy industry. Since, food control authorities lack enough manpower and offices across the country; working in collaboration with these sector organisations will complement the efforts by the food control authorities; thus facilitating the implementation of the legal demands to improve product quality and safety.

Furthermore, **supplier control and relationships** and customer pressure are important factors for the food companies to adopt the best practices and improve their FSMS. Although dairy companies could discuss about product specifications with farmers (the raw milk suppliers), they are supposed to offer competitive prices to attract more farmers to supply the raw milk to the dairy companies. Moreover, continued purchase of raw milk from farmers even during the high-production season (i.e. rainy season) will ensure royalty and prevent sale of raw milk via the informal channels. Price and demands are the major incentives for farmers to sell milk to the informal channels. Besides, food companies need to act as hubs of knowledge to their suppliers (farmers, hawkers, and agents) and major customers (retailers and supermarkets) on quality and safety related issues (handling and storage conditions) of their products. Dairy processing companies could provide farmers with milking equipment and storage containers to ensure quality/safety of the raw milk. Some large-scale companies including Tanga Fresh Ltd are already offering these services to their farmers/suppliers and are reaping the benefits as on average the company gets more than 50,000 litres of milk/day.

7.5. The priority areas for dairy and fish processing companies to improve their FSMS

The analysed fish and dairy processing companies differ in the level of design and operation of their FSMS that will also determine the type of interventions needed. All companies from both sectors should start by identifying person or team responsible for collection and analysis of the information and oversee the implementation of developed/suggested solutions. Since, majority of dairy companies are micro-and small-scale without fully developed PRPs (GMP and GHP); all clusters could focus on adopting such best practices, improving the sanitation programme (i.e. changing the sanitation procedures), ensure availability of sanitation and production procedures at location, intensify personnel supervision (to ensure compliance with procedures), internal training of operators on the best practices (hygiene and food safety) and independent hygiene audits of employees. All of these measures are feasible and less costly as they could be conducted by qualified personnel within the company (like Production and QA managers) or personnel from the food control authorities and sector organisations (TDB and TAMPA) at a minimal cost. Particularly, for independent audits and personnel training; dairy companies could seek for assistance from TFDA, TBS, TDB, or TAMPA. Likewise, food control authorities and TDB could assist dairy companies to develop supplier specifications.

Strict control of raw materials along the supply chain and at point of receipt is a pre-requisite. As observed with large-scale companies, small-scale companies could also establish milk collection centres and use special refrigerated trucks to collect raw milk and distribute final products. Although investment in milk collection centres and transportation facilities could be relatively expensive, it should be a priority for dairy companies to ensure supply of quality raw materials. Dairy companies could rely on sectoral guidelines or legal microbiological/chemical criteria of the raw materials. The next level could be redesigning of equipment (automation of processing equipment including pasteurisers, sterilisers, and packaging) and buildings (layout, zoning and washing facilities), change the organisational structure (redefining the roles and responsibilities and authorities of staff), develop company specific protocols for validation (recommending use of challenge tests, shelf tests and hygiene performance tests) and use independent expert (third party) for audits/verification of the system and develop company communication policy (information sharing and communication procedures).

Unlike the dairy sector, fish sector is composed of mainly large-scale companies (with relatively more resources and trained personnel) for export market. The improvement of preventive measures should be the priority for fish processing companies because they do not use any intervention processes to reduce pathogens to acceptable levels. They could focus on strict control of raw materials throughout the supply chain and developing specific sampling and measuring plans. Periodic microbiological evaluation of raw materials is necessary to reduce risks of accepting poor quality materials. Fish companies have to develop specific procedures for sanitation and production process and ensure availability of these procedures at location (Chapter 4). Moreover, fish companies should develop company specific validation protocols to assess the effectiveness/adequacy of preventive measures (i.e. hygienic design of equipment and facilities, cooling facilities, sanitation program, personal hygiene requirements, raw material control and product specific measures). Validation of preventive measures should be done by independent experts by use of experimental trials (hygiene performance tests such as chemical and microbiological analysis on final rinse/surface swabs, challenge tests, check product and environment temperature). Moreover, fish companies have to automate their production processes (filleting, skinning and sanitation) and documentation and record keeping (on-line and/ or web-based), and redesign and modify equipment and facilities (building layout, equipment, and cooling facilities, Chapter 4). These intervention measures are essential for fish processing companies (which do not use intervention processes) to reduce food safety hazards in their products to guarantee continued export.

7.6. The usefulness of diagnostic tools used in the case studies

This study applied two diagnostic tools, the FSMS diagnostic tool (DI) (Luning et al., 2008; Luning et al., 2009; Jacxsens et al., 2010b; Luning et al., 2011b) and the Microbiological Assessment Scheme (MAS) (Jacxsens et al., 2009b) to analyse the performance of current FSMS in fish and dairy processing companies. The FSMS-DI (as illustrated in Fig.1.1, Chapter 1) enables systematic analysis and assessment of a company's specific FSMS in view of its context characteristics (Luning et al., 2008; Luning et al., 2009; Luning et al., 2011b). In traditional inspection and audits conducted by either the national food control authorities or third party organisations, the influence of the context characteristics has never been analysed, whereas, it has been clearly demonstrated in multiple studies that the context in which a food business is operating affects the system set-up and operation in for example, global fresh produce chain (Kirezieva et al., 2013; Kirezieva et al., 2015) and European dairy and meat chain (Luning et al., 2015). In addition, previous food safety researches focused on either technological or managerial aspects, as most researchers specialised in either of the two (Sanny et al., 2012). This hampered critical analysis of the design and operation of FSMS in the food production sector. According to Luning and Marcelis (2009a) food quality (safety) management issues cannot just be approached from one discipline due to the dynamic and complex characteristics of both food production systems and the people involved in the production of agriculture and food products. Thus, an extended analysis of food quality (safety) management issues is needed (Luning and Marcelis, 2009a). Therefore, this research applied an innovative approach which addresses major technology-dependent (like equipment, facilities, physical, chemical, and biological processes) and managerial activities (such as people requirements and behaviours) in design and operation of preventive measures, intervention processes and monitoring systems. The diagnostic tools applied in this research could be used as self-assessment tools for companies but also used in quantitative studies to compare performance of FSMS between sectors or study the effect of interventions (Jacxsens et al., 2015).

However, unlike the inspection or auditing where there are comprehensive list of requirements, the FSMS-DI has no such detailed technical requirements but analyse the level of design and operation of the core control and assurance activities of the FSMS, independent from (voluntary) standards requirements. Moreover, an audit against a voluntary standard as BRC or IFS provides a blue print with detailed technical requirements. An audit against requirements of a standard takes 1 to 5 days. The FSMS-DI takes 2-3 h and gives a helicopter view of the FSMS performance, the context riskiness and system output as basis for improvement. Furthermore, the FSMS-DI enables assessment of the system output without conducting typical microbiological assessment. This is possible through the use of the external and internal system output indicators (Jacxsens et al., 2010b). It provides insight in the system output and safety of the products. It assesses whether the company has insight in non conformities, deviating products, or any idea of what is going wrong. These indicators give a first impression on microbiological performance of implemented FSMS without actual microbiological testing of the products (Jacxsens et al., 2010b). Therefore, even small food processing companies without enough financial resources to conduct actual microbial testing could use this instrument to get an indication of the microbiological output of their FSMS.

Microbiological assessment scheme can be applied for vertical screening from raw material to the end products with a limited number of samplings and analysis to obtain an overall profile. Given the financial resources and expertise, even small companies could utilise this instrument to assess its microbiological system output. However, MAS is a process specific tool that needs to be adapted to the company specific production circumstances (Jacxsens et al., 2009b; Jacxsens et al., 2011b). Audits and inspections remain point-in-time assessments that represent a small fraction of the food production time and volume (Powell et al., 2013), whereas MAS is conducted three times in three consecutive months giving the status of microbiological performance of FSMS for an extended time (Jacxsens et al., 2010b).

Although the scheme (MAS) and FSMS-DI have been developed for European food companies, have been adapted and widely used worldwide in various sectors including fish (Noseda et al., 2013; Tong Thi et al., 2014), meat (Sampers et al., 2010; Luning et al., 2011a; Osés et al., 2012), vegetables (de Quadros Rodrigues et al., 2014), and dairy industries (Opiyo et al., 2013; Kamana et al., 2014) as well as service providing organisations like food service organisations/establishments (Lahou et al., 2012; Luning et al., 2013) and companies manufacturing combination of products (meat, fish, plants including herbs and spices) (Daelman et al., 2013). In general, the FSMS-DI and MAS could be used as preliminary tools ahead of third party audits or inspections from food control authorities.

7.7. Recommendations for future research

This study was carried out in fish and dairy processing companies in the mainland, Tanzania. Microbiological assessment was conducted in one fish and one dairy processing company to provide deeper insights into the actual performance of current FSMS in the two sectors. However, typical insights into the microbiological performance of existing FSMS would require MAS conducted in each dairy and fish companies analysed for at least two different seasons (both rain and dry) of the year. This is because prevalence of microbiological hazards differs with seasons and companies have different set-up/design (in terms of infrastructure) and operation of FSMS activities. Besides, most dairy processing companies are micro-and small- scale lacking necessary expertise, experience and resources (like financial and personnel capabilities) to implement the proposed measures for improvement. The next stage would be assisting dairy companies to implement the proposed measures step-by-step in their production processes. Moreover, financial (tax and import duties exemption) and expertise assistance (i.e., from the government, sector organisations, or retailers/business) would be needed for such companies to invest in hygienic design of equipment and buildings and improve their FSMS. Pilot studies to implement HACCP and the best practices in selected small-scale dairy processing companies would be a preferable strategy for improvement.

Likewise, this study was conducted in two sectors only, fish and dairy sectors, other sectors could be analysed by using both tools (FSMS-DI and MAS) to identify the weak points in their systems and propose specific measures for improvement. However, more risk sectors like fruits and vegetables, and meat and poultry, including the tourist industry (hotels and restaurants) could be the priority areas to explore.

Moreover, this study focused on industrial processing chain (micro-level) which deals with 10% of total milk produced in Tanzania. Informal chain which account for 90% of total milk produced is not studied. It is not exactly known what happens along this chain and possible food safety hazards to consumers. Therefore another study is needed to assess the status of the informal supply chain.

Likewise, the primary production level, which was observed as the major source of food safety problems in the food industry, was not analysed. Further studies are required to assess the status of food safety in this part (primary production) of the chain.

The roadmap for improvement was developed for the industrial (micro) level; there is also a need to develop roadmaps for improvement at both sectoral/organisational (meso) and government (macro) levels. In addition, this study proposed the roadmap for improvement of current FSMS in fish and dairy processing companies, however, the proposed intervention measures are yet to be implemented. It is therefore, recommended that an estimate of the costs of the intervention measures to be studied. Other studies are therefore, required to develop the roadmaps for the sectoral and government levels and to perform costs-benefit analysis of the proposed measures.

Moreover, this study focuses on the techno-managerial approach of food safety management systems but also the human factor, the so called 'food safety climate or culture' can play a significant role in the final performance of a food company (Fatimah et al., 2014). This human route is not yet explored in the scientific literature although more recently some research groups are investigating this human dimension (Griffith et al., 2010; Powell et al., 2011; Fatimah et al., 2014).

Personal synthesis

Food safety status assessment is necessary to both developed and developing economies' food industries. However, an assessment of the design and operation of FSMS in food processing companies in a developing economy could be challenging because food industries in most of the developing countries including Tanzania are at their infancy stages. As compared to exporting food sectors in Tanzania, the domestic market oriented sectors are largely composed of micro- and small-scale companies often lacking best practices, trained personnel, and proper regulation. Existence of more than one food control system further complicates the situation; as export sector receives much attention than the domestic market oriented sectors. Although domestic market oriented sectors receive inadequate regulation, over regulation has been a matter of concern by the stakeholders (including researchers) of Tanzanian food industry. Given the lower status of food safety in Tanzania, over regulation and proper enforcement of food laws and regulations are required for compliance. As a matter of fact, over regulation has been perceived by the stakeholders on costs perspective. However, harmonisation of regulatory activities is required for effective enforcement of food laws and regulations by various institutions. Use of several institutions is beneficial as they complement the efforts by other institutions in places/regions which are not regulated. For instance, food control authorities whose offices are located in major cities and face inadequate financial and human resources cannot adequately control the entire food industry; therefore, use of local government authorities complements the food control authorities' efforts.

Although improvement of food safety performance is costly, micro-and small-scale companies with limited resources could improve their FSMS if there is an enabling environment (national food safety policy, proper enforcement of food laws and regulations, business and customers' demands). Some of the analysed micro-and small-scale companies with limited resources performed even better than large-scale companies with relatively more resources. In addition to availability of resources; external pressure and willingness/innovativeness of the companies could significantly influence the design and operation of FSMS. Therefore, despite the fact that food companies in industrialised countries are regarded as role models to companies in developing economy countries, there is yet an opportunity of food companies within similar sector or location to learn from each other how to improve food safety. In spite of dairy sector dealing with high-risk products, there is inadequate control and majority of companies have not yet established and implemented the pre-requisite programmes to guarantee product safety. Furthermore, not all food safety problems occurring in Tanzania are reported due to inadequate documentation, disease monitoring and surveillance systems. Robust procedures and systems for disease monitoring and surveillance are lacking at both national and local levels. Thus, improvement of food safety in Tanzania requires collective efforts from the public and private sectors. The same efforts exerted to the fishery sector needs to be directed to sectors for the domestic market to guarantee quality and safety of food supplies for the domestic market.

REFERENCES

References

Aaku, E.N., Collison, E.K., Gashe, B.A., Mpuchane, S., 2004. Microbiological quality of milk from two processing plants in Gaborone Botswana. Food Control 15, 181-186.

Ababio, F., Adi, D.D., 2012. Evaluating Food Hygiene Awareness and Practices of Food Handlers in the Kumasi Metropolis. Internet Journal of Food Safety 14, 35-43.

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

Ababouch, L., 2000. The role of government agencies in assessing HACCP. Food Control 11, 137-142.

Ababouch, L., 2006. Assuring fish safety and quality in international fish trade. Marine Pollution Bulletin 53, 561-568.

Ababouch, L., 2007. Safety of aquaculture products: consumer protection, international regulatory requirements and traceability. In: Global Trade Conference on Aquaculture, Qingdao, China, 29–31 May, 73-129.

Ababouch, L., Gandini, G., Ryder, J., 2005. Causes of detentions and rejections in international fish trade, Vol 473. Food and Agriculture Organisation, 9251052867.

Abbas, H.K., 2005. Aflatoxin and food safety. CRC, Missisipi, ISBN 0824723031, 616 p.

Abbès, S., Salah-Abbès, J.B., Bouraoui, Y., Oueslati, S., Oueslati, R., 2012. Natural occurrence of aflatoxins (B1 and M1) in feed, plasma and raw milk of lactating dairy cows in Beja, Tunisia, using ELISA. Food Additives and Contaminants: Part B 5, 11-15.

Abegaz, M., 2010. Mobilizing Aid for Trade for SPS-related Technical Cooperation in East Africa. SPS Balance Sheet for Tanzania. Standards and Trade Development Facility. http://www.standardsfacility.org/Files/AidForTrade/Final_Tanzania.pdf.

Abila, R., 2003. Food safety in food security and food trade. Case study: Kenya fish exports. 2020 Vision for Food, Agriculture and the Environment, Focus 10.

Abong'o, B.O., Momba, M.N.B., 2009. Prevalence and characterization of *Escherichia coli* O157: H7 isolates from meat and meat products sold in Amathole District, Eastern Cape Province of South Africa. Food Microbiology 26, 173-176.

Abong'o, B., Momba, M., 2008. Prevalence and potential link between E. coli O157: H7 isolated from drinking water, meat and vegetables and stools of diarrhoeic confirmed and non-confirmed HIV/AIDS patients in the Amathole District-South Africa. Journal of Applied Microbiology 105, 424-431.

Abougrain, A.K., Nahaisi, M.H., Madi, N.S., Saied, M.M., Ghenghesh, K.S., 2010. Parasitological contamination in salad vegetables in Tripoli-Libya. Food Control 21, 760-762.

Adedeji, O.B., Ibrahim, S.O., 2011. Assessment of microbial safety of fresh shrimps offered for sales at Alesinloye and Eleyele markets in Ibadan, Southwestern Nigeria. Journal of Applied Sciences in Environmental Sanitation 6, 239-246.

Adegoke, G., Egunjobi, O., Agbola, S., Olatuberu, C., 2008. Hazard and critical control points of ready-to-eat foods and an abattoir examination in a typical tropical market. International Journal of Food Safety, Nutrition and Public Health 1, 58-67.

Adekunle, I., Olorundare, O., Nwange, C., 2009. Assessments of lead levels and daily intakes from green leafy vegetables of southwest Nigeria. Nutrition and Food Science 39, 413-422.

Adjovi, Y., Bailly, S., Gnonlonfin, B., Tadrist, S., Querin, A., Sanni, A., Oswald, I., Puel, O., Bailly, J., 2014. Analysis of the contrast between natural occurrence of toxigenic Aspergilli of the Flavi section and aflatoxin B1 in cassava. Food Microbiology 38, 151-159.

Agenbag, M.H.A., Lues, J.F.R., 2009. Resource management and environmental health service delivery regarding milk hygiene: A South African perspective. British Food Journal 111, 539-553.

Akande, G., Diei-Ouadi, Y., 2010. Post-harvest losses in small-scale fisheries: case studies in five sub-Saharan African countries, Vol XIII. Food and Agriculture Organization of the United Nations, Rome, ISBN 925106671X, 72 p.

Aksoy, M.A., Beghin, J.C., 2005. Global agricultural trade and developing countries. World Bank Publications, 0821358634.

Al-Harbi, A.H., Uddin, N., 2005. Bacterial diversity of tilapia (*Oreochromis niloticus*) cultured in brackish water in Saudi Arabia. Aquaculture 250, 566-572.

Al-Kandari, D., Jukes, D.J., 2011. Incorporating HACCP into national food control systems - Analyzing progress in the United Arab Emirates. Food Control 22, 851-861.

Alli, I., 2003. Food quality assurance: principles and practices. CRC Press LL, Washington, D.C., ISBN 1-56676-930-2, 141 p.

Amoa-Awua, W.K., Ngunjiri, P., Anlobe, J., Kpodo, K., Halm, M., Hayford, A.E., Jakobsen, M., 2007. The effect of applying GMP and HACCP to traditional food processing at a semi-commercial kenkey production plant in Ghana. Food Control 18, 1449-1457.

Anderson, M., Hinds, P., Hurditt, S., Miller, P., McGrowder, D., Alexander-Lindo, R., 2011. The microbial content of unexpired pasteurized milk from selected supermarkets in a developing country. Asian Pacific Journal of Tropical Biomedicine 1, 205-211.

Anonymous, 2006. A value chain analysis and socio-economic assessment of the dairy industry in Tanzania In: The Sixth National Dairy Development Conference Morogoro Hotel, Tanzania, 2nd June, 2006.

Anonymous, 2007. The increasing importance of quality assuarance standards to smallholder dairy farmers in East and Southern Africa In African smallholders and the challenge of assured compliance: What have we learned from our interventions. (Washington D.C., Land O'Lakes), 14 p.

Apun, K., Yusof, A.M., Jugang, K., 1999. Distribution of bacteria in tropical freshwater fish and ponds. International Journal of Environmental Health Research 9, 285-292.

Arvanitoyannis, I.S., 2009. HACCP and ISO 22000: Application to foods of animal origin. John Wiley and Sons, ISBN 1444320939, 561 p.

Arvanitoyannis, I.S., Varzakas, T.H., 2009. Application of ISO 22000 and comparison with HACCP on industrial processing of common octopus (*Octopus vulgaris*) – Part I. International Journal of Food Science and Technology 44, 58-78.

Atanda, O., Oguntubo, A., Adejumo, O., Ikeorah, J., Akpan, I., 2007. Aflatoxin M1 contamination of milk and ice cream in Abeokuta and Odeda local governments of Ogun State, Nigeria. Chemosphere 68, 1455-1458.

Auerswald, L., Morren, C., Lopata, A.L., 2006. Histamine levels in seventeen species of fresh and processed South African seafood. Food Chemistry 98, 231-239.

Aworh, O.C., 2008. The role of traditional food processing technologies in national development: the West African experience, In: Robertson, G.L., Lupien, J.R. (Eds.) Using Food Science and Technology to Improve Nutrition and Promote National Development International Union of Food Science and Technology, ISBN 978-0-9810247-0-7, 1-18 pp.

Aziz, N.H., Moussa, L.A.A., 2002. Influence of gamma-radiation on mycotoxin producing moulds and mycotoxins in fruits. Food Control 13, 281-288.

Badri, S., Filliol, I., Carle, I., Hassar, M., Fassouane, A., Cohen, N., 2009. Prevalence of virulence genes in *Escherichia coli* isolated from food in Casablanca (Morocco). Food Control 20, 560-564.

Bagge-Ravn, D., Gardshodn, K., Gram, L., Vogel, B.F., 2003. Comparison of sodium hypochlorite-based foam and peroxyacetic acid-based fog sanitizing procedures in a salmon smokehouse: survival of the general microflora and *Listeria monocytogenes*. Journal of Food Protection 66, 592-598.

Bagumire, A., 2009. Impact of the global financial and economic crisis on the fish industry in Uganda and Tanzania UNIDO, Vienna. URL https://www.unido.org/fileadmin/user_media/Services/LDC_SSC/Tanzania%20&%20Uganda%20Fisheries%20study%20-%20draft.PDF.

Bagumire, A., Todd, E.C.D., Muyanja, C., Nasinyama, G.W., 2009a. National food safety control systems in Sub-Saharan Africa: Does Uganda's aquaculture control system meet international requirements. Food Policy 34, 458-467.

Bagumire, A., Todd, E.C.D., Nasinyama, G.W., Muyanja, C., 2010. Food safety regulatory requirements with potential effect on exports of aquaculture products from developing countries to the EU and US. African Journal of Food Science and Technology 1, 031-050.

Bagumire, A., Todd, E.C.D., Nasinyama, G.W., Muyanja, C., Rumbeiha, W.K., Harris, C., Bourquin, L.D., 2009b. Potential sources of food hazards in emerging commercial aquaculture industry in sub-Saharan Africa: a case study for Uganda. International Journal of Food Science and Technology 44, 1677-1687.

Bai, L., Ma, C.-l., Yang, Y.-s., Zhao, S.-k., Gong, S.-l., 2007. Implementation of HACCP system in China: A survey of food enterprises involved. Food Control 18, 1108-1112.

Ball, B., Wilcock, A., Aung, M., 2009. Factors influencing workers to follow food safety management systems in meat plants in Ontario, Canada. International Journal of Environmental Health Research 19, 201-218.

Bankole, S., Schollenberger, M., Drochner, W., 2006. Mycotoxins in food systems in Sub Saharan Africa: A review. Mycotoxin Research 22, 163-169.

Bankole, S.A., Mabekoje, O.O., Enikuomehin, O.A., 2003. *Fusarium* spp. and fumonisin BI in stored maize from Ogun State, Nigeria. Tropical Science 43, 76-79.

Bankole, S.A., Schollenberger, M., Drochner, W., 2010. Survey of ergosterol, zearalenone and trichothecene contamination in maize from Nigeria. Journal of Food Composition and Analysis 23, 837-842.

Belli, P., Cantafora, A.F.A., Stella, S., Barbieri, S., Crimella, C., 2013. Microbiological survey of milk and dairy products from a small scale dairy processing unit in Maroua (Cameroon). Food Control 32, 366-370.

Bempah, C.K., Donkor, A., Yeboah, P.O., Dubey, B., Osei-Fosu, P., 2011. A preliminary assessment of consumer's exposure to organochlorine pesticides in fruits and vegetables and the potential health risk in Accra Metropolis, Ghana. Food Chemistry 128, 1058-1065.

Benabbes, L., Ollivier, J., Schaeffer, J., Parnaudeau, S., Rhaissi, H., Nourlil, J., Le Guyader, F.S., 2013. Norovirus and other human enteric viruses in Moroccan shellfish. Food and Environmental Virology 5, 35-40.

Benkerroum, N., Tamime, A., 2004. Technology transfer of some Moroccan traditional dairy products (*lben, jben* and *smen*) to small industrial scale. Food Microbiology 21, 399-413.

Bensassi, F., Zaied, C., Abid, S., Hajlaoui, M.R., Bacha, H., 2010. Occurrence of deoxynivalenol in durum wheat in Tunisia. Food Control 21, 281-285.

Bilalis, D., Stathis, I., Konstantas, A., Patsiali, S., 2009. Comparison between HACCP and ISO 22000 in Greek organic food sector. Journal of Food, Agriculture and Environment 7, 237-242.

Board of External Trade, 2003. The fish sector export development strategy Board of External Trade, Dar es Salaam. URL http://www.tantrade.or.tz/docs/FishDevelopment.pdf.

Boari, C.A., Pereira, G.L., Valeriano, C., Silva, B.C., Morais, V.M., Figueiredo, H.C.P., Piccoli, R.H., 2008. Bacterial ecology of tilapia fresh fillets and some factors that can influence their microbial quality. Ciência e Tecnologia de Alimentos 28, 863-867.

Bolwig, S., Riisgaard, L., Gibbon, P., Ponte, S., 2013. Challenges of Agro-Food Standards Conformity: Lessons from East Africa and Policy Implications. European Journal of Development Research 25, 408-427.

Bonfoh, B., Roth, C., Traoré, A.N., Fané, A., Simbé, C.F., Alfaroukh, I.O., Nicolet, J., Farah, Z., Zinsstag, J., 2006. Effect of washing and disinfecting containers on the microbiological quality of fresh milk sold in Bamako (Mali). Food Control 17, 153-161.

Bonfoh, B., Wasem, A., Traoré, A.N., Fané, A., Spillmann, H., Simbé, C.F., Alfaroukh, I.O., Nicolet, J., Farah, Z., Zinsstag, J., 2003. Microbiological quality of cows' milk taken at different intervals from the udder to the selling point in Bamako (Mali). Food Control 14, 495-500.

Breiman, R.F., 2008. Lessons from the 2006-2007 Rift Valley fever outbreak in East Africa: implications for prevention of emerging infectious diseases. Future Virology, 411-417.

Breurec, S., Poueme, R., Fall, C., Tall, A., Diawara, A., Bada-Alambedji, R., Broutin, C., Leclercq, A., Garin, B., 2010. Microbiological quality of milk from small processing units in Senegal. Foodborne Pathogens and Disease 7, 601-604.

Brown, M.H., Gill, C.O., Hollingsworth, J., Nickelson Ii, R., Seward, S., Sheridan, J.J., Stevenson, T., Sumner, J.L., Theno, D.M., Usborne, W.R., Zink, D., 2000. The role of microbiological testing in systems for assuring the safety of beef. International Journal of Food Microbiology 62, 7-16.

Buchholz, U., Bernard, H., Werber, D., Böhmer, M.M., Remschmidt, C., Wilking, H., Deleré, Y., an der Heiden, M., Adlhoch, C., Dreesman, J., Ehlers, J., Ethelberg, S., Faber, M., Frank, C., Fricke, G., Greiner, M., Höhle, M., Ivarsson, S., Jark, U., Kirchner, M., Koch, J., Krause, G., Luber, P., Rosner, B., Stark, K., Kühne, M., 2011. German Outbreak of Escherichia coli O104:H4 Associated with Sprouts. New England Journal of Medicine 365, 1763-1770.

Cabrera, R., Cochran, M., Dangelmayr, L., D'Aguilar, G., 2010. African capacity building for meat exports: Lessons from the Namibian and Botswanan beef industries. Currents: International Trade LJ 19, 55.

Carpentier, B., Cerf, O., 2011. Review — Persistence of *Listeria monocytogenes* in food industry equipment and premises. International Journal of Food Microbiology 145, 1-8.

Charimba, G., Hugo, C., Hugo, A., 2012. The incidence of diarrhoeagenic *Escherichia coli* in minced beef and boerewors. Food Research International 47, 353-358.

Chytiri, S., Chouliara, I., Savvaidis, I.N., Kontominas, M.G., 2004. Microbiological, chemical and sensory assessment of iced whole and filleted aquacultured rainbow trout. Food Microbiology 21, 157-165.

Codex Alimentarius Commission, 2003. General principles of food hygiene. CAC/RCP 1-1969 (Codex Alimentarius Commission), 31 p.

Codex Alimentarius Commission, 2004. Code of hygienic practice for milk and milk products. Codex Alimentarius Commision (CAC)/RCP 57-2004. (FAO/WHO), 49 p.

Codex Alimentarius Commission, 2007. Guidelines on the application of general principles of food hygiene to the control of *Listeria monocytogenes* in foods. CAC/GL 61 - 2007 (FAO/WHO), 28 p.

Codex Alimentarius Commission, 2008. Guidelines for the validation of food safety control measures. Codex Alimentarius Commission (CAC)/GL 69, 1-16.

Codron, J.-M., Adanacioğlu, H., Aubert, M., Bouhsina, Z., El Mekki, A.A., Rousset, S., Tozanli, S., Yercan, M., 2014. The role of market forces and food safety institutions in the adoption of sustainable farming practices: The case of the fresh tomato export sector in Morocco and Turkey. Food Policy 49, Part 1, 268-280.

Coffey, R., Cummins, E., Ward, S., 2009. Exposure assessment of mycotoxins in dairy milk. Food Control 20, 239-249.

Confederation of Tanzania Industries, 2013. Simplifying compliance with regulations to enhance ease of doing business in Tanzania Confederation of Tanzania Industries (CTI), Dar es Salaam. URL http://www.cti.co.tz/uploads/SIMPLIFYING_COMPLIANCE_WITH_REGULATIONS_REPORT.PDF.

Cormier, R., Mallet, M., Chiasson, S., Magnússon, H., Valdimarsson, G., 2007. Effectiveness and performance of HACCP-based programs. Food Control 18, 665-671.

Costa Dias, M.A., Sant'Ana, A.S., Cruz, A.G., Faria, J.A.F., Fernandes de Oliveira, C.A., Bona, E., 2012. On the implementation of good manufacturing practices in a small processing unity of mozzarella cheese in Brazil. Food Control 24, 199-205.

Daby, P., Sigurlinnason, S.A., 2003. Critical view of the fish processing sector in Mauritius with particular reference to seafood safety and quality assurance. URL http://www.unuftp.is/static/fellows/document/daby03prf.pdf.

Daelman, J., Jacxsens, L., Lahou, E., Devlieghere, F., Uyttendaele, M., 2013. Assessment of the microbial safety and quality of cooked chilled foods and their production process. International Journal of Food Microbiology 160, 193-200.

Darko, G., Acquaah, S.O., 2008. Levels of organochlorine pesticides residues in dairy products in Kumasi, Ghana. Chemosphere 71, 294-298.

Darko, G., Akoto, O., 2008. Dietary intake of organophosphorus pesticide residues through vegetables from Kumasi, Ghana. Food and Chemical Toxicology 46, 3703-3706.

Darko, G., Akoto, O., Oppong, C., 2008. Persistent organochlorine pesticide residues in fish, sediments and water from Lake Bosomtwi, Ghana. Chemosphere 72, 21-24.

Day, J.W., Kemp, W.M., Alejandro, Y., Crump, B.C., 2012a. Estuarine ecology. Wiley-Blackwell, ISBN 978-0-471-75567-8, 568 p.

Day, R., Tambi, E., Odularu, G., 2012b. An analysis of compliance with selected sanitary and phytosanitary measures in eastern and southern Africa. Forum for Agricultural Research in Africa (FARA), Accra, ISBN 9789988843837, 60 p.

de Quadros Rodrigues, R., Loiko, M.R., Minéia Daniel de Paula, C., Hessel, C.T., Jacxsens, L., Uyttendaele, M., Bender, R.J., Tondo, E.C., 2014. Microbiological contamination linked to implementation of good agricultural practices in the production of organic lettuce in Southern Brazil. Food Control 42, 152-164.

Demirbas, N., & Karagozlu, C., 2007. HACCP in the Turkey dairy industry. Agro-food Industry Hi-Tech 18, 36-37.

Demirbas, N., Karagozlu, C., 2008. Constraints in meeting food safety and quality requirements in the Turkish dairy industry: a case study of Izmir province. Journal of Food Protection 71, 440-444.

Demirbaş, N., Karahan, Ö., Kenanoğlu, Z., Karagözlü, C., 2006. The evaluation of the developments in food safety systems formation in the world for dairy industry from the standpoint of Turkey. Agricultural Economics-Czech 52, 236-243.

Dillman, A., Ijumba, M., 2011. Dairy value chain (Dar es Salaam, Samall and Medium Enterprises Competitiveness Facility), 64 p.

Dogheim, S.M., El-Marsafy, A.M., Salama, E.Y., Gadalla, S.A., Nabil, Y.M., 2002. Monitoring of pesticide residues in Egyptian fruits and vegetables during 1997. Food Additives and Contaminants 19, 1015-1027.

Doijad, S., Barbuddhe, S.B., Garg, S., Kalekar, S., Rodrigues, J., D'Costa, D., Bhosle, S., Chakraborty, T., 2011. Incidence and genetic variability of *Listeria* species from three milk processing plants. Food Control 22, 1900-1904.

Dolan, C., Humphrey, J., 2004. Changing governance patterns in the trade in fresh vegetables between Africa and the United Kingdom. Environment and Planning A 36, 491-510.

Domenech, E., Amorós, J.A., Escriche, I., 2013. Effectiveness of Prerequisites and the HACCP Plan in the Control of Microbial Contamination in Ice Cream and Cheese Companies. Foodborne Pathogens and Disease. 10, 222-228.

Domenech, E., Amorós, J.A., Martorell, S., Escriche, I., 2012. Safety assessment of smoked fish related to *Listeria monocytogenes* prevalence using risk management metrics. Food Control 25, 233-238.

Dutton, M.F., Mwanza, M., de Kock, S., Khilosia, L.D., 2012. Mycotoxins in South African foods: a case study on aflatoxin M1 in milk. Mycotoxin Research 28, 17-23.

East African Community, 2006a. East African standard, raw cow milk specification (East African Community), 1-2 pp.

East African Community, 2006b. Pasteurized milk - Specification. In Draft COMESA/East African Standard, EAS 69 (East African Community), 7 p.

East African Community, 2006c. Yoghurt- Specification. In Draft COMESA/East African Standard, EAS 33, 9 p.

East African Community, 2010a. Fresh and frozen fin fish — Part 1: Whole fish — Specification (CD/K/513-1:2010). East African Community, Arusha, 19 p.

East African Community, 2010b. Fresh and frozen ground fish block and fillet- Part 2: Groundfish block and fillet-Specification (CD/K/513-2:2010). East African Community, Arusha, 23 p.

Ediage, E.N., Hell, K., De Saeger, S., 2014. A comprehensive study to explore differences in mycotoxin patterns from agro-ecological regions through maize, peanut, and cassava products: a case study, Cameroon. Journal of Agricultural and Food Chemistry 62, 4789-4797.

Edward, N.S., 2004. Complying with European Union requirements for fish exports: The Uganda Experience. In: Regional seminar on strengthening the capacities of the intermediary organizations to fully participate in ACP/EU negotiations Nairobi, Kenya, 25th-26th May, 2004.

Egan, M., Raats, M., Grubb, S., Eves, A., Lumbers, M., Dean, M., Adams, M., 2007. A review of food safety and food hygiene training studies in the commercial sector. Food Control 18, 1180-1190.

Ejeta, G., Molla, B., Alemayehu, D., Muckle, A., 2004. Salmonella serotypes isolated from minced meat beef, mutton and pork in Addis Ababa, Ethiopia. Revue de médecine Vétérinaire 155, 547-551.

El-Senousy, W.M., Costafreda, M.I., Pintó, R.M., Bosch, A., 2013. Method validation for norovirus detection in naturally contaminated irrigation water and fresh produce. International Journal of Food Microbiology 167, 74-79.

El Marnissi, B., Belkhou, R., Morgavi, D.P., Bennani, L., Boudra, H., 2012. Occurrence of aflatoxin M1 in raw milk collected from traditional dairies in Morocco. Food and Chemical Toxicology 50, 2819-2821.

Elbashir, A.A., Ali, S.E.A., 2014. Aflatoxins, ochratoxins and zearalenone in sorghum and sorghum products in Sudan. Food Additives and Contaminants: Part B 7, 135-140.

Elshrek, Y.M., Madi, N.S., El-Bakoush, A.A., El-Tawil, A., 2008. Microbiological studies of spiced beef burgers in Tripoli city, Libyan Arab Jamahiriya. Eastern Mediterranean Health Journal 14, 172-178.

Elzupir, A.O., Elhussein, A.M., 2010. Determination of Aflatoxin M_1 in dairy cattle milk in Khartoum State, Sudan. Food Control 21, 945-946.

Emongor, R., Kirsten, J., 2009. The impact of South African supermarkets on agricultural development in the SADC: a case study in Zambia, Namibia and Botswana. Agrekon 48, 60-84.

English, P., Jaffee, S., Okello, J., 2004. Exporting out of Africa: the Kenya horticulture success story. In: Scaling Up Poverty Reduction: A Global Learning Process Conference. Shanghai. 25th-27th May, 2004.

Erkan, N., Özden, Ö., 2008. Quality assessment of whole and gutted sardines (*Sardina pilchardus*) stored in ice. International Journal of Food Science and Technology 43, 1549-1559.

Eskola, E., 2005. Agricultural marketing and supply chain management in Tanzania: A case study. Economic and Social Research Foundation. URL http://www.tanzaniagateway.org/docs/agriculturalmarketingandsupplychainmanagementintanzania.pdf.

European Union, 2002. Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. In Official Journal of the European Communities, L 31 (1-24), The European Parliament and the Council of the European Union, ed. (Brussels, Belgium), 24 p.

European Union, 2004a. Commision Regulation (EC) No. 853/2004 of 29 April 2004 laying down specific hygiene rules for food of animal origin. Official Journal of the European Union L 139.

European Union, 2004b. Regulation (EC) No 852/2004 of the European parliament and of the council of 29 April 2004 on the hygiene of foodstuffs. Official Journal of the European Union L 139, 1-54.

European Union, 2005. Commission Regulation (EC) No. 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. Official Journal of the European Communities L 139, 1-29.

European Union Commission, 1998. Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. Official Journal of the European Communities L 330/32, 23.

Falana, A., Denloye, S., Mainasara, O., Ubiaru, M., Udegbunaam, C., Adesanlu, A., Babatunde, A., Uwamadi, C., Uzegbu, G., Adewusi, E., 2005. Determination of profiles of human bacteria pathogens in Nigerian fish and seafood for export. In Food Safety and Quality Management (Kent, United Kingdom, Food Africa Secretariat), 12 p.

Fandohan, P., Gnonlonfin, B., Hell, K., Marasas, W., Wingfield, M., 2005. Natural occurrence of Fusarium and subsequent fumonisin contamination in preharvest and stored maize in Benin, West Africa. International Journal of Food Microbiology 99, 173-183.

FAO/WHO, 2003. Assuring food safety and quality. Guidelines for strengthening national food control systems In Food and Nutrition Paper. No. 76. URL http://www.fao.org/3/a-y8705e.pdf.

FAO/WHO, 2004. Developing and maintaining food safety control systems for Africa current status and prospects for change. In: Second FAO/WHO global forum of food safety regulators, Bangkok, 12-24th October, 2004, 1-6.

FAO/WHO, 2005. FAO/WHO Regional Conference on Food Safety for Africa. http://www.fao.org/docrep/meeting/010/a0215e/a0215e00.htm.

FAO/WHO, 2007. FAO/WHO guidance to governments on the application of HACCP in small and/or less-developed food businesses. FAO Food Nutrition Paper 86, 84. URL http://www.fao.org/3/a-a0799e.pdf.

FAO/WHO, 2009. Code of practice for fish and fishery products. In CAC/RCP 52-2003, , FAO/WHO, ed., 1-134 pp.

Fasina, F., Njage, P., Ali, A., Yilma, J., Bwala, D., Rivas, A., Stegeman, A., 2015. Development of disease-specific, context-specific surveillance models: Avian influenza (h5n1)-related risks and behaviours in African countries. Zoonoses and Public Health. DOI: 10.1111/zph.12200.

Fatimah, U.Z.A.U., Strohbehn, C.H., Arendt, S.W., 2014. An empirical investigation of food safety culture in onsite foodservice operations. Food Control 46, 255-263.

Faye, B., Loiseau, G., 2002. Sources of contamination in dairy supply chains and approaches to quality control. In: Proceedings of the International Workshop, CIRAD-FAO, 11-13 December, 2000, Montpellier, France.

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

Fold, N., Gough, K.V., 2008. From smallholders to transnationals: The impact of changing consumer preferences in the EU on Ghana's pineapple sector. Geoforum 39, 1687-1697.

Food and Agriculture Organisation, 2007. Strengthening the national food control system. Country Report: Tanzania. In Capacity building needs assessment series (Rome, FAO), 80 p.

Food and Veterinary Office, 2007. The Public Health controls and the conditions of production of fishery products. Final report of a mission carried out in Tanzania from 25th September to 6th October 2006 Food and Veterinary Office, Brussels. URL http://ec.europa.eu/food/fvo/act_getPDF.cfm?PDF_ID=5607.

Food and Veterinary Office, 2009. The Food and Veterinary Office Mission in Benin from 9-15th June 2009 concerning the conditions of production and export of fishery products to the European Union European Commission, Food and Veterinary Office, Brussels. URL http://ec.europa.eu/food/fvo/audit_reports/index.cfm.

Food and Veterinary Office, 2011a. Audit Reports. URL http://ec.europa.eu/food/fvo/audit_reports/index.cfm.

Food and Veterinary Office, 2011b. Final report of a mission carried out in South Africa from 21-31 January 2011 in order to evaluate the operation of controls over the production of game meat (mammalian) and meat products destined for export to the European Union, as well as certification procedures European Commision, Food and Veterinary Office, Brussels. URL http://ec.europa.eu/food/fvo/audit_reports/index.cfm.

Food and Veterinary Office, 2011c. Final report of an audit carried-out in Tanzania from 15-24th June 2011 in order to evaluate the control systems in place governing the production of fishery products intended for export to the European Union European Commision, Food and Veterinary Office, Brussels. URL http://ec.europa.eu/food/fvo/audit_reports/index.cfm.

FPEAK, 2007. Kenya-GAP = Global GAP: A first for Africa. URL http://www.fpeak.org/27-36.pdf.

Francesconi, G.N., Heerink, N., D'Haese, M., 2010. Evolution and challenges of dairy supply chains: Evidence from supermarkets, industries and consumers in Ethiopia. Food Policy 35, 60-68.

Franz, C.M., Huch, M., Mathara, J.M., Abriouel, H., Benomar, N., Reid, G., Galvez, A., Holzapfel, W.H., 2014. African fermented foods and probiotics. International Journal of Food Microbiology 190, 84-96.

Frohberg, K., Grote, U., Winter, E., 2006. European Union Food Safety Standards, Traceability and Other Regulations: a Growing Trade Barrier to Developing Countries' Exports. In Invited Paper, International Association of Agricultural Economists (Gold Coast, Australia). URL http://core.ac.uk/download/pdf/6653447.pdf

Fulponi, L., 2006. Private voluntary standards in the food system: The perspective of major food retailers in OECD countries. Food Policy 31, 1-13.

Geheb, K., Kalloch, S., Medard, M., Nyapendi, A.-T., Lwenya, C., Kyangwa, M., 2008. Nile perch and the hungry of Lake Victoria: Gender, status and food in an East African fishery. Food Policy 33, 85-98.

Germain, C., 2005. Traceability implementation in developing countries, its possibilities and its constraints A few case studies. URL ftp://ftp.fao.org/es/esn/food/traceability.pdf.

Ghali, R., Hmaissia-khlifa, K., Ghorbel, H., Maaroufi, K., Hedili, A., 2008. Incidence of aflatoxins, ochratoxin A and zearalenone in Tunisian foods. Food Control 19, 921-924.

Ghenghesh, K.S., Belhaj, K., El-Amin, W.B., El-Nefathi, S.E., Zalmum, A., 2005. Microbiological quality of fruit juices sold in Tripoli–Libya. Food Control 16, 855-858.

Giovannucci, D., Ponte, S., 2005. Standards as a new form of social contract? Sustainability initiatives in the coffee industry. Food Policy 30, 284-301.

Golub, S., McManus, J., 2008. Horticulture exports and African development. In: United Nations Conference on Trade and Development, Geneva.

Gossner, C.M.-E., Schlundt, J., Ben Embarek, P., Hird, S., Lo-Fo-Wong, D., Beltran, J.J.O., Teoh, K.N., Tritscher, A., 2009. The Melamine Incident: Implications for International Food and Feed Safety. Environmental Health Perspectives 117, 1803-1808.

Gran, H.M., Mutukumira, A.N., Wetlesen, A., Narvhus, J.A., 2002. Smallholder dairy processing in Zimbabwe: the production of fermented milk products with particular emphasis on sanitation and microbiological quality. Food Control 13, 161-168.

Gran, H.M., Wetlesen, A., Mutukumira, A.N., Rukure, G., Narvhus, J.A., 2003. Occurrence of pathogenic bacteria in raw milk, cultured pasteurised milk and naturally soured milk produced at small-scale dairies in Zimbabwe. Food Control 14, 539-544.

Griffith, C.J., Livesey, K.M., Clayton, D., 2010. The assessment of food safety culture. British Food Journal 112, 439-456.

Grimaud, P., Sserunjogi, M.L., Grillet, N., 2007. An evaluation of milk quality in Uganda: value chain assessment and recommendations. African Journal of Food Agriculture and Nutrition Development 7, 1-16.

Guobjoernsdottir, B., Einarsson, H., Thorkelsson, G., 2005. Microbial adhesion to processing lines for fish fillets and cooked shrimp: influence of stainless steel surface finish and presence of gram-negative bacteria on the attachment of *Listeria monocytogenes*. Food Technology and Biotechnology 43, 55-61.

Hanak, E., Boutrif, E., Fabre, P., Pineiro, M., 2000. Food safety management in Developing countries. In: Proceedings of the international workshop, CIRAD-FAO, 11-13.

Hatanaka, M., Bain, C., Busch, L., 2005. Third-party certification in the global agrifood system. Food Policy 30, 354-369.

Hayburn, G., 2014. Challenges for auditing and food safety management systems: a point of view. Perspectives in Public Health 134, 196-197.

Hell, K., Gnonlonfin, B., Kodjogbe, G., Lamboni, Y., Abdourhamane, I., 2009. Mycoflora and occurrence of aflatoxin in dried vegetables in Benin, Mali and Togo, West Africa. International Journal of Food Microbiology 135, 99-104.

Hellström, A.M., Vázques-Juárez, R., Svanberg, U., Andlid, T.A., 2010. Biodiversity and phytase capacity of yeasts isolated from Tanzanian *togwa*. International Journal of Food Microbiology 136, 352-358.

Hempen, M., Unger, F., Münstermann, S., Seck, M., Niamy, V., 2004. The hygienic status of raw and sour milk from smallholder dairy farms and local markets and potential risk for public health in The Gambia, Senegal and Guinea. URL http://www.itc.gm/Downloads/animalhealthworkingpaperno3.pdf.

Henry, D., Picha, D., 2000. Processing and packaging of Rwandan agricultural products Chemonics International, Inc., Kigali. URL http://www.foodnet.cgiar.org/market/Rwanda/reports/Chemonics8.pdf.

Henry, L., Kishimba, M.A., 2006. Pesticide residues in Nile tilapia (Oreochromis niloticus) and Nile perch (Lates niloticus) from Southern Lake Victoria, Tanzania. Environmental Pollution 140, 348-354.

Henson, S., 2007. Review of Case Studies and Evaluations of Sanitary and Phytosanitary Capacity: Kenya, Tanzania and Uganda. In: STDF Aid for Trade, Dar es Salaam, 30/09/2007. URL http://www.standardsfacility.org/Files/AidForTrade/Consultation_EA_S.Henson.pdf

Henson, S., Brouder, A.M., Mitullah, W., 2000. Food safety requirements and food exports from developing countries: the case of fish exports from Kenya to the European Union. American Journal of Agricultural Economics 82, 1159-1169.

Henson, S., Holt, G., Northen, J., 1999. Costs and benefits of implementing HACCP in the UK dairy processing sector. Food Control 10, 99-106.

Henson, S., Jaffee, S., 2007. Developing country responses to the enhancement of food safety standards. New Frontiers in Environmental and Social Labeling, 193-220.

Henson, S., Masakure, O., Boselie, D., 2005. Private food safety and quality standards for fresh produce exporters: The case of Hortico Agrisystems, Zimbabwe. Food Policy 30, 371-384.

Henson, S., Masakure, O., Cranfield, J., 2011. Do Fresh Produce Exporters in Sub-Saharan Africa Benefit from GlobalGAP Certification? World Development 39, 375-386.

Henson, S., Mitullah, W., 2004. Kenyan Exports of Nile Perch: impact of food safety standards on an export-oriented supply chain. In Policy Research Working Paper (World Bank), 87 p.

Henson, S., Reardon, T., 2005. Private agri-food standards: Implications for food policy and the agri-food system. Food Policy 30, 241-253.

Henson, S.J., 2008. The role of public and private standards in regulating international food markets. Journal of International Agricultural Trade and Development 4, 63-81.

Herath, D., Hassan, Z., Henson, S., 2007. Adoption of food safety and quality controls: Do firm characteristics matter? Evidence from the Canadian food processing sector. Canadian Journal of Agricultural Economics 55, 299-314.

Herath, D., Henson, S., 2006. Does Canada Need Mandatory HACCP? Evidence from the Ontario Food Processing Sector. Canadian Journal of Agricultural Economics 54, 443-459.

Holleran, E., Bredahl, M.E., Zaibet, L., 1999. Private incentives for adopting food safety and quality assurance. Food Policy 24, 669-683.

Holzapfel, W., 2002. Appropriate starter culture technologies for small-scale fermentation in developing countries. International Journal of Food Microbiology 75, 197-212.

Ikutegbe, V., Sikoki, F., 2014. Microbiological and biochemical spoilage of smoke-dried fishes sold in West African open markets. Food Chemistry 161, 332-336.

Ilyukhin, S.V., Haley, T.A., Singh, R.K., 2001. A survey of control system validation practices in the food industry. Food Control 12, 297-304.

International Commission on Microbiological Specifications for Foods, 2002. Microorganisms in Food 7. Microbiological Testing in Food Safety Management, 1 Edition. Kluwer Academic/Plenum, New York, ISBN: 0306472627, 363 p.

ISO, 1999. Microbiology of Food and Animal Feeding Stuffs —Preparation of Test Samples, Initial Suspension and Decimal Dilutions for Microbiological Examination. In Part 1: General rules for the preparation of the initial suspension and decimal dilutions (International Standardisation Organisation).

ISO, 2004. ISO 18593:2004. Microbiology of food and animal feeding stuffs-Horizontal methods for sampling techniques from surfaces using contact plates and swabs (International Standard Organisation), 8 p.

ISO, 2005. ISO 22000:2005. Food safety management systems-Requirements for any organization in the food chain (Switzerland, International Standard Organisation).

ISO, 2008a. ISO 9001: 2008. Quality management systems-Requirements (Switzerland, International Standard Organisation).

ISO, 2008b. Milk and Milk products - Guidance on sampling (ISO 707) (Internation Standard Organisation), 40 p.

ISO, 2010. Microbiology of food and animal feeding stuffs: Preparation of test samples, initial suspension and decimal dilutions for microbiological examination In Part 5: Specific rules for the preparation of milk and milk products.

ISO, 2012. The ISO Survey of Management System Standard Certifications – 2012 International Standard Organisation. URL www.iso.org.

Jabbar, M., Baker, D., Fadiga, M., 2010. Demand for livestock products in developing countries with a focus on quality and safety attributes: Evidence from Asia and Africa. ILRI (aka ILCA and ILRAD), Nairobi, ISBN 929146256X, 168 p.

Jackson, L., 2006. Towards a South African model for food safety auditor registration. British Food Journal 108, 16-26.

Jacxsens, L., Devlieghere, F., Uyttendaele, M., 2009a. Quality Management Systems in the Food Industry. St Kliment Ohridski University Press, Sofia, Bulgaria, ISBN 978-90-5989-275-0, 141 p.

Jacxsens, L., Kirezieva, K., Luning, P.A., Ingelrham, J., Diricks, H., Uyttendaele, M., 2015. Measuring microbial food safety output and comparing self-checking systems of food business operators in Belgium. Food Control 49, 59-69.

Jacxsens, L., Kussaga, J., Luning, P.A., Van der Spiegel, M., Devlieghere, F., Uyttendaele, M., 2009b. A Microbial Assessment Scheme to measure microbial performance of Food Safety Management Systems. International Journal of Food Microbiology 134, 113-125.

Jacxsens, L., Kussaga, J., Santilana Farakos, S.M., Kousta, M., Drosinos, E.H., Uyttendaele, M., Luning, P.A., 2011a. Quality Assurance Standards and Guidelines Evaluation Grid. Food Science and Law 5, 14-25.

Jacxsens, L., Luning, P.A., Marcelis, W.J., van Boekel, T., Rovira, J., Oses, S., Kousta, M., Drosinos, E., Jasson, V., Uyttendaele, M., 2011b. Tools for the performance assessment and improvement of food safety management systems. Trends in Food Science and Technology 22, Supplement 1, S80-S89.

Jacxsens, L., Luning, P.A., van der Vorst, J.G.A.J., Devlieghere, F., Leemans, R., Uyttendaele, M., 2010a. Simulation modelling and risk assessment as tools to identify the impact of climate change on microbiological food safety – The case study of fresh produce supply chain. Food Research International 43, 1925-1935.

Jacxsens, L., Uyttendaele, M., Devlieghere, F., Rovira, J., Gomez, S.O., Luning, P.A., 2010b. Food safety performance indicators to benchmark food safety output of food safety management systems. International Journal of Food Microbiology 141, S180-S187.

Jaffee, S., Henson, S., 2004. Standards and agro-food exports from developing countries: rebalancing the debate, Vol 3348. World Bank Publications.

Jaffee, S., Henson, S., Sewadeh, M., Pentney, P., Musonda, F., 2005. Tanzania's agro-food trade and emerging sanitary and phytosanitary (SPS) standards: toward a strategic approach and action plan World Bank. URL http://siteresources.worldbank.org/INTRANETTRADE/Resources/Topics/Standards/Tanzania_Standards_Draft_22Mar.pdf.

Jaffee, S., Masakure, O., 2005. Strategic use of private standards to enhance international competitiveness: Vegetable exports from Kenya and elsewhere. Food Policy 30, 316-333.

Jaffee, S.M., Henson, S., 2005. Agro-food exports from developing countries: the challenges posed by standards. Global Agricultural Trade and Developing Countries, 91-114.

James, B., Adda, C., Cardwell, K., Annang, D., Hell, K., Korie, S., Edorh, M., Gbeassor, F., Nagatey, K., Houenou, G., 2007. Public information campaign on aflatoxin contamination of maize grains in market stores in Benin, Ghana and Togo. Food Additives and Contaminants 24, 1283-1291.

Jayasinghe-Mudalige, U., Henson, S., 2007. Identifying economic incentives for Canadian red meat and poultry processing enterprises to adopt enhanced food safety controls. Food Control 18, 1363-1371.

Jayasuriya, S., MacLaren, D., Metha, R., 2006. Meeting food safety standards in export markets: issues and challenges facing firms exporting from developing countries. In: IATRC Summer Symposium, Food Regulation and Trade: Institutional Framework, Concepts of Analysis and Empirical Evidence, Bonn, Germany, 28-30.

Jensen, T.K., Nielsen, J., Larsen, E.P., Clausen, J., 2010. The fish industry- toward supply chain modeling. Journal of Aquatic Food Product Technology 19, 214-226.

Johnson, J.L., 2010. From Mfangano to Madrid: The global commodity chain for Kenyan Nile perch. Aquatic Ecosystem Health and Management 13, 20-27.

Jongwanich, J., 2009. The impact of food safety standards on processed food exports from developing countries. Food Policy 34, 447-457.

Josupeit, H., 2006. The market for Nile perch. FAO GLobeFish Research Programme, Vol 84. FAO, Rome, 94 p.

Kaaya, A.N., Kyamuhangire, W., 2006. The effect of storage time and agroecological zone on mould incidence and aflatoxin contamination of maize from traders in Uganda. International Journal of Food Microbiology 110, 217-223.

Kadigi, R.M.J., Mdoe, N.S.Y., Senkondo, E., Mpenda, Z., 2007. Effects of food safety standards on the livelihoods of actors in the Nile Perch value chain, Vol Safe Policy Brief. Danish Institute for International Studies, Copenhagen, 1-4 pp.

Kaijage, J., 2004. Small scale dairy production and milk marketing in the southern highlands of tanzania. The Interim Tanzania Dairy Board, 24.

Kamana, O., Ceuppens, S., Jacxsens, L., Kimonyo, A., Uyttendaele, M., 2014. Microbiological Quality and Safety Assessment of the Rwandan Milk and Dairy Chain. Journal of Food Protection 77, 299-307.

Kamika, I., Takoy, L.L., 2011. Natural occurrence of Aflatoxin B1 in peanut collected from Kinshasa, Democratic Republic of Congo. Food Control 22, 1760-1764.

Kang'ethe, E., Aboge, G., Arimi, S., Kanja, L., Omore, A., McDermott, J., 2005. Investigation of the risk of consuming marketed milk with antimicrobial residues in Kenya. Food Control 16, 349-355.

Karaman, A.D., 2012. Food safety practices and knowledge among Turkish dairy businesses in different capacities. Food Control 26, 125-132.

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

Karimuribo, E.D., Kusiluka, L.J., Mdegela, R.H., Kapaga, A.M., Sindato, C., Kambarage, D.M., 2005. Studies on mastitis, milk quality and health risks associated with consumption of milk from pastoral herds in Dodoma and Morogoro regions, Tanzania. Journal of Veterinary Science 6, 213.

Karipidis, P., Athanassiadis, K., Aggelopoulos, S., Giompliakis, E., 2009. Factors affecting the adoption of quality assurance systems in small food enterprises. Food Control 20, 93-98.

Kasozi, G., Kiremire, B., Bugenyi, F., Kirsch, N., Nkedi-Kizza, P., 2006. Organochlorine residues in fish and water samples from Lake Victoria, Uganda. Journal of Environmental Quality 35, 584-589.

Katerere, D., Stockenström, S., Thembo, K., Balducci, G., Shephard, G., 2007. Investigation of patulin contamination in apple juice sold in retail outlets in Italy and South Africa. Food Additives and Contaminants 24, 630-634.

Kayode, O., Sulyok, M., Fapohunda, S., Ezekiel, C., Krska, R., Oguntona, C., 2013. Mycotoxins and fungal metabolites in groundnut-and maize-based snacks from Nigeria. Food Additives and Contaminants: Part B 6, 294-300.

Keller, S.G.F., 2004. Quality management systems in small and medium food processing enterprises- experience of South Africa. In: Quality Enhancement in Food Processing through HACCP Quality enhancement in food processing through HACCP (Hazard Analysis and Critical Control Point), India, 26th February-4th March 2002, 44-57.

Keshia, N., Denise, L., 2010. Potential cross-contamination of the ready-to-eat dried meat product, *biltong*. British Food Journal 112, 350-363.

Kimanya, M.E., De Meulenaer, B., Tiisekwa, B., Ndomondo-Sigonda, M., Devlieghere, F., Van Camp, J., Kolsteren, P., 2008. Co-occurrence of fumonisins with aflatoxins in home-stored maize for human consumption in rural villages of Tanzania. Food Additives and Contaminants 25, 1353-1364.

Kirezieva, K., Luning, P.A., Jacxsens, L., Allende, A., Johannessen, G.S., Tondo, E.C., Rajkovic, A., Uyttendaele, M., van Boekel, M.A.J.S., 2015. Factors affecting the status of food safety management systems in the global fresh produce chain. Food Control 52, 85-97.

Kirezieva, K., Nanyunja, J., Jacxsens, L., van der Vorst, J.G.A.J., Uyttendaele, M., Luning, P.A., 2013. Context factors affecting design and operation of food safety management systems in the fresh produce chain. Trends in Food Science and Technology 32, 108-127.

Kivaria, F., Noordhuizen, J.P.T.M., Kapaga, A., 2006. Evaluation of the hygienic quality and associated public health hazards of raw milk marketed by smallholder dairy producers in the Dar es Salaam region, Tanzania. Tropical Animal Health and Production 38, 185-194.

Kivaria, F.M., Noordhuizen, J.P.T.M., Msami, H.M., 2007. Risk factors associated with the incidence rate of clinical mastitis in smallholder dairy cows in the Dar es Salaam region of Tanzania. The Veterinary Journal 173, 623-629.

Konecka-Matyjek, E., Turlejska, H., Pelzner, U., Szponar, L., 2005. Actual situation in the area of implementing quality assurance systems GMP, GHP and HACCP in Polish food production and processing plants. Food Control 16, 1-9.

Kpodo, K., Thrane, U., Hald, B., 2000. Fusaria and fumonisins in maize from Ghana and their co-occurrence with aflatoxins. International Journal of Food Microbiology 61, 147-157.

Kurwijila, L., Lore, T., Omore, A., 2006a. Technologies for enhancing value addition, quality and safety of milk produced by smallholder farmers in Africa. In Fourth All Africa Conference on Animal Agriculture (AACAA) (Arusha, ILRI).

Kurwijila, L.R., Bennett, A., 2011. Dairy development institutions in East Africa: Lessons learned and options FAO. URL http://www.fao.org/docrep/013/k9649e/k9649e00.pdf.

Kurwijila, L.R., Boki, K.J., 2003. A review of the small scale dairy sector-Tanzania. URL http://www.fao.org/fileadmin/templates/ags/docs/dairy/P1assessmenttanzania.pdf.

Kurwijila, L.R., Mwingira, J., Karimuribo, E., Shirima, G., Lema, B., Ryoba, R., Kilima, B., 2011. Safety of animal source foods in Tanzania: a situational analysis International Livestock Research Institute, Nairobi.

Kurwijila, L.R., Omore, A., Staal, S., Mdoe, N.S.Y., 2006b. Investigation of the risk of exposure to antimicrobial residues present in marketed milk in Tanzania. Journal of Food Protection 69, 2487-2492.

Kussaga, J.B., Jacxsens, L., Tiisekwa, B.P.M., Luning, P.A., 2014a. Food safety management systems performance in African food processing companies: a review of deficiencies and possible improvement strategies. Journal of the Science of Food and Agriculture 94, 2154-2169.

Kussaga, J.B., Luning, P.A., Tiisekwa, B.P.M., Jacxsens, L., 2014b. Challenges in performance of food safety management systems: a case of fish processing companies in Tanzania. Journal of Food Protection 77, 621-630.

Kussaga, J.B., Luning, P.A., Tiisekwa, B.P.M., Jacxsens, L., 2015. Current performance of food safety management systems of dairy processing companies in Tanzania. International Journal of Dairy Technology 68 227-252.

Kussaga, J.B., P.A., L., Jacxsens, L., Tiisekwa, B.P.M., 2013. Diagnosis of food safety management systems performance in food processing sectors for export and domestic markets. African Journal of Food Science and Technology 4, 240-250.

Kvenberg, J., Stolfa, P., Stringfellow, D., Spencer Garrett, E., 2000. HACCP development and regulatory assessment in the United States of America. Food Control 11, 387-401.

Lahou, E., Jacxsens, L., Daelman, J., Van Landeghem, F., Uyttendaele, M., 2012. Microbiological performance of a food safety management system in a food service operation. Journal of Food Protection 75, 706-716.

Lamuka, P.O., 2014. Public health measures: challenges of developing countries in management of food safety, In: Motarjemi, Y. (Ed.) Encyclopedia of Food Safety. Academic Press, Waltham, ISBN 978-0-12-378613-5, 20-26 pp.

Land O'Lakes, 2007. The increasing importance of quality assuarance standards to smallholder dairy farmers in East and Southern Africa Land O'Lakes Washington D.C.

Larcher, A., 2006. Costs of Agri-food Safety and SPS Compliance: United Republic of Tanzania, Mozambique and Guinea: Tropical Fruits. URL http://unctad.org/en/docs/ditccom20052_en.pdf.

Lawley, R., 2010. Food Safety and Traceability Strategies: Key hazards, risks and technological developments, Ltd, B.I., ed. URL http://www.eularinet.eu/img/contents_archives/document/11/10/21/39_2011_10_21_07_38_02.pdf.

Lewis, L., Onsongo, M., Njapau, H., Schurz-Rogers, H., Luber, G., Kieszak, S., Nyamongo, J., Backer, L., Dahiye, A.M., Misore, A., 2005. Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in eastern and central Kenya. Environmental Health Perspectives 113, 1763.

Lindblad, M., 2007. Microbiological sampling of swine carcasses: A comparison of data obtained by swabbing with medical gauze and data collected routinely by excision at Swedish abattoirs. International Journal of Food Microbiology 118, 180-185.

Lokuruka, M.N.I., 2009. Scombrotoxicosis In African Fisheries-Its Implications For International Fish Trade: An Overview. African Journal of Food, Agriculture, Nutrition and Development 9, 1617-1634.

Lore, T., Omore, A., Staal, S., 2005. Types, levels and causes of post-harvest milk and dairy losses in sub-Saharan Africa and the Near East: Phase two synthesis report ILRI, Nairobi. URL http://hdl.handle.net/10568/3741.

Luning, P.A., Bango, L., Kussaga, J., Rovira, J., Marcelis, W.J., 2008. Comprehensive analysis and differentiated assessment of food safety control systems: a diagnostic instrument. Trends in Food Science and Technology 19, 522-534.

Luning, P.A., Chinchilla, A.C., Jacxsens, L., Kirezieva, K., Rovira, J., 2013. Performance of safety management systems in Spanish food service establishments in view of their context characteristics. Food Control 30, 331-340.

Luning, P.A., Jacxsens, L., Jasson, V., Marcelis, W.J., Kussaga, J., Van der Spiegel, M., Kousta, M., Osés, S., Rovira, J., Devlieghere, F., 2010. Tools to support the self assessment of the performance of food safety management systems. In: SME workshop:¿ Cómo puedo aumentar la seguridad alimentaria de mis productos?= How to improve the food safety of my products, 31-43.

Luning, P.A., Jacxsens, L., Rovira, J., Osés, S.M., Uyttendaele, M., Marcelis, W.J., 2011a. A concurrent diagnosis of microbiological food safety output and food safety management system performance: Cases from meat processing industries. Food Control 22, 555-565.

Luning, P.A., Kirezieva, K., Hagelaar, G., Rovira, J., Uyttendaele, M., Jacxsens, L., 2015. Performance assessment of food safety management systems in animal-based food companies in view of their context characteristics: A European study. Food Control 49, 11-22.

Luning, P.A., Marcelis, W.J., 2006. A techno-managerial approach in food quality management research. Trends in Food Science and Technology 17, 378-385.

Luning, P.A., Marcelis, W.J., 2007. A conceptual model of food quality management functions based on a techno-managerial approach. Trends in Food Science and Technology 18, 159-166.

Luning, P.A., Marcelis, W.J., 2009a. A food quality management research methodology integrating technological and managerial theories. Trends in Food Science and Technology 20, 35-44.

Luning, P.A., Marcelis, W.J., 2009b. Food quality management: Technological and managerial principles and practices. Wageningen Academic Publishers, Wageningen, ISBN 978-90-8686-116-3, 425 p.

Luning, P.A., Marcelis, W.J., Rovira, J., van Boekel, M.A.J.S., Uyttendaele, M., Jacxsens, L., 2011b. A tool to diagnose context riskiness in view of food safety activities and microbiological safety output. Trends in Food Science and Technology 22, S67-S79.

Luning, P.A., Marcelis, W.J., Rovira, J., Van der Spiegel, M., Uyttendaele, M., Jacxsens, L., 2009. Systematic assessment of core assurance activities in a company specific food safety management system. Trends in Food Science and Technology 20, 300-312.

LVFO, 2012. Lake Victoria Fisheries Organisation. URL http://www.lvfo.org/index.php.

Madbouly, A.K., Ibrahim, M.I., Sehab, A.F., Abdel-Wahhab, M.A., 2012. Co-occurrence of mycoflora, aflatoxins and fumonisins in maize and rice seeds from markets of different districts in Cairo, Egypt. Food Additives and Contaminants: Part B 5, 112-120.

Maertens, M., Swinnen, J.F.M., 2009. Trade, Standards, and Poverty: Evidence from Senegal. World Development 37, 161-178.

Magwira, C.A., Gashe, B.A., Collison, E.K., 2005. Prevalence and antibiotic resistance profiles of Escherichia coli O157: H7 in beef products from retail outlets in Gaborone, Botswana. Journal of Food Protection 68, 403-406.

Mahnine, N., Meca, G., Elabidi, A., Fekhaoui, M., Saoiabi, A., Font, G., Mañes, J., Zinedine, A., 2011. Further data on the levels of emerging Fusarium mycotoxins enniatins (A, A1, B, B1), beauvericin and fusaproliferin in breakfast and infant cereals from Morocco. Food Chemistry 124, 481-485.

Makun, H.A., Gbodi, T.A., Akanya, H.O., Salako, E.A., Ogbadu, G.H., 2009. Fungi and some mycotoxins found in mouldy Sorghum in Niger State, Nigeria. World Journal of Agricultural Sciences 5, 5-17.

Mamalis, S., Kafetzopoulos, D.P., Aggelopoulos, S., 2009. The new food safety standard ISO 22000. Assessment, comparison and correlation with HACCP and ISO 9000: 2000. The practical implementation in victual business. In: 113th EAAE seminar "A resilient European food industry and food chain in a challenging world", Chania, Crete, Greece, 16.

Martins, E.A., Germano, P.M.L., 2008. Microbiological indicators for the assessment of performance in the hazard analysis and critical control points (HACCP) system in meat lasagna production. Food Control 19, 764-771.

Masakure, O., Henson, S., Cranfield, J., 2009. Standards and export performance in developing countries: Evidence from Pakistan. The Journal of International Trade and Economic Development 18, 395-419.

Mashinini, K., Dutton, M.F., 2006. The incidence of fungi and mycotoxins in South Africa wheat and wheat-based products. Journal of Environmental Science and Health Part B 41, 285-296.

Matumba, L., Monjerezi, M., Khonga, E.B., Lakudzala, D.D., 2011. Aflatoxins in sorghum, sorghum malt and traditional opaque beer in southern Malawi. Food Control 22, 266-268.

Mbarki, R., Jerbi, T., Sadok, S., 2008. Potential future challenges to the application of gamma irradiation to seafood in Tunisia. Journal of Food Processing and Preservation 32, 458-468.

McSwane, D., Linton, R., 2000. Issues and concerns in HACCP development and implementation for retail food operations. Journal of Envrionmental Health-Denver 62, 15-18.

Mensah, L.D., Julien, D., 2011. Implementation of food safety management systems in the UK. Food Control 22, 1216-1225.

Mestres, C., Bassa, S., Fagbohoun, E., Nago, M., Hell, K., Vernier, P., Champiat, D., Hounhouigan, J., Cardwell, K., 2004. Yam chip food sub-sector: hazardous practices and presence of aflatoxins in Benin. Journal of Stored Products Research 40, 575-585.

Mgonja, J.T., Luning, P., Van der Vorst, J.G.A.J., 2013. Diagnostic model for assessing traceability system performance in fish processing plants. Journal of Food Engineering 118, 188-197.

Mhone, T.A., Matope, G., Saidi, P.T., 2011. Aerobic bacterial, coliform, *Escherichia coli* and *Staphylococcus aureus* counts of raw and processed milk from selected smallholder dairy farms of Zimbabwe. International Journal of Food Microbiology 151, 223-228.

Milanzi, M., 2012. The impact of barriers on export behavior of a developing country firms: evidence from Tanzania. International Journal of Business and Management 7, 10-21.

Milios, K.T., Drosinos, E.H., Zoiopoulos, P.E., 2014. Food safety management system validation and verification in meat industry: carcass sampling methods for microbiological hygiene criteria – A review. Food Control 43, 74-81.

Millogo, V., Ouédraogo, G., Agenäs, S., Svennersten-Sjaunja, K., 2008. Survey on dairy cattle milk production and milk quality problems in peri-urban areas in Burkina Faso. African Journal of Agricultural Research 3, 215-224.

Millogo, V., Svennersten Sjaunja, K., Ouédraogo, G.A., Agenäs, S., 2010. Raw milk hygiene at farms, processing units and local markets in Burkina Faso. Food Control 21, 1070-1074.

Minten, B., Randrianarison, L., Swinnen, J.F.M., 2009. Global retail chains and poor farmers: evidence from Madagascar. World Development 37, 1728-1741.

Mirkena, A.A., 2010. Microbiological safety of pasteurised and raw milk from milk processing plants in and around Addis Ababa. MSc. Addis Ababa University.

Mohale, S., Medina, A., Rodríguez, A., Sulyok, M., Magan, N., 2013. Mycotoxigenic fungi and mycotoxins associated with stored maize from different regions of Lesotho. Mycotoxin Research 29, 209-219.

Mohamed, M.E.M., Awadallah, M.A.I., Amin, M.A., Abou-Elez, R.M.M., 2011. Role of *Atherina* Species in transmitting some bacterial diseases to human. Journal of American Science 7, 174-185.

Molins, R., Masaga, F., 2006. Assessment of capacity building needs of the food control system. United Republic of Tanzania FAO, Rome.

Moll, H.A.J., Staal, S.J., Ibrahim, M.N.M., 2007. Smallholder dairy production and markets: A comparison of production systems in Zambia, Kenya and Sri Lanka. Agricultural Systems 94, 593-603.

Molla, B., Alemayehu, D., Salah, W., 2003. Sources and distribution of Salmonella serotypes isolated from food animals, slaughterhouse personnel and retail meat products in Ethiopia: 1997-2002. Ethiopian Journal of Health Development 17, 63-70.

Motarjemi, Y., 2002. Impact of small scale fermentation technology on food safety in developing countries. International Journal of Food Microbiology 75, 213-229.

Motarjemi, Y., 2014. Public health measures: modern approach to food safety management: an overview, In: Motarjemi, Y. (Ed.) Encyclopedia of Food Safety. Academic Press, Waltham, ISBN 978-0-12-378613-5, 1-12 pp.

Mrema, N., Mpuchane, S., Gashe, B.A., 2006. Prevalence of Salmonella in raw minced meat, raw fresh sausages and raw burger patties from retail outlets in Gaborone, Botswana. Food Control 17, 207-212.

Mugula, J., Nnko, S., Narvhus, J., Sorhaug, T., 2003. Microbiological and fermentation characteristics of *togwa*, a Tanzanian fermented food. International Journal of Food Microbiology 80, 187-199.

Muhammad, S., Shehu, K., Amusa, N., 2004. Survey of the market diseases and aflatoxin contamination of tomato (MILL) fruits in Sokoto, northwestern Nigeria. Nutrition and Food Science 34, 72-76.

Mukisa, I., Kyoshabire, R., 2010. Microbiological, physico-chemical and sensorial quality of small-scale produced stirred yoghurt on the market in Kampala city, Uganda. Nutrition and Food Science 40, 409-418.

Mullins, L.J., 2007. Management and organisational behaviour, 9th Edition. Pearson Education Ltd, Harlow, ISBN 0273708880, 896 p.

Mupunga, I., Lebelo, S., Mngqawa, P., Rheeder, J., Katerere, D., 2014. Natural Occurrence of Aflatoxins in Peanuts and Peanut Butter from Bulawayo, Zimbabwe. Journal of Food Protection 77, 1814-1818.

Muriuki, F., Ogara, W., Njeruh, F., Mitema, E., 2001. Tetracycline residue levels in cattle meat from Nairobi salughter house in Kenya. Journal of Veterinary Science 2, 97-101.

Musonda, F.M., Mbowe, W., 2002. The impact of implementing SPS and TBT agreements: case of fish export to European Union by Tanzania. URL http://www.cuts-international.org/sps-analysis-sps_case_tan.htm.

Mutukumira, A.N., Jukes, D.J., 2003. The development of national food safety control system in Sub-Saharan Africa – issues and opportunities. In: Food Africa, Congress centre/palais de congress, Yaoundé, Cameroon, 5–9 May 2003.

Neeliah, S.A., Goburdhun, D., 2007. National food control systems: a review. Food Reviews International 23, 35-51.

Neeliah, S.A., Goburdhun, D., Neeliah, H., 2009. National food control systems: lessons from Mauritius. Ecology of Food and Nutrition 48, 137-156.

Neeliah, S.A., Goburdhun, D., Neeliah, H., 2012. Are Mauritian fishery exporters minding the standards gap? Agrekon 51, 59-82.

Neeliah, S.A., Neeliah, H., Goburdhun, D., 2011. Sanitary and phytosanitary issues for fishery exports to the European Union: A Mauritian insight. Journal of Development and Agricultural Economics 3, 56-68.

Nel, S., Lues, J., Buys, E., Venter, P., 2004. Bacterial populations associated with meat from the deboning room of a high throughput red meat abattoir. Meat Science 66, 667-674.

Neven, D., Reardon, T., 2004. The rise of Kenyan supermarkets and evolution of their horticulture product procurement systems. Development Policy Review 22, 669-699.

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

Nguz, K., Shindano, J., Samapundo, S., Huyghebaert, A., 2005. Microbiological evaluation of fresh-cut organic vegetables produced in Zambia. Food Control 16, 623-628.

NIRAS, 2010. Final report on survey on dairy products market in Tanzania (Dar es Salaam, Rural Livelihood Development Company), 75 p.

Nishiura, A., 2010. The food industry and supermarkets in Eastern Africa: a preliminary report on research in Tanzania and Ethiopia Institute of Developing Economies. URL http://www.ide.go.jp/English/Publish/Download/Report/2009/pdf/2009_406_ch2.pdf.

Njiru, M., Kazungu, J., Ngugi, C.C., Gichuki, J., Muhoozi, L., 2008. An overview of the current status of Lake Victoria fishery: Opportunities, challenges and management strategies. Lakes and Reservoirs: Research and Management 13, 1-12.

Njobeh, P.B., Dutton, M.F., Koch, S.H., Chuturgoon, A., Stoev, S., Seifert, K., 2009. Contamination with storage fungi of human food from Cameroon. International Journal of Food Microbiology 135, 193-198.

Njombe, A.P., Msanga, Y.N., Mbwambo, N., Makembe, N., 2011. The Tanzanian dairy industry: status, opportunities and prospects. In The 7th African Dairy Conference and Exhibition (MovenPick Palm Hotel, Dar es Salaam), 22 p.

Nkondola, E.S., Arnason, V., Blomsterberg, F., 2006. Developing a traceability system for fish factories in Iceland and Tanzania The United Nations University, Reykjavik, Iceland. URL http://www.unuftp.is/static/fellows/document/eileen06prf.pdf.

Nkwe, D.O., Taylor, J.E., Siame, B.A., 2005. Fungi, aflatoxins, *Fumonisin* B_1 and zearalenone contaminating sorghum-based traditional malt, wort and beer in Botswana. Mycopathologia 160, 177-186.

Noseda, B., Tong Thi, A., Rosseel, L., Devlieghere, F., Jacxsens, L., 2013. Dynamics of microbiological quality and safety of Vietnamese *Pangasianodon hypophthalmus* during processing. Aquaculture International 21, 709-727.

Nzouankeu, A., Ngandjio, A., Ejenguele, G., Njine, T., Wouafo, M.N., 2010. Multiple contaminations of chickens with *Campylobacter, Escherichia coli* and *Salmonella* in Yaounde (Cameroon). The Journal of Infection in Developing Countries 4, 583-686.

Obadina, A., Oyewole, O., Sanni, L., Tomlins, K., Westby, A., 2008. Identification of hazards and critical control points (CCP) for cassava fufu processing in South-West Nigeria. Food Control 19, 22-26.

Obadina, A.O., Oyewole, O.B., Sanni, L.O., Tomlins, K.I., Westby, A., 2010. Improvement of the hygienic quality of wet 'fufu' produced in South West Nigeria. Food Control 21, 639-643.

Okello, J.J., Narrod, C., Roy, D., 2007. Food safety requirements in African green bean exports and their impact on small farmers. International Food Policy Research Institute. URL http://www.ifpri.org/publication/food-safety-requirements-african-green-bean-exports-and-their-impact-small-farmers.

Okello, J.J., Swinton, S.M., 2007. Compliance with international food safety standards in Kenya's green bean industry: Comparison of a small-and a large-scale farm producing for export. Applied Economic Perspectives and Policy 29, 269-285.

Okoli, I., Aladi, N., Etuk, E., Opara, M., Anyanwu, G., Okeudo, N., 2005. Current facts about the animal food products safety situation in Nigeria. Ecology of Food and Nutrition 44, 359-373.

Okonko, I., Adejoye, O., Ogun, A., Ogunjobi, A., Nkang, A., Adebayo-Tayo, B., 2009. Hazards analysis critical control points (HACCP) and microbiology qualities of sea-foods as affected by handler's hygience in Ibadan and Lagos, Nigeria. African Journal of Food Science 3, 35-50.

Okonko, I.O., Ogunjobi, A.A., Adejoye, O.D., Ogunnusi, T.A., Olasogba, M., 2008. Comparative studies and Microbial risk assessment of different water samples used for processing frozen sea-foods in Ijoraolopa, Lagos State, Nigeria. African Journal of Biotechnology 7, 2902-2907.

Olafsdóttir, G., Martinsdóttir, E., Oehlenschläger, J., Dalgaard, P., Jensen, B., Undeland, I., Mackie, I.M., Henehan, G., Nielsen, J., Nilsen, H., 1997. Methods to evaluate fish freshness in research and industry. Trends in Food Science and Technology 8, 258-265.

Olatoye, I., Ehinmowo, A., 2011. Oxytetracycline residues in edible tissues of cattle slaughtered in Akure, Nigeria. Nigerian Veterinary Journal 31, 93-102.

Oloo, J.E.O., 2010. Food safety and quality management in Kenya: An overview of the roles played by various stakeholders. African Journal of Food, Agriculture, Nutrition and Development 10, 4379-4397.

Oluwafemi, F., Badmos, A., Kareem, S., Ademuyiwa, O., Kolapo, A., 2014. Survey of aflatoxin M1 in cows' milk from free-grazing cows in Abeokuta, Nigeria. Mycotoxin Research 30, 207-211.

Omore, A., Kaitibe, S., 2007. Can Small scale actors exploit growing demand for quality and safety in animal source food markets in east Africa? . In First International Conference on Food Safety of Animal Products (Amman, Jordan, 12-14th November,2007).

Omore, A., Staal, S., Wanyoike, F., Osafo, E., Kurwijila, L., Barton, D., Mdoe, N., Nurah, G., Aning, G., 2009. Market mechanisms and efficiency in urban dairy products markets in Ghana and Tanzania International Livestock Research Institute, Nairobi.

Onjong, H.A., Wangoh, J., Njage, P.M.K., 2014a. Current food safety management systems in fish-exporting companies require further improvements to adequately cope with contextual pressure: case study. Journal of Food Science 79, M2031-2039.

Onjong, H.A., Wangoh, J., Njage, P.M.K., 2014b. Semiquantitative analysis of gaps in microbiological performance of fish processing sector implementing current food safety management systems: a case study. Journal of Food Protection 77, 1380-1389.

Opiyo, B.A., Wangoh, J., Njage, P.M.K., 2013. Microbiological performance of dairy processing plants is influenced by scale of production and the implemented food safety management system: a case study. Journal of Food Protection 76, 975-983.

Orji, M.U., Onuigbo, H.C., Mbata, T.I., 2005. Isolation of Salmonella from poultry droppings and other environmental sources in Awka, Nigeria. International Journal of Infectious Diseases 9, 86-89.

Osés, S.M., Luning, P.A., Jacxsens, L., Santillana, S., Jaime, I., Rovira, J., 2012. Food safety management system performance in the lamb chain. Food Control 25, 493-500.

Ouaouich, A., 2007. A review of the capacity building efforts in developing countries-case study: Africa. In: Sixth World Congress on Seafood Safety, Quality and Trade, 101.

Ouma, S., 2010. Global standards, local realities: private agrifood governance and the restructuring of the Kenyan horticulture industry. Economic Geography 86, 197-222.

Panisello, P.J., Quantick, P.C., 2001. Technical barriers to hazard analysis critical control point (HACCP). Food Control 12, 165-173.

PathogenCombat, 2008. Detailed improvement roadmaps for testing of technological and managerial interventions to improve FSMS in different sectors (Ghent, Ghent University), 22 p.

Pearce, R.A., Bolton, D.J., 2005. Excision vs sponge swabbing – a comparison of methods for the microbiological sampling of beef, pork and lamb carcasses. Journal of Applied Microbiology 98, 896-900.

Phoku, J., Dutton, M., Njobeh, P., Mwanza, M., Egbuta, M., Chilaka, C., 2012. Fusarium infection of maize and maize-based products and exposure of a rural population to fumonisin B1 in Limpopo Province, South Africa. Food Additives and Contaminants: Part A 29, 1743-1751.

Ponte, S., 2007. Bans, tests, and alchemy: Food safety regulation and the Uganda fish export industry. Agriculture and Human Values 24, 179-193.

Ponte, S., Raakjær, J., Campling, L., 2007. Swimming upstream: Market access for African fish exports in the context of WTO and EU negotiations and regulation. Development Policy Review 25, 113-138.

Powell, D.A., Erdozain, S., Dodd, C., Costa, R., Morley, K., Chapman, B.J., 2013. Audits and inspections are never enough: A critique to enhance food safety. Food Control 30, 686-691.

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

Probst, C., Bandyopadhyay, R., Cotty, P., 2014. Diversity of aflatoxin-producing fungi and their impact on food safety in sub-Saharan Africa. International Journal of Food Microbiology 174, 113-122.

Probst, C., Njapau, H., Cotty, P.J., 2007. Outbreak of an acute aflatoxicosis in Kenya in 2004: identification of the causal agent. Applied and Environmental Microbiology 73, 2762-2764.

Radwan, M.A., Salama, A.K., 2006. Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food and Chemical Toxicology 44, 1273-1278.

Ramirez Vela, A., Martin Fernández, J., 2003. Barriers for the developing and implementation of HACCP plans: results from a Spanish regional survey. Food Control 14, 333-337.

Ramnauth, M., Driver, F., Vial, P.B., 2008. Food safety management in the fish industry in Mauritius: knowledge, attitude and perception. British Food Journal 110, 989-1005.

Ransom, E., 2011. Botswana's beef global commodity chain: Explaining the resistance to change. Journal of Rural Studies 27, 431-439.

Rapid Alert System for Food and Feed, 2009. *Salmonella* spp. in Nile perch from Tanzania Rapid Alert System for Food and Feed, Brussels. URL http://ec.europa.eu/food/food/rapidalert/rasff_portal_database_en.htm.

Rapid Alert System for Food and Feed, 2012. RASFF 2011 Annual report European Commision, Luxembourg. URL http://ec.europa.eu/food/food/rapidalert/docs/rasff_annual_report_2011_en.pdf.

Rapid Alert System for Food and Feed, 2014. *Salmonella* spp. in Nile perch from Tanzania Rapid Alert System for Food and Feed, Brussels. URL https://webgate.ec.europa.eu/rasff-window/portal/index.cfm?event=notificationDetail&NOTIF_REFERENCE=2014.0775.

Reardon, T., Berdegué, J.A., Timmer, C.P., Cabot, T., Mainville, D., Flores, L., Hernandez, R., Neven, D., Balsevich, F., 2005. Links among supermarkets, wholesalers, and small farmers in developing countries: conceptualization and emerging evidence. The Future of Small Farms, 45.

Reardon, T., Timmer, C.P., Barrett, C.B., Berdegue, J., 2003. The rise of supermarkets in Africa, Asia, and Latin America. American Journal of Agricultural Economics 85, 1140-1146.

Rembold, F., Hodges, R., Bernard, M., Knipschild, H., Léo, O., 2011. An innovative framework to analyse and compute quantitative postharvest losses for cereals under different farming and environmental conditions in East and Southern Africa Joint Research Centre Institute for Environment and Sustainability, Luxembourg. URL https://www.econbiz.de/Record/african-postharvest-losses-information-system-aphilis-innovative-framework-analyse-compute-quantitative-postharvest-losses-cereals-different-farming/10009556555.

Riba, A., Bouras, N., Mokrane, S., Mathieu, F., Lebrihi, A., Sabaou, N., 2010. Aspergillus section Flavi and aflatoxins in Algerian wheat and derived products. Food and Chemical Toxicology 48, 2772-2777.

RLDC, 2009. Dairy subsector developemnt strategy. URL http://eadd.wikispaces.com/file/view/RuralLivelihoodDevptCompanyDairyStrategy2009.PDF.

RLDC, NIRAS, 2010. Survey on dairy products market in Tanzania Rural Livelihood Development Company, Dar es Salaam. URL http://www.rldc.co.tz/docs/rldcdairy.pdf

Ropkins, K., Beck, A.J., 2000. Evaluation of worldwide approaches to the use of HACCP to control food safety. Trends in Food Science and Technology 11, 10-21.

Roth, E., Rosenthal, H., 2006. Fisheries and aquaculture industries involvement to control product health and quality safety to satisfy consumer-driven objectives on retail markets in Europe. Marine Pollution Bulletin 53, 599-605.

Rowell, A.E., Binkley, M., Alvarado, C., Thompson, L., Burris, S., 2013. Influence of food safety training on grocery store employees' performance of food handling practices. Food Policy 41, 177-183.

Ruteri, J.M., Xu, Q., 2009. Supply chain management and challenges facing the food industry sector in Tanzania. International Journal of Business and Management 4, 70-80.

Salo, S., Ehavald, H., Raaska, L., Vokk, R., Wirtanen, G., 2006. Microbial surveys in Estonian dairies. LWT - Food Science and Technology 39, 460-471.

Sampers, I., Jacxsens, L., Luning, P.A., Marcelis, W.J., Dumoulin, A., Uyttendaele, M., 2010. Performance of food safety management systems in poultry meat preparation processing plants in relation to *Campylobacter* spp. contamination. Journal of Food Protection 73, 1447-1457.

Sampers, I., Toyofuku, H., Luning, P.A., Uyttendaele, M., Jacxsens, L., 2012. Semi-quantitative study to evaluate the performance of a HACCP-based food safety management system in Japanese milk processing plants. Food Control 23, 227-233.

Sanlier, N., 2009. The knowledge and practice of food safety by young and adult consumers. Food Control 20, 538-542.

Sanni, L., Alenkhe, B., Edosio, R., Patino, M., Dixon, A., 2007. Technology transfer in developing countries: Capitalizing on equipment development. Journal of Food Agriculture and Environment 5, 88-91.

Sanny, M., Luning P.A., van Boekel, M.A.J.S., 2012. Variation in acrylamide concentration in french fries: Effects of control measures in food service establishments. PhD Thesis. Wageningen University, Wageningen.

Sarter, S., Sarter, G., Gilabert, P., 2010. A Swot analysis of HACCP implementation in Madagascar. Food Control 21, 253-259.

Savadogo, A., Ouattara, C., Savadogo, P., Ouattara, A., Barro, N., Traore, A., 2004. Microorganisms involved in Fulani traditional fermented milk in Burkina Faso. Pakistan Journal of Nutrition 3, 134-139.

Sawe, C.T., Onyango, C.M., Njage, P.M.K., 2014. Current food safety management systems in fresh produce exporting industry are associated with lower performance due to context riskiness: Case study. Food Control 40, 335-343.

Schillhorn van Veen, T.W., 2005. International trade and food safety in developing countries. Food Control 16, 491-496.

Schoder, D., Maichin, A., Lema, B., Laffa, J., 2013. Microbiological quality of milk in Tanzania: from Maasai stable to African consumer table. Journal of Food Protection 76, 1908-1915.

Scott, B.S., Wilcock, A.E., Kanetkar, V., 2009. A survey of structured continuous improvement programs in the Canadian food sector. Food Control 20, 209-217.

Seaman, P., 2010. Food hygiene training: introducing the food hygiene training model. Food Control 21, 381-387.

Seaman, P., 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, 278-296.

Shale, K., Lues, J., Venter, P., Buys, E., 2005. The distribution of *Staphylococcus spp.* on bovine meat from abattoir deboning rooms. Food Microbiology 22, 433-438.

Shephard, G.S., Burger, H.-M., Gambacorta, L., Gong, Y.Y., Krska, R., Rheeder, J.P., Solfrizzo, M., Srey, C., Sulyok, M., Visconti, A., 2013. Multiple mycotoxin exposure determined by urinary biomarkers in rural subsistence farmers in the former Transkei, South Africa. Food and Chemical Toxicology 62, 217-225.

Shikongo-Nambabi, M., Chimwamurombe, P.M., Venter, S.N., 2010. Factors impacting on the microbiological quality and safety of processed hake. African Journal of Biotechnology 9, 6405-8411.

Shikongo-Nambabi, M.N.N.N., Shoolongela, A., Schneider, M., 2011. Control of Bacterial Contamination during Marine Fish Processing. Journal of Biology and Life Science 3.

Shitandi, A., Sternesjö, Å.S.E., 2001. Detection of antimicrobial drug residues in Kenyan milk. Journal of Food Safety 21, 205-214.

Simon, S.S., Sanjeev, S., 2007. Prevalence of enterotoxigenic *Staphylococcus aureus* in fishery products and fish processing factory workers. Food Control 18, 1565-1568.

Sobukola, O., Adeniran, O., Odedairo, A., Kajihausa, O., 2010. Heavy metal levels of some fruits and leafy vegetables from selected markets in Lagos, Nigeria. African Journal of Food Science 4, 389-393.

Sperber, W.H., 1998. Auditing and verification of food safety and HACCP. Food Control 9, 157-162.

Stevens, A., Kaboré, Y., Perrier-Gros-Claude, J.D., Millemann, Y., Brisabois, A., Catteau, M., Cavin, J.F., Dufour, B., 2006. Prevalence and antibiotic-resistance of Salmonella isolated from beef sampled from the slaughterhouse and from retailers in Dakar (Senegal). International Journal of Food Microbiology 110, 178-186.

Stevenson, W.J., 2006. Operations management, 9th Edition. McGraw-Hill, New York, ISBN-10: 0073290947, 902 p.

Swai, E.S., Schoonman, L., 2011. Microbial quality and associated health risks of raw milk marketed in the Tanga region of Tanzania. Asian Pacific Journal of Tropical Biomedicine 1, 217-222.

Tagne, A., Kongsdal, O., Ngoko, Z., The, C., Mathur, S.B., 2003. *Fusarium pallidoroseum* in maize samples of three agro-ecological zones of Cameroon. Journal of Stored Products Research 39, 367-374.

Tanner, B., 2000. Independent assessment by third-party certification bodies. Food Control 11, 415-417.

Tanzania Standard, 1983. Milk and milk products- microbiological specifications. In Tanzania Standard (TZS) 185:1983 (Tanzania Bureau of Standards).

Tanzania Standard, 1988. TZS 402:1988. Microbiological specification for fish and fish products. Tanzania Bureau of Standards.

Tanzania Standard, 1999. Microbiological specifications for prawns, shrimps and lobsters. TZS 576:1999. (Dar es Salaam, Tanzania Bureau of Standards).

Tanzania Standard, 2009a. TZS 251:2009 (EAS 69:2006) – Pasteurized milk Specification (Dar es Salaam, Tanzania Bureau of Standards).

Tanzania Standard, 2009b. TZS 626:2009 (EAS 67:2006)-Raw cow milk specification (Dar es Salaam, Tanzania Bureau of Standards).

Tanzania Standard, 2009c. TZS 1201:2009: Gouda Cheese Specification (Dar es Salaam, Tanzania Bureau of Standards), 5 p.

Tanzania Standard, 2013. TZS 1625:2013: Cultured sour milk – Specification (Dar es Salaam, Tanzania Bureau of Standards).

Taylor, E., Kane, K., 2005. Reducing the burden of HACCP on SMEs. Food Control 16, 833-839.

Tenhagen, B.-A., Arth, O., Bandick, N., Fetsch, A., 2011. Comparison of three sampling methods for the quantification of methicillin-resistant *Staphylococcus aureus* on the surface of pig carcases. Food Control 22, 643-645.

TFDA, 2011. Guidelines for investigation and control of foodborne diseases. In TFDA/DFS/FRA/GL/001, Tanzania Food and Drugs Authority, ed. (Dar es Salaam), 78 p.

The British Retail Consortium, 2015. BRC global standard for food safety issue 7, ISBN 978-1-78490-227-8

Thorpe, A., Bennett, E., 2004. Market-driven international fish supply chains: The case of Nile perch from Africa's Lake Victoria. International Food and Agribusiness Management Review 7, 40-57.

Tirado, M., Clarke, R., Jaykus, L., McQuatters-Gollop, A., Frank, J., 2010. Climate change and food safety: A review. Food Research International 43, 1745-1765.

Todd, E.C.D., 2006. Challenges to global surveillance of disease patterns. Marine Pollution Bulletin 53, 569-578.

Tong Thi, A., Jacxsens, L., Noseda, B., Samapundo, S., Nguyen, B., Heyndrickx, M., Devlieghere, F., 2014. Evaluation of the microbiological safety and quality of Vietnamese *Pangasius hypophthalmus* during processing by a microbial assessment scheme in combination with a self-assessment questionnaire. Fisheries Science 80, 1117-1128.

Trienekens, J., Zuurbier, P., 2008. Quality and safety standards in the food industry, developments and challenges. International Journal of Production Economics 113, 107-122.

Tsegaye, M., Ashenafi, M., 2005. Fate of *Escherichia coli O157:H7* during the processing and storage of *Ergo* and *Ayib*, traditional Ethiopian dairy products. International Journal of Food Microbiology 103, 11-21.

U.S. Food and Drug Administration, 2009. Fish and fishery products. In Code of Federal Regulations, 21 CFR 123.3. Government Printing Office, Washington, DC.

UNIDO, United Republic of Tanzania, 2012. Tanzania industrial competitiveness report 2012. URL http://www.unido.org/fileadmin/user_media/Services/PSD/TanzaniaIndustrialCompetitivenessReport2012-ebook.pdf.

United Republic of Tanzania, 1981a. TZS 117: 1981. Food-handling of samples for microbiological analysis - code of practice, TBS, ed. (Dar es Salaam, Tanzania Bureau of Standards), 7 p.

United Republic of Tanzania, 1981b. TZS 124:1981. Milk and milk products – Sampling for microbiological examination, TBS, ed. (Dar es Salaam), 17 p.

United Republic of Tanzania, 2003. The Tanzania food, drugs and cosmetics act, 2003 (Dar es Salaam, Tanzania Government Printing Office), 89 p.

United Republic of Tanzania, 2009. The Standards Act No. 2 (Dar es Salaam, Tanzania Government Printing Office).

United Republic of Tanzania, 2010. Fisheries sector development programme. Ministry of Livestock and Fisheries Development, Dar es Salaam, 45 p.

United Republic of Tanzania, 2011a. The economic survey 2011. President's Office, Planning Commission, Dar es Salaam, 267 p.

United Republic of Tanzania, 2011b. Investment opportunities in the livestock industry Ministry of Livestock Development and Fisheries, United Republic of Tanzania, Dar es Salaam. URL http://www.mifugouvuvi.go.tz/wp-content/uploads/2013/06/Livestock-Investment-Opportunities.pdf.

United Republic of Tanzania, 2013. The economic survey 2012. Ministry of Finance, Dar es Salaam, 249 p.

United Republic of Tanzania, 2014. Performance audit on the management of food inspection and surveillance at processing plants and at ports of entry National Audit Office, Dar es Salaam. URL http://nao.go.tz/?wpfb_dl=116.

Unnevehr, L., 2015. Food safety in developing countries: Moving beyond exports. Global Food Security 4, 24-25.

Unnevehr, L., Hirschhorn, N., 2001. Designing effective food safety interventions in developing countries. World Bank, Washington, DC. URL http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTARD/0,,contentMDK:20439030~pagePK:210058~piPK:210062~theSitePK:336682,00.html

Unnevehr, L.J., 2000. Food safety issues and fresh food product exports from LDCs. Agricultural Economics 23, 231-240.

USAID, 2010. Staple foods value chain analysis: Country report- Tanzania. URL http://pdf.usaid.gov/pdf_docs/pa00jxx8.pdf.

Van Boxstael, S., Habib, I., Jacxsens, L., De Vocht, M., Baert, L., Van De Perre, E., Rajkovic, A., Lopez-Galvez, F., Sampers, I., Spanoghe, P., De Meulenaer, B., Uyttendaele, M., 2013. Food safety issues in fresh produce: Bacterial pathogens, viruses and pesticide residues indicated as major concerns by stakeholders in the fresh produce chain. Food Control 32, 190-197.

Van Nierop, W., Duse, A., Marais, E., Aithma, N., Thothobolo, N., Kassel, M., Stewart, R., Potgieter, A., Fernandes, B., Galpin, J., 2005. Contamination of chicken carcasses in Gauteng, South Africa, by Salmonella, *Listeria monocytogenes* and Campylobacter. International Journal of Food Microbiology 99, 1-6.

van Schothorst, M., Zwietering, M.H., Ross, T., Buchanan, R.L., Cole, M.B., 2009. Relating microbiological criteria to food safety objectives and performance objectives. Food Control 20, 967-979.

Varzakas, T.H., Arvanitoyannis, I.S., 2008. Application of ISO22000 and comparison to HACCP for processing of ready to eat vegetables: Part I. International Journal of Food Science and Technology 43, 1729-1741.

von Holy, A., 2004. HACCP hassle for small businesses. South African Food Review 31, 33-34.

von Holy, A., 2005. The application of HACCP in small and less developed businesses. In: A farm-to-table approach for emerging and developed dairy countries, Rome, 167-174.

Warth, B., Parich, A., Atehnkeng, J., Bandyopadhyay, R., Schuhmacher, R., Sulyok, M., Krska, R., 2012. Quantitation of mycotoxins in food and feed from Burkina Faso and Mozambique using a modern LC-MS/MS multitoxin method. Journal of Agricultural and Food Chemistry 60, 9352-9363.

WB, 2005. Food safety and agricultural health standards: challenges and opportunities for developing country exports World Bank. URL http://siteresources.worldbank.org/INTRANETTRADE/Resources/Topics/Standards/standards_challenges_synthesisreport.pdf.

Weatherspoon, D.D., Reardon, T., 2003. The rise of supermarkets in Africa: implications for agrifood systems and the rural poor. Development Policy Review 21, 333-355.

WHO, 2007. Food safety and foodborne illness. URL http://www.who.int/mediacentre/factsheets/fs237/en/.

Wilcock, A., Ball, B., Fajumo, A., 2011. Effective implementation of food safety initiatives: Managers', food safety coordinators' and production workers' perspectives. Food Control 22, 27-33.

Witthuhn, R., Engelbrecht, S., Joubert, E., Britz, T., 2005. Microbial content of commercial South African high-moisture dried fruits. Journal of Applied Microbiology 98, 722-726.

World Bank, 2005. Food safety and agricultural health standards: challenges and opportunities for developing country exports World Bank. URL http://siteresources.worldbank.org/INTRANETTRADE/Resources/Topics/Standards/standards_challenges_synthesisreport.pdf.

Yapp, C., Fairman, R., 2006. Factors affecting food safety compliance within small and medium-sized enterprises: implications for regulatory and enforcement strategies. Food Control 17, 42-51.

Yilma, Z., Faye, B., Loiseau, G., 2007. Occurrence and distribution of species of Enterobacteriaceae in selected Ethiopian traditional dairy products: A contribution to epidemiology. Food Control 18, 1397-1404.

Zaied, C., Abid, S., Zorgui, L., Bouaziz, C., Chouchane, S., Jomaa, M., Bacha, H., 2009. Natural occurrence of ochratoxin A in Tunisian cereals. Food Control 20, 218-222.

Zinedine, A., Brera, C., Elakhdari, S., Catano, C., Debegnach, F., Angelini, S., De Santis, B., Faid, M., Benlemlih, M., Minardi, V., 2006. Natural occurrence of mycotoxins in cereals and spices commercialized in Morocco. Food Control 17, 868-874.

Zinedine, A., Juan, C., Idrissi, L., Mañes, J., 2007a. Occurrence of ochratoxin A in bread consumed in Morocco. Microchemical Journal 87, 154-158.

Zinedine, A., Juan, C., Soriano, J.M., Moltó, J.C., Idrissi, L., Mañes, J., 2007b. Limited survey for the occurrence of aflatoxins in cereals and poultry feeds from Rabat, Morocco. International Journal of Food Microbiology 115, 124-127.

Zinedine, A., Mañes, J., 2009. Occurrence and legislation of mycotoxins in food and feed from Morocco. Food Control 20, 334-344.

Zinedine, A., Soriano, J.M., Juan, C., Mojemmi, B., Molto, J.C., Bouklouze, A., Cherrah, Y., Idrissi, L., Aouad, R.E., Manes, J., 2007c. Incidence of ochratoxin A in rice and dried fruits from Rabat and Sale area, Morocco. Food Additives and Contaminants 24, 285-291.