Effect of post-slaughter handling on physico-chemical and microbiological quality of red meat along the distribution chain in the Eastern Cape Province, South Africa.

By

RANI, Zikhona Theodora

A thesis submitted in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN ANIMAL SCIENCE

Department of Livestock and Pasture Science

Faculty of Science and Agriculture

University of Fort Hare

University of Fort Hare
Together in Excellence

Alice, South Africa

Promoter: Prof Voster Muchenje

Co- Promoters: Prof Celia Hugo and Prof Arno Hugo

Notes

This thesis is presented in the format prescribed by the Department of Livestock and Pasture Science at the University of Fort Hare. It is structured to form several chapters (Papers submitted to different journals) and is prefaced by an introduction chapter with the study objectives, followed by a literature review and concluded with a chapter containing the general discussion and recommendations.

Language, style and referencing format used are in accordance with the requirements of the Department of Livestock and Pasture Science. This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetition between chapters has therefore been unavoidable.

Results from the study have been presented at the following symposia:

1. **Zikhona T. Rani, George Charimba, Celia J. Hugo, and Voster Muchenje.** Microbial contamination at different stages of the distribution chain in the Eastern Cape Province, South Africa. Article presented at the 61st International Congress of Meat Science and Technology, 23-28 August 2015, Clermont-Ferrand, France.

2. **Zikhona T. Rani and Muchenje, V.** Consumers and meat handler's perceptions on meat quality and safety along the distribution chain. Poster presented at the 47th South African Society for Animal Science Congress in Empangeni, Kwa-Zulu Natal Province, **21 – 23 September 2015**.

Articles prepared for publication:

1. **Zikhona T. Rani, Arnold Hugo, Celia J. Hugo, Vimiso Peter and Voster Muchenje, V.** Effect of post-slaughter handling and the distribution chain on the microbiological quality and safety of meat in the formal and informal sector in South Africa: A review. Submitted to the *South African Journal of Animal Science* (Under review).

2. **Zikhona T. Rani and Muchenje, V.** Consumers and meat handler's perceptions on meat quality and safety along the distribution chain. Submitted to Asian- Australasian *Journal of Animal Sciences* (Under review).

3. **Zikhona T. Rani and Muchenje, V.** Physico-chemical quality of red meat during the distribution of carcasses from the abattoir to the retailers. Submitted to CyTA – Journal of Food (Under review).

4. **Zikhona T. Rani, George Charimba, Celia J. Hugo, Arnold Hugo and Voster Muchenje, V.** Microbial profiles of red meat at different stages of the abattoir to retail outlets distribution chain. Submitted to *Journal of Food Safety.* (Under review).

5. **Zikhona T. Rani, George Charimba, Celia J. Hugo Arnold Hugo and Voster Muchenje, V.** Vacuum packing and overwrapping effects during marketing on shelf-life and microbiological quality of red meat. Submitted to *Food Packaging and Shelf-Life Journal* (Under review).

Declaration

I, **Rani Zikhona Theodora,** declare that this dissertation has not been submitted to any University and that it is my original work conducted under the supervision of Prof Voster Muchenje. The research was approved by the University of Fort Hare Research Ethics Committee (Certificate No: **UFH/UREC, MUC0101SRAN01**). All assistance towards the production of this work and all the references contained herein have been duly credited.

RANI Zikhona Theodora   Date: 26 January 2016

(Signature)

Approved as to style and content by:
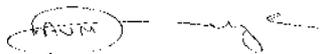
Prof Voster Muchenje
(Promoter)

Abstract

The effect of post-slaughter handling in the distribution chain on red meat quality and

safety in the Eastern Cape Province, South Africa

The broad objective of the study was to investigate the effect of post-slaughter handling in the distribution chain on red meat quality and safety. A survey was conducted among 300 consumers and 100 meat handlers in five different municipalities (Buffalo City, Nkonkobe, Ngqushwa, Lukhanje and Amahlathi) in the Eastern Cape Province of South Africa to investigate their perceptions on meat quality and safety, together with challenges faced by meat handlers during the distribution of meat from the abattoir to retailers. The microbiological profile and physico-chemical quality of red meat at different stages of the abattoir to retail outlets in the distribution chain were also determined. Swabs (n=216) and meat samples (n=450) were collected from beef, pork and mutton carcasses during the loading process of carcasses into trucks at the abattoir, when offloading carcasses at the supply points and during marketing. Physico-chemical qualities such as colour (L* - lightness, b* - redness and a* - yellowness) and meat pH measurements were taken at each point. To determine the microbiological profiles of the carcasses, four microbiological parameters were considered: Total bacteria count (general bacteria), coliform count (related to hygiene and indicator for pathogens), *Escherichia coli* (Gram-negative pathogen) and *Staphylococcus aureus* (Gram-positive pathogen). Two types of packaging (vacuum and overwrapping) were used to determine their effect on shelf-life and microbiological quality of red meat under the normal marketing conditions over a storage duration of 15 days. The results from the study showed low awareness of consumers about the pathogenic diseases which arise from meat. A strong significant association ($p < 0.05$) between educational status and awareness on meat safety was observed. Most of the consumers perceived that quality goes beyond safety such that 35.6% of the respondents indicated that they did not have a problem with consuming spoiled meat, whilst the remaining 64.4 % indicated that they would

reject spoiled meat. Although retailers indicated that they take meat safety into consideration in their shops, 92% of the retailers revealed that they do not perform microbial assessment of meat in their shops. A series of loading and off-loading, temperature fluctuations, environmental temperatures and ques during offloading were reported as the major challenges during transportation of carcasses from the abattoir to the supply points. The microbial counts were significantly (p<0.05) higher in samples from the commercial abattoir than in those from the communal abattoir. *Escherichia coli* was the predominant microbial contaminant in the samples from both abattoirs. When following the chain, total bacterial count (TBC), coliform count (CC) and the levels of *E. coli* contamination increased progressively between the loading and the off-loading points (5.1 to 7.9 log10 CFU/cm^2; 5.0 to 5.6 log10 CFU/cm^2 and 2.7 to 3.7 log10 CFU/cm^2, respectively). The storage period, meat type, distance during transportation and temperature were found to have a significant impact on the microbial levels during the distribution of carcasses. Distribution stage had a significant effect (p<0.05) on some of the physico- chemical meat quality attributes and differences in the lightness (L*) and redness (a*) values between the loading, off-loading and display points were observed. Consumers perceived retailer class as one of the factors influencing meat quality, but according to the instrumental measurements retailer class did not have a significant effect on physico-chemical meat quality. However, distance and storage duration significantly (p<0.05) affected (L*) and (a*) values in the meat during distribution chain. Vacuum and overwrapping packaging significantly affected (p<0.05) the shelf life of meat. Therefore, it was concluded that post-slaughter handling during the distribution chain affects the physico- chemical, microbiological and shelf-life of meat.

Keywords: Meat safety, meat quality, consumer perceptions, meat handler's perceptions, distribution chain, storage duration, ultimate pH, *E. coli*

Dedication

I dedicate this thesis to my late mom; Nikiwe Eubertha Rani. Today I have fulfilled your dream. Thank you for being the best mom that anyone could ever ask for. Though you did not manage to finish this journey with me, but thank you for taking the first steps with me. All that you ever wanted was for me to get educated and to be able to stand on my own. Thank you for giving me the key to life. How I wish that you were here to share these joyful moments with me, I will forever be grateful to you "Maniki" for the life that you have given me; always.

Acknowledgements

When I lost my mom, I nearly thought that it was the end of my journey. God intervened; you were my pillar and my everything. You gave me power, strength and inspiration to pursue my study and finish in record time. I could not ask for more, thank you for protecting me, through thick and thin you protected me. You provided me with everything that I needed to finish this journey and I would like to thank the following individuals whom you have blessed me with for the role that they have played and their contribution towards my studies:

- ❖ Prof. Voster Muchenje, "I do not know on how I can thank you. My journey with you started from when I was still an undergraduate student till today, you have been a part of my life. We've had our own differences but through it all, I always knew that I have your support. "Thank you Prof, for walking this journey of an academic life with me and for grooming me to become a better person. Wherever I go, I will always thank God for blessing me with such a character in my life. You have been the best supervisor that anyone could ever ask for. I will forever be grateful to you for all the support. The skills that I have acquired under your mentorship have developed me into a better researcher. Your ability to work with people from different backgrounds is so impressive". I have learnt a lot from you. May the Lord continue to give you the strength.

- ❖ To my late supervisor "Dr Maphosa", after finishing my Masters, you are one of the few people who encouraged me to pursue with my studies and register for PhD. You told me that I should always aim for the best. Thank you for influencing me to come back to school "Doc", may your soul rest in peace.

- ❖ The UFS team, Prof Celia and Prof Arnold Hugo, Dr George Charimba "thank you for your kindness, support, assistance and valuable contribution towards my work. A special thanks also goes to the DHL team, especially Ms Dloko and Phiwe for their

❖ My special friends who were there to give me the emotional support when in need; and to all the members of the Livestock and Pasture Science Department, thank you for the beautiful moments that we have shared even those who have shared even a minute with me during this period.

❖ My grandma "Mamiya", thank you for your greatest philosophies". Ms Nonceba, Mr Luvo Rani, Mr Nqanqase, my cousins and the rest of my family "Die Rani's" "AmaNtande,oDlomo,"oSophitsho",oHala, Ozondwa-zintshaba bengaz 'ukwenzanto" for the love that you have given me. You guys have made me to realise the importance of having a family".

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

a* - Redness

b*- Yellowness

CC - coliform count

CL% - Cooking loss percentage

E.coli- Escherichia coli

HUE- HUE angle

L*- Lightness

PEC- Presumptive *E.coli*

SAS - Statistical Analysis System

S. aureus- Staphylococcus aureus

T°C – Temperature

TBC - Total Bacteria
Count

WBSF – Warner Braztler Shear Force

Chapter 1: General Introduction

1.1 Background of the study

The popularity and consumption rate of red meat among South Africans has been increasing over the years and it is not expected to decrease in the near future (Schönfeldt and Gibson, 2008). Meat consumption per capita in South Africa in 2009 was 3.7 kg of mutton, 4.1kg of pork and 16.7 kg of beef (NDA, 2010). Recently it has increased to 3.9 kg of mutton, 4.4 kg of pork and 17.9 kg of beef (Meissner *et al.,* 2013). Kearney (2010) and Delgado *et al* (2000) stated that as the standard of living improves, meat consumption also increases. At the same time, consumers continue to demand meat of high eating quality and consumer demands have to be met by producers in order to maintain profitability (Troy and Kerry, 2010; Grunert, 2006). The increasing demand for high quality meat in South Africa means that more meat has to be handled and transported. The Department of Health (DoH), Department of Trade and Industry (DTI), Department of Agriculture, Forestry and Fisheries (DAFF, 2013) and the South African Meat Industry Company (SAMIC, 2006) identified meat handling as one of the major challenges which compromise food safety. Improper handling of carcasses may lead to the development and transfer of pathogenic and spoilage micro-organisms to meat which have resulted in illnesses and deaths after consumption. In addition to this, great economic losses have occurred as a result of product contamination. Therefore, continuous efforts to improve the manner in which food is handled and processed are encouraged. Hygienic handling of carcasses after slaughter is critical for prevention of contamination and to ensure meat safety.

Bryhni *et al*. (2002) stated that as time goes on consumers will continue to demand meat of high eating quality and meat that is safer. The National Department of Agriculture (NDA, 2010) highlighted that judging from the contribution or role that the meat industry has played in the economy of South Africa, it has become increasingly important to optimally align the

quality of food with consumer demands, expectations, and desires. Therefore, role players in the meat supply chain should be encouraged to continue finding ways of delivering meat of high eating quality and meat that is safer as consumer demands radically change with time (Grunert *et al*., 2004). This is a challenge to the meat traders as the meat goes through a number of channels before it gets to the shelves during which its quality could easily be negatively impacted. Richardson *et al*. (2009) refers to this as a distribution chain and whether a retailer is a farmer and produces for himself, the animals have to be slaughtered in an abattoir to cater for the animal welfare issues and follow the distribution chain. However, these challenges have not been addressed in most studies. The majority of research that has been conducted has highlighted several pre-slaughter processes that affect meat eating quality at the farm (Ferguson and Warner, 2008; Grandin and Smith, 2000), during transportation of animals to the abattoir (Chulayo and Muchenje, 2013; Gajana, Nkukwana, Marume, and Muchenje, 2013; Vimiso and Muchenje, 2013), the immediate pre-slaughter period (Miranda-de la Lama *et al.*, 2009, 2012; Muchenje *et al*., 2009; Adzitey, 2011; Njisane and Muchenje, 2013) and the slaughtering process (Mpakama, Chulayo, and Muchenje, 2014).

However, it should be noted that most researchers have neglected the processes that occur after slaughter which affect the quality of meat especially during the distribution of meat to retailers, yet the distribution chain is considered to be a crucial aspect in the meat industry because it includes various critical stages which could affect physico-chemical and microbiological quality of meat before the product reaches the shelves. Although there are some studies which have focussed on the microbiological quality of meat after slaughter to cater for meat safety (Gill, Mc Ginnis and Badoni, 1996; Bell, 1997; Gill *et al*., 1998; Adzitey *et al*., 2011; Adzitey and Huda, 2012; Niyonzima *et al*., 2013), research on post-slaughter factors affecting the physico-chemical and microbiological quality of meat during

distribution of carcasses from the abattoir to retail point in South Africa has not been conducted.

A distribution channel is the network of individuals and organizations involved in the process of moving a product or service from the producer to the end user (National Food Processors Association, 1995). The major focus of the distribution channel is to try and maintain product quality and lengthen the shelf life of the product for it to reach the consumer in the state that they would want the consumer to get it in. Should quality be affected, it will have an influence on consumer's acceptability and profits to be realized by producers, processors and retailers (Warriss, 2000; Adzitey, 2011). For the consumers to purchase meat of high eating quality, meat traders/ handlers need to understand the factors that influence quality (Vimiso *et al*., 2012). In the meat chain, a great number of post-slaughter factors influence the intrinsic quality of meat (Rosenvold and Andersen, 2003). Transportation (distance and temperature); type of packaging used; storage and display conditions (refrigeration and retention length); and bacterial growth contribute significantly to the quality of meat and its shelf life. Transportation of the product to retail outlets and storage has been frequently reported to be a weak link in the chain (Bsgh-Sorensen and Olsson, 1990; Gormley, 1990). If storage temperatures are not properly monitored contamination of carcasses might occur (Gill, 1996). It is therefore important that research on the quality of meat at each stage of distribution chain be conducted, so as to monitor properly as to which stage of the distribution chain is the most critical the most. Also it is crucial that meat handlers at each stage of the distribution chain are interviewed so that the meat industry can be aware of some of the challenges that they might be facing when distributing meat and some improvements that can be made when handling carcasses throughout the supply chain. Therefore, the main objective of this research was to determine the effect of post-slaughter handling in the distribution chain on red meat quality and safety in the Eastern Cape Province, South Africa.

1.2 Justification

In South Africa, illnesses and deaths related to food consumption continue to be reported. In addition to the misery caused, financial loss associated with meat spoilage and food borne illnesses is enormous. Preventing contamination of meat with food-borne pathogens before contaminated foods can be consumed is therefore an essential feature of safeguarding public health. Therefore this project will assess the possibility of contamination with pathogenic and spoilage micro-organisms at each stage of the distribution chain and how they affect meat quality and safety. Microbiological analyses of carcasses from the abattoir following the distribution chain can help identify possible modes of contamination and this will help the responsible authorities to take appropriate steps to improve meat safety not only in abattoirs but also at retail points. This will also help by bringing different players in the value chain together, strengthen their relationship so as to improve the quality of the meat that they produce. It will also drive the meat inspectors to see the importance of building good relationships not only with abattoirs but also with the retailers by conducting meat inspection at all stages of the distribution chain.

Smith and Riethmuller (2000) stated that, although the meat supply chains always appear to be safer and better controlled, it appears that consumers' are not sure or aware about the safety and quality of their food. Consumers are often faced with difficulties in evaluating the safety of meat and its products, even after consumption (Van Wezemael *et al*., 2010). This project will investigate the awareness of consumers on some health risks when buying meat as well as meat handlers when distributing meat. Meat handlers' perceptions on the distribution chain and meat quality are important since they are responsible for selling the product to the consumer at the end of the chain. The novelty of the study is that it is the first of its kind where the quality of meat at each stage of distribution chain will be followed and where meat traders or distributors will be interviewed on challenges that they face during

distribution in the Eastern Cape Province. Better knowledge on which stage of the distribution chain do pathogenic and spoilage micro-organisms develop the most and whether the quality of meat could be affected by retailer class, can help the meat industry to come up with new strategies for improvement. Understanding consumers and meat handlers' perceptions on food safety and quality practices is helpful in reducing food-borne illness and to promote products with better eating quality.

1.3 Objectives of the study

The broad objective of the study was to investigate the effect of post-slaughter handling in the meat distribution chain on meat quality and safety in the Eastern Cape Province of South Africa. Specific objectives were to:

- determine consumer and meat handlers' perceptions on meat quality and safety along the distribution chain;

- determine microbial profiles of red meat at different stages of the abattoir to retail outlets distribution chain;

- determine the physico-chemical quality of red meat during the distribution of carcasses from the abattoir to the retailers ;

- determine how different types of packaging used during marketing affect the shelf-life and microbiological quality of red meat.

1.4 Hypotheses of the study

The null hypothesis tested was that post- slaughter handling does not have an effect on meat quality and safety during the meat distribution chain in the Eastern Cape Province of South Africa. The specific hypotheses tested were the following:

- consumer and handlers' perceptions on meat quality and safety along the distribution chain are similar;

- there are no differences in the microbial profiles of red meat at different stages of the abattoir to retail outlets distribution chain;

- there are no differences in the physico-chemical quality of red meat during the distribution of carcasses from the abattoir to the retailers;

- different types of packaging used in different shops do not have an effect on the microbiological quality and shelf-life of red meat during marketing.

1.5 References

Adzitey, F. 2011. Effect of pre-slaughter animal handling on carcass & meat quality. *International Food Research Journal*, **18:** 484 - 490.

Adzitey, F. and Huda, N. 2012. Effects of post-slaughter carcass handling on meat quality. *Pakistan Veterinary Journal*, **32:** 161–164.

Adzitey, F., Teye, G. A. and Dinko, M. M. 2011. Pre and post-slaughter animal handling by butchers in the Bawku municipality of the Upper East Region of Ghana. *Pakistan Veterinary Journal*, **39:** 177–184.

Bell, R.G. 1997. Distribution and Sources of Microbial Contamination on Beef Carcasses. *Journal of Applied Microbiology* **8:** 292–300.

Bogh-Sorensen, L. and Olsson, P. 1990. The chill chain. In Chilled Food: The State of the Art, ed. T. R. Gormely, Elsevier Applied Science, New York, pp. 245-67.

Bryhni, E.A., Byrne, D.V., Rødbotten, M., Claudi-Magnussen, C., Agerhem, H. and Johansson, M. 2002. Consumer perceptions of pork in Denmark, Norway and Sweden. *Food Quality Preference,* **13:** 257-266.

Chulayo, A.Y. and Muchenje, V.2013. Effect of pre-slaughter conditions on physico-chemical characteristics of mutton from three sheep breeds slaughtered at a smallholder rural abattoir. *South African Journal of Animal Science,* **43**(5-Suppl.1): S64-S68.

Delgado, C., M.W. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois. 2000. Livestock to 2020: The next food revolution. International Meat Secretariat Newsletter, No. 24, January 2000.

Department of Health (DoH), Department of Trade and Industry (DTI), & Department of Agriculture, Forestry and Fisheries (DAFF) 2013. Food safety and food control

in South Africa: specific reference to meat labelling. Government Printers, Pretoria.**Ferguson, D. M. and Warner, R. D**. 2008. Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants? *Meat Science*, **80:** 12-19.

Ferguson, D.M. and Warner, R.D. 2008. Have we underestimated the impact of pre-slaughter stress on meat in ruminants? *Meat Science* **80:** 12-19**.**

Gajana, C.S., Nkukwana, T.T., Marume, U. and Muchenje, V. 2013. Effects of transportation time, distance, stocking density, temperature and lairage time on incidences of pale, exudative (PSE) and the physicochemical characteristics of pork. *Meat Science,* **95:** 520-525.

Gill, C. O. 1996. Extending the storage life of meats. *Meat Science*, **43:** 99–109.

Gill, C.O., Mc Ginnis, J.C. and Badoni, M. 1996. Assessment of the hygienic characteristics of a beef carcass dressing process. *Journal of Food Protection,* **59:** 136 –140.

Gill, C.O., Mc Ginnis J.C. and Bryant, J.1998. Microbial contamination of meat during the skinning of beef carcass hindquarters at three slaughtering plants. *International Journal of Food Microbiology*. **42:** 175 –184.

Gormley, T. R. 1990. Temperature monitoring of chilled foods during air and road freighting. In Processing and Quality of Foods, Vol. 3, Chilled Foods, eds. P. Zeuthen, J. C. Cheftel C. Eri2ksson, T. R. Gormley, P. Link0 8s K. Paulus. Elsevier Applied Science, London. pp. 3.248-3.255.

Grandin, T., and Smith, G. C. 2000. Animal welfare and humane slaughter. In *Encyclopedia of life support systems (EOLSS)* (pp. 1–50). Developed under the auspices of the UNESCO, Eolls Publishers: Paris, France.

Grunert, K. G. 2006. How changes in consumer behaviour and retailing affect competence requirements for food producers and processors. *Economia Agraria y Recursos Naturales*, **6:** 3-22.

Grunert, K. G., Bredahl, L. and Brunsø, K. 2004**.** Consumer perception of meat quality and implications for product development in the meat sector: A review. *Meat Science,* **66:** 259-272.

Kearney, J. 2010. Food consumption trends and drivers. *Philosophical transactions of the royal society B: biological sciences*, **365:** 2793-2807.

Meissner, H. H., Scholtz, M. M. and Palmer, A. R. 2013. Sustainability of the South African Livestock Sector towards 2050 Part 1: worth and impact of the sector. *South African Journal of Animal Science*, **43:** 282-297.

Miranda-de la Lama, G. C., Villarroel, M., Olleta, J. L., Alierta, S., Sanudo, C., and María, G. A. 2009. Effect of the pre-slaughter logistic chain on meat quality of lambs. *Meat Science*, **83 :** 604–609.

Miranda-de la Lama, G. C., Leyva, I. G., Barreras-Serrano, A., Pérez-Linares, C., Sánchez-López, E., María, G. A., and Figueroa-Saavedra, F. 2012. Assessment of cattle welfare at a commercial slaughter plant in the northwest of Mexico. *Tropical Animal Health and Production*, **44:** 497–507.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P.E., and Raats, J. G. 2009. Relationship between pre-slaughter stress responsiveness and beef quality in three cattle breeds. *Meat Science*, **81:** 653–657.

Mpakama, T., Chulayo, A.Y. and Muchenje, V. 2014. Bruising in slaughter cattle and its relationship with creatine kinase levels and beef quality as affected by animal related factors. *Asian Australasian Journal of Animal Science,* **5:** 717 - 725.

National Department of Agriculture (NDA), 2010. Agricultural Marketing strategy for the Republic of South Africa. Department of Agriculture, Forestry and Fisheries, Republic of South Africa.

National Food Processors Association, 1995. HACCP: Establishing Hazard Analysis Critical Control Point Programs, A Workshop Manual (Stevenson, K.E., and D.T. Bernard, Eds). The Food Processors Institute, Washington, DC.

Niyonzima, E., Bora, D., and Ongol, M. P. 2013. Assessment of beef meat microbial contamination during skinning, dressing, transportation and marketing at a commercial abattoir in Kigali city, Rwanda. *Pakistan Journal of Food Science*, **23:** 133–138.

Njisane, Y.Z. and Muchenje, V. 2013. Quantifying avoidance-related behaviour and bleeding times of sheep of different ages, sex and breeds slaughtered at a municipal and commercial abattoirs. *South African Journal of Animal Science,* **43:** 39-42.

Rosenvold, K. and Andersen, H.J. 2003. Factors of significance for pork quality. A review. *Meat Science*, **64:** 219-237.

Richardson, M., Matthews, K., Lloyd, C. and Brian, K. 2009. Meat quality and shelf life. EBLEX, Agriculture and Horticulture Development Board (AHDB).

SAMIC, 2006. South African Meat Industry Company. Classification of South Africa Beef - a Key to Consumer Satisfaction. South African Meat Industry Company, Pretoria, South Africa.

Schönfeldt, H. C. and Gibson, N. 2008. Changes in the nutrient quality of meat in an obesity context. *Meat Science*, **80:** 20-27.

Smith, D. and Riethmuller, P. 2000. Consumer concerns about food safety in Australia and Japan. *British Food Journal*, **102:** 838-855.

Troy, D. J. and Kerry, J. P. 2010. Consumer perception and the role of science in the meat industry. *Meat Science*, **86:** 214-226.

Van Wezemael, L., Verbeke, W., de Barcellos, M. D., Scholderer, J. and Perez-Cueto, F. 2010. Consumer perceptions of beef healthiness: results from a qualitative study in four European countries. *BMC Public Health*, **10**: 342.

Vimiso, P., Muchenje, V., Marume, U. and Chiruka, R. 2012. Preliminary study on consumers and meat traders perceptions of beef quality and how the beef quality is affected by animal welfare practices, *Scientific Research and Essays,* **22:** 2037-2048.

Vimiso P. and Muchenje, V. 2013. A survey on the effect of transport method on bruises, pH and colour of meat from cattle slaughtered at a South African commercial abattoir. *South African Journal of Animal Science*, **43:** 105–111.

Warriss, P.D. 2000. Meat science: An introductory text. CAB International, Cambridge University Press, Cambridge, pp: 1-223.

Chapter 2: Literature Review

(Parts of this section are under review in South African Journal of Animal Science)

2.1 Introduction

Global reports on illnesses and deaths related to food consumption continue to be a scare in most countries. This has 'led to continued efforts in improving the way in which food is handled and processed. Hygienic handling of carcasses after slaughter is critical for prevention of contamination and to ensure meat safety. Dave and Ghaly (2011) stated that meat is a perishable food and a health risk if not handled properly. Improper handling of meat may result in growth of foodborne bacterial pathogens which have been identified as a major challenge to food safety. These micro-organisms might be pathogenic and may result in having serious negative effects on human health. They include *Salmonella, Staphylococcus aureus, Clostridium botulinum, Clostridium perfringens, Listeria monocytogenes, E coli 0157Hl,* shiga toxin producing strains, *Bacillus cereus* and diarrheagenic *Escherichia coli* (Hobbs and Roberts, 1993). A recent government-commissioned report on the South African meat inspection system estimates the cost to the economy in medical, legal, other expenses, and absenteeism from work and school resulting from food-borne disease amount to billions of Rands annually and further recommends a review of meat safety risk management systems and quality assurance practices (Department of Health [DoH], Department of Trade and Industry [DTI], Department of Agriculture, Forestry and Fisheries [DAFF, 2013]). Therefore, continuous efforts to improve food safety systems are encouraged.

Nowadays, research should focus on a farm to fork approach whereby the technological and microbiological quality of meat will be dealt with from the production stage to consumption stage and there are many aspects that are involved. It involves how the animal was raised, transported, pre-slaughter logistics, the slaughtering in an abattoir, distribution, handling at purchasing points and consumption. In all these stages assurance of meat safety and quality

are of paramount importance but for most consumers, quality goes beyond safety (McDonald and Sun, 1999). The meat which is sold to the consumers in South Africa is derived from commercial farmers through the commercial abattoirs where meat handling is strictly governed by the Meat Safety Act of 2000. Despite the fact that most regulations which are set to protect consumer health are followed in most abattoirs, the problem of meat hygiene and safety due to handling and processing of meat still remains a challenge. To ensure that meat which is supplied to the retailers is of good quality and to cater for meat safety, abattoirs hire meat inspectors who legally approve meat for consumption. The unfortunate part is that meat inspection is typically only carried out at the abattoir, yet the distribution stage is the most critical stage during which the quality of meat could easily be compromised. This could possibly allow foodborne pathogens to enter the distribution chain. Furthermore, the meat inspection audit at the abattoir only covers the visual inspection without considering the microbiological tests. Meeting food safety requirements set by the government remains a challenge to almost all food processors. This review covers the impact of post slaughter handling on carcass quality and its implications on meat safety and quality during the distribution stage.

2.2 **Meat Safety and consumer's attitudes towards meat safety**

Food safety is one of the major issues in marketing any kind of food, especially meat. The industry is currently adopting a farm to fork philosophy where it is recognized that minimising contamination, requires all parties to participate (Barbut, 2005). Food safety is an important issue that affects anyone who consumes food. One of the most popular issues of food safety is the outbreak of food borne diseases, or commonly known as food poisoning. Food poisoning is caused by the intake of food which is contaminated with dangerous bacteria (pathogens) or toxins. Sofos (2007) highlighted that most meat safety issues resulting in immediate consumer health problems and recall from the market place of potential

contaminated products are associated with bacterial pathogens. Meat safety during processing, packaging, sorting, transporting, displaying, selling, cooling, serving and eventually consumption ideally should be constantly under tight scrutiny by government officials, food processors, food handlers, food providers and the consumers themselves (Hui *et al*., 2001). The safety of meat and meat products is controlled when proper hygiene practices are being applied throughout the food chain and proper implementation of decontamination interventions inside the meat processing plants (Manios *et al*., 2015). The safety of meat should be ensured by controlling the food chain from the farm of origin, inspection of the carcass before and after slaughter, handling and storage of meat and by protecting the product until it is time for consumption. The National Department of Agriculture (2000) published the Meat Safety (Act No 40 of 2000) which states that there should be measures that provide meat safety and safety of animal products; preservation of vital national standards in respect of South African abattoirs; to regulate the importation and exportation of meat; establishing meat safety schemes; and also to provide matters linked therewith.

Due to rapid technological advancements, consumers in all ages are able to access any information almost instantly. Today's consumers are better educated and hence, more updated about issues regarding food safety as compared to those in the past. Nowadays, a number of factors are taken into consideration when deciding on a purchase. Besides the price of the product, factors such as appearance, convenience, and perceived quality as well as safety influenced the decisions made in the marketplace. Hence, consumers are leaning towards food products that benefit their well-being. Liana *et al.* (2010) reported that this phenomenon has also been found in Malaysia where consumers are now demanding food products which are safe and are of good quality at a reasonable price. However, although specific concern may vary between countries, it is clear that "safety" is becoming an

important issue to consumers in making purchasing decisions, resulting in an effect on future consumption levels. It is supported by the Food, Marketing Institute (FMI), which found that 69 % of consumers considered product safety as a very important factor in food selection (FMI, 1994). In South Africa, there is no sufficient data available which reveals the perceptions of consumers towards meat safety.

Ensuring the safety of food is a shared responsibility among producers, industries, government, and consumers. Moreover, there is a need for improved physical, biological and economical data on safety of meat to be available to consumers, producers, processors and regulators. This data will enable all stakeholders to analyse and comprehend the state and trend of food safety in the country. An understanding of the factors that determine consumer perception of a product's value or cost is of crucial importance to an industry's product innovation, choice of marketing and communication strategy and maintenance of competitive advantage (Jongen and Meulenberg, 1998).

2.3 Microbial organisms which indicate levels of microbial contamination in meat

The safety of raw meat products can be estimated based on indicator organism including total bacteria count (TBC), and coliform count TCC (Barros *et al.*, 2007). TBC gives a quantitative idea about the presence of microorganisms such as bacteria, yeasts and moulds in samples. The coliform bacteria group consists of several genera of bacteria within the family *Enterobacteriaceae*. Total coliforms are a group of bacteria that are widespread in nature. All members of the total coliforms group can occur in human faeces, but some can also be present in animal manure, soil, sub-merged wood and in other places outside the human body. Faecal coliforms are good indicators of contamination from human or other animal waste products and they indicate greater risk of exposure to pathogenic organisms than total coliforms (Moore and Griffith, 2002). Control measures that reduce the bacterial load will reduce the risk of pathogenic bacteria on meat.

15

2.4 Post slaughter carcass handling

Abattoirs are regulated by laws to ensure good standards of hygiene, the prevention of the spread of disease and the minimization of needless animal cruelty (Grandin and Smith, 2000). The way of slaughtering and handling of carcasses plays an important role in product quality and shelf-life of meat and meat products. Adzitey and Huda (2012) reported that poor carcass quality will definitely reflect in poorer meat quality. Meat quality is defined as the most critical factor in a highly competitive meat industry where its profit lies (Robles *et al*., 2009). Most researchers define it on the basis of its conformational and functional qualities (Lawrie and Ledward, 2006; Muchenje *et al*., 2008; Warris, 2000). Important technological meat quality attributes include colour, marbling, pH, tenderness, juiciness and flavour (Bredahl *et al*., 1998; Muchenje *et al.,* 2009) and should these be affected, then profitability will also be affected negatively (Grunert *et al*., 2004).

Since consumers demand meat of high eating quality, there are different approaches which have been used to improve the quality of meat. The approaches that have been used to improve meat quality include the breeding aspect (De Vries *et al*., 1994; Hermesch, 1997), nutritional/feeding strategy (Andersen *et al*., 2005; Field *et al.,* 1990; Priolo *et al*., 2001), animal welfare during transportation (Appleby and Hughes, 1997), and at slaughter (Muchenje *et al*., 2008). However, it is important to note that even after slaughter there are still many post-slaughter practices which significantly contribute to the quality of meat which in turn affect profits, functional properties, eating qualities and the acceptance of the meat by consumers (Adzitey and Huda, 2012). These post-slaughter practices include the way in which the carcass is handled after slaughter, chilling, and other factors. Although some of the factors have been and are still being addressed, there is lack of knowledge regarding the factors influencing meat quality at distribution stage.

Post-slaughter carcass handling begins at the abattoir just after exsanguination and continues through to processing of meat, transportation to the market and finally to consumers (Adzitey and Huda, 2012). Many irreversible quality losses, especially with regard to the hygienic quality, originate from improper slaughtering and carcass handling (FAO, 1990). Faulty meat handling, apart from affecting the quality and shelf-life of meat and processed products, may also endanger the health of consumers. Therefore, good hygiene during slaughtering and meat handling is of great importance for the quality of the final product because the higher the initial contamination, the faster the meat deterioration, especially under high ambient temperatures (NDA, 2007).

Carcasses are inspected after slaughter by qualified meat inspectors. Carcasses approved for consumption are then stamped as an indication that inspection was done and that carcasses do not show any signs of endangering the health of consumers (Meat Safety Act, 2000). However, it should be noted that carcasses are approved in most South African abattoirs based on visual inspection considering factors like bruising and checking major internal organs for signs of animal diseases. Microbiological assessment is not performed. The few abattoirs that perform microbial assessment do not do it as part of their daily assessment and the Department of Veterinary Public Health do it on a monthly basis during audits. The guidelines used to assess the levels of contamination are based on European standards and the supermarket chains that perform microbial assessment on their meat products use their own standards, e.g. Woolworths and Checkers .The South African Meat Safety Laws do not have their own national microbial standards. The European Union recommends that the levels of contamination by total aerobic bacteria and total coliforms do not exceed respectively 5.0 and 2.5 log CFU/g. (CE, 2005). These standards were crafted based on European environmental temperatures which may differ from the temperatures in other regions of the world. Hence this study encourages research on microbial assessment to be done in abattoirs and this could

aid the SA government to set up their own standards that will be mandated for use in each abattoir and by each meat retailer.

Any carcass not approved for consumption after the inspection is condemned and does not enter the market (Adzitey and Huda, 2012). Condemnation may be partial or total depending on the extent to which the meat has been affected. Huge economic losses have been experienced in the meat industry due to condemning of carcasses (Alton *et al*., 2010; White, 2006). Carcasses are then chilled at $4^{o}C$. This is done to impart the development of rigor mortis and prevent growth of micro-organisms on carcasses (Brown *et al*., 2009). Chilled meat is a requirement for further processing. Carcasses are chilled for a period of 24 hours in an abattoir. The rate at which carcasses are chilled after slaughter has an influence on meat quality. Speeding up the rate of chilling will help reduce microbial growth on the carcass surface because the generation time for microorganisms decreases at lower temperatures. Fast chilling also reduces evaporative weight loss, reduce the manifestation of pale soft exudative meat, improve lean colour and water holding capacity, all of which would have negative effects on meat quality (Warriss, 2000; Adzitey and Nurul, 2011). Furthermore, the rate at which temperature drops after slaughter has an influence on the enzyme activity, because enzyme activities are temperature dependent (Adzitey and Huda, 2012).

2.5 Meat distribution chains

In the meat supply chain, livestock move from feedlots/farms to processors who transform them into meat products and organise delivery into the hands of end customers. This supply chain includes: breeders, farmers, stockers/backgrounders, feedlot operators, packers, processors, food-service providers and retailers (Miranda-de la Lama *et al*., 2014). However, the meat distribution chain is part of the supply chain and it stretches from the abattoir to the final retail display (Figure 2.1). A distribution channel is defined as the network of

individuals and organizations involved in the process of moving a product or service from the producer to the end user (National Food Processors Association, 1995).

The main aim of distribution is the retention of an attractive, fresh appearance for the product which will later be displayed, and the retardation of bacterial spoilage. It should be noted that since meat is a highly perishable food (McDonald and Sun, 1999) when distributed to the supply points, some of the most important meat quality attributes can easily be affected and increased of growth of spoilage bacteria may occur. Important meat quality attributes include colour, marbling, pH, tenderness, juiciness and flavour (Bredahl *et al.,* 1998; Muchenje *et al*., 2009). However, at point of purchase, consumers use these attributes as their most important intrinsic quality cues to judge meat quality (Glitsch, 2000) and colour is probably the most important factor (Faustman and Cassens, 1990). After slaughter the colour of meat depends on a principal pigment known as myoglobin which, when mixed with oxygen, it becomes oxymyoglobin, and produces a bright red colour (Walsh and Kerry, 2002; Priolo *et al*., 2001). Therefore it is important that during distribution accumulation of air is avoided as this principal pigment depends on the oxygen status of the environment. Nychas *et al*. (2008) stated that the risk potential, shelf-life and final quality of chilled products, processed and packed under good manufacturing practices and good hygiene practices are determined by the applied temperature conditions in the chilled distribution chain.

ABATTOIR ➡ LOADING ➡ TRANSPORTATION

STORAGE ⬅ RETAILER ⬅ OFFLOADING

PACKAGING ➡ DISPLAY
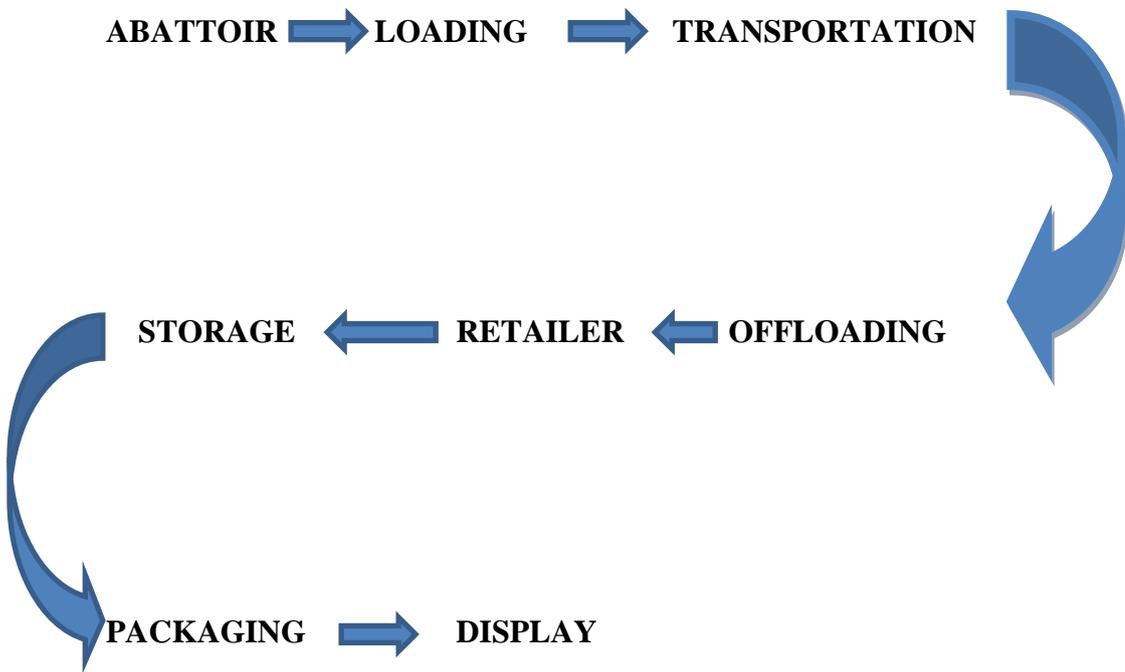
Figure 2.1: Different stages when distributing meat from abattoir to retail point

2.6 Stages affecting the technological and microbiological quality of meat

Richardson *et al.* (2009) stated that the supply chain that stretches from abattoir to final retail display is critical to meat quality. There are a number of factors which affect meat quality in the supply chain (Figure 2.2). Transportation (distance and temperature); type of packaging used; storage (refrigeration and retention length); display; and bacterial growth are the critical factors that contribute significantly to meat quality and its shelf life throughout the distribution chain as depicted in Figure 2.3 and reported in literature (Rosenvold and Andersen, 2003). For consumers to purchase meat of high eating quality, meat traders/handlers need to understand the factors that influence this quality (Vimiso, 2010).

2.6.1 Transportation and storage

Transportation is required throughout production, from the farm to delivery to consumers (Miranda de Lama *et al.*, 2014). Transportation of products to retail outlets and storage has been reported as the weak links in the chain (Bsgh-Sorensen and Olsson, 1990; Gormley, 1990). Before transportation, carcasses are chilled to prevent the growth of micro-organisms and to reduce meat deterioration while it awaits distribution. However, in some abattoirs, especially the small throughput abattoirs, this might not be the case as refrigeration is absent and carcasses are transported without the initial chilling stage. Poor handling of meat during transportation may result in a high rate of contamination and spoilage. It has been reported that when transporting meat, the challenge is to maintain proper refrigeration temperatures and to keep the "cold-chain" from breaking during steps such as palletization, staging, loading and unloading of containers, and in storage (Richardson *et al.*, 2009). It is important that the cold chain is not interrupted as bacteria multiply rapidly in higher temperatures.

Delivery vehicles/containers must be suitable for transporting chilled carcasses. The refrigerated unit must be able to hold the consignment at a constant temperature of a maximum of 7ºC for red meat. Air circulation around the load is vital with airflow between

```
                    ┌─────────────────────────────────┐
                    │          MEAT QUALITY            │
                    └─────────────────────────────────┘
                                     │
                    ┌────────────────┴──────────────────┐
                    │                                    │
        ┌───────────────────────┐          ┌───────────────────────┐
        │    PRE-SLAUGHTER       │          │    POST-SLAUGHTER      │
        │          .             │          │                        │
        └───────────────────────┘          └───────────────────────┘
                    │                                    │
        ┌───────────────────────┐          ┌───────────────────────┐
        │                        │          │                        │
        │ - Animal handling at   │          │  - Carcass handling    │
        │   the farm             │          │                        │
        │                        │          │  - Transportation      │
        │ -Transportation;       │          │                        │
        │  Lairage conditions    │          │  - Storage conditions  │
        │                        │          │                        │
        │ - Slaughter weight     │          │   - Hygiene            │
        │                        │          │                        │
        │ - Slaughter procedure  │          │                        │
        │                        │          │                        │
        └───────────────────────┘          └───────────────────────┘
```
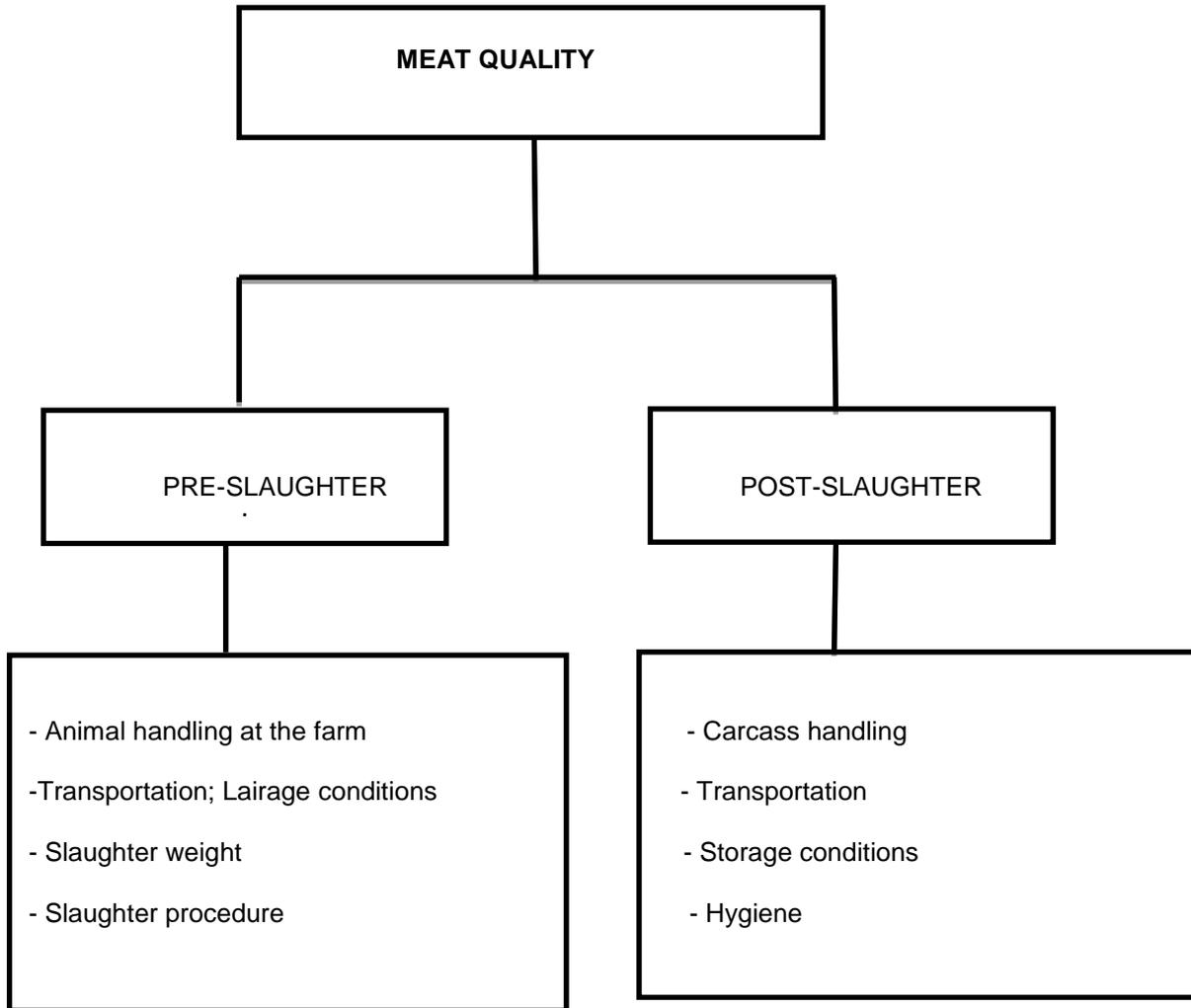
Figure 2.2: Factors affecting meat quality in the supply chain
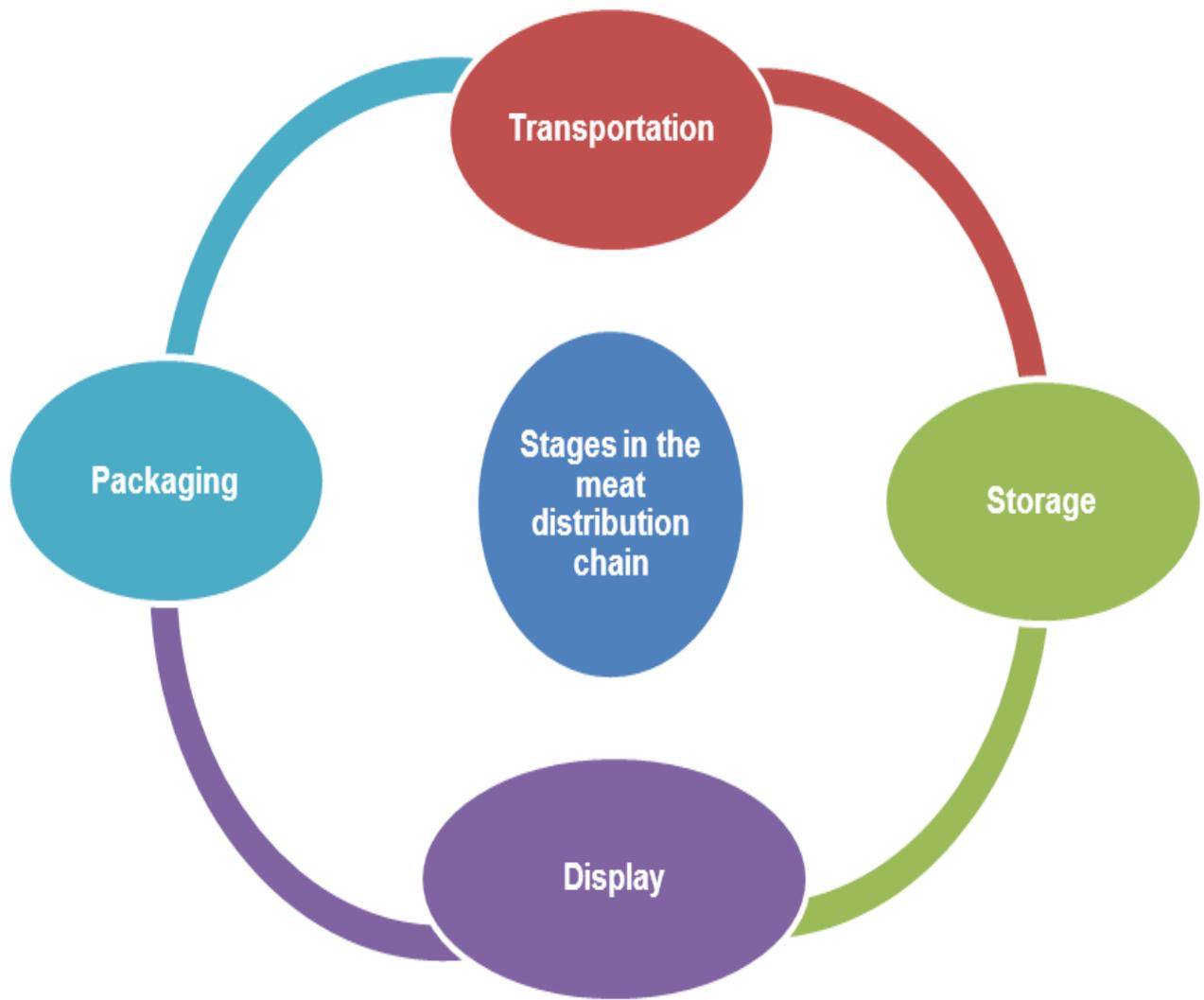
Figure 2.3: Critical stages in the meat distribution chain which affect meat quality

carcasses or boxes ensuring even temperature distribution (Bsgh-Sorensen and Olsson, 1990; Gormley, 1990). Carcasses are supposed to be transported to the meat markets by insulated refrigerated trucks that have high hanging space for the carcasses, but in some cases carcasses are transported in open trucks or non-refrigerated trucks and even trolleys (Seeiso, 2009; Adzitey *et al.,* 2011b). Another problem in transportation is that refrigerated trucks are commonly loaded with consignments for several destinations. Delivery of a load then involves a series of partial unloading (Richardson *et al*., 2009). Storage and maintenance of the cold chain is one of the toughest areas to control in view of the fact that the distribution chain requires dependency on freight haulers and is out of the direct control of the processor. For example, certain truckers will turn off their refrigeration to "save" on fuel and at some point it may take time to put meat into display cabinets or during the off-loading stage.

During the transportation route to the final user, meat and meat products are stored in trucks, retail cabinets and home refrigerators. These points are of great concern for meat quality and safety. According to Koutsoumanis and Taoukis (2005), industrial trucks have different characteristics and performances. The size of the cabinets, initial temperature of the incoming meat, targeted temperature of storage, temperatures of the surroundings, mechanical characteristics (location of refrigeration machinery, compressors, ventilation, and insulation) and energy/cost matters are issues of first priority when considering cold store requirements. It is important that the management approach, ''First In–First Out'' is used in the meat market. This management approach must also be strictly adhered to in all stages of the cold chain, through properly designed handling procedures in the chill storage rooms.

Temperature conditions within the retail cabinets play a significant role in the products final quality status. Zhao *et al.* (1994) stated that the most important factor for maintaining the red

oxymyoglobin colour and keeping lipid oxidation to a minimum is the temperature. Temperature seems to be the most important factor that influences the spoilage as well as the safety of meat (Koutsoumanis and Taoukis, 2005). It should be noted that temperature does not just affect the microbial condition of the meat but colour stability is also affected, with retail appearance significantly affected by storage at 2 and 5 °C compared to storage at below-zero temperatures (Jeremiah and Gibson, 2001). Therefore, different cooling rates affect oxidation or oxygenation of meat and thus change the colour of the meat surface. Bacteria multiply slower when food is refrigerated and freezing food can further slow or even stop the spread of bacteria.

2.6.2 Packaging

The shelf life and quality of fresh meat are strongly influenced by initial meat quality, package parameters and storage conditions (Zhao *et al*., 1994). The logistical function of packaging is mainly to protect the product during movement through distribution channels (Silayoi and Speece, 2007). Packaging plays an important role in the food industry because it helps to protect the product against environmental effects, communicates with the consumer as a marketing tool, provides the consumer with ease of use and time saving convenience (Coles, 2003; Yam, *et al*.,2005). According to Brody (1997), packaging fresh meat is carried out to avoid contamination, delay spoilage, permit some enzymatic activity to improve tenderness, reduce weight loss and where applicable, to ensure an oxymyoglobin or cherry red colour in red meat at retail or customer level. However, initial quality of the meat has to be very good because packaging can only maintain the existing quality of the meat, or delay the onset of spoilage by controlling the factors that contribute to it.

Package design and construction play a significant role in determining the shelf life of a food product. The right selection of packaging materials and technologies maintains product

quality and freshness during distribution and storage. To reduce microbial growth, packaging has to be combined with other treatments, such as refrigeration, which will slow down or stop further growth of microorganisms. Meat can be supplied to the customers packed in a variety of ways. Understanding the packaging options and their effects on meat is very important, since they have an effect on its quality (Brody, 1997).

There are many meat packaging systems currently existing, each with different attributes and applications. These systems range from overwrap packaging, for retail display, to a diversity of specified modified atmosphere packaging (MAP) systems and vacuum packaging, for long term display. The main reasons for MAP of red meats for retail sale are to prolong the microbiological shelf life and to maintain an attractive red colour of the product (Gill, 1996). The principle of MAP is to replace the normal atmosphere by a gas mixture that is suited to the food in question. The main gases used for MAP are nitrogen, carbon dioxide and oxygen. McMillin *et al*. (1999) define MAP as the removal or replacement of the atmosphere surrounding the product before sealing in vapour-barrier materials. The package protects products against deteriorative effects (Yam *et al*., 2005), which may include discoloration, off-flavour and off-odour development, nutrient loss, texture changes, pathogenicity, and other measurable factors (Skibsted *et al*., 1994). One of the most important advantages of MAP is that it increases shelf life allowing less frequent loading of retail display shelves (Davies, 1995). Deterioration in appearance, bacterial spoilage, and loss of exudates are the main problems in the storage of chilled meat. MAP applied to chilled meat can help to overcome these problems and extend the storage life (Taylor, 1977). Retail packaging of meat in MAP is used to provide a stable bloomed red meat colour, which is attractive to the consumer. Vacuum packaging is used to prevent growth of aerobic spoilage organisms, shrinkage, oxidation, and colour deterioration. McDonald and Sun (1999) highlighted that

temperature and the microbiological status of the meat at the time of packing are the most important. Overwrapping facilitates the oxygenation of the meat causing the production of oxymyoglobin and the red colour of "fresh meat" that consumers tend to look for.

2.6.3 Displaying of meat

At display, the colour of meat plays a big role as it is always correlated with freshness and quality by the consumer (O'Grady *et al*., 2000). Meat colour changes during display as myoglobin pigments in the meat surface transform upon exposure to oxygen, from primarily purple deoxymyoglobin to red oxymyoglobin and finally to brown metmyoglobin (Calnan *et al.,* 2013). The display point can be challenging to retailers as the meat might stay for a longer period. The display of meat in plastic materials allows consumer evaluation of the product in an attractive, hygienic and convenient package (Renerre and Labadie, 1993). Meat can also be displayed unwrapped in chilled display cabinets. Cabinets with humidity control reduce drying out. A shelf life of 1 to 2 days is normal. Alternatively, meat is packaged for a variety of reasons. Over-wrapped packaging has a shelf life of 1 to 2 days. Meat in trays overwrapped with a standard permeable film allows air to the meat to give a red colour but protects it from physical contamination. However, its disadvantage is that the meat soon oxidises, changing colour to dark brown. According to Liu *et al.* (1995) consumers discriminate negatively against meat that is discoloured. Modified atmosphere packs have a shelf life of 7 to 10 days (Bingol and Ergun, 2011). Meat is packed in trays with sealed lids which are impermeable to gases in air (usually transparent) and packed with a high-oxygen modified atmosphere (Richardson *et al*., 2009). This keeps the meat red for longer but it browns eventually, usually with a rapid change from red to brown. Vacuum packaging gives meat a shelf life of up to 10 days (Peck *et al.,* 2006). Meat is maintained in the absence of air so remains a purple-red colour. Prolonged pre-retail storage of meat is possible in vacuum packs but only if the temperature is maintained at less than 3º C.

At display, bacteria relevant to meat, meat products and other food are divided into three groups according to the temperature range within which they can grow: mesophiles 10–45 °C, psychrophiles 0–28°C and psychrotrophs 10–45 °C, or slow growth at 0–10 °C. Mesophiles will not grow below 10 °C but psychrotrophs, of which *Pseudomonas* are the more important, will grow even at 0 °C. The nearer to 0°C the storage temperature is, the slower the growth of the spoilage bacteria and the longer the shelf-life (FA0, 1991)

2.7 Microbiological meat spoilage: A major challenge during meat distribution

Meat gives good support for bacterial growth as shown by the numerous reports dealing with the influence of micro-organisms on the storage life of meat products. The main property which explains rapid microbial growth on meats is its composition: 75% water and many different metabolites such as amino-acids, pep-tides, nucleotides, and sugars (Lawrie, 1985). Microbiological organisms and biochemical reactions are the cause for the spoilage of perishable food, particularly where fresh red meat is concerned. The spoilage begins right after slaughter and it is very hard to prevent because the organisms responsible are already present in the food. In live animals, the interior is virtually sterile. However other parts of the animal such as skins, hooves and intestines, contain enormous numbers of bacteria (FAO, 2010). Depending on the slaughter hygiene, these bacteria find their way to the carcass or "contaminate" the meat during slaughterhouse operations. Skinning, scalding, evisceration, dressing and carcass transport are common contamination points. Most bacteria reach the carcass via butchers' hands, tools, contact with equipment or through water, air, etc. The bacterial contamination of meat is not stopped after slaughtering. It is on-going during the operations following the slaughter process, such as meat cutting and meat processing. It is possible to reduce or decelerate the organisms' activities. A well-known and proved measure is cold temperatures. The characteristic microbial population developing in meat and meat

products depends on the effect of the environmental conditions on the growth of those microorganisms introduced due to contamination during handling and processing. Under some conditions, microbial growth may stop and then re-start after adaptation of the microorganisms to a new set of environmental conditions.

Great economic losses resulting from spoilage have occurred. Meat spoilage is not always evident and consumers would agree that gross discolouration, strong off-odours, and the development of slime would constitute the main qualitative criteria for meat rejection (Nychas *et al*., 2008). McDonald and Sun (1999) stated that meat is a highly perishable food product which, unless correctly stored, processed, packaged and distributed, spoils quickly and becomes hazardous due to microbial growth. Meat is considered to be spoiled when it is unfit for human consumption (Bradeeba and Sivakumaar, 2013). Temperature and pH are among the factors that can affect microbial spoilage of meat (Koutsoumanis *et al.,* 2006). The pH of individual meat cuts influence the growth of spoilage bacteria, which should be taken into account when estimating shelf-life (Lawrie, 2006).

2.8 Foodborne pathogens in fresh meat

Food safety is a top priority for food service organizations because mishandling and food contamination can result in serious illnesses for consumers, and business-related losses. According to some reports, the South African meat industry is facing a challenge of growth of foodborne pathogens that affect human health (DoH *et al*., 2013). Therefore important serious measures in the food chain need to be implemented. According to Cassin *et al.* (1998), there has been a growing public concern over the microbiological procedures that might mitigate the risk experienced in safety of foods. Governments and industry have begun to focus attention on the production of foodstuffs as a source of risk to public health. In recent years, the occurrence of pathogenic micro-organisms which affect human health in meat have

been noticed. Foegeding *et al*. (1994) stated that the cost of foodborne disease is estimated to exceed $5 billion per year in the United States and $1.3 billion annually in Canada (Todd, 2001). However, CDSB (2010) and Smith *et al.* (2007) have highlighted that outbreaks of food-borne disease in humans are common in South Africa, but rarely reported. Sofos (2007) identified contamination of meat with pathogenic microorganisms as the most serious meat safety issue as it causes immediate consumer health problems and results in large-scale product recalls from the marketplace.

The consumer is the "fork" in the farm to fork continuum and harmful food pathogens can enter the food chain at any stage (Sargeant *et al*., 2007). Most outbreaks of foodborne illness result from the transfer of harmful microorganisms from meat to humans. There are numerous diseases that humans may contract from endogenously infected meat, such as anthrax, bovine tuberculosis, brucellosis, salmonellosis, listeriosis, trichinosis or taeniasis. There are thousands of types of bacteria that are naturally present in our environment and not all of them cause disease in humans. Bacteria that cause disease are called "pathogens." When certain pathogens enter the food supply chain, they can cause food-borne illness (Behravesh *et al*., 2012). Food-borne illness often shows itself as flu-like symptoms, such as nausea, vomiting, diarrhoea, or fever and may lead to more serious complications. Each year, an estimated 48 million people in the United States experience a foodborne illness. Foodborne illnesses cause about 3,000 deaths in the United States annually (Scallan, 2011). There are prominent pathogens which are associated with meat and meat products. *Campylobacter jejuni* is a pathogen found in the intestinal tracts of animals. It causes food borne illness and the characteristic sings are; fever, headache, muscle pain, diarrhoea (sometimes bloody), abdominal pain and nausea. These signs appear 2 to 5 days after eating food contaminated with this pathogen and the illness may last 7 to 10 days

Clostridium botulinum is widely distributed in nature; in soil, water, on plants, and in intestinal tracts of animals. It grows only in little or no oxygen. It produces one or more of seven toxins (A to G). Toxins A, B and E have been associated with human disease. Types A and B are more commonly linked with meat (Gracey *et al*., 1999). This pathogen produces powerful neurotoxins which affect the nervous system and the symptoms usually appear within 18 to 36 hours, but may take as long as 8 days. The symptoms include one having double vision, droopy eyelids, trouble speaking and swallowing, and difficulty breathing.

Clostridium perfringens is found in soil, dust, sewage, and the intestinal tracts of animals and humans. It grows in little or no oxygen. Symptoms of food poisoning with this pathogen in humans include diarrhoea and gastric pains. These symptoms may appear 8 to 24 hours after eating and usually last about 1 day, but less severe symptoms may persist for 1 to 2 weeks. Human consumption of food contaminated with *Escherichia coli* O157:H7 produces symptoms characterised by diarrhoea or bloody diarrhoea, abdominal cramps, nausea, and malaise. The symptoms begin 2 to 5 days after food is eaten, lasting about 8 days. Some, especially the very young, may develop thrombotic thrombocytopenic purpura and haemolytic uremic syndrome that causes acute kidney failure. *Escherichia coli* O157:H7 has emerged as a primary food safety concern in most countries of the world. Mark and Roberts (1993) reported that the annual cost of the estimated 10 000–20 000 *E. coli* O157:H7-related illnesses is between $216 and580 million dollars.

Listeria monocytogenes is found in the intestinal tracts of humans and animals, soil, and processed foods. The pathogen can grow slowly under refrigeration. Most human cases are sporadic and the illness produced is systemic. The symptoms are fever, chills, headache,

backache, sometimes abdominal pain. *Staphylococcus aureus* is usually transmitted by people-to-food through improper handling. The pathogens multiply rapidly at room temperature to produce a toxin that causes illness. Symptoms in humans are: severe nausea, abdominal cramps, vomiting, and diarrhoea. These symptoms may occur 1 to 6 hours after eating contaminated food. *Salmonella spp* are found in the intestinal tract and faeces of animals. Infections in humans occur through consumption of poorly cooked meat or raw meat. The symptoms in humans are stomach pain, diarrhoea, nausea, chills, fever, and headache. These symptoms usually appear 6 to 48 hours after eating and may last 1 to 2 days. Decontamination procedures using water sprays (potable water or hot water with temperature below 75°C operated under high pressure), physical (use of ultraviolet light, ionizing radiation and ultrasound) and chemical (use of chlorine, hydrogen peroxide, trisodium phosphate and organic acids) methods have been employed in South African abattoirs to reduce initial microbial load on carcasses and to prolong shelf life of meats (Warriss, 2000). However further research on microbial growth on carcass at each stage of the distribution is encouraged.

2.9 Conclusions

From the preceding review it can be seen that the meat distribution chain is an important aspect in the meat industry and the cold chain affects the safety and quality of meat. During distribution, pathogenic and spoilage micro-organisms may grow, therefore it is important that storage temperatures are maintained to control microbial growth. Food safety should be a top priority for food service organizations because mishandling may result in serious illnesses for consumers. Meat that is not properly stored or handled during distribution may not be safe for consumption. The type of meat, method of packaging, and the storage conditions affect the storage life and the microbiological status of the meat product. Maintaining temperatures during distribution is the major key in keeping the quality of meat. It is necessary that changes in meat quality and bacterial growth per each stage of the distribution chain are determined.

2.10 References

Adzitey, F. and Huda, N. 2012. Effects of post-slaughter carcass handling on meat quality. *Pakistan Veterinary Journal,* **32:** 161–164.

Adzitey, F. and Nurul, H. 2011. Pale Soft Exudative (PSE) and Dark Firm Dry (DFD) Meats: causes and measures to reduce these incidences. *International Food Research Journal,* **18:** 11-20.

Adzitey, F., Teye, G. A., Kutah, W. N. and Adday, S. 2011. Microbial quality of beef sold on selected markets in the Tamale Metropolis in the Northern Region of Ghana. *Livestock Research for Rural Development, 23*, Article #5. Retrieved on 27 April 2003, from http://www.lrrd.org/lrrd23/1/kuta23005.htm

Alton, G.D., Pearl, D.L., Bateman, K.G., McNab, W.B. and Berke, O. 2010. Factors associated with whole carcass condemnation rates in provincially-inspected abattoirs in Ontario 2001-2007: Implications for food animal syndromic surveillance. *BMC Veterinary Research*, **6:** 42.

Andersen, H. A., Oksbjerg, N., Young, J. F. and Therkildsen, M. 2005. Feeding and meat quality – a future approach. *Meat Science*, **70:** 543–55.

Appleby, M. C. and Hughes, B. O. 1997. *Animal welfare* (pp. 2-3). Wallingford, UK: CAB International.

Barbut, S. 2005. Poultry product processing (First Indian Reprint, 2005). Pp 215 – 427. CRC- press, London, Noida.

Barros, M. A. F., Nero, L. A., Monteiro, A. A. and Beloti, V. 2007. Identification of main contamination points by hygiene indicator microorganisms in beef processing plants. *Ciência Technologia Alimentos Campinas* , **4:** 856-862.

Bingol, E.B. and Ergun, O. 2011. Effects of modified atmosphere packaging (MAP) on the microbiological quality and shelf life of ostrich meat. *Meat Science*, **88:** 774–785.

Bogh-Sorensen, L. and Olsson, P. 1990. The chill chain. In Chilled Food: The State of the Art, ed. T. R. Gormely, *Elsevier Applied Science*, New York, pp. 245-67.

Bradeeba, K. and Sivakumaar, P. K. 2013. Assessment of microbiological quality of beef, pork and mutton and its environment in retail shops in Chidambaram, Tamil Nadu. *International Journal of Plant, Animal and Environmental Sciences*, **3:** 2231- 4490.

Bredahl, L., Grunert, K. G. and Fertin, C. 1998. Relating consumer perceptions of pork quality to physical product characteristics. *Food Quality and Preference*, **9:** 273–281.

Brody, A. L. 1997. Packaging of food. In A. L. Brody, & K. S. Marsh (Eds.), *The Wiley encyclopedia of packaging* (pp. 699–704) (2nd ed.). New York: Wiley.

Brown, T., Richardson, R. I., Wilkin, C. A., and Evans, J. A. 2009. Vascular perfusion chilling of red meat carcasses − A feasibility study. *Meat Science, 83***:** 666–671.

Cassin M.H., Lammerding, A.M., Todd, E.C.D., Ross, W. and McColl, R.S. 1998. Quantitative risk assessment for *Escherichia coli* O157:H7 in ground beef hamburgers. *International Journal of Food Microbiology*, **41:** 21–44.

Communauté Européenne (CE) 2005. Règlement (CE) No 2073/2005 de la commission du 15 novembre 2005 concernant les critères microbiologiques applicables aux denrées alimentaires. *Journal Officiel L* 338 du 22.12.2005, 26p.

Dave, D. and Ghaly A.E. 2011. Meat Spoilage Mechanisms and Preservation Techniques: A Critical Review. *American Journal of Agricultural and Biological Sciences*, **6:** 486-510.

Davies, A.R. 1995. Advances in Modified Atmosphere Packaging. New Methods of Food Preservation, ed. by G.W. Gould, pp. 304-320.Glasgow, UK., Blackie.

De Vries, A. G., Van der Wal, P. G., Long, T., Eikelenboom, G. and Merks, J. W. M. 1994.Genetic parameters of pork quality and production traits in Yorkshire populations. *Livestock Production Science*, **40:** 277–289.

Department of Health (DoH), 2012. Regulations governing general hygiene requirements for food premises and the transport of food. Foodstuffs Cosmetics and Disinfectants Act (Act No. 54 of 1972).Government Notice No. R. 962.

Department of Health (DoH), Department of Trade and Industry (DTI), & Department of Agriculture, Forestry and Fisheries (DAFF) 2013. Food safety and food control in South Africa: specific reference to meat labelling. Government Printers, Pretoria.

FAO, 1990. Manual on Simple Methods of Meat Preservation. Animal Production and Health Paper, 79, Rome. *Available on:http://www.fao.org/docrep/003/x6932e/x6932e01.htm*

FAO,1991. Guidelines for Slaughtering, Meat Cutting and further processing. Animal Production and Health Paper, 91, Rome. Available on: *http://www.fao.org/docrep/004/t0279e/T0279E00.htm#TOC*

FA0, 2010. Meat Processing Technology**.** Meat processing technology for small- to medium-scale producers**.** Asia. Available on: *http://www.fao.org/docrep/010/ai407e/AI407E00.htm#Contents*

Faustman, C. and Cassen, R.G. 1990 .Influence of aerobic metmyoglobin reducing capacity on colour stability of beef. *Journal of Food Science,* **55:** 1278 -1283.

Field, R. A., Maiorano, G., McCormick, R. J., Riley, M. L., Russell, W. C., Williams, F. L. and Crouse, J. D. 1990. Effects of plane of nutrition and age on carcass maturity of sheep. *Journal of Animal Science*, **68:** 1616–1623.

Food Marketing Institute (FMI), 1994. *Trends: Consumer Attitude and the Supermarket*. Food Marketing Institute: Washington, DC.

Gill, C. O. 1996. Extending the storage life of meats. *Meat Science*, **43:** 99–109.

Glitsch, K. 2000. Consumer perceptions of fresh meat quality: cross national comparison. *British Food Journal*, **102:** 177-194.

Gormley, T. R. 1990. Temperature monitoring of chilled foods during air and road freighting. In Processing and Quality of Foods, Vol. 3, Chilled Foods, eds. P. Zeuthen, J. C. Cheftel C. Eri2ksson, T. R. Gormley, P. Links, K. Paulus. Elsevier Applied Science, London. pp. 3.248-3.255.

Gracey, J.F., Collins, D.S. and Huey, R.J. 1999. *Meat hygiene*, 10th ed. London: Harcourt Brace & Company.

Grandin, T. and Smith, G. C. 2000. Animal welfare and humane slaughter. In *Encyclopedia of life support systems (EOLSS)* (pp. 1–50). Developed under the auspices of the UNESCO, Eolls Publishers: Paris, France.

Grunert, K. G., Bredahl, L. and Brunsø, K. 2004**.** Consumer perception of meat quality and implications for product development in the meat sector: A review. *Meat Science,* **66:** 259-272.

Hermesch, S. 1997. Genetic influences on pork quality. In: Manipulating pig production VI. Edited by P.D.Cranwell, December 1997. Australian Pig Science Association. Pp 82-90.

Hobbs, B. C. and Roberts, D. 1993. *Food Poisoning and Food Hygiene* (pp. 216–220) (6th Ed.). St. Edmundsbury Press: Burry, Bodmin, Cornwall, London, UK.

Jeremiah, L. E. and Gibson, L. L. 2001. The influence of packaging and storage time on the retail properties and case-life of retail-ready beef. *Food Research International,* **34:** 621–631.

Jongen, W. and Meulenberg, M. 1998. Summary and Future Prospects', in *Innovation of Food Production Systems: Product Quality and Consumer Acceptance* (Eds.) W. Jongen and M. Meulenberg, Wageningen Pers, Wageningen, pp. 177-80.

Koutsoumanis, K. P. and Taoukis, P. 2005. Meat safety, refrigerated storage and transport: modeling and management. In J. N. Sofos (Ed.), Improving the Safety of Fresh Meat (pp. 503–561). Cambridge, UK: Woodhead/Publishing, Ltd.

Lawrie, R. A. and Ledward, D. A. 2006. *Lawrie's meat science* (7th Ed.). Cambridge: Woodhead Publishing Limited. ISBN 978-1-84569-159-2.

Liana, M., Radam, A. and Yacob, M.R. 2010. Consumer perception towards meat safety: Confirmatory factor analysis. *International Journal of Economics and Management*, **4:** 305 – 318.

Liu, Q., Lanari, M.C. and Schaefer, D.M. 1995. A review of dietary vitamin E supplementation for improvement in beef quality. *Journal of Animal Science,* 73, 3131−3140.

Manios, S. G., Grivokostopoulos, N. C., Bikouli, V. C., Doultsos, D. A., Zilelidou, E. A., Gialitaki, M. A. and Skandamis, P. N. 2015. A 3- year hygiene and safety monitoring of a meat processing plant which uses materials of global origin. *International Journal of Food Microbiology*, **209**: 60-69.

Meat Safety Act No.40 of 2000. Department of Agriculture, Forestry and Fisheries, Republic of South Africa.

McDonald, K. and Sun, D. W. 1999. Predictive food microbiology for the meat industry: a review. *International Journal of Food Microbiology*, **52:** 1-27.

McMillin, K. W., Huang, N. Y., Ho, C. P. and Smith, B. S. 1999. Quality and shelf-life of meat in case-ready modified atmosphere packaging. **In**: *Quality Attributes in Muscle Foods.* pp. 73– 93. Xiong, Y.L., Shahidi, F., and Ho, C.T., Eds., ACS Symposium Series, Plenum Publishing, New York.

Miranda-de la Lama, G. C. Villarroel, M. and María, G. A. 2014. Livestock transport from the perspective of the pre-slaughter logistic chain: A review. *Meat Science,* **98:** 9–20.

Moore, G. and Griffith, C. 2002. A comparison of surface sampling methods for detecting coliforms on food contact surfaces, *Journal of Food Microbiology,* **19:** 65–73.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P. E. and Raats, J. G. 2008. Meat quality of Nguni, Bonsmara and Aberdeen Angus steers raised on a natural pasture in the Eastern Cape, South Africa. *Meat Science*, **79:** 20-28.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P.E. and Raats, J. G. 2009. Relationship between pre-slaughter stress responsiveness and beef quality in three cattle breeds. *Meat Science*, **81:** 653–657.

National Department of Agriculture (NDA). 2000. Meat Safety Act (Act No. 40 of 2000). http://www.nda.agric.za. (Accessed 20 August 2015).

National Department of Agriculture (NDA) 2007. Meat Inspectors Manual: Abattoir Hygiene. *Veterinary Public Health,* Republic of South Africa.

National Food Processors Association, 1995. HACCP: Establishing Hazard Analysis Critical Control Point Programs, A Workshop Manual (Stevenson, K.E., and D.T. Bernard, Eds). The Food Processors Institute, Washington, DC.

Nychas G. J., Skandamis, P. N., Tassou, C.C. and Koutsoumanis, K. P. 2008. Meat spoilage during distribution. *Meat Science*, **78:** 77‑89.

O'Grady, M. N., Monahan, F. J., Burke, R. M. and Allen, P. 2000. The effect of oxygen level and exogenous α-tocopherol on the oxidative stability of minced beef in modified atmosphere packs. *Meat Science,* **55:** 39–45.

Peck, M. W., Goodburn, K. E., Betts, R. P. and Stringer, S. C. 2006. *Clostridium botulinum in vacuum packed (VP) and modified atmosphere packed (MAP) chilled foods*. Final Project.

Priolo, A., Micol, D. and Agabriel, J. 2001. Effects of grass feeding systems on ruminant meat colour and flavour: A review. *Animal Research*, **50:** 185–200.

Renerre, M. and Labadie, J. 1993. *Fresh red meat packaging and meat quality.*Proceedings of 39th International Congress of Meat Science and Technology, Calgary, Canada, 1–6 August, pp. 361–387.

Richardson, M., Matthews, K., Lloyd, C. and Brian, K. 2009. *Meat quality and shelf life*. EBLEX, Agriculture and Horticulture Development Board (AHDB).

Robles, R., Vannin, L. and Alvarez, R. 2009. Quality beef schemes and consumer perception. In *Proceedings of the 113th EAAE Seminar*, 3-6 September 2009, Chania, Crete, Greece.

Rosenvold, K. and Andersen, H. J. 2003. Factors of significance for pork quality. A review. *Meat Science*, **64:** 219-237.

Sargeant, J. M., Ramsingh, B., Wilkins, A., Travis, R. G., Gavrus, D. and Snelgrove, J.W. 2007 Constraints to Microbial Food Safety Policy: Opinions from Stakeholder Groups along the Farm to Fork Continuum. *Zoonoses and Public Health.* **54:** 177- 184.

Seeiso, T. M. 2009. *Bacteriological quality of meat in Lesotho*. Ph.D. Thesis. University of Pretoria, South Africa.

Silayoi, P. and Speece, M. 2007. The importance of packaging attributes: a conjoint analysis approach. *European Journal of Marketing,* **41:** 1495–1517.

Skibsted, L. H., Bertelsen, G. and Qvist, S. 1994. *Quality changes during storage of meat and slightly preserved meat products.* Proceedings of 40th International Congress of Meat Science and Technology, The Hague, Netherlands, 28 August-2 September, 1–10.

Smith, A.M., Gouws, A.M, Hoyland, G., Sooka, A., Keddy and K.H. 2007. Outbreaks of food-borne disease; a common occurrence but rarely reported. *South African Medical Journal*, **97:** 1272.

Sofos, N. F. 2007. Challenges to meat safety in the 21st century. *Meat Science*, *78*, 3–13.

Todd, E. 2001. *Foodborne and waterborne disease in Canada: 1994-1995*. Ontario: Health Canada, Health Products and Food Branch.

Vimiso, P. 2010. Effects of marketing channel on bruising, ultimate pH and colour of beef; and stakeholder perception on the quality of beef from cattle slaughtered at a smallholder abattoir. MSc Thesis, University of Fort Hare, South Africa.

Walsh, H.M. and Kerry, J.P. 2002. Meat processing, Improving quality. In B.S. Kerry, J.P., J.F. Kerry, & D. Ledward (Eds), Meat Packaging (pp- 437- 439). England: CRC Press LLC and Woodhead Publishing Ltd.

Warriss, P. D. 2000. Meat science, An introductory text. CAB International, Cambridge University Press, Cambridge.

White,   M.   2006.   Wholecarcass   condemnation. http://www.nadis.org.uk/BPEX%20Bulletins/Carcase%20Condemnation.pdf. Accessed on 14 December, 2010.

Yam, K. L., Takhistov, P. T. and Miltz, J. 2005. Intelligent packaging: Concepts and applications. *Journal of Food Science,* **70:** R1-R10.

Zhao, Y., Wells, J. H. and McMillin, K. W. 1994. Applications of dynamic modified atmosphere packaging systems for fresh red meats: review. *Journal of Muscle Foods,* **5 :** 299- 328.

Chapter 3: Consumer and handlers' perceptions on meat quality and safety along the distribution chain

(*Submitted to* Asian- Australasian *Journal of Animal Sciences)*

Abstract

The objective of the study was to investigate the perceptions and knowledge of consumers and meat handlers' on meat quality and its safety throughout the distribution chain. Data was collected randomly from a total of 300 consumers and meat handlers' using a structured questionnaire in five different municipalities in the Eastern Cape Province of South Africa. Descriptive statistics were computed on the age groups, gender, race, educational status, and distribution chain dimensions. The X^2 test was used to determine associations between respondent's demographical characteristics and their perceptions on meat quality, safety and challenges faced by meat handlers during distribution. The results revealed that 53.69% retailers and 99, 9% of abattoir workers were male, above 50 years of age, with more than 10 years of working experience in the meat sector. The majority of the consumers used colour and price to predict meat quality while handlers used freshness. Expiry dates, change in colour and aroma were considered as the best indicators of meat safety. The results further showed that 60% of the consumers prefer meat from butcheries over meat sold from retail shops. Meat from high class shops was considered to be safer than low class shops. A strong significant association ($p < 0.05$) between educational status and awareness of meat safety was observed where 55% of the consumers showed lack of knowledge about pathogenic diseases. Meat handlers reported the series of loading and offloading, temperature fluctuations, environmental temperatures and ques during offloading as the major challenges during transportation of carcasses from the abattoir to the supply points. It was concluded that consumers and meat handlers have different perceptions about meat quality. Meat handlers generally believe that the distribution chain has an effect on meat quality.

Key words: Consumers, meat handlers, meat quality, meat safety, purchasing-decisions

3.1 Introduction

Perception is defined as a process in which individuals select, organise and interpret information using appropriate body stimuli (Novak, 2011). In general perception is an opinion of something viewed by an individual or community. Consumers are the final link in the food chain and therefore in a competitive market, the objectives of farmers, processors and retailers should correspond to consumers' demands (Sans, Fontguyon and Briz, 2005). Bryhni *et al*. (2002) stated that consumers subjectively evaluate quality and it has become increasingly important to optimally align the quality of food with consumer demands, expectations, and desires. Consumer's perception of meat and meat products has been identified as a critical issue for the meat industry because it directly impacts on its profitability (Troy and Terry, 2010). Should consumers develop any negative perception towards meat, it could result in less demand thereby influencing their purchasing behaviour, consequently leading to losses for the meat industry. Consumer perceptions change with time, but it is difficult to predict this change because of the complex dynamics which drive the change (Sharma and Lal, 2012; Five-Shaw and Rowe, 1996). Therefore, to better understand the consumer-decision making process while purchasing meat, it is important for meat handlers to identify which attributes consumers rely on and how they perceive and weigh them to reach a final decision.

Previously, the industry faced challenges in terms of consumer perception in areas of health (nutrition), animal welfare and convenience. Recently, the aspect of meat safety has been raised (Sofos, 2002). Food safety is an important issue facing current consumers, the food industry and the government (Liana, Radam and Yacob, 2010). Since several food safety crises have occurred globally in recent years, the production of safe animal food products has become one of the most important aspects of quality for both consumers and retailers. The high sensitivity of consumers to food safety issues cannot be ignored by the participants

within the supply chain. Despite the fact that the international food management agencies have already provided guidelines to member countries about safe handling procedures such as HACCP and Good Manufacturing Practices (Ali *et al*., 2010), the knowledge and perceptions of meat handling practices used in most developing countries particularly the African countries remain largely unknown.

Since consumers cannot easily assess food safety risks, their perception of food safety is, in part, a matter of trust in the food chain. The food industry is built on trust and the trust is divided into two key components: trust in the safety of the food and trust in the value of the products (Grier, 2002). Consumers expect that the products they buy from a store will be safe to eat. The consumer has an understanding of the value equation attached to various meat cuts and products (Colmenero, 2000). For instance, they know that they will pay more for a loin cut than for a hip or rib cut. At the same time they expect that the quality difference will provide them with the value they expect from each. The lack of trust in value occurs when the quality does not correspond with the price. If a retailer, processor or producer breaks the trust in safety or value, then the results can be devastating to the business (Grier, 2002). Hence it is important that both retailers' and suppliers' (abattoir workers) perceptions on meat quality and safety are determined.

In the meat chain, retailers are arguably more vulnerable than their partners because they are the point of contact with consumers. They are an important stakeholder in the meat production system, providing structure to the distribution channel. Meat retailers play a key role in the purchasing behaviour of their customers and are the main source of information for their buying selection. Consumers are often uncertain as to the quality of the products they buy and usually cannot taste nor prepare meat before purchasing it in retail stores (Holm and Kildevang, 1996). Their decisions are based on predicting or judging the quality of meat by using visual inspection, their previous experiences, and great diversity of non-sensory

information such as packaging and the information available on the label (Lazano and Krystallis, 2010). Brunso *et al.* (2002) observed that it is important to know the intrinsic and extrinsic cues that consumers associate with product quality. Ottesen (2006) also advised that farmers and traders should focus their value adding activities on those aspects that consumers value as most important. These aspects include factors such as appearance, juiciness, taste, tenderness, price, package appearance, colour, size, brand name and food safety and they all influence consumers' decisions to purchase meat in the retail store (Vimiso *et al.*, 2012; Viana *et al.*, 2014).

The meat that we consume today is examined in the abattoirs and throughout the distribution chain more than it has ever been in the past. However, regardless of this, most producers still strive to gain a reputation as a reliable supplier of meat that meets consumer's standards (Sepulveda *et al.*, 2008). To achieve and maintain a good reputation and to cater for consumers' expectations, it is important that challenges faced by the meat handlers (retailers and abattoir workers) to deliver meat that is safe and of high eating quality are considered. Previous studies have shown that scientific developments in the food safety field and food safety communication have played a role in consumer's ability to gain and maintain trust in the food that they purchase (Viegas, 2012). However, it should be noted that several studies which have been addressed focussing on perceptions on food safety have been conducted in different countries (Redmond and Griffith, 2004; Muhammad *et al.*, 2010; Haileselassie *et al.* 2013; Nesbitt *et al.*, 2014), but research on perceptions of consumers in South Africa especially black consumers from rural areas is lacking. It is important to note that the perception trends may differ systematically by the given income, educational background and race of consumers; either because tastes may differ between race groups due to culture or because of a different history. Also, there is not much information available on the quality and safety perceptions of meat handlers operating at different stages of the production chain.

Vimiso *et al*. (2012) conducted a study following the chain on farmers and handler's perceptions but the study particularly focussed on animal welfare and meat quality and the meat safety issue was not covered especially during the distribution stage, yet this stage is considered as the most critical phase during which the quality of meat could easily be affected. Therefore, this study was designed to investigate the knowledge and perceptions of consumers and meat handlers' on meat quality and safety throughout the distribution chain in the Eastern Cape Province, South Africa.

3.2 Materials and methods

3.2.1 Study site

The study was conducted in five different municipalities in the Eastern Cape Province of South Africa, where consumers and meat handlers were selected and interviewed. The chosen municipalities were Buffalo City Municipality (East London and King Williams Town), Nkonkobe Municipality (Alice, Adelaide and Fort Beaufort, Ngqushwa Municipality (Peddie), Lukhanje Municipality (Queenstown), and Amahlathi Municipality (Sutterheim and Cathcart). Selected areas under these five municipalities were further stratified into urban (East London, King Williams Town, Queenstown, Stutterheim, Cathcart, Adelaide, and Fort Beaufort) and rural (Alice, Middledrift and Peddie) towns according to their geographical location. A total of 41 butcheries were used in the study, three in Alice, three in Fort Beaufort, two in Adelaide, two in Ngqushwa, five in King Williams town, twelve in East London, two in Sutterheim, one in Cartcarth, and eleven in Queenstown. Selection of the butcheries was based on meat reception for re-sale from abattoirs and whether they stocked the meat types selected for the study (beef, pork and mutton). Two abattoirs were also chosen to represent a high throughput (East London abattoir) and a low throughput (Adelaide abattoir). East London abattoir is located 120 km away from Alice (Nkonkobe Municipality),

Adelaide abbatoir is located at S 33^0 58 83` and E $25^0$ 38 54`, away from Alice and both are governed by the Meat Safety Act No. 40 of 2002 and SAMIC (2006).

3.2.2 Selection of the respondents

The respondents were divided into two major categories: consumers and meat handlers. Meat handlers were sub-divided into two groups: retailers and abattoir workers. Retailers included butchery owners, butchery managers and butchery sales supervisors or sales assistants. Abattoir workers included abattoir managers, supervisors, truck drivers /meat transporters and delivery personnel. A total of 400 respondents (300 consumers, 50 retailers and 50 abattoir workers) were randomly selected and interviewed. Consumers purchasing pork, beef or mutton from the selected retail shops and butcheries in the chosen areas were selected. A few homesteads from the villages were also visited.

3.2.3 Ethical Consideration

Permission to interview meat handlers and consumers was obtained from the Ethical Committee of the University of Fort Hare (UFH/UREC, MUC0101SRAN01). Before the interviews were conducted, each person was asked to sign a consent form.

3.2.4 Data collection

The data used in the present study was obtained from 400 respondents. Data was collected by means of personal interviews using standardized structured questionnaires. Prior to data collection a group of trained enumerators that could effectively communicate to the respondents in vernacular (Xhosa) and English languages were recruited to administer the questionnaires. Consumers were interviewed at different points: either at the point of purchase or as they left the shops, with permission from the butcher and shop owners, and some door to door visits were also carried out. Retailers were interviewed at their work stations during working hours. Abattoir workers were interviewed on post slaughter handling at all stages of the distribution chain. The amount of time taken to interview each respondent

from the three groups was 10 minutes. The structured questionnaire used in this research captured information such as consumer and meat handlers' demographic information i.e. educational qualifications, occupation, age, gender, duration of employment in meat sector, etc. Aspects on distribution and meat quality were assigned to one of the following dimensions: transportation, storage, packaging and displaying of meat (Appendix 1, 2 and 3).

3.2.5 Statistical analyses

Frequencies for consumer profile, meat handlers and their perceptions were determined using the PROC FREQ procedures of the Statistical Analyses Systems (SAS) (2003). The chi-square test of association was computed using SAS (2003) to determine associations between age, gender, employment status, educational qualification, and distribution chain dimensions. Mean perceived importance scores were determined using PROC MEAN procedure of SAS (2003).

3.3. Results and Discussion

3.3.1. Consumers, retailers and meat handler's demographic characteristics

The distribution of participants according to municipalities is shown in Figure 3.1, Figure 3.2 and Figure 3.3. Buffalo city municipality had the highest number of participants for the consumers (34%) followed by Nkonkobe municipality (29%). The highest number of retailers interviewed in this study were found in Buffalo City municipality (43%) with the least number of participants residing in Amahlathi municipality (10%). The highest number of participants observed from the Buffalo City municipality can be associated with the fact that it is composed of urban areas with more retail outlets compared to other municipalities. The East London abattoir (ELA) had more participants (74%) compared to the Adelaide abattoir (AA) (26%) and this is due to the fact that East London abattoir is a high throughput abattoir with more workers compared to Adelaide which is a low throughput abattoir composed of about 10- 15 workers. The socio-economic profiles of the respondents who participated in the

surveys are shown in Table 3.1. Of the 300 consumers who were interviewed in this study, 53.69% were males and 44.63% were females. It was
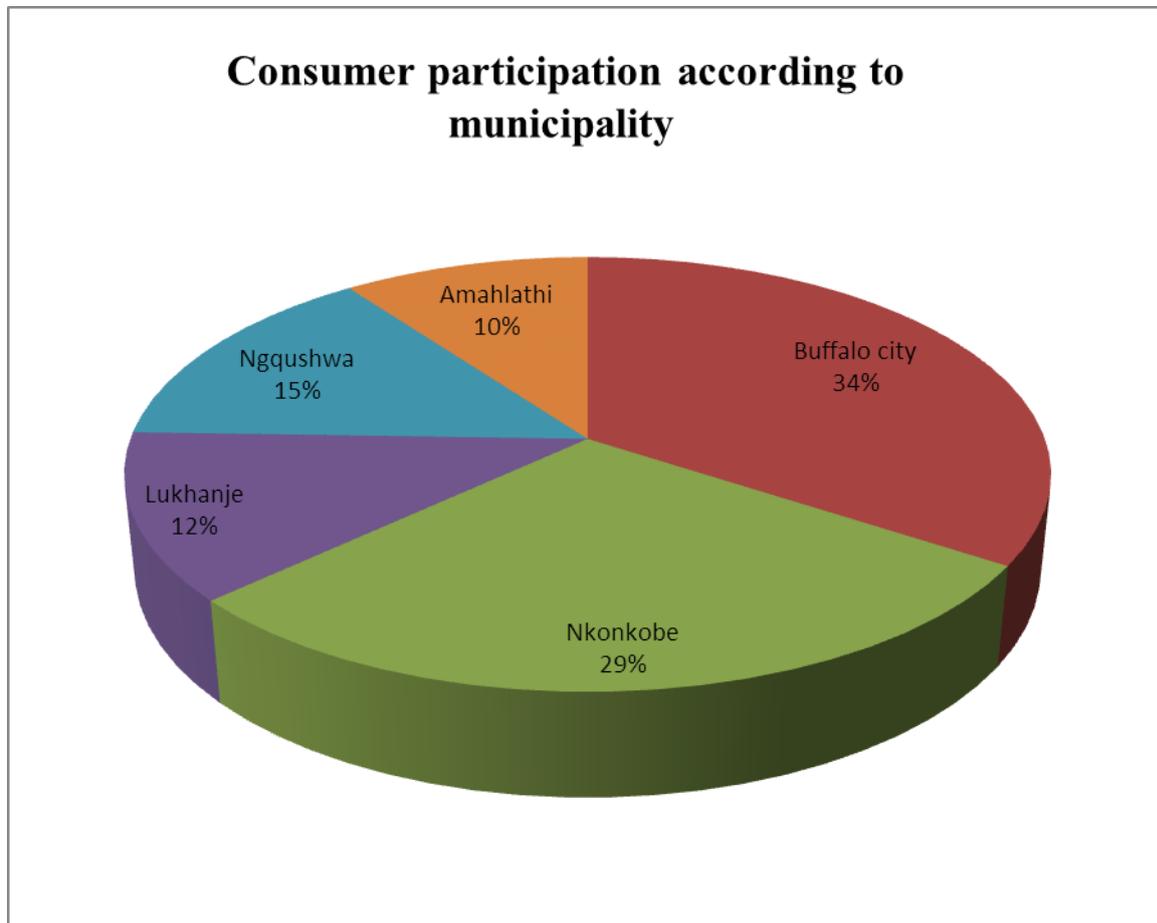
Figure 3.1: **Number of consumers who participated in the survey from different municipalities (%)**

Figure 3.2: Number of the retailers who participated in the survey from different municipalities (%)
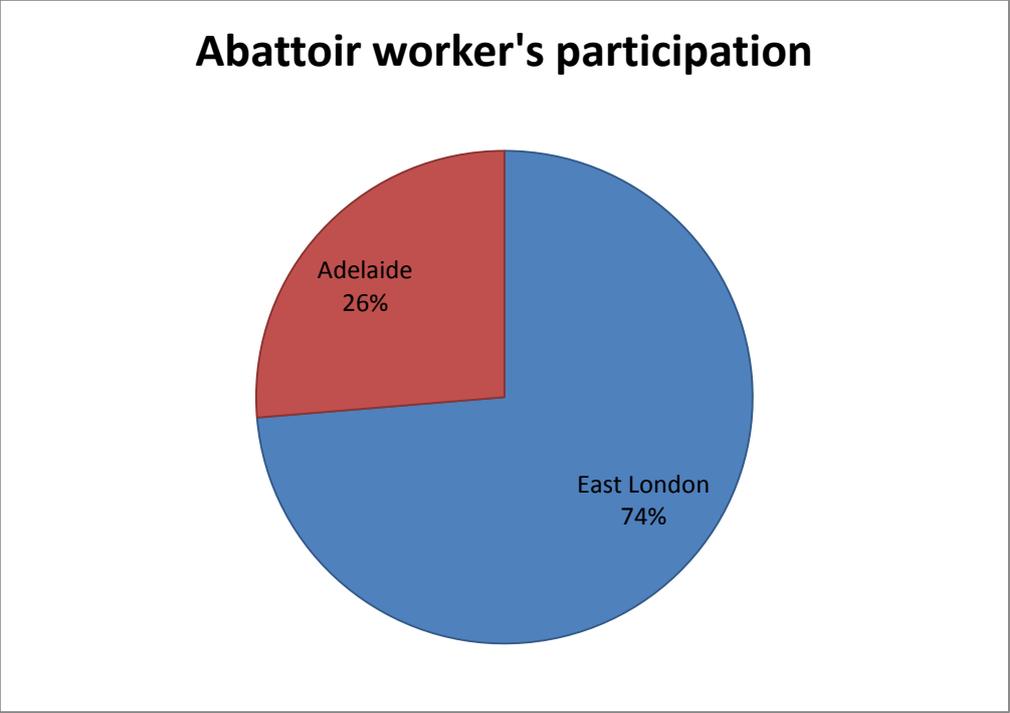
Figure 3.2: Number of abattoir workers who participated in the survey (%)

Table 3.1: Demographic characteristics of consumers, retailers and abattoir workers interviewed (n = 400)

Variable	Category	Frequencies (%)		
		Consumers	Retailers	Abattoir workers
Age	<20	4.46	12.24	0.00
	21-30	26.17	16.33	18.42
	31-40	17.11	24.49	23.68
	41-50	36.91	24.49	28.95
	>50	15.10	22.45	28.95
Gender	Male	53.69	81.63	100.00
	Female	44.63	18.37	0.00
Race	Black	69.80	36.73	47.37
	White	8.39	48.98	26.32
	Coloured	20.81	14.29	23.68
	Indians	1.0	0.00	2.63
Educational status	No formal education	16.44	0.00	23.68
	Grade 1-7	25.50	16.33	23.68
	Grade 8-12	40.60	59.18	42.11
	Tertiary	17.45	24.49	10.53
Occupation	Employed	50.34	100	100
	Un- employed	18.12	0.00	0.00
	Student	4.03	0.00	0.00
	Pensioner	15.44	0.00	0.00
	Entrepreneur	12.08	0.00	0.00
Location	Urban	42.62	67.35	75
	Rural	56.04	32.65	25

also observed that majority of retailers/ butcher managers were males (81.63%) while the remaining were female. Approximately, 49% of retailers were white while 37% were black and the remaining 14% were coloureds. The majority of consumers interviewed were black (69.8%) followed by coloureds (20.81%), with whites (20.81%) and Indians having the least number of participants. The highest percentage of abattoir workers were black (47.37%) followed by whites (26.32%), coloureds (23.68%) and Indians with few participants (2.63%).

It was observed that the age of the consumers ranged from 41 to 50 years while retailers and abattoir workers were above 50 years old. The reason for this age range for the retailers can be associated with their experience in the meat sector as the majority had reported to be having more than 10- 30 years of experience. The majority of participants in all the three groups interviewed in this study had basic education (Grade 8-12) there were no retailers without formal education. Most retailers and abattoir workers were from urban areas with the majority of consumers residing in rural areas.

3.3.2 Perceptions on factors relating to meat purchasing and safety

Results on consumer preference for different meat types are shown in Figure 3.4. The majority of the consumers (38%) preferred to purchase pork, followed by beef (32.7%) and mutton (29.3%). Consumers had high preference for pork since it is perceived as the most affordable and healthier meat compared to beef and mutton. According to De Silva1 (2010), it was scientifically proven that lean pork is low in fat and cholesterol which makes it healthier than other meat types, or excelling in taste and tenderness, depending on the specific cut and handling throughout the meat chain. Mutton was less preferred because consumers believe that at most times it is sold at a higher price and some reported not to like its aroma when cooked. These findings are in line with results that were found by Ahmed (2007), where most consumers did not purchase mutton because of its high price and the negative perception
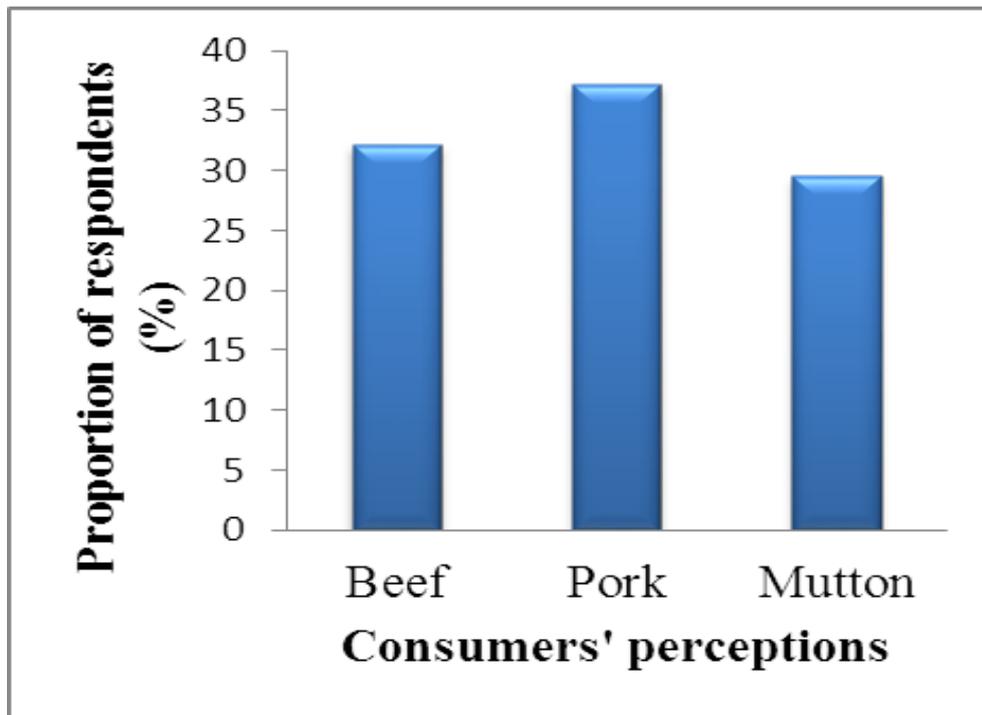
Figure 3.3: **Perceptions of consumers on the type of meat that is purchased and preferred the most**

towards its aroma. Those who reported not to like beef stated that it's less tender, less healthy and at most times lacks juiciness which makes it tougher. However, some general disagreement between the consumer's and retailer's perceptions on this aspect was observed (Figure 3.5). On the contrary, most retailers reported beef as the most preferred meat in their shops (46%), followed by pork (40%) and mutton (14%). The results is in agreement with the study by Vimiso *et al.* (2012), where consumers preferred beef more than any other meat products. Viljoen and Gericke (2001) also found that half of the studied group of consumers consumed beef four to ten times out of thirty days.

Grier (2002) stated that in order for consumers to define and for producers to produce meat of consistently high eating quality, a thorough understanding of the important factors which influence quality is imperative. A number of factors have got an influence on meat quality and consumers purchasing decisions during marketing (Troy and Kerry, 2010). At the point of purchase consumers use cues to evaluate quality and cues such as price, packaging, labelling, freshness and colour are of importance. Retailers depend on consumers perceptions towards these cues in order for them to make decisions. In the current study colour has been regarded as the most important factor. Faustman and Cassens (1990) also regarded colour as an important factor since it is a visual measure of freshness and quality. However, consumers in this study regarded change in colour as an indicator of meat spoilage more than quality. The majority of consumers (58%) indicated that green spots and bad smell are the best indicators of meat spoilage, whilst 22% regarded change in colour as the best indicator of meat spoilage (Figure 3.6). According to the USDA (2011) change in colour alone does not mean the product is spoiled. The meat should have an off odour, be sticky or tacky to the touch, or it may be slimy.
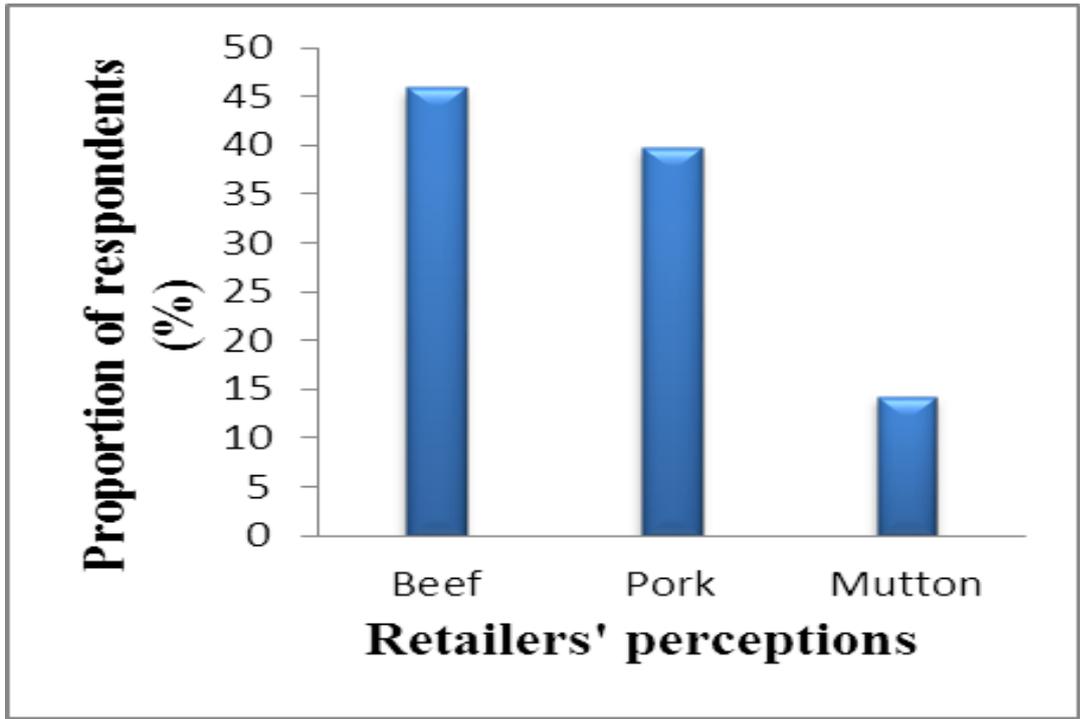
Figure 3.4: Retailer's perceptions on the type of meat that is purchased and preferred the most
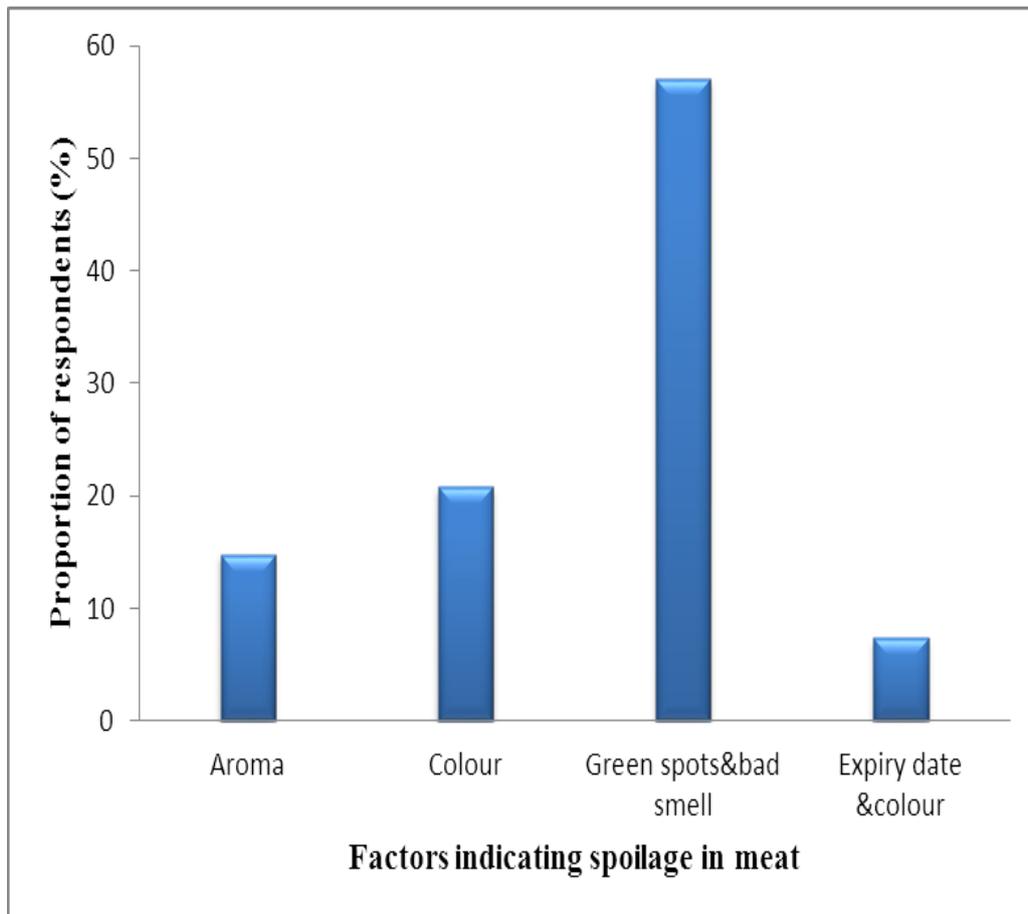
Figure 3.5: Perceptions on factors which indicate meat spoilage

These consumers further indicated that at times during purchasing, one may not be able to recognise the change in meat colour due to the infra-red lights which are normally used at display. Others at times find it difficult to determine the bad smell due to different senses and mixed feelings that arise during shopping. Therefore, they perceived that expiry dates documented on meat packages play a significant role to indicate meat spoilage more than its visual appearance. To predict meat safety consumers used expiry dates. Of all the consumers interviewed, 78% agreed that it is important to consider the expiry date when making purchasing decisions for meat as indicated in Figure 3.7. However, 22% of respondents still felt that it is not important to consider expiry dates when making a purchasing decision. Figure 3.8 below represents consumer's perception on whether they do trust expiry dates written on meat packages. Findings in this study revealed that (58%) of the consumers trust expiry dates written on meat packages. However divergent views were recorded in this aspect whereby (37.5%) were against this opinion. These consumers prefer judging the quality of meat by visual assessment. According to the USDA (2011), expiry date is not a safety date. There is a distinction to note that there are generally several dates associated with food. There is a sell by date, a best by date and an expiration date. Normally expiry date refers to the last date a food should be eaten or used. The term "Best before" refers to quality and taste standards. The length of time that food is good after this date depends on the product. However it should be noted that for meat consumers should consider "sell-by dates". Because meat is a perishable product, therefore most sell-by dates are found on perishables. The date is a guide for stores to know how long they can display a particular product and that it is not safe to consume a product beyond the stated date.
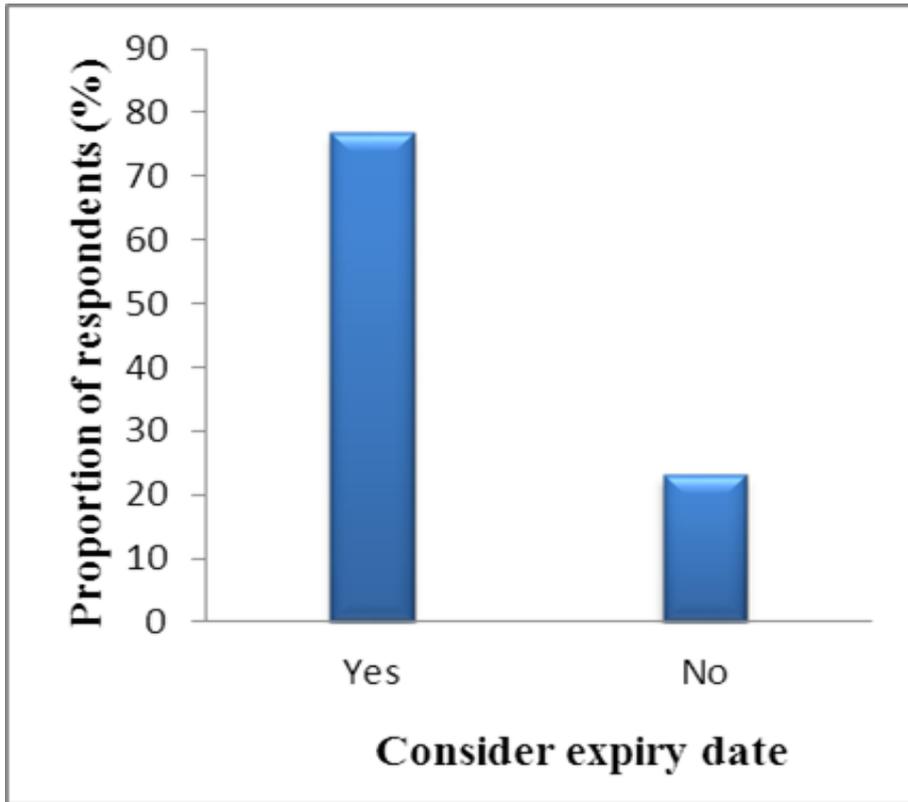
Figure 3.6: Consumers perceptions on expiry date as a good indicator of meat quality.
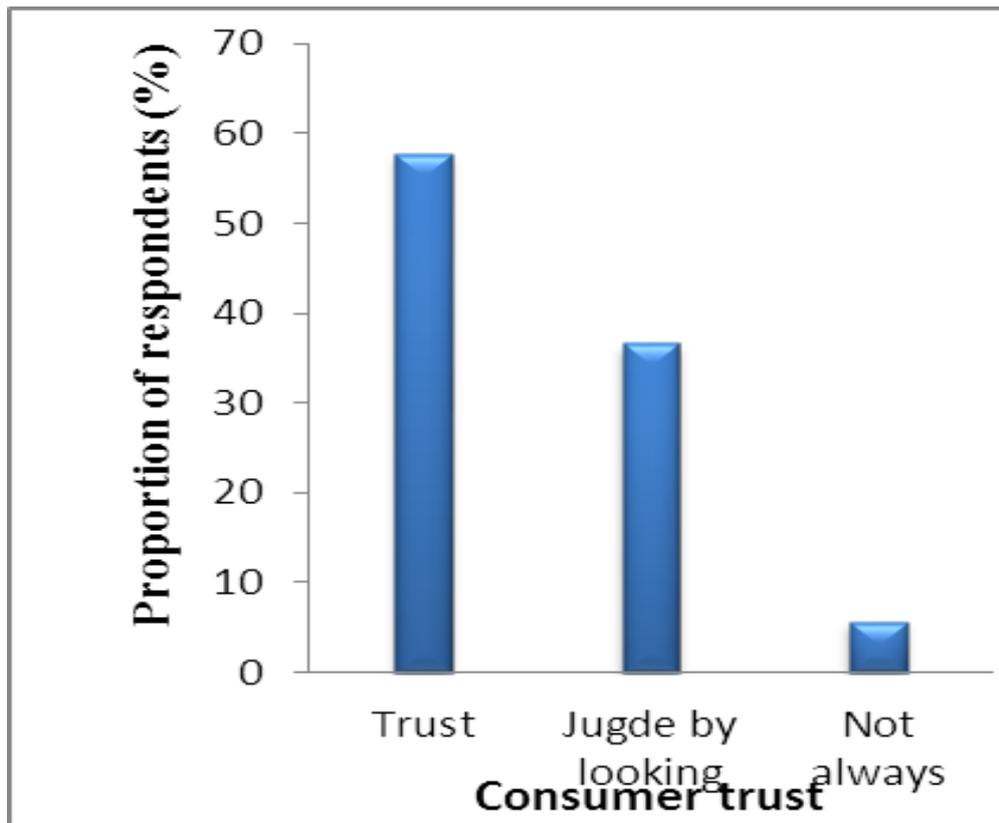
Figure 3.7: Consumers perceptions on whether they trust expiry date as a good indicator of meat quality.

Consumers were further interviewed on their opinion regarding consuming spoiled meat (Figure 3.9). Respondents were categorised as blacks, white or coloureds. A small proportion of black respondents (35.6%) indicated that they do consume spoiled meat provided that they cook it with water and vinegar or fry it to get rid of the bad aroma. Some of the coloured respondents (15%) indicated that they prepare it for their dogs, whereas the majority of white respondents (49.4%) throw it away. Those consumers who reported to throw away spoiled meat were aware that it may not be good for their health, and those who reported not to have a problem with consuming spoiled meat believe that spoiled meat has never killed anyone before, if they can still get rid of the bad aroma why not consume it. This response was observed mostly from black respondents and almost all the white consumers indicated that they either reject or throw away meat immediately once they presume that it is spoiled. The fact that some black respondents had shown not to have a problem with consuming spoiled meat shows lack of knowledge of meat safety towards their health. Case (1998) conducted a study focussing on black consumption patterns where she found that most black consumers buy lower quality foods, thus they faced far lower average prices.

When consumers are about to purchase meat, there are some primary factors which influence their purchasing decisions. Price has been regarded as the most important primary factor which affects consumer's decisions. In the current study, consumers' response towards meat that is sold at a cheaper price are shown in (Figure 3.10). About 52% of the consumers indicated that they will never purchase meat which is sold at a cheaper price since they believe that more often, price is reduced towards or prior the end of the expiry date which may not be good for their health. However, a contrasting opinion was observed where 20% of the respondents reported that they would purchase it immediately, and the remaining (28%) revealed that they would think twice about it as cheaper price may indicate bad or low quality.
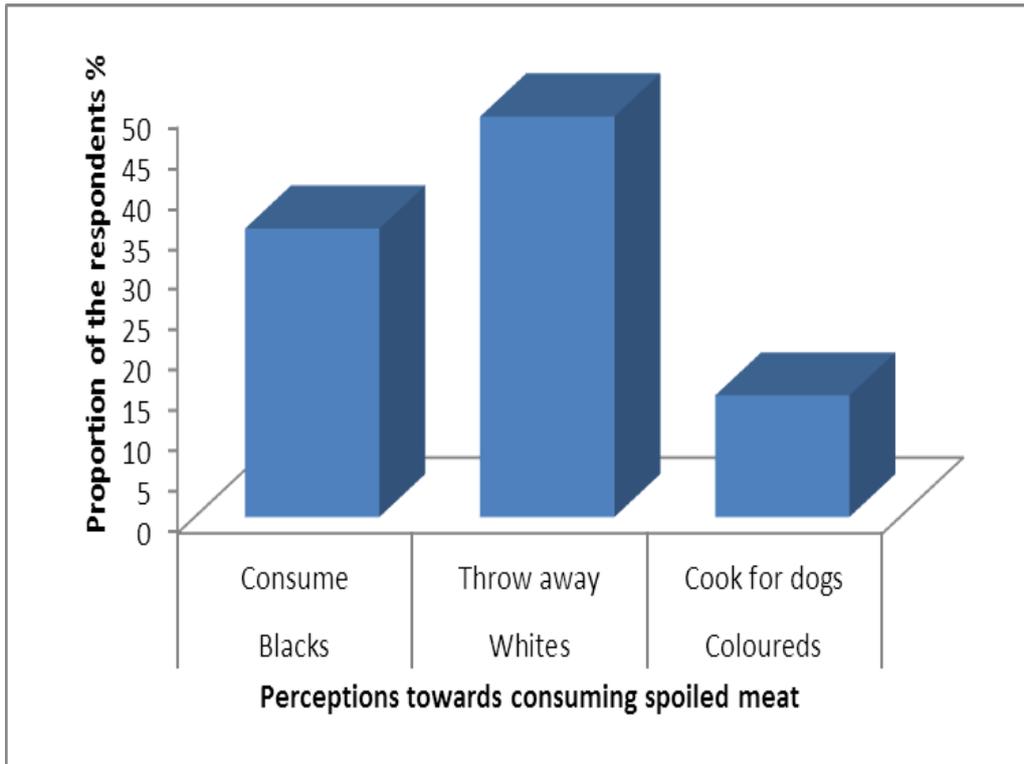
Figure 3. 8: Consumer's perceptions by race towards consuming spoiled meat
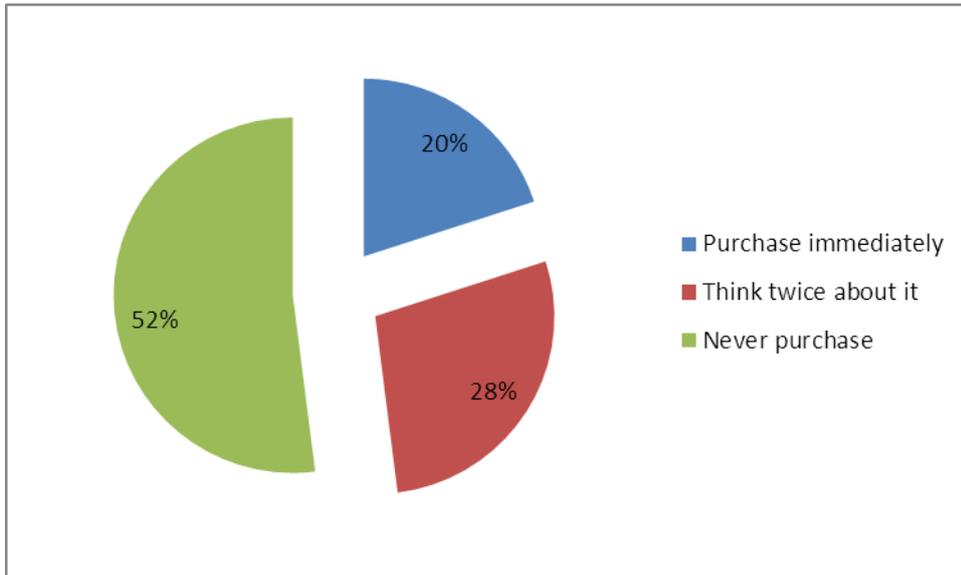
Figure 3.9: Consumer's perceptions towards meat which is sold at a cheaper price

Findings in this study further showed that packaging (35%) is a primary factor which influence consumer choice when purchasing meat. However, a contrasting opinion was observed where 65% of the respondents indicated that they do not consider the type of packaging before they buy meat. They further explained that they do not even have knowledge on the types of packaging used in shops neither do they know the difference, they just care about what they are purchasing and taking home for as long as it is in a good condition. Consumers were further interviewed on whether they think it would be important for them to know the background information of the carcass at the point of purchase (Figure 3.11). The majority of the consumers (53%) felt that it would be in their best interest if the background information of an animal would be documented and form part of labelling in meat packages at the point of purchase. For an example knowing information about the sex of an animal and age at slaughter would assist them to be able to predict / determine some of the meat quality attributes like tenderness when making their purchasing decisions.

Observations during data gathering revealed that place of purchase is another important factor which affects consumers' purchasing decisions. In the current study, consumers rated the place of purchase as one of the most important quality cues that can be used as good indicator of meat quality. These results are in line with the study by Becker *et al.* (2000) where the place of purchase was ranked as most helpful in assessing meat quality in the shop. Divergent views on meat quality in relation to the place where it was purchased were observed. Consumers gave an indication that there is a difference in the quality of meat purchased from a butchery and retail shops and that difference lies in the freshness of the meat where butcheries always target to sell fresh meat hence this is the only product they specialise in compared to shops where meat is usually kept for a longer period. The results revealed that more than 50% of the consumers prefer to purchase meat from a butcher than in retail shop/ supermarket chains as shown in Figure 3.12 below.
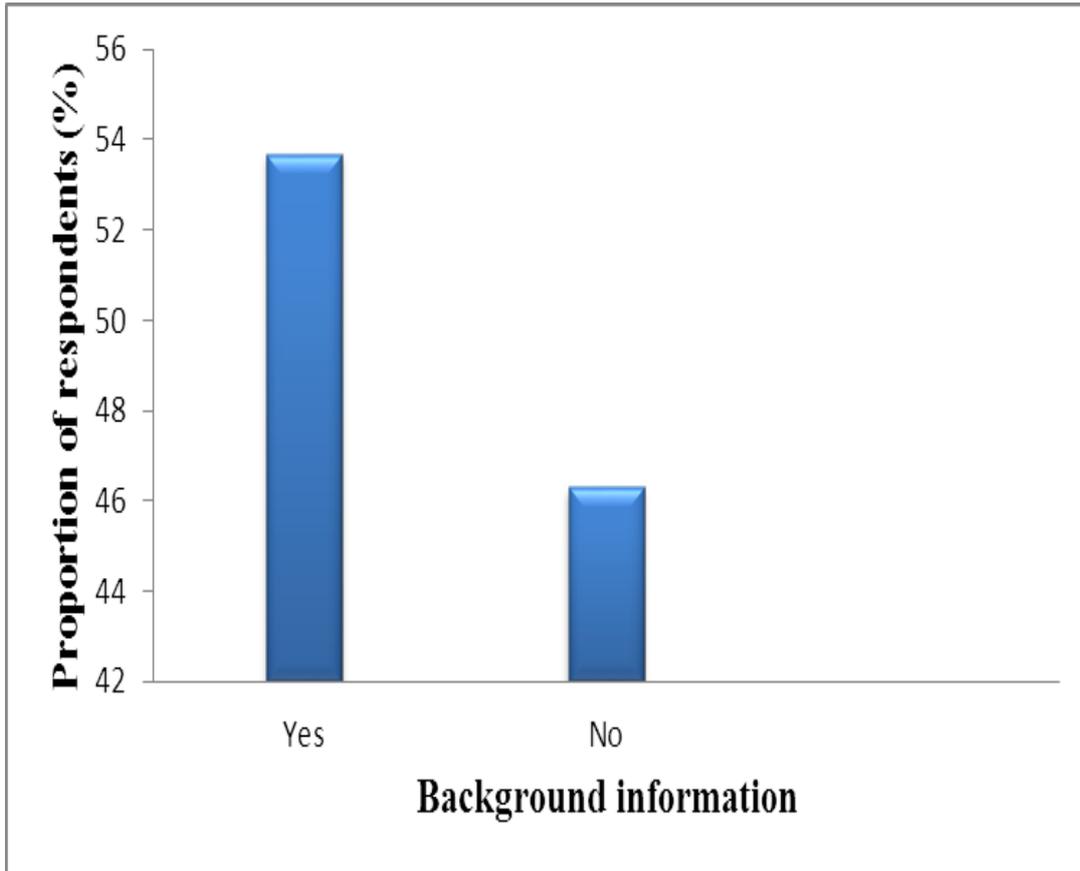
Figure 3.10: Consumer's perceptions on whether it is important to know the background information of the meat at point of purchase

Figure 3. 11: Perceptions on place of preference for purchasing meat

Consumers perceived that butcheries sell fresh and stamped meat at a more affordable or cheaper price compared to retail outlets. They also liked the fact that butcheries sell meat in bulk at a reasonable price. Although this was the case, 39% of the consumers still preferred to purchase meat from the retail shops with the perception that shops (e.g. Woolworths, Shoprite, Spar, etc.) are hygienically more clean than most butcheries (e.g. Mabovula, Crave, etc.). They also perceived that meat sold from shops is safer as it is sold in packages covered with an expiry date as a re-assurance that their meat is still in a good state for consumption. Consumers further highlighted that when purchasing meat it is important to consider the class of a shop where purchases are made as meat from high class shops is considered to be safer than meat which is purchased from low class shops. Divergent views were however observed as a small proportion of consumers (34%) felt that there is no need to consider neither class nor rank shops when making their purchasing decisions.

3.3.3 Perceptions pertaining to meat safety at the point of purchase

In the current study, consumers were interviewed on their understanding of meat safety. More than 65% of the respondents revealed that meat safety refers to the hygienic state of raw meat and whether it can be prepared and consumed without causing any sickness to human beings . Others perceived that meat safety refers to meat with high eating quality. The results are shown in Figure 3.13. Results showed that consumers were aware (41%) that meat when not handled or stored correctly may attain pathogenic organisms which may be harmful to their health. However, more than half of the population wass unaware. It was observed that educational status play an important socio- economical role in this aspect as the highest percentage of consumers who were aware of the pathogenic organisms were mostly educated respondents. Consumers were further interviewed whether they keep different types of raw meat (e.g. beef, pork, mutton, chicken and fish) in contact with each

other when stored in the refrigerator and whether they read instructions on safe handling and

storage
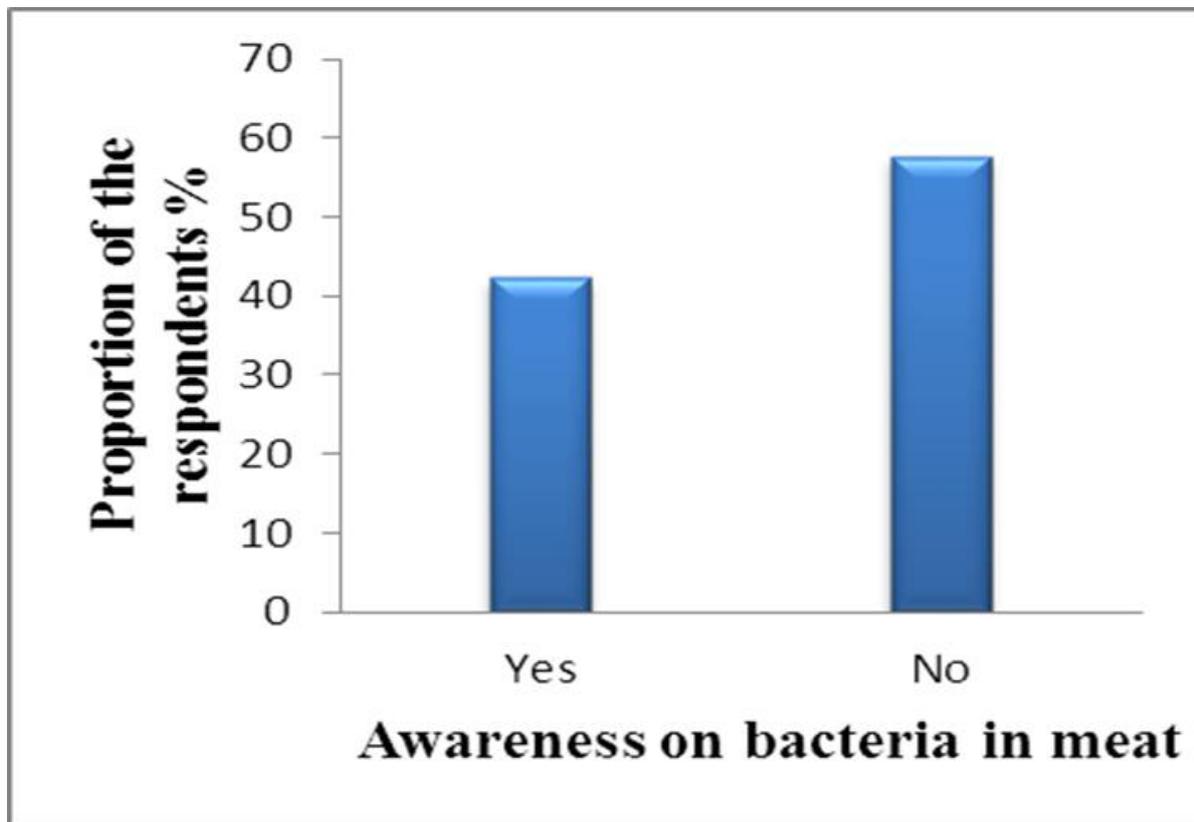
Figure 3. 12: Consumer's perceptions about awareness regarding pathogenic organisms

documented on meat packages. Findings in this study indicated that, more than 80% of the consumers kept raw meat in contact with each other. A small proportion of the respondents (35%) considered instructions on safe handling and storage written on meat packages whereas the remaining 65% revealed that they do not frequently read the instructions and may only consider them when purchasing an item for the first time.

The perceptions of consumers on whether they purchase meat from the street vendors (Figure 3.14) and if there is a difference in meat sold from streets and retail shops (Figure 3.15) are shown below. Of all the consumers, 58% revealed that they do purchase meat from the street vendors whilst 42% highlighted that they would never purchase meat sold from the streets. The reasons given were that consumers perceive that meat displayed on the streets is not hygenically clean and may not be fresh nor safe for their health, although some would not purchase it just to proctect their public image or believe it would demote their social status in the community. It was interesting to observe that none of the white consumers had reported to purchase meat from the streets. When asked if there is a difference in the quality of meat sold from the street vendors compared to the retail shops, the majority (52%) disapproved of the notion , whereas 29% perceived that there is a difference as meat sold from the streets is disposed outside where there is accumulation of air which affects meat colour and freshness. In street vending, the meat is usually displayed without any packaging and they do not have a "sell by date" (Adesiyun, 1995). Contamination through flies, dust and moulds may occur. Meat from the streets is not refrigerated and according to Carvalho (2012), meat is sensitive to temperature changes and must be stored at 5º C to 10 ºC from abattoir to consumer to minimise the growth of bacteria on the meat. This is an indication that the meat they are buying might not be safe for their health as the meat marketers may also be unsure of the end date. Bacterial growth may result infood-borne illnesses which have been reported to account for the majority of illnesses reported in most developed countries. Some consumers reported
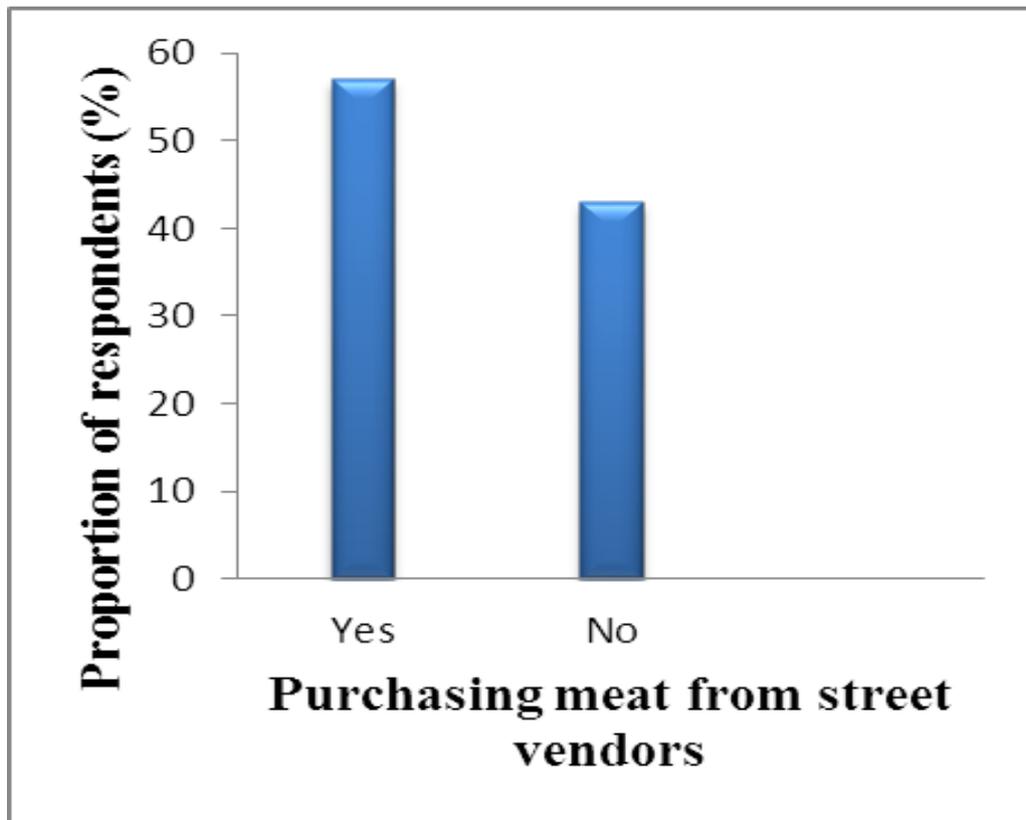
Figure 3.13: Consumer's perceptions on whether they do purchase meat from the street vendors
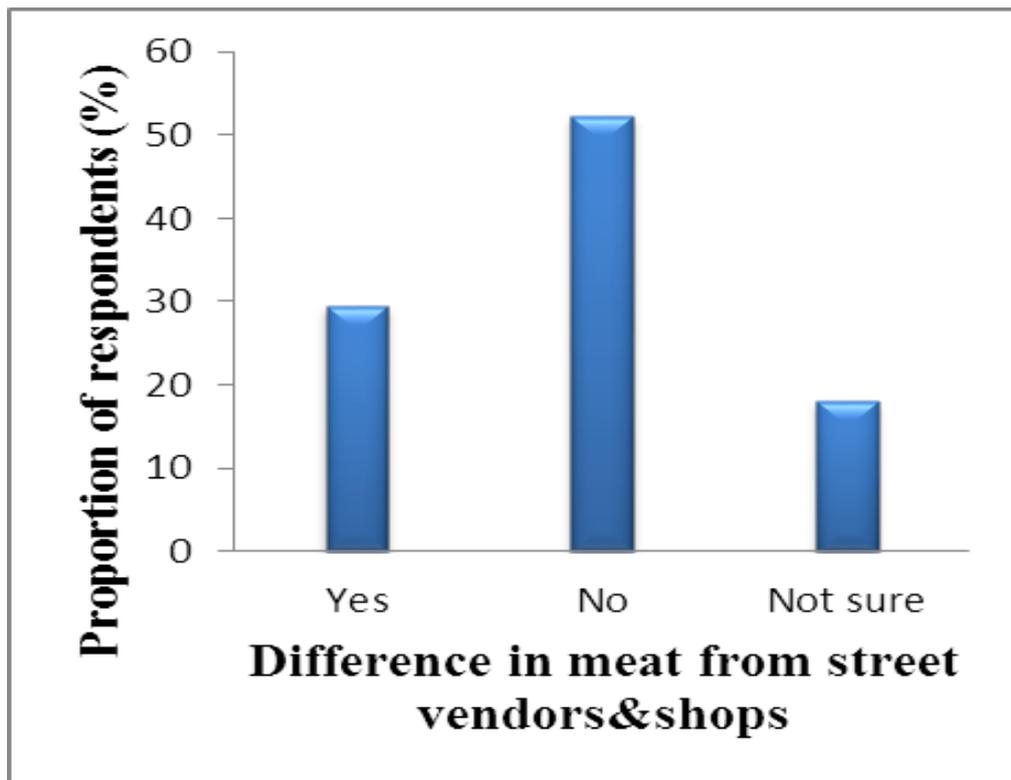
Figure 3.14: Consumer's perceptions on whether there's a difference in meat sold from streets and retail shops

that even the aroma or smell of raw meat which is dispalyed for a longer period is not appetising at times. Contrasting views on this matter were observed as the remaining (19%) were not sure if there is a difference. They reported that meat sold from the streets at times may be fesher than the one purchased from the shops and sold at an affordable or cheaper price.

The study further revealed perceptions of consumers on meat handling at abbatoir or retail shops , and results are shown in Figure 3.16. Most consumers (57.8%) reported that they do care/ observe if the meat handler wears protective clothing or not before they purchase meat. Others (37%) revealed that they do not care, they just purchase what they want and believe that the quality and freshness of meat does not rely on the meat marketers clothing, it's the price and appearance they consider the most.

Consumer's knowledge or awareness on the type of diseases which can arise from the transfer of harmful microorganisms from meat to humans is shown in Figure 3.17. Most consumers show lack of knowledge (71%) on this aspect; where they revealed that they have never heard of diseases like anthrax, bovine tuberculosis, brucellosis, salmonellosis, listeriosis and trichomoniasis. Shigellosis is the only disease that they had reported to be familiar with. In a study by Nesbitt *et al.* (2014), Canadian consumers showed good general awareness of food safety. This knowledge gap on meat safety which has been demonstrated by the consumers in the current study can be associated to the fact that, food-borne diseases are generally under-reported and poorly investigated in South Africa (Frean *et al.,* 2003). The consumers were further interviewed if they have purchased meat which has caused diseases to their families and 60 % revealed that they have never experienced it, whilst the rest were not sure. Instead consumers raised a question especially those who fell in the age range of
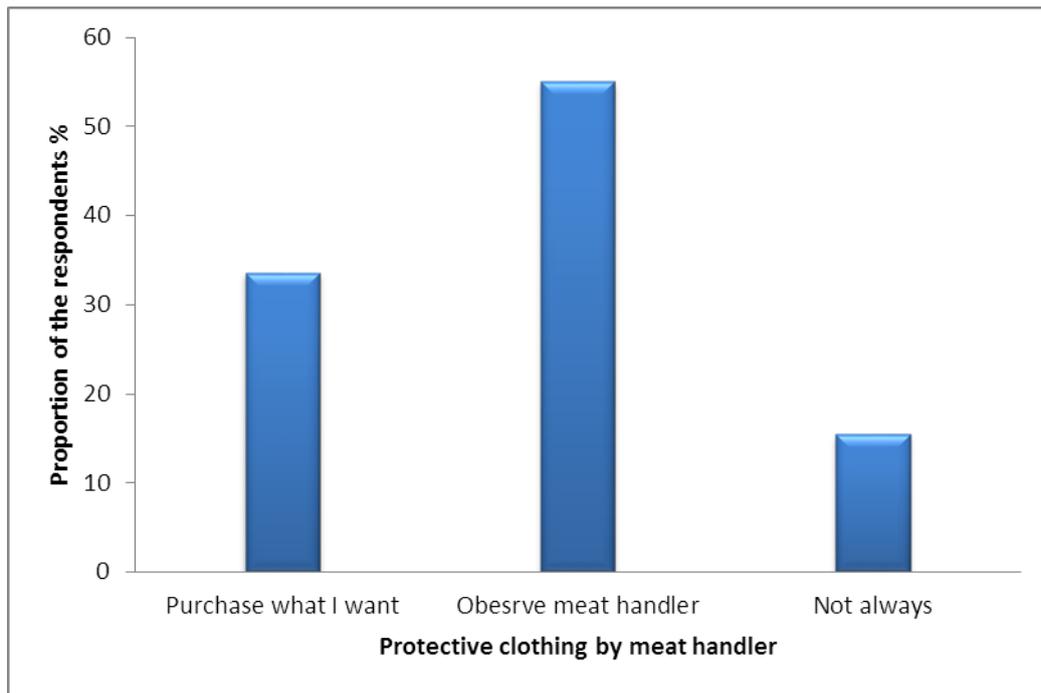
Figure 3.15: Consumer's perceptions on whether they care if the meat handler wear protective clothing
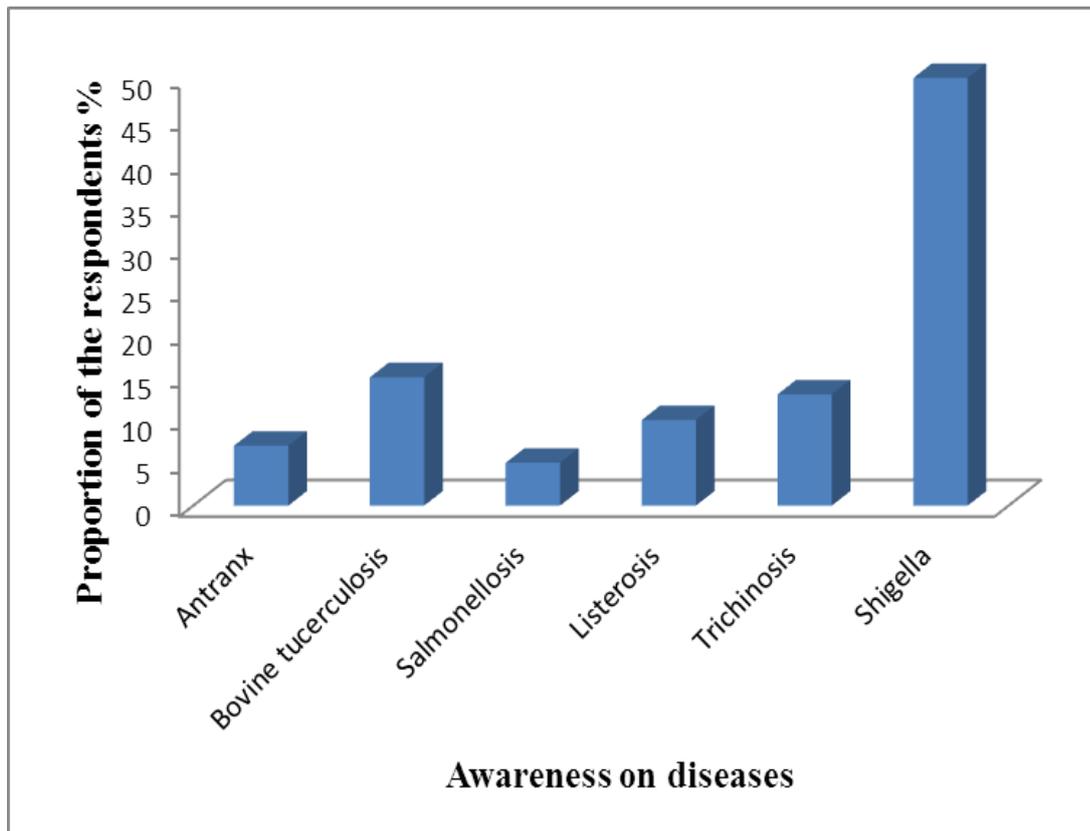
Figure 3.16: Consumer's knowledge on type of diseases which arise from transfer of pathogenic micro-organisms in raw meat

more than 50 years on "how can one tell or know even if they get sick from consuming meat that the disease would have arised from it?

3.3.4 Retailers perceptions on factors relating to meat quality and cues used to predict consumers purchasing decisions during marketing

Retailer's perceptions on shelf life of different types of meat are shown in Figure 3.18 and Figure 3.19 respectively. The results indicated that different meat types do not have the same shelf-life as 65% of retailers regarded beef as the type of meat with a prolonged shelf-life followed by mutton (20%) and pork was perceived as the type of meat with a shortest shelf life (10%). However, 5% of the retailers still perceived that beef, pork and mutton do have the same shelf-life as they cannot exceed a period of 3 days during display. Reason for this perception could be linked to retailer's previous experience in the meat sector. It is important to note that for every product that is sold in a shop an expiry date is provided. An expiry date indicates the shelf life or a period in which a particular type of a product can still be consumed, if it exceeds that period then the product is no longer safe for consumption. For most products (e.g. milk, juice, sugar, etc.) expiry dates are determined or stamped by the manufacturing companies, but meat is a perishable product which shelf life cannot entirely depend on the slaughter date but also depends on handling. Therefore abattoirs are not responsible for determining expiry dates for meat as the duration period after it has departed from the abattoir can only depend on each retailer. Therefore, a question on who determines the expiry date of meat in shops was included (Figure 3.20). Findings in this study revealed that 82% of the retailers perceived that expiry dates for meat should be determined by butcher managers as they are trained and are more knowledgeable on this aspect.

Few retailers (5%) reported that expiry dates should to be determined by the environmental manager whereas the remaining 10% believed that they should be determined by the meat scientists. Retailers further revealed that expiry dates in meat are estimated using a scale
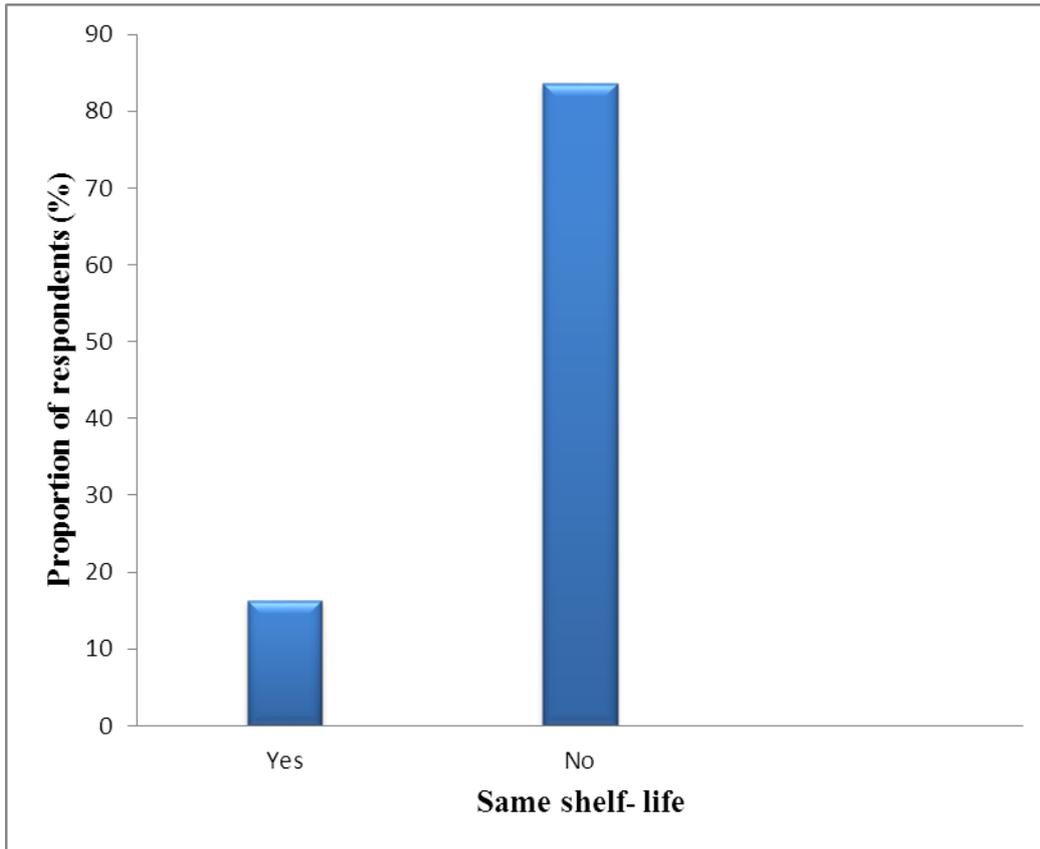
Figure 3. 17: Retailers perceptions on whether different meat types have the same shelf life
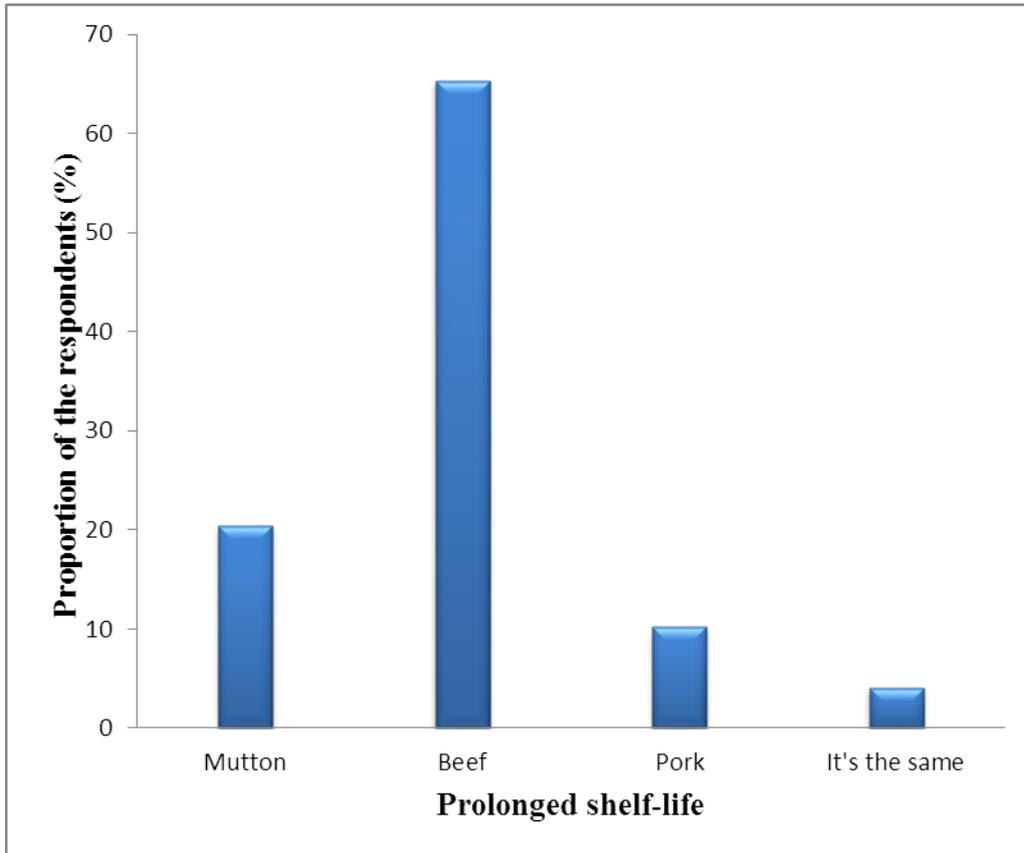
Figure 3. 18: Retailers perceptions on shelf life of different meat types and the one which they perceive to have a prolonged shelf-life
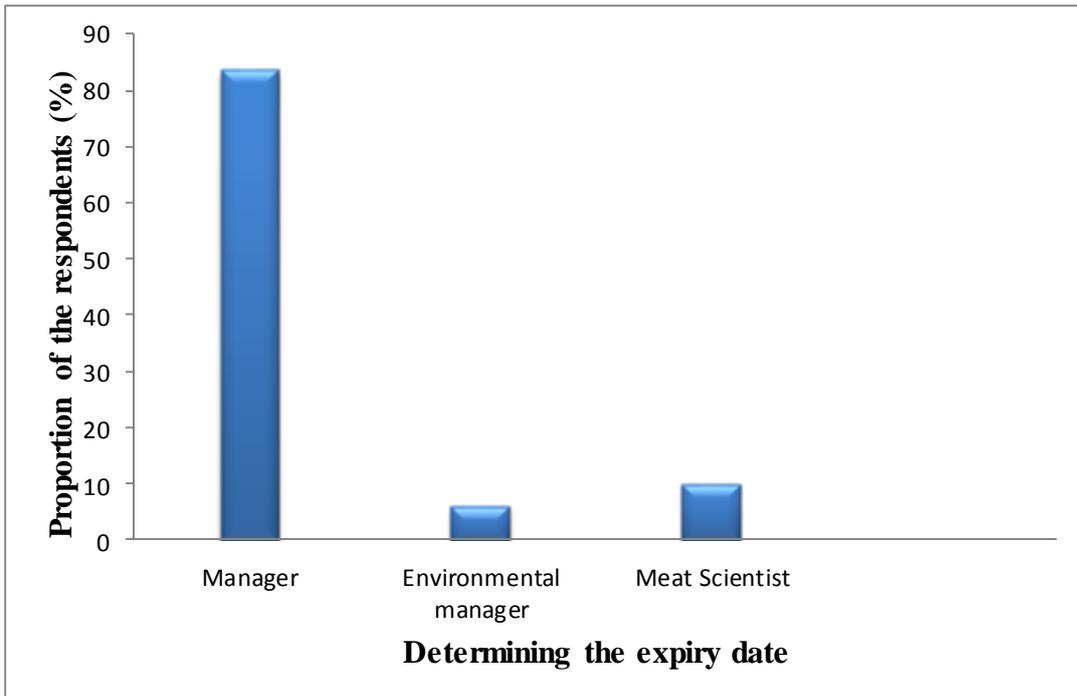
Figure 3. 19: Retailer's perceptions regarding the person responsible for determining expiry dates of meat in retail shops

regardless of the duration or storage days that the carcass would have spent in an abattoir or in their storage rooms. However, more than 60% of retailers from ordinary butcheries in rural areas reported that they do not use a scale to determine expiry dates in meat, they just assess colour and aroma of the meat to verify if it is in a good condition to be sold to the consumers. When interviewed on how do they verify that the meat which is sold to the consumers is not contaminated, some of the retailers replied that, the fact that consumers have never came back to complain about food poisoning from the meat that they purchased in their shops, clearly indicated that they sell clean and safe meat. A manager from a high class butcher further explained that they always maintain their temperatures and believe in selling nothing less but high quality and safe meat. When asked if they do consider microbial inspection in their shops, 92% reported that they do not do microbial inspection as carcasses were already inspected at the abattoir. However, they indicated that they do follow the HACCP procedures to make sure that they sell safe meat. This implied that meat inspection ended at the abattoir and assessments along the distribution chain to protect consumers health were not adhered to. Divergent views on this aspect were however recorded and the remaining 8% of retailers revealed that they do perform microbial assessment in their shops as their customers have shown some sensitivity towards mat safety. It was interesting to observe that the 8% response on meat safety was from white retailers residing in urban areas and where the majority of their customers where considered to be white. Therefore it is not known whether retailers and consumers from other nationalities considered the aspect of meat safety as less important, whether they were ignorant can be due to lack a of knowledge on this aspect.

Perceptions on who determines prices of meat in their shops are presented in Figure 3.21. The majority (47%) reported that prices are determined by the manager, whilst others (25%) revealed that prices are determined from their head offices. However, 28% of the retailers

Figure 3.20: Retailer's perceptions regarding the person responsible for determining prices of meat

reported that prices are determined by the amount that they would have paid at the abattoir when placing orders to purchase the carcasses in relation to the profit that they would gain. Figure 3.22 demonstrates retailer's perceptions on storage days before the meat could be displayed on shelves. The results revealed that storage days/ period before the meat could be displayed in shelves differs per each shop. Thirty six percent of the retailers perceived that meat should be given a day in storage after it has been delivered in their shops before display whilst 20% reported that the storage duration before display depends on the demand for meat in their shops. However, other retailers (20%) believed that meat should be cut and placed on display as soon as it arrives if it is already dry. They believe in selling fresh and top quality meat whereas 13% believed that meat can be kept for 2 to 3 days on storage before display without disturbing its quality for as long as you maintain the correct temperatures. Retailers were further interviewed on whether they think consumers care about the background information of the animal before slaughter when purchasing meat (Figure 3.23). The results revealed that 42% of the retailers believed that consumers do care about the background information of an animal, as they would frequently ask questions pertaining to this subject at the point of purchase. Some of the questions included were: is this meat coming from a female or male animal; what was it fed on, any idea on when was it slaughtered? Therefore given the chance, they would suggest that on the packaging, information on the background information of an animal should be added/ provided. However, 30% of the retailers still perceived that consumers do not care about the background information of an animal and only consider what they are buying and taking home, and 28% were clueless on consumer's views pertaining to this aspect.
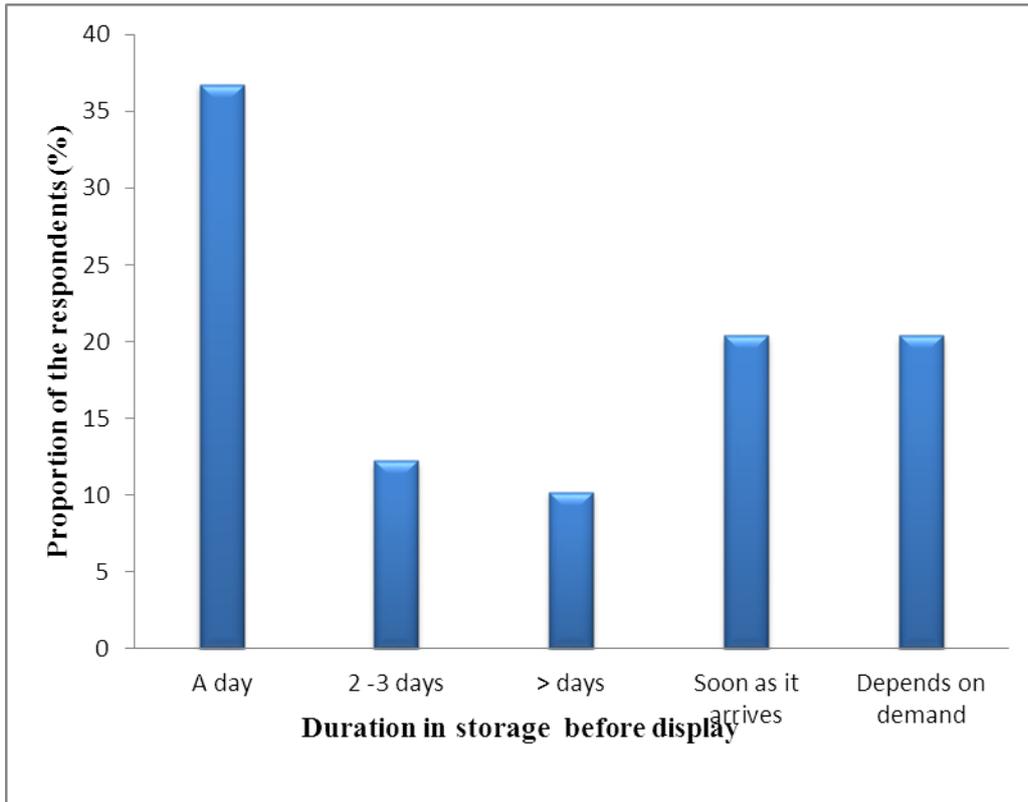
Figure 3.21: Retailer's perceptions on storage days before the meat could be displayed in shelves
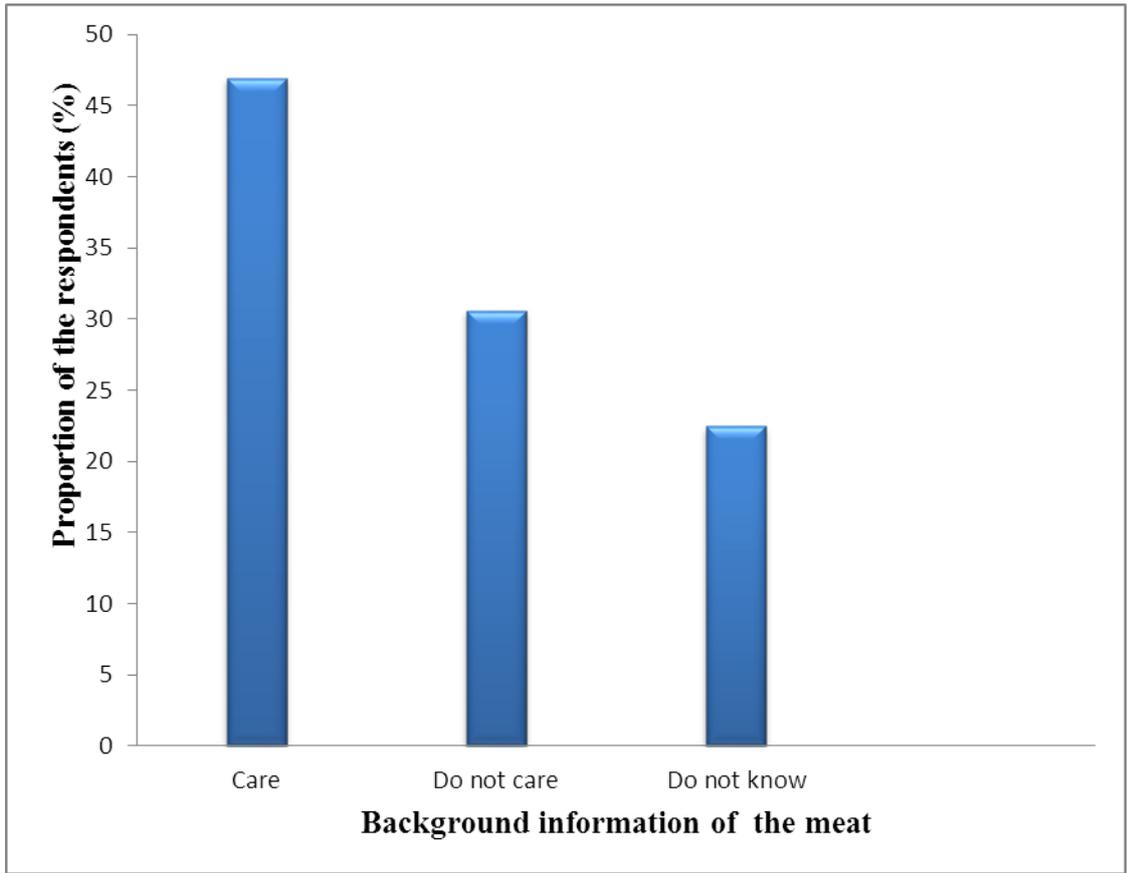
Figure 3.22: Retailers perceptions on whether consumers care about where their meat comes from

3.3.5 Handlers' perceptions on meat quality and challenges faced during the distribution chain

Abattoir workers especially those who are responsible for transporting meat to the retailers were interviewed on their perceptions pertaining to meat quality and some of the challenges they faced when transporting meat to the retailers. The majority of abattoir workers interviewed in the survey (39.47%) had an experience of more than 10- 30 years working in the meat sector. The commercial abattoir where the interviews took place supplies meat to retailers and at times directly to the consumers and the informal meat marketers. The small-holder abattoir only supplies meat to the butcheries and offal to the informal meat marketers. Therefore, a question on whether their clients have rejected or returned meat that has been supplied back to the abattoir, was included (Figure 3.24).

The majority of the abattoir workers (70%) reported that at times they do experience or encounter such challenges where meat would be rejected. Reasons for rejection are mainly due to incorrect order, incorrect age, over-matured and incorrect cutting (Figure 3.25). When asked if they think the quality of meat differs according to the supplier, most of the respondents (71%) reported that the quality of meat does differ according to the supplier and differences are due to handling, storage temperatures, storage days and size of the facility at slaughter. Meat handlers were further interviewed on which meat quality attribute is affected the most by the reasons stated above and 44.74% perceived that tenderness is affected the most followed by colour (36.84%). Since consumers indicated that meat quality differ per each retailer, a question pertaining to meat handlers as to what causes the difference in meat quality once it reaches the supply points was included. Meat handlers perceived that the way in which carcasses are handled by the retailers, storage conditions and temperature are what caused the difference in meat per each retail store.
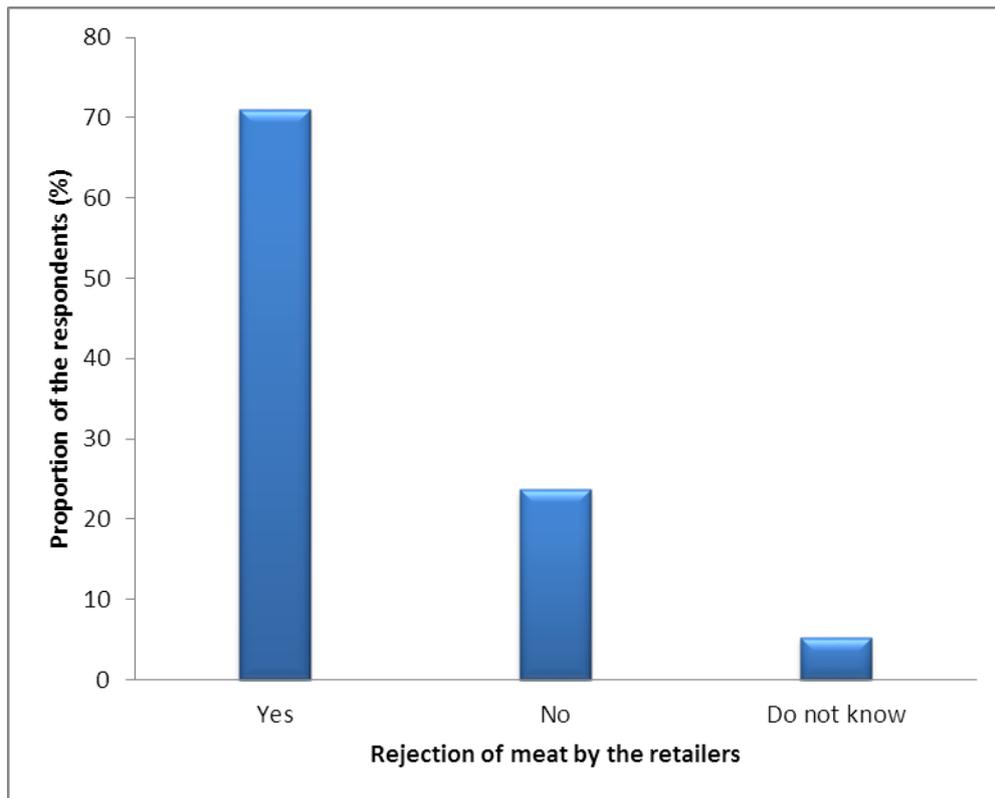
Figure 3.23: Retailers perceptions on the rejection of meat by the consumers
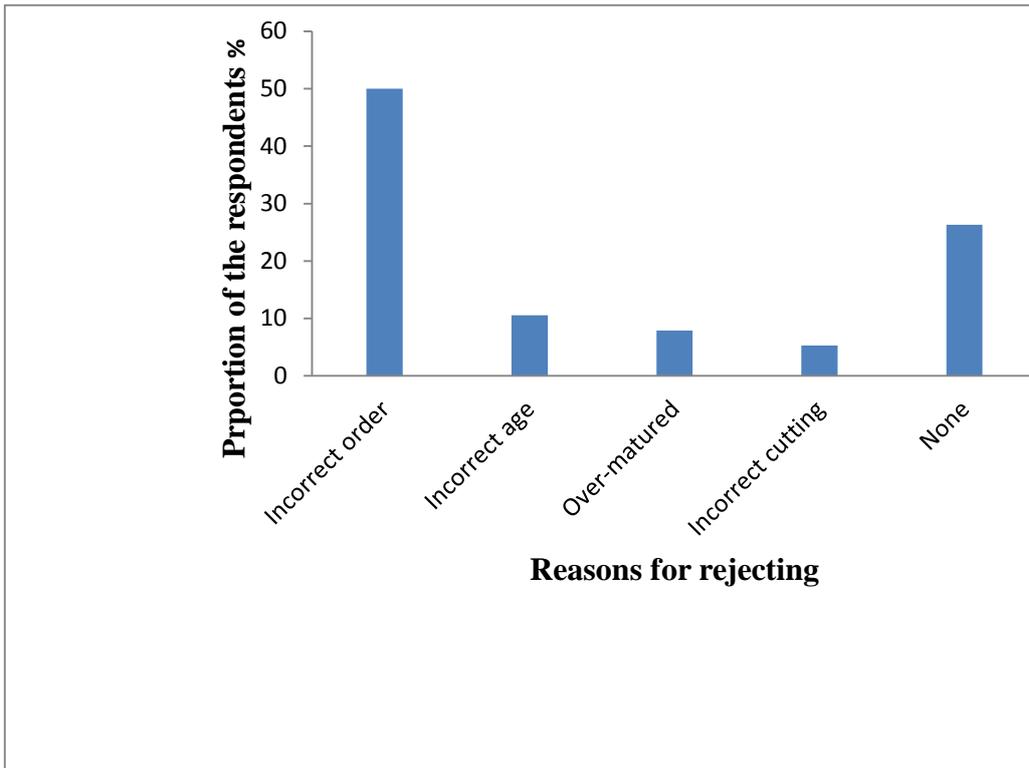
Figure 3.24: Retailers perceptions on their reasons to reject meat when delivered from the abattoir

Meat handlers were interviewed on what temperature the meat is stored at the abattoir before delivery and after how long. Respondents from the commercial abattoir reported that carcasses are stored at 7˚C in the chillers before delivery and the storage duration depends on the demand or orders made by the retailers. However, for the low-throughput abattoir, meat handlers reported that they do not have a chiller, carcasses are transported the same day after slaughter to the butcheries. The fact that carcasses are chilled in chiller rooms before delivery in the commercial abattoir is in accordance to law. Brown *et al.* (2009) stated that this is done to impart the development of rigor mortis and prevent growth of micro-organisms on carcasses. However, respondents from the low-throughput abattoir indicated that they do not chill their carcasses, which implies that the manner in which they operate maybe against the law.

Meat handlers were further interviewed on whether they do mix different types of meat during transportation to the supply points. The majority (71,5%) agreed that they do mix different types of meat in their trucks during delivery except for Halaal meat and they believe that it does not have an effect on the quality. When asked if mixing different types of meat does not have an effect on the meat safety, as each carcass might have different microbial loads, the respondents indicated they that they do not normally consider it as the carcasses are accepted based on visual inspection by the retailers or assessing pH and colour measurements during off- loading to the supply points. Meat handlers were asked if they perceived distance as a problem / challenge during transportation of carcasses and 52, 53% perceived it as a challenge especially for long distances whereas 47.47% did not perceive distance as a challenge when transporting carcasses as long as temperatures in trucks are maintained. Some reported that it is difficult to maintain constant temperatures in trucks during delivery, as during off - loading at each supply point the doors would be open for quite some time resulting in a slight increase in temperatures. Truck drivers reported that the shortest distance

that they cover when transporting carcasses was 1 km and 1800 km was the longest distance. The series of loading and offloading, temperature fluctuations or control, environmental temperatures and ques during offloading were reported as the major challenges during transportation of carcasses from the abattoir to the supply points. This is in line with findings by Richardson *et al.* (2009) where transportation and storage temperatures were found as the major factors affecting meat quality in the supply chain.

The results on the association between demographic information and consumers perceptions on factors affecting their purchasing decisions and meat safety are shown in Table 3.2. The age group of the respondents was associated ($p< 0.05$) with the following aspects: the expiry date and type of meat which is considered to be healthier. This positive association between age group of the respondents and viewing expiry dates makes sense, as older people (>50 years) may have difficulties reading or even forget to check it. The fact that there was a relationship between age group and educational status of the respondents towards expiry date is psychologically sensible as educated consumers may be interested to read expiry dates each time they purchase a product since they are used to reading often, unlike an un-educated consumer who may find it difficult to read nor to understand what is written on the packaging. The current study indicated that there is an association between gender and selecting the price of meat. This can be due to the fact that women spend more time when purchasing a product in a shop as compared to men who just purchase what they want (Devasahayam, 2005). Gender also had a significant influence on the type of meat which is purchased the most, place of purchase, and the choice of purchasing meat from the street vendors. During data gathering most male respondents had indicated that most of their purchases especially during lunch hour are made from the street vendors and they do not have time to compare prices when making purchasing decisions.

Table 3.2: Association between demographic information and consumers perceptions on factors affecting their purchasing decisions and meat safety

Demographic factors	Purchased the most	Expiry date	Ranking shops	Price of meat	Place of purchase	Street vendors	Awareness	Protective clothing	Disease outbreaks	Healthier meat	Difference in meat from butcher/shop
Age	NS	***	NS	NS	NS	NS	NS	NS	NS	**	NS
Gender	***	NS	NS	*	***	**	NS	*	NS	NS	NS
Race	NS	NS	NS	**	***	***	*	*	**	NS	NS
Educational status	NS	***	**	*	*	**	***	*	***	NS	**
Employment status	*	NS	**	*	*	*	NS	NS	NS	**	***

*** p < 0.001; **p < 0.01; *p < 0.05

There was an association between race and price that consumers are willing to pay for meat, place of purchase, awareness about meat safety, and the choice of purchasing meat from the street vendors. Also educational status of the consumers had a positive association with the factors affecting their purchasing decisions (expiry date, price, shop class/ ranking,) and their awareness about meat safety. Most educated consumers reported that they cannot purchase meat from the streets and have shown awareness about disease outbreaks which have occurred due to mishandling of food. Employment status determined the type of meat and price that one is willing to pay when purchasing meat as well as ranking the class of shops when making purchasing decisions.

3.4 Conclusion

Findings from this study revealed that the way in which consumers and handlers use quality attributes to predict meat quality and safety differs. To predict meat safety consumers used expiry dates but to indicate quality, colour or visual assessment was used. It was revealed that consumers would be interested if the background information of the animal can be documented on meat packages as it would assist to predict meat quality. Consumers showed lack of knowledge about the diseases which may arise from eating meat. Although meat handlers generally perceived distribution chain as having an effect on meat quality, meat safety was ignored. In conclusion, lack of awareness of food safety among the consumers and retailers was shown, indicating that there remain areas that need improvement and further education.

3.5 References

Adesiyun, A. A. 1995. Bacteriologic quality of some Trinidadian ready - to - eat consume foods and drinks and public health risks to consumers. *Journal of Food Protection,* **58:** 651- 655.

Ahmed, A. F. 2007. Consumers' perception and attitude towards mutton consumption in Peninsular Malaysia. *Journal of International Society for Southern Asian Agricultural Sciences.* (Abstract).

Ali, N. H., Farooqui, A. and Khan, A. 2010. Microbial contamination of raw meat and its environment in retail shops in Karachi, Pakistan. *The Journal of Infection in Developing Countries ,***4:**382-388.

Aklilu, Y. 2002. An audit of the livestock marketing status in Kenya, Ethiopia and Sudan. Volume1. Nairobi, Kenya: Community-Based Animal Health and Participatory Epidemiology Unit, Pan African Programme for the Control of Epizootics, and the Organization of Africa Union/Inter-Africa Bureau for Animal Resources.

Becker, T., Benner, E. and Glitsch , K. 2000. Consumer perception of fresh meat quality in Germany. *British Food Journal,* **102:** 246-266.

Bosona, T. G., and Gebresenbet, G. 2011. Cluster building and logistics network integration of local food supply chain. *Biosystems Engineering,* **108:** 293–302.

Brown, T., Richardson, R. I., Wilkin, C. A. and Evans, J. A. 2009. Vascular perfusion chilling of red meat carcasses – A feasibility study. *Meat Science*, **83:** 666–671.

Brunso, K., Ahle Fjord, T. and Grunert, K. G. 2002. Consumers food choice and quality perception. Aarhus V, Denmark: The Aarhus School of Business.

Bryhni, E.A., Byrne, D.V., Rødbotten M., Claudi- Magnussen C., Agerhem, H. and Johansson, M. 2002. Consumer perceptions of pork in Denmark, Norway and Sweden. *Food Quality and Preference,* **13:** 257-266.

Case, A. 1998. Income distribution and expenditure patterns in South Africa. Mimeo. PhD Thesis. Princeton University, United States of America.

Carvalho, C. M., Kropinski, A. M., Ferreira, E. C., Azeredo, J. and Santos, S. B. 2012. Phages as therapeutic tools to control major foodborne pathogens: *Campylobacter and Salmonella* (pp. 179-214). INTECH Open Access Publisher.

Colmenero, F. J. 2000. Relevant factors in strategies for fat reduction in meat products. *Trends in Food Science and Technology*, **11 :** 56-66.

De Silva1, P. H. G. J., Atapattu, N.S.B.M. and Sandika, A.L. 2010. A study of the socio-cultural parameters associated with meat purchasing and consumption pattern: A case of Southern Province, Sri Lanka. *The Journal of Agricultural Sciences*, **5:** 71- 79.

Devasahayam, T. M. 2005. Power and pleasure around the stove: The construction of gendered identity in middle–class south Indian Hindu households in Urban Malaysia. *Woman's Studies International Forum,* **28:** 1- 20.

Faustman, C. and Cassen, R. G. 1990 .Influence of aerobic metmyoglobin reducing capacity on colour stability of beef. *Journal of Food Science*, **55:** 1278 -1283.

Five-Shaw, C. and Rowe, G. 1996. Public perceptions of everyday food hazards: A psychometric study, risk analysis, **16:** 487-500.

Frean, J., Koornhof, H. and Keddy, K. 2003. Chapter 43. Incidence of food-borne illness in Southern Africa. http://www.crcnetbase.com/doi/abs/10. 1201 /97 802 03912065.ch43.

Glitsch, K. 2000. Consumer perceptions of fresh meat quality: cross-national Comparison", *British Food Journal*, **102:** 177-194.

Haileselassie1, M., Taddele, H., Adhana, K. and Kalayou, S. 2013. Food safety knowledge and practices of abattoir and butchery shops and the microbial profile of meat in Mekelle City, Ethiopia. *Asian Pacific Journal of Tropical Biomedicine*, **3:** 407 – 412.

Holm, L. and Kildevang, H. 1996. Consumers' views on food quality. A qualitative interview study. *Appetite*, **27:** 1-14.

Lazarova, R. and Krystallis, A. 2010. Consumer's perception of food quality and its relation to the choice of food. *Unpublished master thesis, Aarhus Universitet, Aarhus, Denmark.*

Liana, M., Radam, A. and Yacob, M.R. 2010. Consumer perception towards meat safety: Confirmatory Factor Analysis. *Journal of Economics and Management*, **4:** 305 – 318.

Meat Safety Act. 2000. Act No. 40 of 2000. http://rvav.co.za/wp-ontent/uploads/2012/04/Meat-Safety-Act.pdf, Accessed 17th April 2013.

Muhammad, S., Sherif, S. and Gheblawi, M. 2010. Consumers' attitudes and perceptions of food safety in the United Arab Emirates. *Journal of Food Distribution Research,* **41**: 75-84.

Nesbitt, A., Thomas, M. K., Marshall, B., Snedeker, K., Meleta, K., Watson, B. and Bienefeld, M. 2014. Baseline for consumer food safety knowledge and behaviour in Canada. *Food Control Journal,* **38:**157-173.

Novak, J. 2011. Consumer Behaviour. Internal Influences - Emotion and Perception. http://marketingteacher.com/lesson-store/lesson-internal-influencesm emotionperception. html. Accessed on 18 March 2011.

Ottesen, G. G. 2006. Do upstream actors in the food chain know end-users' quality perceptions? Findings from the Norwegian salmon farming industry. *Supply Chain Management: An International Journal*, **11**: 456-463.

Pierre S., De Fontguyon, G. and Briz, J. 2005. Meat Safety as a tool of differentiation for retailers: Spanish and French examples of meat « Supply chain brands ». *International Journal of Retail & Distribution Management*, **8**: 618-635.

Redmond, E. C. and Griffith, C. J. 2004. Consumer perceptions of food safety risk, control and responsibility. *Appetite Journal,* **43:** 309–313.

Richardson, M., Matthews, K., Lloyd, C. and Brian, K. 2009. Meat quality and shelf life. EBLEX, Agriculture and Horticulture Development Board (AHDB).

SAMIC (South African Meat Industry Company), 2006. Classification of South Africa Beef - a Key to Consumer Satisfaction. South African Meat Industry Company, Pretoria, South Africa.

SAS, 2003. Users guide, version 9. USA: Statistical Analysis System Institute Inc.

Sans, P., De Fontguyon, G. and Briz, J. 2005. Meat safety as a tool of differentiation for retailers: Spanish and French examples of meat "supply chain brands". *International Journal of Retail & Distribution Management*, **33:** 618-635.

Seward, R.A. 2003. Definition of food safety. In: Food Safety Handbook, R.A. Schmidt and G.E. Rodrick (eds), pp 3-9. John Wiley and Sons, Inc. New Jersey.

Sepulveda, W., Maza, M. T. and Mantecón, A. R. 2008. Factors that affect and motivate the purchase of quality-labelled beef in Spain. *Meat Science,* **80:**1282–1289.

Sofos, J. N. 2002. Approaches to Pre-harvest food safety assurance. In: Food Safety Assurance and Veterinary Public Health; Volume 1, Food Safety Assurance in the Pre-Harvest Phase. F.J.M. Smulders and J.D.Collins (Eds.) Wageningen Academic Publishers, Wageningen, The Netherlands, p.23-48.

Sharma, S. and Lal, K. 2012.Changing consumer behaviour- A challenge for sustainable business growth. *International Journal of Marketing, Financial Services & Management Research*, **1:** 2277- 3622.

Troy, D. J., and Kerry, J. P. 2010. Consumer perception and the role of science in the meat industry. *Meat Science*, **86:** 214-226.

Viana, M. M., dos Santos Silva, V. L and Trindade, M. A. 2014. Consumers' perception 308 of beef burgers with 309 different healthy attributes. *LWT-Food Science Technology*, 59**:** 1227-1232.

Viegas, I., Santos, J. M.L., Barreto, A. and Fontes, M.A. 2012. Meat safety: A brief review on concerns common to science and consumers. *International Journal of Sociology of Agriculture and Food,* **19:** 275–288

Viljoen, A.T. and Gericke, G.J. 2001. The food habits and food preferences of white and coloured South African men in the army (1993– 1994). *Journal of Family Ecology and Consumer Science,* **29:** 1–12.

Vimiso, P. 2010. Effects of marketing channel on bruising, ultimate pH and colour of beef; and stakeholder perception on the quality of beef from cattle slaughtered at a smallholder abattoir. MSc Thesis, University of Fort Hare, South Africa.

Vimiso, P., Muchenje, V., Marume, U. and Chiruka, R. 2012. Preliminary study on consumers and meat trader's perceptions of beef quality and how the beef quality is affected by animal welfare practices, *Scientific Research and Essays,* **22:** 2037- 2048.

Chapter 4: Microbial profiles of red meat at different stages of the abattoir to retail outlets distribution chain

(*Submitted to Journal of Food Safety*)

Abstract

The study was carried out to compare microbial contamination of meat from a communal and commercial abattoir at three stages of the distribution chain. A total of 216 swab samples from beef, pork and mutton carcasses were collected during the loading process of carcasses into trucks at the abattoir, when off-loading carcasses at the supply points and during marketing. The samples were immediately transported to the laboratory and subjected to total bacterial count, coliform count, *E. coli* count and *Staphylococcus aureus* detection. The results indicated that the microbial counts were significantly ($p < 0.05$) higher in samples from the commercial abattoir than in those from the communal abattoir. The results further showed significant microbial contamination of carcasses with all bacterial groups in all the stages except for *S. aureus* which was not detected at all from the samples from the commercial abattoir. However, *E. coli* was the predominant microbial contaminant in the samples from both abattoirs. Total bacterial count, coliform count and the levels of *E. coli* contamination increased progressively between the loading and the off-loading points (5.1 to 7.9 log CFU/cm^2; 5.0 to 5.6 log CFU/cm^2 and 2.7 to 3.7 log CFU/cm^2, respectively). Subsequently, a slight decrease at the display points was observed. Compared to the European microbiological standards for meat, levels of contamination by total bacteria and coliforms at all stages were found to be above the acceptable range. The storage period, meat type, distance during transportation and temperature were found to have a significant impact on the microbial levels during the distribution of carcasses. Beef carcasses had the highest levels (6.0 log CFU/cm^2) of microbial counts in both abattoirs while pork had 4.7 log CFU/cm^2 and mutton had 5.7 log CFU/cm^2. Furthermore, as the storage duration increased, the levels of microbial contaminants also increased. It was therefore concluded that microbial contaminants on raw meat from the abattoir to the retail point exceeded the acceptable limits and this increases the rate of meat spoilage and the risk of foodborne illness.

Key words: Microbial contamination, abattoir, meat type, loading, off-loading, storage duration

4.1 Introduction

Meat is regarded as an excellent source of protein in human diet but at the same time is highly susceptible to microbial contamination (Komba *et al*., 2012). The meat, available at retail outlets comes through a long chain of slaughtering and transportation, where each step may pose a risk of microbial contamination. Therefore, food scientists, government agencies and food processors all have responsibilities to design ways and means to minimize and eliminate the hazards and provide consumers with safe meat (Doyle *et al*., 1997; Davies and Board, 1998; Bourgeois *et al.*, 1999). It is generally accepted that it is not feasible to produce meat without some degree of bacterial contamination (Mills, 2014). In live animals, the muscle is virtually sterile, however, other parts of the animal such as skins, hooves and intestines, contain enormous numbers of bacteria. Depending on the slaughter hygiene practices, these bacteria find their way to the carcass or contaminate the meat during slaughterhouse operations. Skinning, scalding, evisceration, dressing and carcass transportation are common contamination points during the slaughter distribution processes, and contamination may also occur during carcass cutting and meat processing. Most bacteria are transferred to the carcass via butchers' hands, tools, contact with equipment or through water and air (Khedkar *et al*., 2003).

However, the aim of the meat handlers should be to ensure that the initial number of microorganisms on meat is as low as possible because the intention of the meat industry is to produce meat with as low numbers of microbes as reasonably possible, in order to maximise shelf-life and minimise the occurrence of organisms associated with food-borne illness (MTU, 2010). Smith *et al*. (2007) stated that it is important to control growth of micro-organisms on meat to avoid outbreaks of food-borne diseases which have occurred in other countries. In South Africa, there is lack of pathological reports on food-borne illness. This can be attributed to the current health regulation which states that notification is required only

when five or more cases are reported by one physician or at one medical institution (Department of National Health and Population Development, 1989). This regulation has not been reviewed in the last 2 decades. It should be noted that most of the research done was conducted prior to 1994 and there is paucity of information on the current reports.

Vorster *et al*. (1994) reported that although South African meat and meat products are contaminated with bacterial pathogens at relatively low levels, it could pose a health risk to some individuals. Nevertheless, Nortje (1987) conducted a study on microbial contamination in the meat chain and made recommendations which could assist in lowering microbial levels in meat. These include strict control on the maintenance of the cold chain throughout the meat production chain and effective management of sanitation programmes from the abattoir to the markets. Unfortunately, these recommendations have not been implemented as Vorster, Greebe and Nortje (1994) and Nortje, Vorster, Greebe and Steyn (1999) have shown the presence of *Escherichia coli (E. coli), Staphylococcus aureus (S. aureus), Bacillus cereus* and *Yersinia enterocolitica* in the retail meats of South Africa. In order to improve on this, microbiological contamination of meat has to be controlled through a complete, continuous abattoir to consumer system. Establishing low microbial levels in meat will boost consumers' confidence in the meat products (Bernue´s *et al.*, 2003) and will give assurances of quality in the market. Consequently, it is very important to implement proper hygiene and safety procedures not only during slaughter but also when handling and processing meat.

In South Africa, abattoirs which deliver meat to retailers for the consumers to purchase are governed by the Meat Safety Act of 2000. Meat processors at the abattoirs have adopted a range of protocols and adhere to regulations to ensure that meat that is produced is of high quality and is safe for consumption, and that chances of microbial contamination are minimised. However, it is important to note that when meat is being distributed from the abattoir to the supply points, it is out of the direct control of the abattoir of origin. Meat

inspection is typically only carried out at the abattoir, yet the distribution stage is the most critical stage during which the quality of meat could easily be compromised. This could possibly allow food-borne pathogens and more spoilage bacteria to enter the distribution chain.

Sofos (2007) identified contamination from pathogenic microorganisms as the most serious meat safety issue as it causes immediate consumer health problems. According to Scallan *et al.* (2011), food-borne illnesses cause about 3,000 deaths in the United States of America and the cost of foodborne disease is estimated to exceed $5 billion per year. A recent government-commissioned report on the South African meat inspection system estimates the cost to the economy in medical, legal, other expenses, and absenteeism from work and school resulting from food-borne diseases to amount to billions of Rands annually and further recommends a review of the meat safety risk management systems and quality assurance practices (Department of Health [DoH], Department of Trade and Industry [DTI], & Department of Agriculture, Forestry and Fisheries [DAFF, 2013]). Therefore, continuous efforts to improve food safety systems are encouraged.

It is generally agreed that determination of microbial counts and coliform counts is essential for monitoring the hygiene status of the abattoirs and verifying the microbiological status of meat. Today, the main cause of foodborne disease is micro-organisms. Microbiological analysis therefore, plays a central role in quality control in the food sector. In South Africa, meat inspection audits at the abattoir only covers the visual inspection, there are no microbiological tests which are done. Pathogens such as *S. aureus* and *E. coli* cannot be detected by the eye (Govender *et al*., 2013). Moreover, if there are pathogenic micro-organisms that are introduced to meat at the abattoir, chances are that during transportation and marketing they can continue to multiply.

In South Africa, safe meat production, processing and distribution are managed by two main regulatory entities, the (DAFF) and the DoH (Govender *et al*., 2013). However these public meat monitoring agents do not have a meat Microbiological Monitoring Programme. According to the Meat Safety Act No. 40 of 2000 the Minister may establish a scheme for the improvement of meat safety. Therefore improvement of meat safety that will incorporate microbiological assessment of meat at the abattoir after slaughter and in shops is encouraged. Hence, the aim of this study was to compare microbial contamination at different stages of the distribution chain between communal and commercial abattoirs in the Eastern Cape Province of South Africa.

4.2 Materials and methods

4.2.1 Description of the study site

The study was conducted in a commercial abattoir in East London situated under Buffalo City Metropolitan Municipality and a communal abattoir in Adelaide under Nxuba Municipality in the Eastern Cape Province of South Africa. The East London abattoir is located 120 km away from Alice (where the University of Fort Hare is based) at latitudes and longitudes of 32.97 ° S and 27.87 ° E and the Adelaide abattoir is located 30 km away from Alice at 32.8 ° S and 26.9 ° E. Both abattoirs are governed by the Meat Act of 2000 and SAMIC (2006). The East London abattoir is equipped with modern technology and slaughters up to 1000 livestock units per day, while Adelaide operates with low modern technology and slaughters less than 40 animals per day. Three retail shops supplied by the commercial abattoir and one butchery supplied by the communal abattoir were also selected and visited.

4.2.2 Sample collection/sampling procedure

A total of 216 swab samples were collected from beef, pork and mutton carcasses at three stages; loading, off - loading and display (n=12 for each species at each stage). Sampling was carried out aseptically by swabbing the muscular surface of each carcass with sterile cotton swabs moistened in sterile 0.1% buffered peptone water (BPW). Carcasses were randomly selected at the abattoir before loading the trucks for delivery to the retail shops. An area of 16 cm^2 marked with a sterile frame of 4 cm $\times$ 4 cm on each site of the carcass was rubbed for 30 seconds and swabs were transferred to a screw-capped McCartney bottle containing 10 ml of sterile 0.1% BPW.

Bacterial counts vary from carcass to carcass and on different sites on the same carcass, therefore different sites from each carcass were used in each of the three species. For beef carcasses, brisket, neck, perineal and medial areas were used. For mutton carcasses, neck, brisket, flank and perineal areas were used. For pork carcasses, the area between the elbow and the midline cut, the area below the level of the axis joint and the base of the tail towards the hock were used. All carcasses were loaded in the same truck and followed to the supply points with distance from the abattoir having been recorded. Bar codes were used to trace carcasses for identification purposes. Swab samples were then collected from the same carcasses during off-loading at the supply points. Appointments were made with the butchery managers for purchasing of meat samples from the same carcasses at the display outlets where an area of 6.25 cm^2 demarcated using a sterile frame of 2.5 cm $\times$ 2.5 cm was swabbed. The swab samples were transported to the University of Free State for laboratory analysis in an ice box at 4° C to prevent microbial growth during sample transportation.

4.2.3 Ethical Consideration

Ethical principles were considered in this study to conform to the national and international standards governing research of this nature with the request to collect swab samples reviewed

and approved by the Research Ethics Committee of the University of Fort Hare, South Africa (UFH/UREC, MUC0101SRAN01).

4.2.4 Microbiological analyses

Samples were analysed immediately upon arrival at the laboratory. Four microbiological parameters were considered in this study: Total bacteria count (general bacteria), coliform count (related to hygiene and indicator for pathogens), *Escherichia coli* (Gram-negative pathogen) and *Staphylococcus aureus* (Gram-positive pathogen).

4.2.4.1 Total Bacteria Count

Tenfold serial dilutions of the samples were prepared in 0.1% BPW up to 10^{-8} after which 1 ml aliquots of the respective dilutions were gently mixed as pour plates with 15-20 ml of Standard Plate Count Agar (SPCA, Oxoid CM463). After setting, the agar plates were incubated at 32°C for 48 hrs. Colonies were counted using a digital Colony Counter (CJ Labs, RSA). Counts per cm^2 were estimated depending on area of template used.

4.2.4.2 Coliform and *E. coli* counts

The sample dilutions were cultivated as pour plates with Violet Red Bile Agar with MUG (VRBM, Oxoid CM0978). The plates were incubated at 37 °C for 24 hrs. Coliforms were enumerated as the purple-red colonies while generic *E. coli* were enumerated as the number of fluorescent colonies after subjecting the VRBM agar plates to ultraviolet radiation at 364 nm. Counts per cm^2 were estimated depending on area of template used.

4.2.4.3 *Staphylococcus aureus*

Sample dilutions were spread-plated on Baird Parker Agar (Oxoid, CM025), a selective medium for the isolation and counting of coagulase positive staphylococci, followed by aerobic incubation at 37 °C for 48 hrs as described by Bhandare *et al*. (2007). Presumptive colonies were counted and population per cm^2 estimated depending on area of template used.

The presumptive colonies were confirmed using the API® Staph kit (Biomerieux) according to the manufacturer's instructions.

4.2.5 Statistical analysis

Microbiological counts were transformed to log (base 10) and means were calculated. The Generalized Linear Model of Statistical analysis System (SAS, 2011) was used to determine the effect of meat type, distribution stage, shop class, storage period, distance and temperature on the microbial contaminants. Pearson correlation analysis was carried out between distance, temperature, meat type, stage, shop class, storage period and the response variables (TBC, CC, presumptive *E. coli* and *S. aureus*). Mean separation was conducted using the student t-test.

4.3 Results and Discussion

4.3.1 Microbial counts as affected by abattoir, meat type and distribution stage

Figure 4.1 represents the microbial contamination levels of beef, pork and mutton carcasses before transportation from the commercial and communal abattoirs. The targeted pathogenic contaminants were *E. coli* (G-ve) and *S. aureus* (G+ve). According to some previous research conducted, it was reported that among bacterial contaminants of meat which are always isolated, *E. coli* and *S. aureus* appear to be the most predominant pathogens (Vorster *et al*., 1994; Okonko *et al*., 2009; Ukut *et al*., 2010; Haileselassie *et al*., 2013).

Total bacteria counts and coliform counts were also evaluated (Figure 4.1). Ahmad *et al*. (2013) highlighted that TBC is used as a measure of microbial quality of meat and the presence of microbes in high numbers fast tracks the spoilage of the meat. Coliform counts are used in assessing the microbiological safety and quality of meat (Onwumere, 2014). The results in the present study showed that microbial levels for TBC, CC and *E. coli* were higher in the commercial abattoir (6.9 log CFU/cm^2; 4.7 log CFU/cm^2 and 2.6 log CFU/cm^2) than the microbial levels observed from the
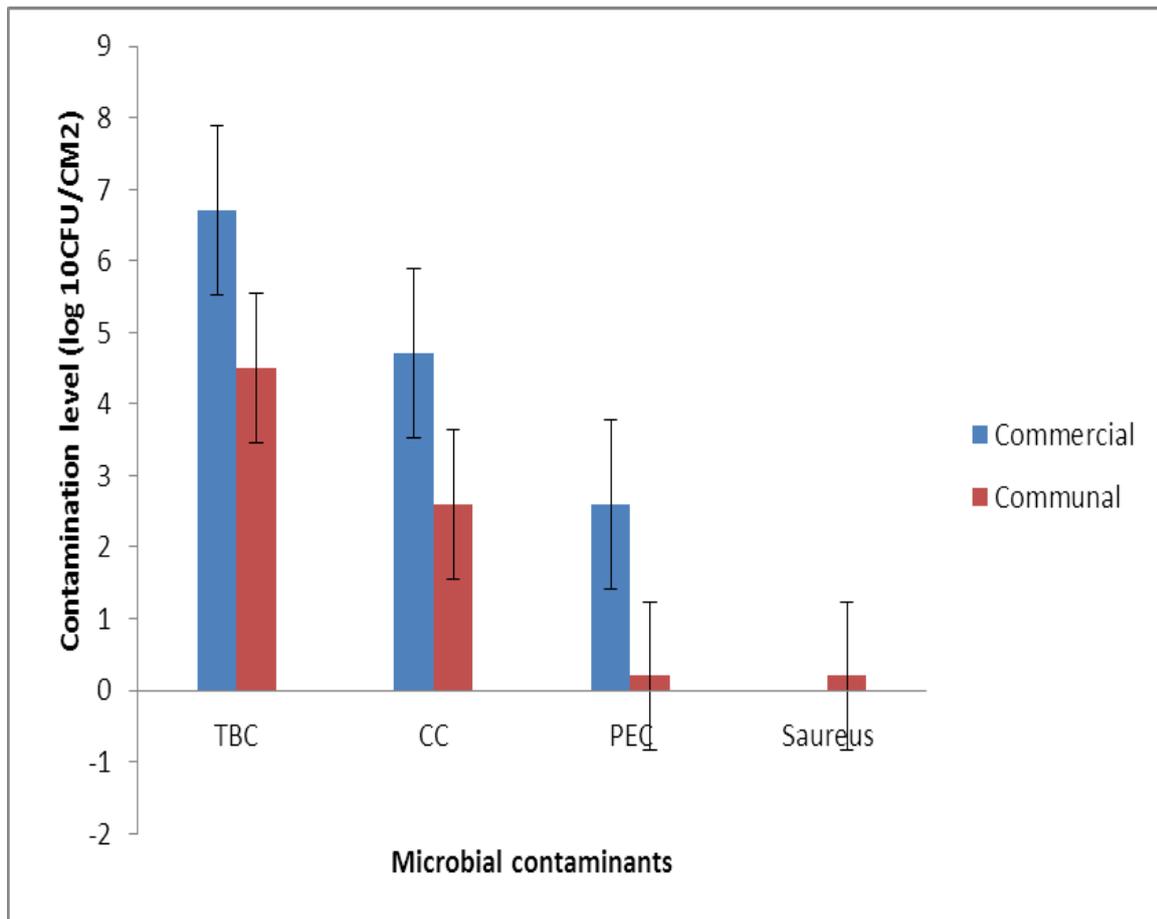
Figure 4.1: Contamination levels in beef, pork and mutton carcasses in a commercial and a communal abattoir (TBC= Total bacteria count; CC= coliform count; PEC= Presumptive *E.coli*)

communal abattoir (4.5 log CFU/cm^2, 2.6 log CFU/cm^2 and 0.2 log CFU/cm^2) respectively.

The higher microbial load in carcasses from the commercial abattoir is alarming because their presence may indicate possible occurrence of food-borne diseases. This can be attributed to the fact that the commercial abattoir slaughters up to 1000 livestock units per day, with an appreciable large number of workers handling the meat on the floor compared to the communal abattoir which slaughters less than 40 animals per day. Although it was observed that meat handlers wore protective clothing or gloves most of the times when handling the meat, there were no sanitizers used for decontamination after touching each carcass and each carcass may be handled by five different people. Therefore, cross contamination between meat handlers' responsible for packing the carcasses in chiller rooms at the commercial abattoir or dressing for transportation may occur. Microbes can adhere to the surface of the gloves worn by meat handlers and can serve as a source of cross-contamination if not changed frequently (Lues and van Tonder, 2007). This may, therefore, contribute to bacterial contamination of meat. Muinde *et al.* (2005) stated that meat handlers might be sources of contamination of meat with microorganisms. In previous research conducted by Aycicek *et al*. (2004) it was reported that the hands of food handlers were implicated in 42% of food-borne outbreaks that occurred between 1975 and 1998 in the United States of America. Furthermore, cross-contamination may also occur from mixing different types of meat from different species, whereas at the communal abattoir they only slaughter one type of species per day without having to mix beef, pork or mutton carcasses at the same time. Ntanga (2013) highlighted that in most cases at the abattoirs, differences in microbial load are mostly due to lack of good processing practices, good handling practices and sanitary standard operating procedures along the production chain.

Nevertheless, *S. aureus* was not detected at all from carcasses that were collected from the commercial abattoir but was found at the communal abattoir. According to Ahmed *et al*.

(2013), the presence of *S. aureus* in meat indicates poor sanitary quality of abattoirs, this might also be the case in the studied communal abattoir although the levels which were detected were found to be low (0.2 log CFU/cm^2).

Results on the microbial contamination levels per meat type at different stages from the abattoir to the supply points are shown in Table 4.1. Significant differences among different stages for beef, pork and mutton on total bacteria count, coliform count and *E. coli* were observed. Beef carcasses from the commercial abattoir had higher levels of microbial contamination for all tested bacteria, followed by mutton and pork. Similar results were reported by Bradeeba and Sivakumaar (2013), where beef showed higher general viable counts than mutton and pork. Haileselassie *et al.* (2012) highlighted that poorly organized farm to table production chains and poor standard sanitary operational procedures practised by the abattoir personnel, including poor personnel hygiene, are some of the risk factors which contribute to the high microbial load.

The levels of TBC among beef, mutton and pork from the commercial abattoir were 7.7, 7.2 and 5.9 log CFU/cm^2 respectively and coliform counts were 5.8, 4.2 and 3.9 log CFU/cm^2 respectively for the loading stage at the abattoir. The high levels of total bacteria counts in this study are in accordance with previous studies (Alvarez- Astorga *et al*., 2002; Bhandare *et al*., 2007; Haque *et al*., 2008; Hassan *et al*., 2010). However, according to CE (2005), compared to the European Microbiological standards for meat, these values were considered to be out of the acceptable range hence these counts put consumers' health at risk. The European Union recommends that the levels of contamination by total bacteria and total coliforms not to exceed 5.0 and 2.5 log CFU/g, respectively.

Table 4. 1: **Least square means and (±SE) of microbial counts per meat type at different stages of the distribution chain in each abattoir**

		Commercial				Communal			
		Microbial contaminants				*Microbial contaminants*			
Stage	**Meat Type**	Total Bacteria Count (log CFU/cm^2)	Coliform count (log CFU/cm^2)	Presumptive *E. coli* (log CFU/cm^2)	*S. aureus* (log CFU/cm^2)	Total Bacteria Count (log CFU/cm^2)	Coliform count (log CFU/cm^2)	Presumptive *E. coli* (log CFU/cm^2)	*S. aureus* (log CFU/cm^2)
Loading	**Mutton**	7.2 ± 0.16^b	4.2 ± 0.39^a	1.2 ± 0.34^a	$0.0\pm.000^a$	4.9 ± 0.42^c	2.6 ± 0.34^b	0.2 ± 0.15^a	$0.0\pm.000^a$
	Pork	5.9 ± 0.35^a	3.9 ± 0.29^a	1.8 ± 0.44^a	$0.0\pm.000^a$	2.9 ± 0.20^a	0.7 ± 0.29^a	0.2 ± 0.14^a	0.3 ± 0.24^b
	Beef	7.7 ± 0.17^b	5.8 ± 0.30^b	4.7 ± 0.26^c	$0.0\pm.000^a$	4.0 ± 0.39^b	2.3 ± 0.28^b	0.4 ± 0.23^b	$0.0\pm.000^a$
Off-loading	**Mutton**	6.1 ± 0.36^a	3.6 ± 0.30^a	3.2 ± 0.92^b	$0.0\pm.000^a$	4.80 ± 0.45^b	2.6 ± 0.30^b	0.1 ± 0.14^b	$0.0\pm.000^a$
	Pork	6.5 ± 0.40^a	4.8 ± 0.41^b	2.7 ± 0.43^b	$0.0\pm.000^a$	3.2 ± 0.23^a	0.9 ± 0.27^a	$0.0 \pm .000^a$	0.4 ± 0.23^b
	Beef	7.7 ± 0.20^b	5.8 ± 0.22^b	4.9 ± 0.16^c	$0.0\pm.000^a$	5.0 ± 0.27^b	2.7 ± 0.48^b	0.7 ± 0.27^c	$0.0\pm.000^a$
Display	**Mutton**	5.4 ± 0.35^a	4.1 ± 0.35^a	1.2 ± 0.49^a	$0.0\pm.000^a$	6.1 ± 0.40^b	5.2 ± 0.36^b	0.1 ± 0.15^b	0.5 ± 0.32^b
	Pork	7.0 ± 0.37^b	4.5 ± 0.25^b	2.5 ± 0.56^b	$0.0\pm.000^a$	4.7 ± 0.35^a	2.3 ± 0.31^a	$0.0 \pm .000^a$	0.4 ± 0.35^b
	Beef	6.7 ± 0.40^{ab}	6.1 ± 0.36^c	1.8 ± 0.68^a	$0.0\pm.000^a$	4.8 ± 0.47^a	4.8 ± 0.66^b	0.1 ± 0.17^b	$0.0\pm.000^a$

[abc] Means in the same column for beef, pork and mutton (within each stage) with different superscripts are significantly different ($p < 0.05$)

Agbodaze *et al*. (2005) proposed that if the total plate count is less than 5.0 log CFU/g and coliforms count are less than 3.5 log CFU/g the meat could be classified as having low risk as far as transmission of pathogenic bacteria to consumers is concerned. Therefore, the lower levels for total bacteria counts and coliform counts from carcasses which were delivered from the communal abattoir, is in accordance with the stipulated range. The counts for beef, mutton and pork were 4.0, 4.9 and 2.9 log CFU/cm^2 respectively for the total bacteria counts and coliform counts were 2.3, 2.6 and 0.7 log CFU/cm^2 respectively. Therefore compared to the commercial abattoir, the levels of microbial contamination from carcasses that were delivered from the communal abattoir at the loading stage were low.

These results were not expected as the commercial abattoirs are expected to operate with standards of hygiene. This can be justified by the fact that South African abattoirs do not have a microbiological monitoring programme to determine the hygienic status of the carcass after slaughter and before transportation to the supply points, therefore there are no standards which can be followed. During carcass inspection, it is only the physiological status of the carcass which is assessed. Therefore, risk factors which contribute to the high microbial load in meat are not considered. The few abattoirs that perform microbial assessment do not do it as part of their daily assessment and the Department of Veterinary Public Health does it on a monthly basis during audits.

The guidelines used to assess the levels of contamination are based on European standards and the supermarket chains that perform microbial assessment on meat products use their own standards. These standards were crafted based on European environmental temperatures which may differ from the temperatures in the Southern African region. This shows that there is a lack of adequate regulations related to meat safety, particularly the Meat Safety Act of 2000. Abattoirs are regulated by this law to ensure good standards of hygiene. Therefore, it can be said that there is need to introduce a microbiological assessment approach in abattoirs

which can be made part of their daily practices. Since the South African Meat Safety Laws do not have their own national microbial standards, there is also a need for the South African government to set up their own standards that will be mandated for use in order for the meat handlers at the abattoirs to be more conscious when handling carcasses.

The lower levels observed from the communal abattoir may be due to the fact that there was no cross-contamination of microbes between carcasses from different species since different types of animals were slaughtered on different days and delivered on the same day after slaughter. Therefore, their storage period at the abattoir was shorter compared to the commercial abattoir which might have reduced chances of microbial load increase on the meat. Further, beef was observed with significantly ($p < 0.05$) higher levels of microbial contamination for *E. coli* compared to pork and mutton in both abattoirs. In a study by Bohaychuk *et al.* (2011) beef carcasses were observed with higher levels of *E. coli* than pork carcasses. The higher levels of *E. coli* in beef carcasses can be attributed to the fact that cattle have always been regarded as the main reservoir for *E. coli* O157:H7 (Elder *et al*., 2000) and according to Duffy, Cummins, Nally, O'brien and Butler (2006), beef and beef products are regarded as main vehicles for transmission of the pathogen.

Also, a significant ($p < 0.05$) increase in levels of contamination with *E. coli* between the loading and off-loading points from carcasses that were delivered from the commercial abattoir was observed on all meat types. For mutton the increase was between 1.2 to 3.2 log CFU/cm^2; for pork the increase was between 1.8 to 2.7 log CFU/cm^2 and beef ranged between 4.7 to 4.9 log CFU/cm^2. This could be associated with poor handling by the meat handlers who are responsible for loading and off-loading the carcasses. Also, contact between carcasses and meat handler's protective clothing could result in cross-contamination of microbes as the carcasses were put on the workers shoulders during loading from the chiller rooms to trucks. It could also be associated with temperature fluctuations during

transportation as doors, when off-loading, would be open for quite some time at each supply point resulting in an increase in temperature inside the trucks.

However, a slight decrease in the microbial load at the display point for the three meat types was observed. The decrease for mutton was 1.2 log CFU/cm^2, pork decreased significantly (P <0.05) by 2.5 log CFU/cm^2 and beef had a decrease of 1.8 log CFU/cm^2. This contradicts with the theory by Forest *et al*. (1985) whereby retail shop meat is expected to contain higher microbial load because of the large amount of exposed surface area, more readily available water, nutrient and greater oxygen penetration. The significant (p <0.05) increase in levels of contamination for TBC and CC between loading and the off-loading points in the communal abattoir could be associated with handling during transportation as the trucks that were used to deliver the carcasses were just ordinary vans with no refrigerators. Bogh-Sorensen & Olsson (1990) and Gormley (1990) reported transportation of product to retail outlets and storage as the most commonly weak links in the chain.

Staphylococci are natural flora of skin and mucous membranes of animals and humans which can cause meat contamination (Nørrung *et al*., 2009). *Staphylococcus aureus* presence indicates poor sanitary quality of abattoirs and retail outlets. In the present study, *S. aureus* was not detected at all from samples gathered from the commercial abattoir. *Staphylococcus aureus* positive samples were detected from the communal abattoir on pork carcasses from loading to the display point, although not at high levels. For mutton, the S. *aureus* was not detected at the loading and off-loading stages, but was observed in small levels (0.5 log CFU/cm^2) at the display point. Similar results in pork carcasses were observed whereby the levels of contamination for *S. aureus* increased with stage. However, for beef carcasses, *S. aureus* was not detected at all the stages. The presence of *Staphylococcus* on meat in this study can be worrying because certain strains of this bacteria cause food-borne infections

(Mogessie, 1994). Therefore, *S. aureus* should actually be absent on and in any kind of food product.

Observations showed that there was a significant ($p < 0.05$) difference between the mean microbial load of carcasses at the abattoir and retail meat outlets. There was a higher microbial load on the abattoir meat compared to retail meat outlets. Such higher microbial counts could be attributed to poor hygienic practices and how the meat was handled in the abattoir. Adetunde *et al.* (2011) also reported high levels of total contamination at the abattoir showing that contamination begins at the slaughter house. These results contradict the findings by Haileselassie *et al*. (2012) in which the mean values of microbial load of abattoir meat were low (5.04 log CFU/g) compared to butcher shops 5.75 log CFU/g.

4.3.2 Microbial counts as affected by shop class, storage period, distance and temperature.

In Chapter 3, the perceptions of meat handlers on meat safety and challenges faced during distribution were observed. However, it is important to determine these factors under a practical set-up and see if they match with handler's perceptions. Results on factors affecting microbial load on meat during distribution from the abattoir to the supply points are shown in Table 4.2. Shop class, storage period, distance and temperature have shown to have a significant ($p < 0.05$) impact on the microbial load on meat during distribution. Top class and middle class shops accepted carcasses that were delivered from the commercial abattoir and the communal abattoir supplied meat to the butcheries. There was a significant ($p< 0.05$) difference in the levels of microbial contamination between carcasses that were sold from the top and middle class shops. Meat sold from the middle class shops were observed with higher levels of microbial contamination for TBC, CC and *E. coli* compared to meat sold from high class shops. The levels of total bacteria count on meat from high class shops fell within the acceptable range (4.8 log CFU/cm^2), implying that meat purchased by the consumers from

Table 4.2: Least square means and (±SE) of beef, pork and mutton carcass contamination as affected by shop class, storage period and distance

Description	Total Bacteria Count (log CFU/cm^2)	Coliform Count (log CFU/cm^2)	Presumptive E. coli (log CFU/cm^2)	*S. aureus* (log CFU/cm^2)
Class				
Top class shop	4.8 ± 0.61^a	2.9 ± 0.61^a	1.9 ± 0.67^a	0.1 ± 0.23^a
Middle class shop	5.7 ± 0.58^{ab}	4.2 ± 0.57^b	2.3 ± 0.63^b	0.0 ± 0.21^a
Butchery	6.1 ± 0.61^b	4.1 ± 0.60^b	1.6 ± 0.66^a	0.1 ± 0.22^a
Storage period				
Commercial				
>1 h	6.8 ± 0.22^b	4.7 ± 1.44^a	3.5 ± 0.36^c	$0.0 \pm .000^a$
24 h	6.1 ± 0.27^a	4.6 ± 0.24^a	1.5 ± 0.35^a	$0.0 \pm .000^a$
48 h	6.9 ± 0.27^c	5.1 ± 0.38^b	2.3 ± 0.53^{ab}	$0.0 \pm .000^a$
72 h	7.2 ± 0.23^b	4.7 ± 0.28^a	2.9 ± 0.39^b	$0.0 \pm .000^a$
Communal				
>1 h	4.3 ± 0.23^b	2.1 ± 0.23^a	0.3 ± 0.11^b	0.1 ± 0.08^a
2 h	3.9 ± 0.25^a	1.9 ± 0.22^a	0.3 ± 0.10^b	0.1 ± 0.07^a
48h	5.3 ± 0.26^c	3.9 ± 0.33^b	0.1 ± 0.07^a	0.3 ± 0.16^b
Distance				
Commercial				
0 km	6.9 ± 0.17^b	5.0 ± 0.21^b	2.4 ± 0.29^a	$0.0 \pm .000^a$
1.8 km	5.9 ± 0.23^a	3.9 ± 1.14^a	2.2 ± 0.46^a	$0.0 \pm .000^a$
2 km	7.8 ± 0.23^c	5.6 ± 0.22^c	4.7 ± 0.19^c	$0.0 \pm .000^a$
25 km	7.0 ± 0.31^b	4.9 ± 0.29^b	3.0 ± 0.45^b	$0.0 \pm .000^a$
Communal				
0 km	4.6 ± 0.19^b	2.9 ± 0.23^b	0.2 ± 0.06^a	0.2 ± 0.09^a
1.5 km	4.3 ± 0.23^a	2.1 ± 0.24^a	0.3 ± 0.11^a	0.1 ± 0.08^a

[abc] Means in the same column for beef, pork and mutton with different superscripts are significantly different ($p < 0.05$)

these shops was safe for consumption. This shows that hygienic practises by meat handlers from top class shops are followed as the butchery managers had indicated that most of their workers were sent for training on meat handling. They also indicated that in their shops microbiological assessment of carcasses before display is performed to check if the meat is still in good condition, although this is not done as part of their daily assessment.

Nevertheless, consumers do not consider the microbiological quality when purchasing meat hence they cannot tell the risk of incurring a food-borne illness at the time of purchase or consumption of a food item, because the extent of microbial contamination or the level of chemical residues cannot be observed (Roberts *et al*., 2003). Consumers use their senses in their descriptions of safe food, and feel that food that looks or smells bad should not be eaten (Seward, 2003). In a study by Rani *et al*. (2013) consumers confirmed that meat quality cannot be detected by the class of shop, and Becker *et al.* (2000) highlighted that for most consumers, quality goes beyond safety.

Carcasses that were delivered to the butchery had the highest levels of microbial contamination for TBC (6.1 log CFU/cm^2) and CC (4.1 log CFU/cm^2). The presence of such high counts in the investigated samples could indicate improper handling or inadequate storage and display conditions during sale as the butcher managers during sampling from the middle class shops had shown to have less knowledge on the proper storage temperatures that are supposed to be used. Also, disinfectants were not used regularly. Ali *et al*. (2010) reported that butcher men lack knowledge of disinfecting and sanitizing, they clean their shops once in 24 hours with detergent and water which is not enough to maintain the hygienic environment in the butchery. Regular cleaning and disinfecting of the retail outlets is important since it helps to reduce microbial contamination. Based on this, it can be suggested that meat sold from this butchery may not be safe for consumption. Jay (1996) highlighted

that these microbial groups are safety indicators, therefore the presence of high counts may indicate possible presence of pathogens.

The results of the study further showed that there was a significant difference between contamination loads on carcasses that were stored for different periods in both abattoirs. Carcasses that were stored at the commercial abattoir after being taken out of the chiller room for less than an hour had TBC of 6.8 log CFU/cm^2 whereas carcasses from the communal abattoir had less counts (4.3 log CFU/cm^2). The high microbial load on carcasses from the commercial abattoir could have resulted from changes in temperature after the carcasses were taken out of the chiller and the duration period before they were loaded into the trucks which could have led to the multiplication of the microbes. Total bacterial count is considered an index of quality, which gives an idea about the hygienic measures during processing and helps in the determination of the keeping quality of the product (Aberle *et al*., 2001). A sudden decrease in the microbial load on carcasses that were kept for 24 hrs was observed. This can be due to the fact that during the 24 hour storage period, the carcasses were stored in chiller rooms and cold temperatures inhibit the growth of micro-organisms on meat. A drastic increase of microbial load on carcasses which were delivered at the commercial abattoir after 48 hrs (6.9 log CFU/cm^2) and 72 hrs (7.2 log CFU/cm^2) was observed. Also in the communal abattoir, a sudden increase in the microbial load on carcasses which had a storage period of 48 hrs was observed (5.3 log CFU/cm^2). This shows that the longer the storage period of carcasses in an abattoir, the greater is the chance of microbial contamination levels to increase. Therefore, according to the observed results, meat handlers at the abattoirs would be advised not to keep carcasses for more than 48 hrs or to decrease the storage period of carcasses in an abattoir to avoid growth of microbes and to ensure that safe meat is delivered to the consumers.

The distance which is covered by the vehicles when transporting the meat to the supply points was found to have a significant impact on the microbial load developing on meat. In the results, zero distance represents the abattoir (distance before the truck moves to the supply point) and the microbial contamination at the commercial abattoir at zero distance for TBC, CC and *E. coli* was 6.9, 5.0 and 2.4 log CFU/cm^2 respectively. A decrease for when the carcasses were transported to the supply point after 1.8 km was observed (5.9, 3.9 and 2.2 log CFU/cm^2). However, when they were off-loaded in a retail shop after 2 hrs, another increase in the microbial load was observed (7.8, 5.6 and 4.7 log CFU/cm^2) and after 25 km the microbial counts were between (7.0, 4.9 and 3.0 log CFU/cm^2). The increase in the microbial load between carcasses which were off-loaded after 1.8 and 2 km could have resulted from the accumulation of air during the off-loading of carcasses because truck doors at 1.8 km were open for quite some time during off-loading hence a slight increase in temperature of the refrigerated truck was observed. Gill (1996) highlighted that if the storage temperatures are not properly monitored, meat contamination or multiplication of bacteria in meat may occur which results in economic losses. Hence this could explain the increase of the microbial load on carcasses which were delivered at 2 km since they were loaded in the same truck.

Temperature also played a significant role on microbial load. In the communal abattoir there was no chiller room and the vehicle used for transportation of the carcasses to the butchery was just an ordinary van. Therefore, average daily temperatures were recorded. When the daily temperatures were 18 ˚C, TBC and CC ranged between 3.2 and 0.9 log CFU/cm^2 respectively. Nevertheless, *E. coli* was not detected from these carcasses at this temperature. However, an increase in microbial contamination for TBC, CC and *E. coli* on carcasses which were delivered when daily temperatures were 20 ˚C was observed. The values ranged between 3.9, 1.9 and 0.2 CFU/cm^2. Also at 22 ˚C, higher microbial counts were observed

(4.9, 2.8 and 0.5 log CFU/cm^2. Temperature fluctuations in trucks from the commercial abattoir were between 5 and 7 ˚C. The normal temperature used to keep the carcasses in the trucks was 7 ˚C, but at the off-loading points an increase of 6 and 5 ˚C was observed.

The Pearson correlation analysis between the microbial contaminants and factors affecting the microbial load on meat is shown in Table 4.3. The results revealed that there was no significant correlation ($p > 0.05$) between distance and meat type. However, a significant negative correlation between distance and distribution stage was observed, although a positive significant correlation ($p < 0.05$) with microbial contaminants (TBC, CC and *E. coli*) was observed. Storage period also had a significant negative correlation with the microbial contaminants on meat, although no relationship with *S. aureus* was observed. This means that, the longer the distance, and the longer the storage period, the higher the level of microbial contamination on meat. Temperature also had a positive correlation ($p < 0.05$) with distribution stage and shop class. This can be related to the fact that different shops used different temperatures for storage as well as the fluctuating temperatures experienced at different stages and when distributing the carcasses.

Table 4.3: Pearson correlation analysis between factors affecting bacterial load on meat and microbial contaminants

	Temperature	Meat Type	Stage	Shop Class	Storage period	TBC	CC	PEC	*S. aureus*
Distance	-0.19**	0.01	-0.19**	-0.09	-0.01	0.24**	0.18**	0.25***	-0.06
Temperature		-0.01	0.34***	0.55***	-0.43***	-0.46***	-0.53***	-0.31***	0.01
Meat Type			-0.01	0.01	0.12	0.05	0.18**	0.22***	-0.06
Stage				0.80***	-0.34***	-0.49***	-0.36***	-0.57***	0.21*
Shop Class					-0.31***	-0.52***	-0.45***	-0.53***	0.17*
Storage period						0.37***	0.43***	0.22**	-0.05
TBC							0.75***	0.57***	-0.07
CC								0.54***	-0.13*
PEC									-0.13*

Significantly correlated at *p<0.05; **p<0.01, ***p<0.001

TBC= Total bacteria count; CC= coliform count; PEC= Presumptive *E.coli*

4.4 Conclusions

It can be concluded that meat from both commercial and communal abattoirs contained higher levels of contamination by *Escherichia coli*, total bacteria and coliform counts, it exceeded the acceptable limits. The contamination levels obtained were even higher on meat from the commercial abattoir throughout the distribution chain compared to the communal abattoir. A significant increase of carcass contamination between loading and the offloading points was observed. Additionally, the bacterial counts of meat samples sold through the middle class shops and butcheries were found to be higher compared to top class shops. Therefore there is a need for meat handlers and retailers to rigidly enforce standard hygienic practices throughout the distribution chain. In addition, microbiological assessment of carcasses in abattoirs and during marketing should be introduced in order to ensure meat safety. However, there will be a need to devise efficient methods to practically perform such practices on daily basis.

4.5 References

Aberle, E. D., Forrest, J., Gerrard, D . E. and Mills, E. W. 2001. Principles of Meat Science (4th ed). Hunt Publishing Co., Kendall, USA. 106-402.

Adetunde, L. A., Glover, R. L. K., Oliver, A. W. O. and Samuel, T. 2011. Source and distribution of microbial contamination on Beef and Chevron in Navrongo, Kassena Nankana District of Upper East Region in Ghana. *Journal of Animal Production Advances,* **1:** 21-28.

Adhikari, B. M., Subedi, R. P. and Subba, D. 2014. A study on standard of buffalo meat hygiene in Dharan. *Journal of Food Science and Technology Nepal,* **7:** 99-101.

Agbodaze, D., Nmal, P. N. A., Robertson, F. C., Yeboah-Manu, D., Owusu-Darko, K. and Addo, K. K. 2005. Microbiological quality of "Khebab" consumed in the Accra Metropolis. *Ghana Medical Journal,* **39:** 46-49.

Ahmad, M. U. D., Sarwar, A., Najeeb, M. I., Nawaz, M., Anjum, A. A., Ali, M. A. and Mansur, N. 2013. Assessment of microbial load of raw meat at abattoirs and retail outlets. *The Journal of Animal and Plant Sciences*, **23:** 745-748.

Ali, N. H., Farooqui, A., Khan, A., Khan, A.Y. and Kazmi, S. U. 2010. Microbial contamination of raw meat and its environment in retail shops in Karachi, *Pakistan Journal of Infection in Developing Countries*, **4:** 382-388

Alvarez-Astorga M., Capita, R., Alonso-Calleja, C., Moreno, B., Del, M. and Garcia-Fernandez C. 2002. Microbiological quality of retail chicken by-products in Spain. *Meat Science*, **62:** 45-50.

Aycicek, H., Aydogan, H., K¨uc¸¨ukkaraaslan, A., Baysallar, M. and Bas¸ustao˘glu, A. C. 2004. Assessment of the bacterial contamination on hands of hospital food handlers. *Food Control,* **15**: 253–259.

Becker, T. E., Benner, E. and Glitsch, K. 2000. Consumer perception of fresh meat quality in Germany. *British Food Journal*, **102:** 246-266.

Bohaychuk, V. M., Gary, E. G. and Pablo, R. B. 2011. Microbiological baseline study of beef and pork carcasses from provincially inspected abattoirs in Alberta, Canada. *The Canadian Veterinary Journal*, **52**: 1095–1100.

Bernue´s, A., Olaizola, A. and Corcoran, K. 2003. Extrinsic attributes of red meat as indicators of quality in Europe: an application for market segmentation. *Food Quality and Preference*, **14:** 265–276.

Bourgeois, L. J., Duhaime, I. M. and Stimpert, J. L. 1999. Strategic Management: A Managerial Perspective, 2nd ed. Fort Worth: The Dryden Press.

Bogh-Sorensen, L. and Olsson, P. 1990. The chill chain. In Chilled Food: The State of the Art, ed. T. R. Gormely, Elsevier Applied Science, New York, pp. 245-67.

Bhandare, S. G., Sherikar, A. T., Paturkar, A. M., Waskar, V. S. and Zende, R. J. 2007. A comparison of microbial contamination on sheep/goat carcasses in a modern Indian abattoir and traditional meat shops. *Food Control,* **18:** 854-858.

Bradeeba, K. and Sivakumaar, P. K. 2013. Assessment of microbiological quality of beef, pork and mutton and its environment in retail shops in Chidambaram, Tamil Nadu. *International Journal of Plant, Animal and Environmental Sciences,* **3:** 2231- 4490.

Communauté Européenne (CE), 2005. Règlement (CE) No 2073/2005 de la commission du 15 novembre 2005 concernant les critères microbiologiques applicables aux denrées alimentaires. Journal Officiel L 338 du 22.12.2005, 26p

Davies, A. and Board, R. G. 1998. The Microbiology of Meat and Poultry (preface), London, Blackie Academic and Professional.

Department of Health (DoH), Department of Trade and Industry (DTI), & Department of Agriculture, Forestry and Fisheries (DAFF) 2013. Food safety and food control in South Africa: specific reference to meat labelling. Government Printers, Pretoria.

Doyle, M. P., Beuchat, L. R. and Montville, T. J. (Eds,), 1997. Food Microbiology: Fundamentals and Frontiers. ASMPress, Washington DC.

Duffy, G., Cummins, E., Nally, P., O'Brien, S. and Butler, F. 2006. A review of quantitative microbial risk assessment in the management of *Escherichia coli* O157:H7 on beef. *Meat Science,* **74:** 76–88.

Elder, R. O., Keen, J. E., Siragusa, G. R., Barkocy-Gallagher, G. A., Koohmaraiae, M. and Laegreid, W. W. 2000. Correlation of enterohaemorrhagic *E. coli* O157:H7 prevalence in faeces, hides, and carcasses of beef cattle during processing. *Proceedings of the National Academy of Sciences (PNAS)*, **97:** 2999–3003.

Forest, D. C., Harold, D. A., Judge, B. A. and Robert, E. A. 1985. Different Types of Meat and Meat products consumed by Nigerians. Principles of Meat Science. Pub. WA. Freeman and Co. Pop; p. 4-178.

Gill, C. O. 1996. Extending the storage life of meats. *Meat Science*, **43:** 99–109.

Gormley, T. R. 1990. Temperature monitoring of chilled foods during air and road freighting. In Processing and Quality of Foods, Vol. 3, Chilled Foods, eds. P. Zeuthen, J. C. Cheftel C. Eriksson,T. R. Gormley, P. Link08s and K. Paulus. Elsevier Applied Science, London. pp. 3.248-3.255.

Govender, R., Naidoo, D. and Buys, E. M. 2013. Managing meat safety at South African abattoirs. *International Journal of Biological, Food, Veterinary and Agricultural Engineering,* **7**: 124-129.

Haque, M. A., Siddique, M. P., Habib, M. A., Sarkar, V. and Chou, **K. A.** 2008. Evalvation of sanitary quality of goat meat obtained from slaughter yards and meat stalls at late market hours. *Bangladesh Journal of Veterinary Medicine*, **6:** 87–92.

Hassan, A. N., Farooqui, A., Khan, A., Khan, A. Y. and Kazmi, S. U. 2010. Microbial contamination of raw meat and its environment in retail shops in Karachi, Pakistan. *The Journal of Infection in Developing Countries*, **4:** 382-388.

Jay, J. M. 1996. Modern Food Microbiology (5th ed.). New York: Chapman and Hall. pp. 603-752.

Komba, E. V. G., Komba, E. V., Mkupasi, E. M., Mbyuzi, A. O., Mshamu, S., Luwumbra, D., Busagwe, Z. and Mzula, A. 2012. Sanitary practices and occurrence of zoonotic conditions in cattle at slaughter in Morogoro Municipality, Tanzania: implications for public health. *Tanzania Journal of Health Research,* **14(2):** DOI: ttp://dx.doi.org/10.4314/thrb.v14i2.6

Khedkar, C. D., Khedkar, G. D., Gyanath, G. and Kalyankar, S. D. 2003. Buffalo Meat. In: *Encyclopedia of Food Science and Nutrition,* 2nd edition, Academic Press, Oxford, pp. 699-705.

Lues, J. F. R. and van Tonder, I. 2007. The occurrence of indicator bacteria on hands and aprons of food handlers in the delicatessen sections of a retail group. *Food Control,* **18:** 326– 332.

Meat Safety Act No. 40 of 2000. Department of Agriculture, Forestry and Fisheries, Republic of South Africa.

Mills, J., Donnison, A. and Brightwell, G. 2014. Factors affecting microbial spoilage and shelf-life of chilled vacuum-packed lamb transported to distant markets: A review. *Meat Science*, **98:** 71–80.

Mogessie, A. 1994. Microbial flora and incidence of some foodborne pathogens on fresh beef from butcher's shops in Awassa, Ethiopia. *Bulletin of Animal Health Production ,* **42**: 273-277.

Muinde, O. K. and Kuria, E. 2005. Hygienic and sanitary practices of vendors of street foods in Nairobi, Kenya. *African Journal of Food Agriculture and Nutritional Development,* **5:** 1-14.

Nørrung, B., Andersen, J. K. and Buncic, S. 2009. Main concerns of pathogenic microorganisms in meat. In Safety of Meat and Processed Meat (pp. 3-29). Springer New York.

Nortje, G. L. 1987. Microbial ecology of fresh meat with reference to abattoir, wholesale & retail situations. PhD Thesis, University of Pretoria.

Nortje´, G. L., Vorster, S. M., Greebe, R. P. and Steyn, P. L. 1999. Occurrence of *Bacillus cereus* and *Yersinia enterocolitica* in South African retail meats. *Journal of Food Microbiology*, **16:** 213–217.

.

Ntanga, P. D. 2013. Assessment of microbial contamination in beef from abattoir to retail meat outlets in Morogoro Municipality, Tanzania. MSc Thesis, Sokoine University of Agriculture, Tanzania.

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

Onwumere, O. S. 2014. Microbial contamination of fresh meat processed in public abattoir and slaughter slab system of operations. *Global Journal of Animal Scientific Research,* **2:** 220-223.

Rani, Z. T., Hugo, A. and Muchenje, V. 2013. Perceptions of rural consumers on the quality of mutton in the Eastern Cape Province, South Africa. *Scientific Research and Essays Journal,* **8:** 1992-2248.

Roberts, T., Buzby, J. and Lichtenberg, E. 2003. Economic consequences of foodborne hazards. In: Food Safety Handbook. R.H. Schmidt and G.E. Rodrick (Eds), pp 89-124. John Wiley and Sons, Inc., New Jersey.

SAS, 2011. Users guide, version 9. USA: Statistical Analysis System Institute Inc.

SAMIC. 2006. South African Meat Industry Company. Classification of South Africa Beef - a Key to Consumer Satisfaction. South African Meat Industry Company, Pretoria, South Africa.

Smith, A. M., Gouws, A. M, Hoyland, G., Sooka, A. and Keddy, K. H. 2007. Outbreaks of food-borne disease; a common occurrence but rarely reported. *South African Medical Journal*, **97**(12): 1272.

Sofos, N. F. 2007. Challenges to meat safety in the 21st century. *Meat Science,* 78: 3–13.

Scallan, E., Griffin, P. M., Angulo, F. J., Tauxe, R. V. and Hoekstra, R. M. 2011. Foodborne illness acquired in the United States—unspecified agents. *Emerging Infectious Diseases,* **17:** 16–22.

Seward, R. A. 2003. Definition of food safety. In: Food Safety Handbook, R.A. Schmidt and G.E. Rodrick (eds), pp 3-9. John Wiley and Sons, Inc. New Jersey.

Ukut, I. O. E., Okonko, I. O., Ikpoh, I. S., Nkang, A. O., Udeze, A. O. and Babalola, T. A. 2010. Assessment of bacteriological quality of fresh meats sold in Calabar metropolis, Nigeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry*. **9:** 89-100.

Vorster, S. M., Greebe, R. P. and Nortje, G. L. 1994. Incidence of *Staphylococcus aureus* and *Escherichia coli* in ground beef, broilers and processed meats in Pretoria, South Africa. *Journal of Food Protection*, **57:** 305-310.

Zhao, C., Ge, B., DeVillena, J., Sudler, R., Yeh, E., White, D. G., Wagner, D. and Meng, J. 2001. Prevalence of *Campylobacter* spp., *Escherichia coli*, and *Bacillus cereus* serovars in retail chicken, turkey, pork, and beef from the Greater Washington, D.C., area. *Journal of Applied Environmental Microbiology,* **67:** 431-5436.

127

Chapter 5: Physico-chemical quality of red meat during the distribution of carcasses from the abattoir to the retailers

(Submitted to the CyTA – Journal of Food)

Abstract

The present study investigated the physico-chemical quality of red meat during the distribution of carcasses from the abattoir to the retailers. A total of four hundred and fifty meat samples were collected in a commercial abattoir from beef (n=150), pork (n=150) and mutton (n=150) carcasses at three stages (50 at each stage): during the loading process of carcasses into trucks, at the offloading point and during marketing. Carcasses were traced by means of bar codes for traceability during transportation from the abattoir to the retailers which are supplied by the abattoir. In each stage ultimate pH (pHu), meat temperature (Tm), and colour (L*, a*, and b*) measurements were measured and recorded. Chroma (C*) and Hue angle (h) were calculated. Samples were immediately transported to the laboratory in cooler boxes with ice where cooking losses (CL %) and Warner Braztler shear force (WBSF) were determined. The results revelead that the retailer class did not have a significant ($p > 0.05$) effect on the majority of the meat quality attributes. Distribution stage had a significant effect ($p<0.05$) on some of the meat quality attributes, especially the a* values for all meat types and differences between the loading (18.5 ± 0.93), off-loading (15.8 ± 0.93) and display (20.2 ± 0.94) points were observed. Also, distance had a significant effect on L*, a*, Hue Angle and Chroma values. Storage duration at the abattoir after slaughter and at retail point significantly affected L* and redness values in meat. Therefore, it was concluded the distribution chain affects the physico-chemical quality of red meat especially during the offloading of carcasses.

Keywords: Meat quality, distribution stage, pHu, storage duration, retailer class

5.1 Introduction

One of the most essential food product characteristics to consider throughout the supply chain is product quality (Smith and Sparks, 1994). Labuza (1982) stated that maintaining high food is of vital importance for supply chain performance. Controlling the product quality throughout the food supply chain has been identified as one of the most challenging tasks in today's food industry (Rong *et al*., 2011). Trienekens and Zuurbier (2008) stated that quality assurance will dominate the process of production and distribution in food chains in the future. However, regardless of this, quality standards should always be met when the product is sold to the consumer. Therefore continuous efforts to improve the quality of meat that is delivered to consumers are encouraged. The main aim of the supply chain and distribution channel is to try and maintain product quality. Should quality be affected, consumers can strongly reject the meat hence high chances of developing a negative attitude towards the product in future may occur.

It is speculated that the distribution chain may have a profound influence on the essential meat quality attributes like juiciness, tenderness, firmness and appearance. In Chapter 3, the perceptions of meat handlers on the effect of the distribution chain were observed. Meat handlers perceived that the distribution chain has an effect on the quality of meat supplied to the consumers. Therefore, it is important to determine changes in the physico – chemical quality of meat which is distributed from the abattoirs to the retail shops and to see if the meat handler's perception matches with results of the instrumental measurements. According to Tejeda *et al.* (2008) and Muchenje *et al*. (2008), physico-chemical characteristics are some of the determinants of meat quality and its acceptability by consumers. Muchenje *et al.* (2009) highlighted that meat is composed of physical and chemical components. Chemical attributes include the pH. Physical attributes include tenderness, colour, cooking loss, flavour and juiciness of the meat. However, the major parameters considered in the assessment of

meat quality are appearance, juiciness, tenderness, and flavour (Lawrie, 1998). How marketable or how much meat sells from display shelves depends on immediate visual meat quality and subsequent on-plate-on-palate feeling. Troy and Kerry (2010) and Girolami *et al.* (2013) indicated that colour is the first meat quality attribute in meat acceptance by consumers. Meat is expected to have a desirable colour that is uniform throughout the entire cut. However, the surface of meat changes from red to brown during retail display due to the formation of metmyoglobin and other individual factors and their interactions prior to purchase (Mancini and Hunt, 2005). This, in a way reflects changes in pH, overall flavour, tenderness, cooking loss and juiciness of the meat.

Previously in the meat supply chain, the meat quality has only been catered for considering the production stage. Researchers' main focus was based on manipulating the feed or diet consumed by an animal and relate it to the quality of the meat that the animal would produce (Wood *et al*., 1999; Priolo *et al.*, 2001; Nuernberg *et al*., 2005; Muchenje *et al*., 2008). Recently, animal welfare issues during the pre-slaughter and the slaughter process to cater for better meat eating quality and carcass inspection have been introduced (Warris, 1990; Ferguson and Warner, 2008; Chulayo and Muchenje, 2015). However, after the carcasses have been inspected, they are transported from the abattoir to the supermarket- chains or butchers for consumers to purchase. There is scarcity of information or no researches conducted which follow the supply chain, specifically the distribution stage to insure that the meat quality remains the same. Gormley (1990) revealed that transportation of the product to retail outlets and storage have been reported to commonly be a weak link in the chain.

Vimiso and Muchenje (2013) and Gajana *et al*. (2013) revealed that distance during transportation of animals from the farm to the abattoir before slaughter has an effect on the quality of meat produced. However, there is no information available on the effect of distance

after slaughter, when transporting carcasses to the supply points on the quality of the meat. Therefore, it is important to determine factors which play a significant role in affecting the quality of meat during distribution chain, from the abattoir to retail shops. These include distance covered from the abattoir to the supply points, storage temperature and storage duration.

In Chapter 3 and some studies by Steenkamp and Wedel (1991), consumers revealed that the quality of meat which is purchased from different shops differ. It should be borne in mind that, the retailers which sell meat directly to consumers fall into different categories. There are those classified as top class (guaranteed to sell high quality products), middle class and ordinary retailers (Rani, Nantapo, Hugo and Muchenje, 2014). These different retailers most of the time are supplied by the same suppliers. Therefore, it is important to understand as to what drives the quality of meat to change once it reaches the retailers. Could it be the difference in retailers' storage, temperatures, packaging type used per each shop, storage duration or are the differences driven by other factors? Also, there is scanty information on the post-slaughter handling of carcasses and meat by different classes of retailers in both rural and urban set-ups on how they handle their meat so as to see on which precautions could be taken for improvement. Hence, the main aim of this research was to determine changes in the physico-chemical quality of red meat during the distribution of carcasses from the abattoir to the retailers**.**

5.2 Materials and methods

5.2.1 Description of the study site and Ethical clearance

The study was conducted at a selected high throughput abattoir in East London situated in the Eastern Cape Province of South Africa. The abattoir is located 120 km South East of the University of Fort Hare, Alice campus at latitudes and longitudes of 32.97^0S and 27.87^0E and

542 m above sea level and is governed by the Meat Safety Act of 2000 and SAMIC (2006). This abattoir slaughters up to 1000 livestock units per day and delivers loads of carcasses to the retail shops per day. Permission to conduct the study was reviewed and approved by the Research Ethics Committee of the University of Fort Hare, South Africa (UFH/UREC, MUC0101SRAN01).

5.2.2 Experimental design

A total of four hundred and fifty samples were collected from mutton (n=150), beef (n=150) and pork (n=150) carcasses during the loading stage at the abattoir, at the offloading point and during marketing. Therefore, a make-up of fifty samples (n=50) were collected in each of the three different stages. Fifty carcasses for each species were randomly selected at the abattoir before loading the trucks for delivery to the retail shops where different portions of meat samples were collected. The measurements of pHu and colour coordinates (L*, a* and b*) were carried out. All carcasses were loaded in the same truck and followed to the supply; points with distance (km) from the abattoir having been recorded. At the offloading point, before the carcasses were packed at the storage room, meat samples were collected from the same carcasses and the pH_u and colour coordinates were taken to check if there is a difference in the meat quality traits between the two stages. Bar codes were used to trace carcasses for identification purposes. Appointments were made with the butcher managers for purchasing of meat samples from the same carcasses at the display outlets. The storage temperature at which the meat was kept under by the retailers, as well as the storage duration (number of days it takes for the meat to be displayed in shelves after reaching retailers as well as storage days after slaughter at the abattoir) were recorded. At the display point or when the meat was displayed in shelves for the consumers to purchase, other meat samples from the same carcasses were purchased where ultimate pH (pHu) and colour coordinates were measured. All the samples were delivered to the Meat Science Laboratory in a cooler box containing ice

at $\leq 4^{\circ}$C where they were kept in a fridge to await for cooking loss and tenderness evaluations.

5.2.3 Meat quality measurements

5.2.3.1 Determination of ultimate pH, meat temperature and colour

A portable fibre-optic pH and Tm meter probe with a sharp metal sheath to prevent damage from raw meat (CRISON pH 25 Instruments S.A., Alella, Spain) was used to measure the ultimate pH and temperature of the meat samples from beef, pork and mutton carcasses at each stage. The pH meter was calibrated before taking measurements using pH 4, pH 7 and pH 9 standard solutions (CRISON Instruments, SA, Spain). Both pHu and Tm were recorded accordingly.

Colour measurements were taken from different cuts of mutton, beef and pork samples; chump, leg chop, loin chop, rib chop, shoulder chop, and brisket chop. The lightness (L*), redness (a*) and yellowness (b*) values (Commission International De I'Eclairage, 1976) were determined using a Minolta colour-guide 45/0 BYK-Gardener GmbH machine, with a 20 mm diameter measurement area and illuminant D65-day light, 10° observation angle. The machine was calibrated in each stage before taking measurements using the green, black and white colour standard samples provided for this purpose. Three readings were taken from each portion by rotating the instrument at 90° between each measurement, in order to obtain a representative average value of the colour. The colour values were recorded and compared with pHu of the same meat samples. The Chroma and Hue angle (HA) were calculated using the following formulae (Ulbricht and Southgate, 1991): Chroma (C), which is related to the colour intensity of the meat, was calculated according to the formula: $C* = [(a*^2 + b*^2)^{0.5}]$ (Lanari $et\ al.$, 1995); and Hue angle (HA), in degrees, was calculated according to the formula: $HA = [(\tan^{-1}(b*/a*)]$ (Rippoll $et\ al.$, 2011).

5.2.2.2 Warner-Bratzler shear force and cooking losses determination

For determination of cooking loss and Warner-Bratzler shear force (WBSF) values, samples were taken out of the fridge a day before and were left to thaw at 25ºC, room temperature. Samples were weighed, labelled and placed in plastic bags before cooking in a water bath. Labelled samples were cooked for 45 minutes at 85°C (Yang et al. 2010), cooled and weighed again to measure cooking loss. Cooking loss (CL) was calculated using the following formula:

$$Cooking\ Loss\ (CL)\% = \frac{weight\ before\ cooked - weight\ after\ cooked}{weight\ before\ cooked} \times 100$$

After measurement of cooking loss, the samples were then used to determine WBSF values. Three sub samples measuring 10 mm in diameter were cored parallel to the grain of the meat from each cut/portion. The samples were sheared perpendicular to the fibre direction using a Warner Bratzler (WB) shear device mounted on an Instron (Model 3344) Universal testing apparatus (cross head speed at 400mm/min, one shear in the centre of each core). The mean maximum load (N) was recorded for the batch.

5.2.4 Statistical Analysis

The physico-chemical meat quality parameters (pH, L*, a* and b*, CL, WBSF values) were analysed. A factorial experiment with three factors (Distribution stage, effect of storage duration at the abattoir after slaughter and at the retailers storage rooms; and effect of distance) was laid out in a randomised complete block design and Analysis of variance was calculated by PROC general linear model in SAS (Statistical Analysis Systems, 2011), using the following model:

Yijk =μ+αi + βj + P_k + Eijk

Where;

Yijk = response variable (L*, a*, and b*, pH, CL, tenderness)

μ = Overall mean common to all observations

α_i = effect of i-th distribution stage

β_j =effect of j-th storage duration

P_k = effect of   k-th distance

E_{ijk} =random error

5.3 Results and Discussion

Results of the retailer class effects on physico-chemical attributes of red meat are presented in Table 5.1. There were significant retailer effects ($p<0.05$) on the L*value and WBSF of the meat. However, b*, a*, Hue Angle, Chroma and meat temperature were not affected by the retailer class. The pHu range was similar whether meat was purchased from a butcher, top or middle class shop. The pHu range in the current study was between 6.2 and 6.3. Muchenje *et al*. (2008) stated that meat with pH above 6.0 is undesirable as it leads to dark firm dry meat. According to Hoffman *et al*. (2003), higher pH (>5.8) leads to undesirable meat colour which is unattractive to consumers. Young *et al*. (2005) stated that an pH_u greater than 6.0 is usually regarded as a critical value and is associated with DFD condition in both pork and beef. Therefore, the observed pHu in current study could be considered to be on the higher range.

Nevertheless, Cloete *et al.* (2008) reported an ultimate pH range of 6.4. Also in a study by Škrlep and Candek-Potokar (2005) and Rani *et al*. (2014), the ultimate pH of the meat samples ranged up to 6.4. Although the pHμ of meat at point of purchase might be high, it does not necessarily mean that the meat is not desirable, but it might mean it does not have the same desirable colour it had immediately after slaughter, maybe due to storage conditions. This therefore proves that the ultimate pH at the point of purchase for meat is greater than 6.0. Although there was a significant difference in the L* values for the different retailer classes, but the lightness values did not differ that much. According to the results of the meat quality attributes, there is no difference in the quality of meat purchased from a butcher, top class and

Table 5.1: Mean values (± SE) for colour (L*, a* b*), pH, Hue Angle, Chroma, tenderness and cooking loss% of red meat as affected by shop type

	Butcher	Middle	Top
Lightness (L*)	$28.1^{ab}\pm 2.14$	$29.3^{b}\pm2.14$	$27.2^{a}\pm 2.14$
Redness (a*)	14.9 ± 0.93	14.5 ± 0.93	14.5 ± 0.93
Yellowness (b*)	10.1 ± 0.89	9.6 ± 0.91	9.4 ± 0.90
Hue Angle	6.2 ± 0.62	6.3 ± 0.60	6.2 ± 0.62
Chroma	18.0 ± 1.12	17.6 ± 0.99	17.4 ± 1.00
pH$_u$	6.3 ± 0.16	6.2 ± 0.12	6.3 ± 0.17
WBSF (N)	$21.4^{ab}\pm1.74$	$20.7^{a}\pm 1.75$	$22.6^{b}\pm 0.93$
Meat Temperature (°C)	20.6 ± 2.13	21.1 ± 2.15	21.9 ± 2.14

[abc] Means in the same row without the same superscripts are significantly different (P < 0.05)

SE = standard error; WBSF= Warner-Bratzler shear force; N= Newtons; °C= Degress Celcius; Top class = High priced retailers; Middle class= moderately priced

middle class shops. However, these results contradicts with findings by Becker *et al*. (2000) who found that the place of purchase was ranked as the most useful in assessing meat quality in the shop, implying that the quality of meat purchased from different shops differ.

The results on physico-chemical properties of beef, pork and mutton as affected by the distribution stage are presented in Table 5.2. There was a significant difference ($P < 0.05$) in L*, a* and b* values for beef, pork and mutton. L* values for mutton and pork did not differ that much at the offloading stage but significant differences in the L* values for beef across different stages were observed. Lightness (L*) value at the loading point for beef were 34.5 ± 2.20. At the offloading point, a significant decrease was observed (L*= 29.9 ± 1.01). Differences in L* values for beef could be due to the fact that beef carcasses were fragmented into quarters at the abattoir before transportation and this was done to cater for the space in trucks during delivery. Due to the fact that the muscles of the beef carcasses were exposed to air, changes in colour on the surface of the carcasses were expected to occur. Faustman *et al.* (2010) stated that colour change in meat can be attributed to either oxygenation or oxidation of the pigment myoglobin. During this process the atmosphere oxygen bonds to myoglobin (Lindahl, 2003; Mancini and Hunt 2005).

Myoglobin becomes red (oxymyoglobin) due to oxygenation whilst deoxygenated myoglobin is purple, and turns brown (metmyoglobin) due to oxidation (Faustman, 1990). It should be noted that after slicing or cutting the carcass, the surface typically changes in colour from purple to red due to oxygenation, or blooming. This 'bloom' extends a few millimetres below the surface of meat. Oxidation initiates at the junction of the oxygenated and deoxygenated layers where the oxygen partial pressure is low (Hunt *et al*., 1991). This junction moves progressively towards the meat surface and in the process the surface colour changes from

red to brown. Faustman (1990) stated that management of meat colour stability can be achieved by manipulating a range of non-genetic factors such as vitamin E concentration and

Table 5.2: Mean values (± SE) for colour (L*, a* b*), pH, Hue Angle, Chroma, tenderness and cooking loss% of red meat as affected by meat type

Stage	Meat type	L*	a*	b*	Hue Angle	Chroma	pH_u	CL%	Tm
Loading	Beef	$34.5^b \pm 2.20$	$18.5^c \pm 0.93$	$9.6^b \pm 0.90$	$5.5^b \pm 0.63$	$18.5^b \pm 1.00$	$6.4^c \pm 0.12$	$22.0^a \pm 1.76$	$23.4^b \pm 2.16$
	Pork	$51.6^c \pm 2.01$	$10.6^a \pm 0.94$	$11.6^c \pm 0.91$	$5.1^a \pm 0.60$	$20.6^c \pm 0.99$	$6.1^a \pm 0.12$	$21.8^a \pm 1.75$	$24.4^b \pm 2.15$
	Mutton	$32.5^a \pm 2.10$	$15.6^b \pm 0.92$	$7.9^a \pm 0.87$	$8.1^b \pm 0.61$	$13.8^a \pm 1.12$	$6.3^b \pm 0.12$	$20.9^a \pm 1.69$	$15.8^a \pm 2.13$
Off-loading	Beef	$29.9^a \pm 1.01$	$15.8^c \pm 0.93$	$9.7^b \pm 0.90$	$5.9^b \pm 0.63$	$18.5^b \pm 1.00$	$6.3^c \pm 0.12$	$21.1^a \pm 1.76$	$23.5^b \pm 2.15$
	Pork	$50.3^c \pm 1.01$	$8.6^a \pm 0.92$	$10.6^c \pm 0.91$	$5.5^a \pm 0.60$	$21.7^c \pm 0.99$	$6.1^a \pm 0.12$	$22.8^a \pm 1.75$	$23.4^b \pm 2.15$
	Mutton	$31.7^b \pm 1.30$	$11.2^b \pm 0.94$	$7.7^a \pm 0.87$	$8.8^b \pm 0.61$	$14.7^a \pm 1.12$	$6.1^b \pm 0.12$	$22.9^a \pm 1.69$	$14.6^a \pm 2.14$
Display	Beef	$31.2^a \pm 1.01$	$20.2^c \pm 0.94$	$8.9^b \pm 0.90$	$6.3^b \pm 0.63$	$17.8^b \pm 1.00$	$6.4^c \pm 0.12$	$23.4^a \pm 1.76$	$23.5^b \pm 2.15$
	Pork	$49.7^c \pm 2.02$	$11.5^a \pm 0.93$	$10.0^c \pm 0.91$	$6.2^a \pm 0.60$	$22.6^c \pm 0.99$	$6.2^a \pm 0.12$	$23.9^a \pm 1.69$	$22.9^b \pm 2.15$
	Mutton	$33.6^b \pm 2.10$	$17.1^b \pm 0.92$	$8.7^a \pm 0.87$	$8.4^b \pm 0.61$	$15.8^a \pm 1.12$	$6.4^b \pm 0.12$	$21.6^a \pm 1.69$	$15.4^a \pm 2.14$

[a,b,c] Means in the same column without the same superscripts are significantly different ($P < 0.05$); SE = standard error; L*= Lightness; a*= redness; b* = yellowness; CL%= Cooking Loss, TM= Meat Temperature

chill rate. However, it should be noted that although there were some differences in L* values for beef along the different stages, but the L* values still fell within the stipulated range. Therefore, the L* values indicated freshness in meat at all distribution chain stages.

Differences in pork and mutton carcasses did not occur because during delivery, the carcasses were delivered as a whole, therefore there was no penetration of oxygen straight to the muscle. Differences in the redness (a*) values across different species were observed. Beef was observed with higher a* value (18.5 ± 0.93) compared to pork (10.6 ± 0.94) and mutton (15.6 ± 0.92). Differences in the colour of meat from different species were expected. However differences in redness values across different species decreased and later on increased with stage. At the off-loading point, a slight decrease in a*values were observed in all the species. Pork was observed with (8.6 ± 0.92), beef (15.8± 0.93) and mutton (11.2 ± 0.94) and then a significant increase at the diplay point or during marketing occurred. These differences could be associated to the fact that, the muscles that were collected and measured at the offloading point were taken from the surface of the carcasses, hence colour changes in the surface might have occurred due to exposure to oxygen.

The significant increase in the redness values at the display point can be due to the fact that, the muscle purchased during marketing is trimmed from the inner parts of the carcass where the penetration of oxygen does not occur. Hence different muscles turn to differ in colour. Significant differences for b*, Hue Angle, Chroma and Meat Temperature were observed across different species or meat types, but no differences occurred across the distribution stages. There were no significant differences in the cooking loss values of different meat type although differences were observed across different stages. Monsón *et al*. (2005) defines meat tenderness as a function of collagen content, heat stability and myofibrillar structure of muscle, though these appear to be affected mainly by the rate of growth of species rather than

breed. WBSF (Warner Bratzler Shear Force value) were lower during the loading stage compared to the offloading and display points in all meat types. The observed yellowness values in the current study fell into the stipulated range which is 6.1-11.3 and this agrees with findings by (Muchenje *et al*., 2008).

The results on effect of distance on colour (L*, a* b*), pH, Hue Angle, Chroma, tenderness and cooking loss% of red meat are depicted in Table 5.3. This distance (km) was recorded when trucks that were carrying the carcasses were followed to the shops for delivery. Zero measures the distance at the abattoir after loading the carcasses. Distance had a significant effect on L*, a*, Hue Angle and Chroma values. The L* values which were recorded from the carcasses at the abattoir did not change after reaching the supply points at 15, 20 and 25km. However, a significant difference on L* values carcasses that were transported at 60km was observed. This could imply that, the longer the distance that is covered when transporting the carcasses, the greater are the chances of the meat quality traits to be affected since there are usually a lot of offloading points to other retailers along the way whereby doors could be open for longer periods with air flowing inside the trucks.

Koutsoumanis and Taoukis (2005) highlighted that size of the cabinets, initial temperature of the incoming meat, targeted temperature of storage, temperatures of the surroundings, mechanical characteristics (location of refrigeration machinery, compressors, ventilation, and insulation) and energy/cost matters are issues of first priority when considering cold store requirements during transportation. However, b*, pH_u, cooking loss, and meat temperature were not affected by distance. The results on temperature and distance were not expected as change in temperature inside the trucks during the offloading points were observed. However, this proves that the storage temperatures used in the vehicles transporting the carcasses are important in maintaining quality of the meat.

Table 5.3: Mean values (± SE) for colour (L*, a* b*), pH, Hue Angle, Chroma, tenderness and cooking loss% of red meat as affected by distance covered from the abattoir to the supply points

	Distance (km)				
Parameter	0	15	20	25	60
Lightness (L*)	28.7[a] ± 1.98	20.8[a] ± 7.45	30.3[a] ± 1.61	32.7[a] ± 1.52	34.8[b] ± 1.68
Redness (a*)	11.4[a] ± 0.86	11.4[a] ± 3.32	15.4[b] ± 0.70	15.4[b] ± 0.66	16.7[c] ± 0.73
Yellowness (b*)	9.5[a] ± 0.84	10.3[a] ± 3.13	9.8[a] ± 0.67	10.6[a] ± 0.65	9.9[a] ± 0.70
Hue Angle	8.1[c] ± 0.58	7.2[c] ± 2.22	6.04[b] ± 0.46	6.16[b] ± 0.44	5.4[a] ± 0.48
Chroma	15.0[a] ± 1.04	18.7[b] ± 0.79	18.4[b] ± 0.84	18.7[b] ± 0.79	19.5[b] ± 0.87
pH_u	6.1[a] ± 0.15	6.3[a] ± 0.12	6.3[a] ± 0.12	6.3[a] ± 0.12	6.4[a] ± 0.12
CL%	23.0[a] ± 1.61	23.2[a] ± 1.34	24.5[a] ± 1.31	24.5[a] ± 1.23	25.6[a] ± 1.36
WBSF	18.3[a] ± 3.72	20.4[a] ± 1.34	19.6[a] ± 1.76	21.3[a] ± 1.34	22.6[a] ± 1.32
Tm	20.7[a] ± 1.98	20.6[a] ± 7.61	23.1[a] ± 1.60	22.1[a] ± 1.52	24.2[a] ± 1.67

[abc] Means in the same row without the same superscripts are significantly different (P < 0.05)

SE = standard error; WBSF= Warner-Bratzler shear force; CL%= Cooking Loss

Table 5.4 shows the results on effect of storage duration (in days) at the abattoir after slaughter and at retail shops on some of the important meat quality attributes. This storage duration represents the number of days at storage in the abattoir after slaughter and at the shops after delivery before display. The meat handlers at the abattoir during the data collection revealed that carcasses can be kept for more than two weeks in their chiller rooms after slaughter before transportation to the retail shops. However, at the retail shops, the meat is not sold immediately after reaching their shops. It can still be stored for a number of days before cutting for the marketing purposes or for consumer purchasing (Alba, 1997). Storage duration had a significant effect ($p < 0.05$) on meat temperature, lightness (L*) and redness (a*) values. However, b*, Hue angle, ultimate pH and the cooking loss were not affected by the storage duration.

Table 5.4: Mean values (± SE) for colour (L*, a* b*), pH, Hue Angle, Chroma, tenderness and cooking loss% of red meat as affected by storage duration at the abattoir after slaughter and at retail shops

	Storage day									
Parameter	**10**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Lightness (L*)	$31.0^b \pm 2.45$	$25.1^a \pm .01$	$27.9^a \pm 2.25$	$31.5^b \pm 2.06$	$22.7^a \pm 4.67$	$31.3^a \pm 2.21$	$29.7^b \pm 3.39$	$23.8^a \pm 7.64$	$26.3^a \pm 3.91$	$32.7^b \pm 2.58$
Redness (a*)	$15.7^a \pm 1.07$	$14.5^a \pm 0.87$	$14.6^a \pm 0.97$	$14.5^a \pm 0.89$	$13.2^a \pm 2.03$	$14.4^a \pm 0.96$	$14.5^a \pm 1.47$	$10.7^a \pm 3.32$	$18.0^b \pm 1.70$	$16.9^b \pm 1.12$
Yellowness (b*)	$10.3^a \pm 1.03$	$9.9^a \pm 0.84$	10.1 ± 0.94	$9.7^a \pm 0.87$	$7.4^a \pm 1.96$	$10.4^a \pm 0.93$	$9.3^a \pm 1.43$	$6.3^a \pm 3.21$	$11.9^b \pm 1.64$	$11.7^b \pm 1.08$
Hue Angle	$5.5^a \pm 0.71$	$6.3^b \pm 0.58$	$6.1^b \pm 0.65$	$5.9^a \pm 0.60$	$5.8^a \pm 1.36$	$6.5^b \pm 0.64$	$5.8^a \pm 0.98$	$9.8^c \pm 2.22$	$5.3^a \pm 1.14$	$9.8^c \pm 1.14$
Chroma	$18.8^a \pm 1.18$	$17.7^a \pm 1.05$	$17.9^a \pm 1.17$	$17.4^a \pm 1.07$	$15.0^a \pm 2.44$	$18.0^a \pm 1.15$	$17.5^a \pm 1.07$	$11.9^a \pm 3.99$	$21.9^b \pm 2.05$	$20.5^a \pm 1.34$
pH$_u$	$6.1^a \pm 0.19$	$6.2^a \pm 0.12$	$6.0^a \pm 0.17$	$6.2^a \pm 0.15$	$6.3^a \pm 0.65$	$6.1^a \pm 0.17$	$6.3^a \pm 0.26$	$6.3^a \pm 0.58$	$6.4^a \pm 0.29$	$6.6^a \pm 0.19$
CL%	$22.9^a \pm 1.98$	$22.3^a \pm 1.64$	$22.8^a \pm 1.98$	$23.3^a \pm 1.67$	$18.3^a \pm 3.79$	$22.7^a \pm 1.79$	$21.6^a \pm 2.75$	$19.8^a \pm 6.20$	$20.1^a \pm 3.17$	$22.0^a \pm 2.09$
Tm	$24.7^a \pm 2.44$	$21.6^a \pm 2.01$	$22.5^a \pm 2.24$	$20.8^a \pm 2.05$	$20.3^a \pm 4.66$	$22.3^a \pm 2.19$	$17.7^a \pm 3.38$	$18.1^a \pm 7.61$	$23.9^a \pm 3.89$	$20.3^a \pm 2.57$

[abc] Means in the same row without the same superscripts are significantly different (P < 0.05); SE = standard error; Tm= Meat Temperature; CL%= Cooking Loss

5.4 Conclusion

In the current study, the results showed that the retailer class does not have an impact on the quality of the meat sold in different shops. This therefore implies that, where one purchases the meat or the class of the shop does not determine the quality of the meat being sold in a shop but quality depends on handling and storage temperatures used by the retailers. Results from this study showed that pH_u at point of purchase ranges above the normal range prior to purchase. Ultimate pH at the point of purchase is above 6.0. Distribution stage had an effect on the quality of the meat, mainly the lightness (L*) and redness (a*) values. Also storage duration and distance affected L* and a* values of meat. Temperature and pH_u were not affected by the distribution chain stages. It was concluded that the distribution chain does have an effect on some of the important meat quality attributes, specifically the colour (L* and a*values) of the meat.

5.5 References

Alba, J., Lynch, J., Weitz, B., Janiszewski, C., Lutz, R., Sawyer, A. and Wood, S. 1997. Interactive home shopping: consumer, retailer, and manufacturer incentives to participate in electronic marketplaces. *The Journal of Marketing*, **1:** 38-53.

Becker, T., Benner, E. and Glitsch, K. 2000. Consumer perception of fresh meat quality in Germany. *British Food Journal,* **102:** 246-266.

Commission International De I'Eclairage (CIE). 1976. Colorimetry. 2nd edition. Vienna, Switzerland.

Chulayo, A. Y. and Muchenje, V. 2015. A balanced perspective on animal welfare for improved meat and meat products: review. *South African Journal of Animal Science*, **45:** 452-469.

Cloete, J.J.E., L.C. Hoffman and S.W.P. Cloete 2008. Carcass characteristics and meat quality of progeny of five Merino dam lines crossed with Dormer and Suffolk sires. S. *African Journal of Animal Sciences*, 38: 355-366

Ferguson, D. M., and Warner, R. D. 2008. Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants? *Meat Science*, **80:** 12-19.

Faustman, C., Mancini, R. A., Sun, Q. and Suman, S. P. 2010. Myoglobin and lipid oxidation: Mechanistic basis and control. In S. K. Lee (Ed.), International Congress of Meat Science and Technology. Jeju, Korea.

Fautsman, C. and R.G. Cassens.1990. The biochemical basis for discoloration in fresh meat: A review. *Journal of Muscle Foods*, **1:** 217 – 243.

Gajana, C.S., Nkukwana, T.T., Marume, U. and Muchenje, V. 2013. Effects of transportation time, distance, stocking density, temperature and lairage time on

incidences of pale, exudative (PSE) and the physicochemical characteristics of pork. *Meat Science, 95***:** 520-525.

Girolami, A., Napolitano, F., Faraone, D. and Braghieri, A. 2013. Measurement of meat colour using a computer vision system. *Meat Science*, **93:** 111-118.

Gormley, T. R. 1990. Temperature monitoring of chilled foods during air and road freighting. In Processing and Quality of Foods, Vol. 3, Chilled Foods, eds. P. Zeuthen, J. C. Cheftel C. Eri2ksson, T. R. Gormley, P. Link0 K. Paulus. *Elsevier Applied Science*, London. pp. 3.248-3.255.

Hoffman, L.C., M. Muller, S. W. P. Cloete, and D. Schmidt, 2003. Comparison of six crossbred lamb types: sensory, physical and nutritional meat quality characteristics. *Meat Science*, **65:** 1265-1274.

Hunt, M. C., Acton, J. C., Benedict, R. C., Calkins, C. R., Cornforth, D. P., Jeremiah, L. E., Olsen, D. G., Salm, C. P., Savell, J. W. and Shivas, S. D. 1991. Guidelines for meat color evaluation (pp. 1–17). Kansas State University, Manhattan, KS: American Meat Science Association.

Koutsoumanis, K. P. and Taoukis, P. 2005. Meat safety, refrigerated storage and transport: modeling and management. In J. N. Sofos (Ed.), Improving the Safety of Fresh Meat (pp. 503–561). Cambridge, UK: Woodhead/Publishing, Ltd.

Labuza, T.P. 1982. Shelf-life Dating of Foods. Food & Nutrition Press, Westport, CT, USA.

Lanari, M.C., Schaefer, D.M., and Scheller, K.K. 1995 Dietary vitamin E supplementation and discoloration of pork bone and muscle following modified atmosphere packaging. *Meat Science,* **41:** 237–250.

Lawrie, R.A. 1998.Lawrie's meat science.6th ed Cambridge, England: Woodhead Publishing Ltd. pp. 442.

Lindahl, G. 2003. Colour measurements in meat. *New Food* , *6***:** 74–76.

Mancini, R. A. and Hunt, M. 2005. Current research in meat colour. *Meat Science*, **71:** 100-121.

Monsón, F., Sañudo, C. and Sierra, I. 2005. Influence of breed and ageing time on the sensory meat qulity and consumer acceptability in intensively reared beef. *Meat Science*, **71:** 471-479.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P. E. and Raats, J. G. 2008. Meat quality of Nguni, Bonsmara and Aberdeen Angus steers raised on a natural pasture in the Eastern Cape, South Africa. *Meat Science*, **79:** 20-28.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P. E., Hugo A. and Raats, J. G. 2009. Some biochemical aspects pertaining to beef eating quality and consumer health: A review. *Food Chemistry,* **112:** 279-289.

Nuernberg, K., Dannenberger, D., Nuernberg, G., Ender, K., Voigt, J., Scollan, N. D. and Richardson, R. I. 2005. Effect of a grass-based and a concentrate feeding system on meat quality characteristics and fatty acid composition of longissimus muscle in different cattle breeds. *Livestock Production Science*, **94:** 137-147.

Priolo, A., Micol, D. and Agabriel, J. 2001. Effects of grass feeding systems on ruminant meat colour and flavour. A review. *Animal Research*, *50***:** 185-200.

Rani, Z. T., Nantapo, C. W., Hugo, A. and Muchenje, V. 2014. Differences in health-related Fatty Acids, intramuscular fat and the physico-chemical quality in mutton as affected by season, place of purchase and meat portion. *Asian-Australasian Journal of Animal Sciences*, **27:** 1630- 1637.

Ripoll, R., Joy, M., and Muñoz, F. 2011. Use of dietary vitamin E and selenium (Se) to increase the shelf life of modified atmosphere packaged light lamb meat. *Meat Science,* **87:** 88–93.

Rong, A., Akkerman, R. and Grunow, M. 2011. An optimization approach for managing fresh food quality throughout the supply chain. *International Journal of Production Economics*, *131***:** 421-429.

SAS 2011. Users guide, version 9. USA: Statistical Analysis System Institute Inc.

SAMIC, 2006. South African Meat Industry Company. Classification of South Africa Beef - a Key to Consumer Satisfaction. South African Meat Industry Company, Pretoria, South Africa.

Smith, D. and Sparks, L. 2004. Temperature controlled supply chains. In: Bourlakis, M.A., Weightman, P.W.H. (Eds.), Food Supply Chain Management. Blackwell Publishing, Oxford, UK, pp. 179–198.

Steenkamp, J. B. E. and Wedel, M. 1991. Segmenting retail markets on store image using a consumer-based methodology. *Journal of Retailing*, **67:** 300.

Troy, D.J. and Kerry, J.P. 2010. Consumer perception and the Role of Science in the Meat Industry. *Meat Science,* **86:** 214–226.

Tejeda, J. F., Pena, R. E. and Andres A. I. 2008. Effect of live weight and sex on physicochemical and sensorial characteristics of Merino lamb meat. *Meat Science,* **80:** 1061-1067.

Trienekens, J. and Zuurbier, P. 2008. Quality and safety standards in the food industry, developments and challenges. *International Journal of Production Economics*, **113:** 107–122.

Ulbricht, T. L. V. and Southgate, D. A. T. 1991. Coronary heart disease: seven dietary factors. *The Lancet*, **33:** 985-992.

Vimiso, P. and Muchenje, V. 2013. A survey on the effect of transport method on bruises, pH and colour of meat from cattle slaughtered at a South African commercial abattoir. *South African Journal of Animal Science*, **43:** 105-111.

Warriss, P. D. 1990. The handling of cattle pre-slaughter and its effects on carcass and meat quality. *Applied Animal Behaviour Science*, **28:** 171-186.

Wood, J. D., Enser, M., Fisher, A. V., Nute, G. R., Richardson, R. I. and Sheard, P. R. . *society*, **58:** 363-370.

Young, O. A., Hopkins, D. L. and Pethick, D. W. 2005. Critical control points for meat quality in the Australian sheep meat supply chain.. *Animal Production Science*, **45:** 593-601.

Chapter 6: Vacuum packing and overwrapping effects during marketing on shelf-life and microbiological quality of red meat

(*Submitted to Food Packaging and Shelf-Life Journal*)

Abstract

The study investigated the effect of vacuum packing and overwrapping on the physico-chemical and microbiological shelf life of red meat during marketing. Two types of packaging systems commonly used by the retailers were selected and used in this study: vacuum packaging and overwrapping. A total of 108 fresh loin meat samples of beef (n= 36), pork (n= 36) and mutton (n= 36) were purchased from a local butchery. Samples were immediately transported to the laboratory in cooler boxes with ice and stored in a refrigerator at 4 °C for storage duration of 15 days. To monitor shelf life, physico-chemical traits such as colour (CIE-L*, lightness; a*, redness; and b*, yellowness) and pH measurements were taken on days 0, 3, 6, 9, 12, and 15 with 3 replicates (n =18) per each meat type. Microbial analysis of the meat samples was carried out on the respective days of sampling. The samples were subjected to total bacterial count, coliform count, *E. coli* and *Staphylococcus aureus* detection. Packaging had a significant effect ($p < 0.05$) on colour (L*, a* and b*) among different meat types. Vacuum packed mutton and pork loin samples were observed with low L* values (34.5 ± 1.05) and (45.9 ±1.05) which were significantly different ($p< 0.05$) in comparison to overwrapped samples. Total bacteria counts, coliform count and *E. coli* increased significantly ($p< 0.05$) with storage duration. In conclusion, both packaging systems could not sustain a high quality in meat. However, according to the results the overwrapped samples were of better quality than the vacuum packed samples.

Key words: Microbiological quality, physico- chemical quality, shelf- life, storage duration, meat colour, pH_u, packaging

6.1 Introduction

Throughout the history of mankind people have been eating meat as it is a dense source of nutrients that are vital for growth and development (Pereira and Vincente, 2013). However, despite its contribution as a complete nutrient source meat has developed a bad reputation as a result of reported negative impacts that meat consumption may have on human health. Although scientific research has shown its multiple health benefits, there are numerous reports which have been released globally on illnesses and deaths related to meat consumption due to foodborne diseases (Global Salm-Surv, 2003; Greig and Ravel, 2008; Tauxe *et al*., 2010). This is seen as an addition to its existing bad reputation as meat has previously been identified as a source of saturated fatty acids which have a potential to cause chronic diseases such as cardiovascular diseases (Simopoulus, 2006). Pothakos *et al*. (2015) and Véronique (2008) highlighted that because meat is a perishable product due to its biological composition, it is recognized as a carrier of microbial contaminants especially if appropriate handling practices are not followed. These microbial contaminants are divided into pathogenic and spoilage organisms. If the levels of microbial contaminants in meat exceed the expected levels, they could adversely affect the shelf life of meat products and renders its unwholesome and unfit for human consumption (Ntanga, 2013). The most common pathogenic bacteria in meat include *Salmonella, Staphylococcus aureus, Escherichia coli, Bacillus cereus* and *Clostridium botulinum* as reported by (Borch and Arinder, 2002).

Confusion exists between spoilage organisms and pathogens. Guinane (2005) clarified this when describing the difference between spoilage organisms and pathogens by stating, "spoilage organisms won't make you sick, as in instigating an infection and creating a real illness." However, spoilage organisms make food undesirable. This affects consumer's preference and acceptability towards the product as well as expected profits to be realized by

the producers/ retailers. This is why the meat industry works diligently to reduce and eliminate both pathogenic and spoilage bacteria in meat especially during marketing.

Preservation methods such as refrigeration have been postulated to be effective in maintaining meat nutritive quality and more importantly, microbial safety (Sebranek and Bacus, 2007). Zhou *et al.* (2010) described refrigeration as a preservation method used to reduce microbial proliferation whilst maintaining original characteristics of the food product over a time. This is achieved through keeping meat at a low/ chilling temperature which helps supress growth of common spoilage and pathogenic micro-organisms (Lücke, 2000). Storage of meat at 0 - 4°C for several days is popular and convenient in most South African retail shops during marketing. However, chilled meat has a shorter shelf-life due to microbial growth, high oxidative stress which all compromise food safety, nutritive value and consumer preferences (Fregonesi *et al.*, 2014).

It should be noted that the demand and supply for each product in a shop fluctuates, and if the demand for meat and meat products decreases, it can only mean that the products should be kept for extended periods in a shop. For other products this may not be a problem but for perishable products like meat, this may be a challenge as techniques used to extend shelf life of meat may be required. Singh and Singh (2005) defined shelf life as the amount of time that passes before meat becomes unpalatable or unfit for human consumption because of the growth of spoilage organisms. Brooks (2008) described shelf-life as the length of time meat can be displayed under refrigeration before a colour change occurs. This colour changes from the bright, cherry-red colour to another colour, such as brown, is caused by a change in the protein myoglobin. Myoglobin is the colour pigment in muscle and is responsible for binding oxygen. While this colour change is not harmful and does not denote spoilage, it results in a

154

colour that customers find undesirable. Muchenje *et al*. (2009) stated that consumer prefer light pink to bright red meat and consider dark coloured meat as meat from diseased animals. Most retailers describe shelf-life as the length of time before the product will spoil, or more specifically, the time required for spoilage organisms to reach an unacceptable level. Smolander (2004) highlighted that to extend the shelf-life of meat, meat producers and retailers should find ways to create unfavourable conditions for spoilage organisms. This has been seen in recent studies focusing on understanding ways in which shelf life of meat can be improved. Approaches used in improving shelf life of meat include; monitoring carcass handling during the slaughtering process (Dickson *et al.,* 1991 ,Wong *et al.,* 2002), evaluating the microbial levels of meat at the abattoir after slaughter (Dickson and Anderson, 1992; Nyanga, 2013; Niyonzima *et al.,* 2013; Nyamakwere, 2015), application of preservation methods such as incorporating phenolic compounds –containing natural plant resources (Qwele *et al.,* 2013; Falowo *et al*., 2014; Nkukwana *et al.,* 2015) and other preservation methods to reduce microbial proliferation.

Packaging has been identified as the most convenient method used to sustain shelf life of meat during marketing or at retail point (Coles, 2003). Packaging protects products against deteriorative effects, which may include discolouration, off-flavour and off-odour development, nutrient loss, texture changes, pathogenicity and other measurable factors (Zhou *et al.,* 2010). However, there are different types of packaging methods used and each one plays a significant role. These include modified atmospheric, vacuum and air-permeable overwrap (Lee, 2010; Lorenzo and Gómez, 2012). McMillin *et al*. (1999) highlighted that retail packaging of meat in modified atmosphere (MA) with 70–80% oxygen is useful to provide a stable bloomed red meat colour, which is attractive to the consumer. Levels below 15% carbon dioxide (CO_2) do not inhibit microorganism growth satisfactorily while levels

above 40% may result in package collapse because the CO_2 is absorbed by the meat tissue. Thus, the inclusion of 20–30% CO_2 prolongs the shelf life by inhibiting bacterial growth (McMillin, 2008). The air-permeable overwrap allows oxygen to penetrate. According to Zakrys *et al.* (2008) a high concentration of oxygen may cause quality deterioration through lipid and protein oxidation. In a study by Lee (2010), it was revealed that a low CO/high CO_2 atmosphere is effective for preserving retail-ready meat. However, regardless of these findings but still the most common form of fresh meat packaging in the retail marketplace in South Africa is air-permeable overwrap. This form is utilized by the majority of retailers in South Africa because it is the most economical. While this package type is the most economical, it also yields the shortest case-life due to continued exposure to oxygen and the oxidation of the myoglobin, eventually resulting in a brown colour (Brooks, 2007).

There are plenty of studies which have been conducted in different countries focussing on the effect of packaging in meat (Véronique**,** 2007; McMillin, 2008; Suman *et al.*, 2010; Lorenzo and Gomez, 2012). However, most studies aim at analysing the advantages of each packaging yet retailers in South Africa aim or consider what is economical. Retailers in South Africa are divided into rural and urban retailers. According to published data, there is no scientific data available on the use of packaging methods commonly used by the retailers in South Africa and how they affect shelf life of meat. Distributing information on the most efficient packaging type to the South African retailers may help by boosting the food safety levels and promote meat with a prolonged shelf life. This will contribute to the profit projected to be gained by the retailers. Also, most studies available have assessed the shelf-life of meat focussing mainly on the microbiological quality of meat (Parlapani *et al.*, 2015). Cardello (1995) proposed that to assess shelf-life, objective indexes related to both microbiological and physico-chemical characteristics have to be typically measured. Physico-chemical characteristics involve changes in the physical appearance (texture, adour, colour)

and chemical structure of substances (Deumier, 2006). Therefore, the objective of the current study was to determine how vacuum packing and overwrapping affect the physico-chemical and microbiological shelf life of red meat during marketing. The study also aims to determine the most feasible packaging type that can be used by the retailers during marketing in South Africa which can provide prolonged shelf-life in meat.

6.2 Materials and methods

6.2.1 Description of the study site and Ethical clearance

The study was conducted at the Livestock and Pasture Sciences Meat Science laboratory, University of Fort Hare. The research protocol was approved by the Ethic Committee of the University of Fort Hare, South Africa (Approval number: UFH/UREC, MUC0101SRAN01).

6.2.2. Sampling procedure

A total of 108 loin samples from beef (n=36), pork (n=36) and mutton (n=36) were purchased from a local butchery and immediately delivered in a cooler box containing ice at ≤4°C to the Livestock and Pasture Sciences Meat Science laboratory, at the University of Fort Hare. All representative samples were packed using vacuum packaging (n =54) and overwrapping (n =54), appropriately labelled and stored under the normal marketing conditions in a refrigerator at 4^oC for storage duration of 15 days. To determine shelf-life, physico-chemical traits such as colour (CIE-L*, lightness; a*, redness; and b*, yellowness) and pH_u measurements were taken and recorded on days 0, 3, 6, 9, 12, and 15 with 3 replicates (n =3) on each day. Therefore a total of eighteen (n =18) samples per each meat type were used under each packaging. To determine the microbiological status, the swab technique was used for sample collection. This procedure is non-destructive and is used to collect meat surface samples with Swab Rinse Kit (SRK) foam spatulas for microbiological analysis. Sterile gloves were used at all times and were changed between different meat types and packaging systems. Swab samples were collected aseptically on the respective days of sampling and this

was done prior taking the shelf-life measurements. The colour and pH_u of samples were measured after microbial analysis (about five minutes after opening the tray). The swab samples were transported to the University of the Free State for laboratory analysis in an ice box at 4˚C to prevent microbial growth during sample transportation.

6.2.3 Physico-chemical meat quality measurements

6.2.3.1 Determination of ultimate pH, meat temperature and colour

The determination of ultimate pH, meat temperature, and colour are similar to the method described in Chapter 5, Section 5.2.3.

6.2.3.2 Microbial analysis

Samples were analysed immediately upon arrival at the laboratory. The microbial analysis of Total bacteria count (general bacteria), coliform count (related to hygiene and indicator for pathogens), *Escherichia coli* (Gram-negative pathogen) and *Staphylococcus aureus* (Gram-positive pathogen) are similar to the method described in Chapter 4, Section 4.2.4.

6.2.3 Statistical Analysis

The physico-chemical meat quality parameters indicating the shelf-life of meat (L*, a* and b*, pH, T_m) and microbial contaminants (TBC, CC, *E.coli*, *S. aureus*) were analysed using the Statistical Analysis Systems (SAS, 2003). Microbial counts were log transformed to achieve normality of the data. A factorial experiment with two factors (packaging type and storage duration) was laid out in a randomised complete block design and Analysis of variance was calculated by PROC general linear model in SAS (Statistical Analysis Systems, 2003), using the following model:

$Y_{ijk} = \mu + \alpha_i + \beta_j + E_{ijk}$

Where

Y_{ijk} = response variable (L*, a*, b*, TBC, CC, *E.coli, S. aureus*)

μ = Overall mean common to all observations

αi = effect of i-th packaging type

βj =effect of j-th storage duration

Eijk =random error

6.3 Results and Discussion

6.3.1 Effect of overwrapping and vacuum packaging on the physico-chemical and microbiological quality of beef, pork and mutton loin samples

The results showing the effect of vacuum and overwrapping packaging on the physico-chemical and microbiological quality of beef, pork and mutton are presented in Table 6.1. Significant ($p < 0.05$) differences for L*, a* and b* values among different meat types and across different types of packaging were observed. Mutton and pork loin samples stored under vacuum packaging showed the lowest $L*$ values (34.5 ± 1.05; 45.9 ±1.05) which were significantly different ($p < 0.05$) in comparison to overwrapped samples (36.7 ± 1.05 and 51.9 ±1.05). However, higher L* values for beef were observed in vacuum packed samples (35.1 ±1.05) compared to overwrapped samples (33.8 ± 1.05). Higher L* values indicated meat with a more desirable appearance. This implied that overwrapped mutton and pork meat had an attractive, bright colour, whereas beef sustained it's colour under vacuum packaging conditions. The findings for the L* value in pork contradicts with the reports that were made in most studies whereby higher L* values were found in meat that is packed under vacuum than in overwrapped packaging (Smith *et al*., 1983; Karabagias, 2011). This is mainly due to the fact that vacuum packaging is known as a packaging system with very low or no levels of oxygen whilst overwrapping allows some levels of oxygen to penetrate. Very low oxygen concentrations in packs have been reported to be responsible for the discolouration of fresh meat (Rousset and Renerre, 1990). Although the residual oxygen composition in the current study was not measured, the L* values for vacuum packed samples suggested the presence of residual oxygen which

Table 6.1: Least square means and (±SE) for colour (L*, a*, and b*), pH, and microbial counts on beef, pork and mutton loin samples as affected by the packaging type

	Meat Type					
	Mutton		**Pork**		**Beef**	
Parameter	**Overwrap**	**Vacuum**	**Overwrap**	**Vacuum**	**Overwrap**	**Vacuum**
N	**18**	**18**	**18**	**18**	**18**	**18**
Lightness (L*)	36.7 ^{ab} ± 1.05	34.5 ^{a} ± 1.05	51.9 ^{c} ±1.05	45.9 ^{b} ±1.05	33.8 ^{a} ± 1.05	35.1 ^{ab} ± 1.05
Redness (a*)	11.3 ^{bc} ± 0.39	13.9 ^{c} ± 0.39	3.1 ^{a} ±0.39	9.6 ^{b} ±0.39	10.3 ^{b} ± 0.39	13.1 ^{c} ± 0.39
Yellowness (b*)	10.2 ^{ab} ± 0.39	10.5 ^{ab} ± 0.39	8.9 ^{a} ±0.39	12.4 ^{b} ±0.39	8.9 ^{a} ± 0.39	10.4 ^{ab} ± 0.39
pH$_u$	6.9 ^{a} ±0.18	6.9 ^{a} ± 0.18	6.7 ^{a} ±0.18	6.9 ^{a} ±0.18	7.1 ^{a} ± 0.18	6.6 ^{a} ± 0.18
T$_m$	14.3 ^{b} ± 0.29	12.4 ^{a} ± 0.29	12.6 ^{a} ±0.29	12.6 ^{a} ±0.29	12.6 ^{a} ± 0.29	13.4 ^{a} ± 0.29
TBC	10.4 ^{a} ± 0.33	9.9 ^{a} ± 0.33	10.2 ^{a} ±0.33	9.7 ^{a} ± 0.33	10.4 ^{a} ± 0.33	10.7 ^{b} ± 0.33
Coliform count (CC)	8.9 ^{a} ± 0.35	8.7 ^{a} ± 0.35	8.3 ^{a} ±0.35	8.5 ^{a} ± 0.35	8.1 ^{a} ± 0.35	9.1 ^{b} ± 0.35
E.coli	0.6 ^{a} ± 0.53	2.9 ^{c} ± 0.53	1.3 ^{b} ±0.53	0.3 ^{a} ± 0.53	1.2 ^{b} ± 0.53	0.4 ^{a} ± 0.53

SE = standard error; pHu = ultimate pH; T$_{m=}$ Meat temperature; BC= Total bacteria count; *E.coli= Escherichia coli*

^{abc} Means in the same row with different superscripts are significantly different (p<0.05)

could have penetrated during the packaging process. This could be avoided by applying strict measures or by using O2-scavenger protection to maintain better colour stability, as recommended by Rousset and Renerre (1990).

According to the Commission International De I' Eclairage (1976), $L*$ value in meat measures a condition known as dark, firm and dry (DFD) in meat. Priolo *et al*. (2001) further explains that when the muscle glycogen has been used up rapidly during the handling, transport and pre-slaughter period, after slaughter there is little lactic acid production which results in DFD meat. However, the observed L* values in the current study for all the meat types fell within the stipulated range, meaning that the meat was in good quality. Nevertheless, a* and b* values were significantly different among the three meat types ($p < 0.05$) but similarities between the packaging types were observed. Redness (a*) and (b*) yellowness values for overwrapped mutton, pork and beef samples were low compared to the higher values for samples stored under vacuum packaging. Berruga *et al*. (2005) made similar observations whereby redness (a*) values were more stable in samples that were kept in vacuum packaging.

A significant ($p < 0.05$) difference in the internal temperature (Tm) of the different meat types across the two types of packaging were observed for mutton and beef. However, similarities for the internal temperature (Tm) in vacuum packed and overwrapped pork samples were observed. In the current study, the mean value of pH_u values ranged between 6.7 and 7.1 for overwrapped samples and ranges for vacuum packed samples were between 6.6 and 6.9 across all meat types. Muchenje *et al*. (2008) stated that meat with a pH above 6.0 is undesirable as it leads to dark firm dry meat. According to Gregory (2008), pH in mutton is expected to range between 5.75 and 6.00. Therefore, the observed pH in the current study

ranging from 6.6- 7.1 could be considered to be on the higher and unacceptable side. According to Zhang *et al.* (2005), meat ultimate pH is widely used as an indicator of meat quality and carcasses are often categorised according to its pH. Briefly, low pH_u meat (pH_u < 5.8) is most ideal with regards to consumer acceptability and palatability and high pH_u meat (pH_u 6.2) is darker in appearance and more susceptible to microbial spoilage.

High levels for TBC and CC in vacuum and overwrapped samples were observed in the current study. Total bacterial counts for mutton, pork and beef samples stored under vacuum packaging ranged between 9.9; 9.7 and 10.7 CFU/cm^2 respectively and coliform counts were between 8.7, 8.5, and 9.1 log CFU/cm^2 respectively. Levels for TBC in overwrapped samples ranged between 10.4, 10.7 and 10.4 log CFU/cm^2 respectively. Although the levels on vacuum packed meat samples were lower compared to overwrapped samples, the observed microbial levels were superior to the ICMSF (International Commission for Microbial Specifications in Food) recommended microbiological limits for fresh meat (ICMSF, 1986). Also, the European Union recommends that the levels of contamination by TBC and CC not to exceed 5.0 and 2.5 log CFU/g, respectively. The higher levels in the current study could be associated with the storage duration of these samples at the time of purchase as the carcasses were stored for more than 8 days before display at the retail shop. This could possibly mean that the spoilage micro-organisms proliferated as the time progressed. However, the levels for *E. coli* were low. The levels of *E. coli* in mutton, pork and beef samples that were stored using overwrapped packaging ranged between 0.6, 1.3 and 1.2 log CFU/cm^2. It was observed that vacuum packed mutton samples had higher levels of *E.coli* at 2.9 log10 CFU/cm^2, with pork at 0.3 log CFU/cm2 and beef at 0.4 log CFU/cm^2. *Staphylococcus* was not detected in any of the tested meat samples.

6.3.2 Effect of storage duration on the colour (L*, a*, b*), pH, temperature and microbial counts in beef, pork and mutton loin samples

The shelf life of beef, pork and mutton stored at 4 °C for the storage duration of 15 days is shown in Figure 6.1. Initially, the meat freshness was excellent. L* values for mutton, pork and beef at day zero were 34.± 1.83; 52.± 1.83 and 32.9±1.83 respectively. However, the fresh characteristics (L*, a*, and b*) decreased gradually with time. A decrease in the L* values for pork between day 0 and day 3 was observed, whereas for beef and mutton a gradual increase was observed. Several authors have reported lightness increases in different meat and meat products during refrigerated storage (Fernandez-Lopez *et al*., 2006 and Kusmider *et al*., 2002). However, after day 3, a gradual decrease in the L* values for beef and mutton till the end of storage time was observed, whereas for pork L* values were stable until the end of storage. Also, some fluctuations in the redness (a*- Figure 6.2) and yellowness (b*- Figure 6.3) values along the storage period were observed, whereby the values were increasing and decreasing as the storage days progressed.

These changes can be associated with the changes in the pH. Gispert *et al.* (2000) reported that there is a strong relationship between pHu, muscle temperature and colour of the meat. Also, Werner *et al.* (2013) indicated that pHu is the key to quality and is the standard measurement that determiners colour and tenderness of meat. In the current study, pH_u increased with storage period (Figure 6.4). At day 12, the increase reached 7.8 which was beyond the normal values. This indicates that spoilage at day 12 might have occurred because high pH in meat indicates undesirable meat. Brito (2003) highlighted that an increase in pHu leads to darker meat which is susceptible to bacterial spoilage and reduced flavour which makes it less acceptable to consumers. Also meat temperature decreased with storage duration (Figure 6.5). Dransfield and Sosnicki (1999) highlighted that the onset of discolouration occurs more rapidly at higher temperatures.
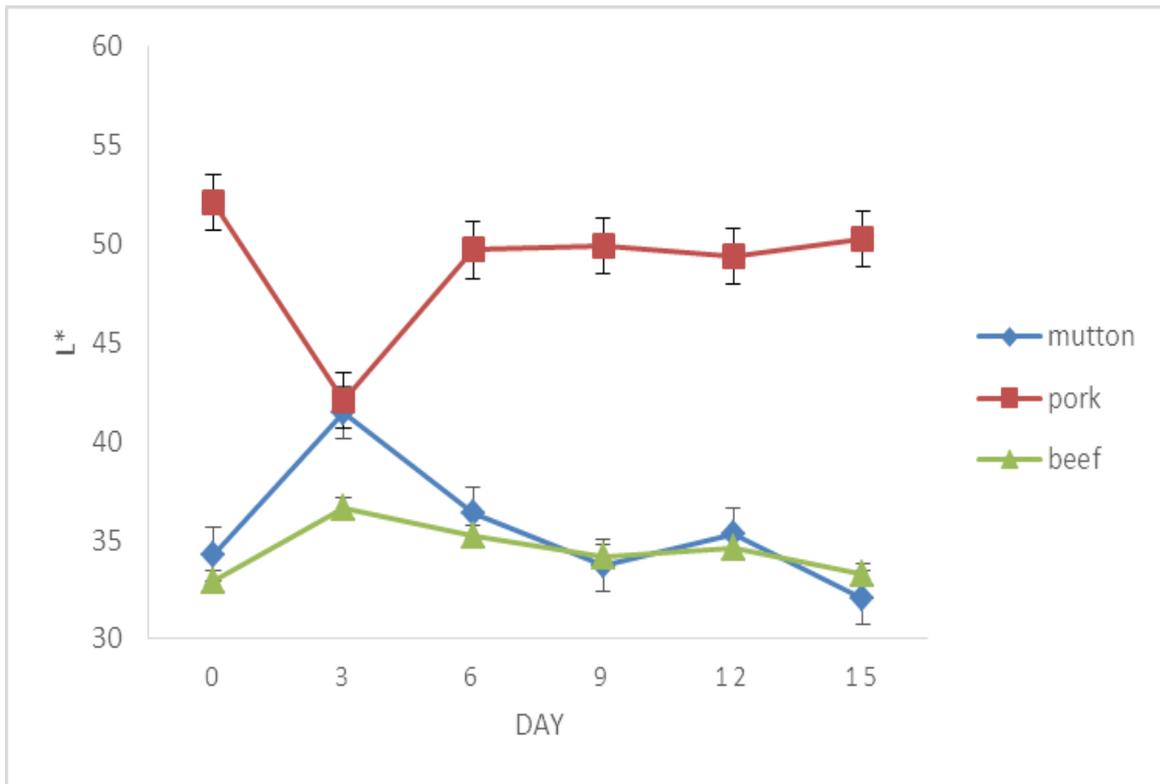
Figure 6.1: **Lightness (L*) value for mutton, pork and beef during a 15 days storage period at 4 °C**
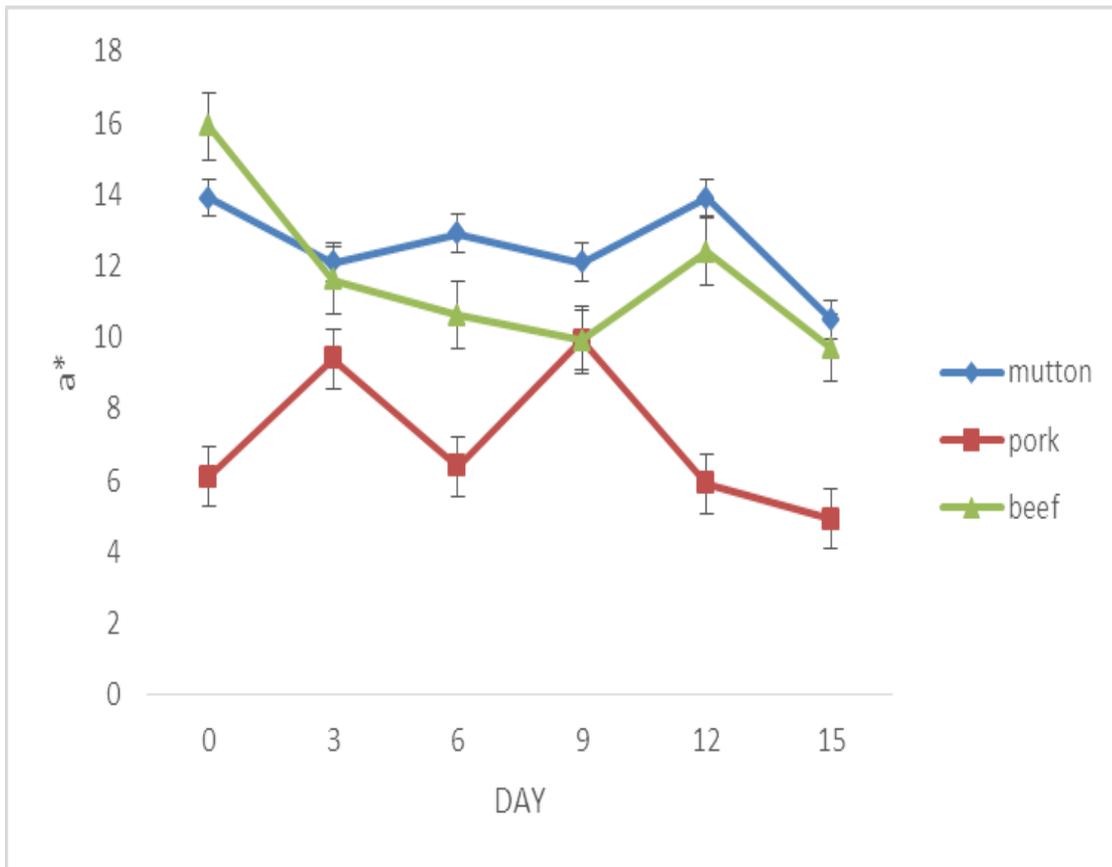
Figure 6.2: Redness (a*) values for mutton, pork and beef during a 15 days storage period at 4 °C
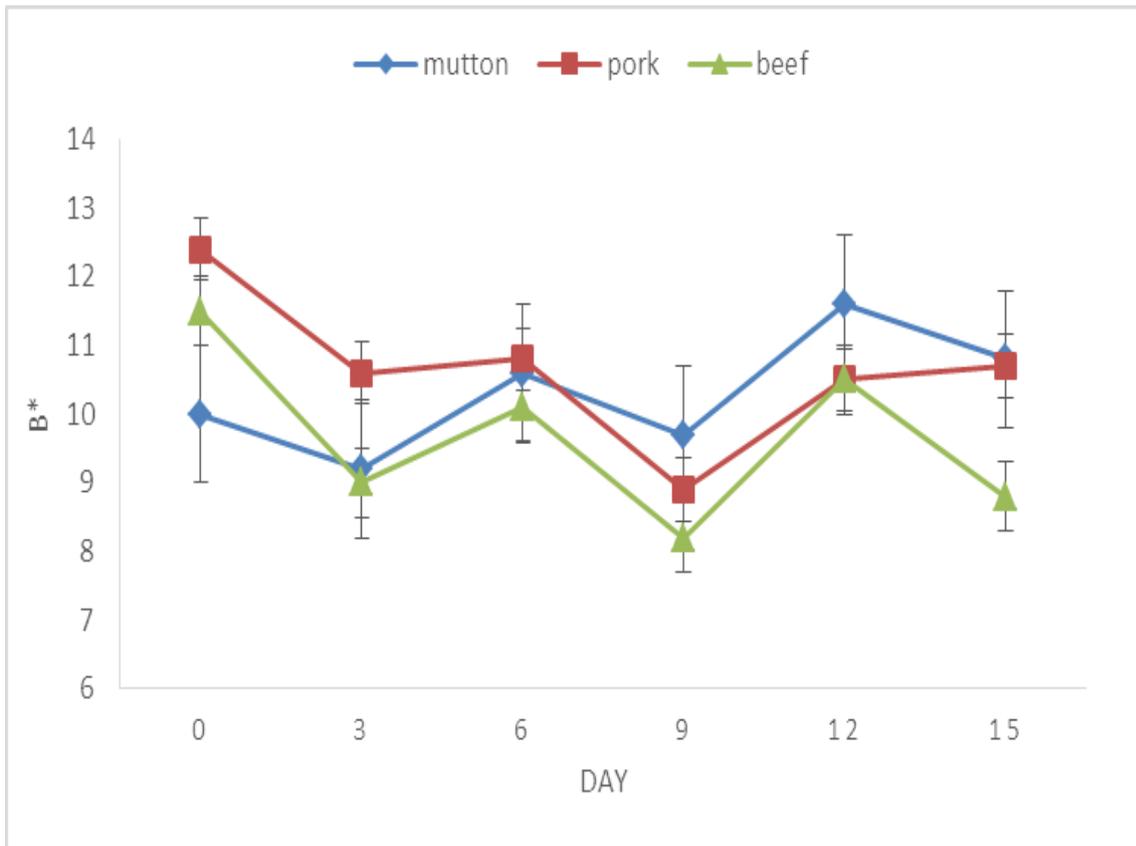
Figure 6.3: **Yellowness (b*) values for mutton, pork and beef during a 15 days storage period at 4 °C**
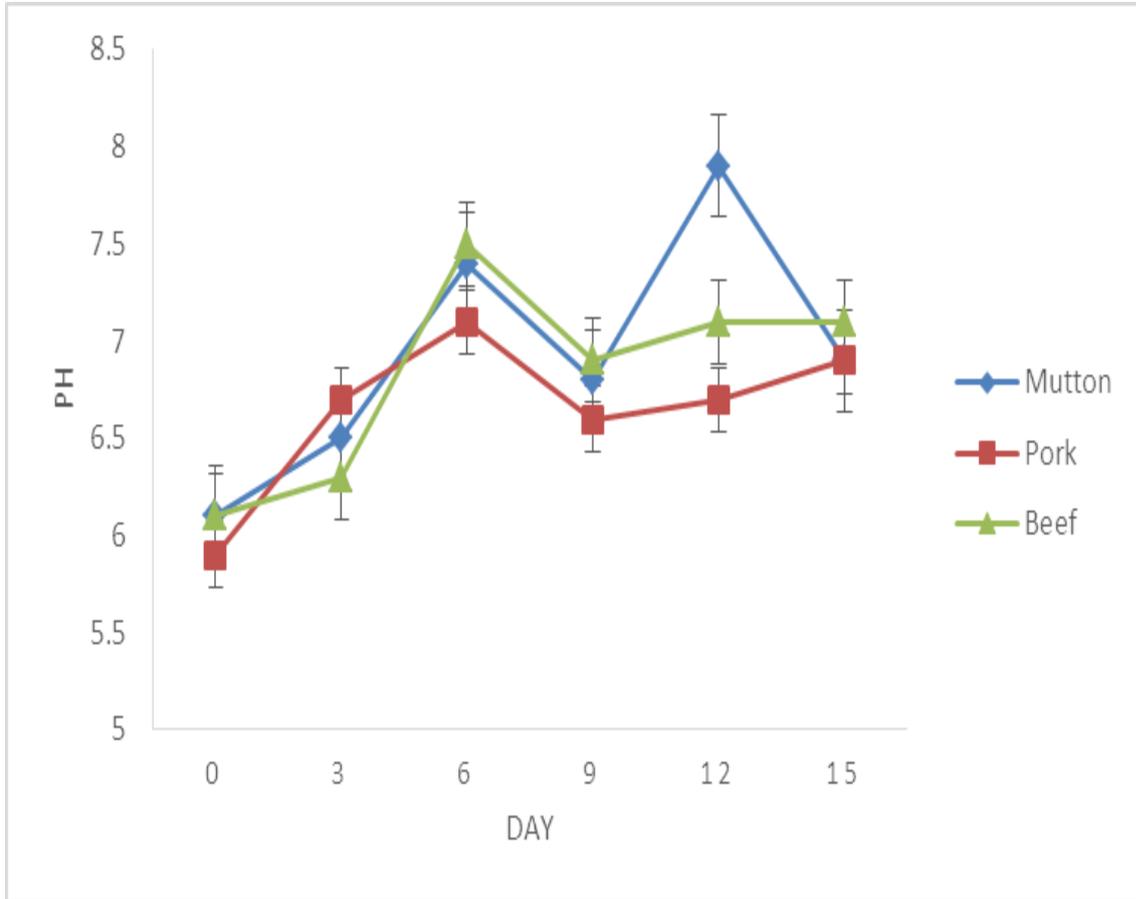
Figure 6.4: Ultimate pH (pH$_u$) of beef, pork and mutton during a 15 days storage period at 4 °C
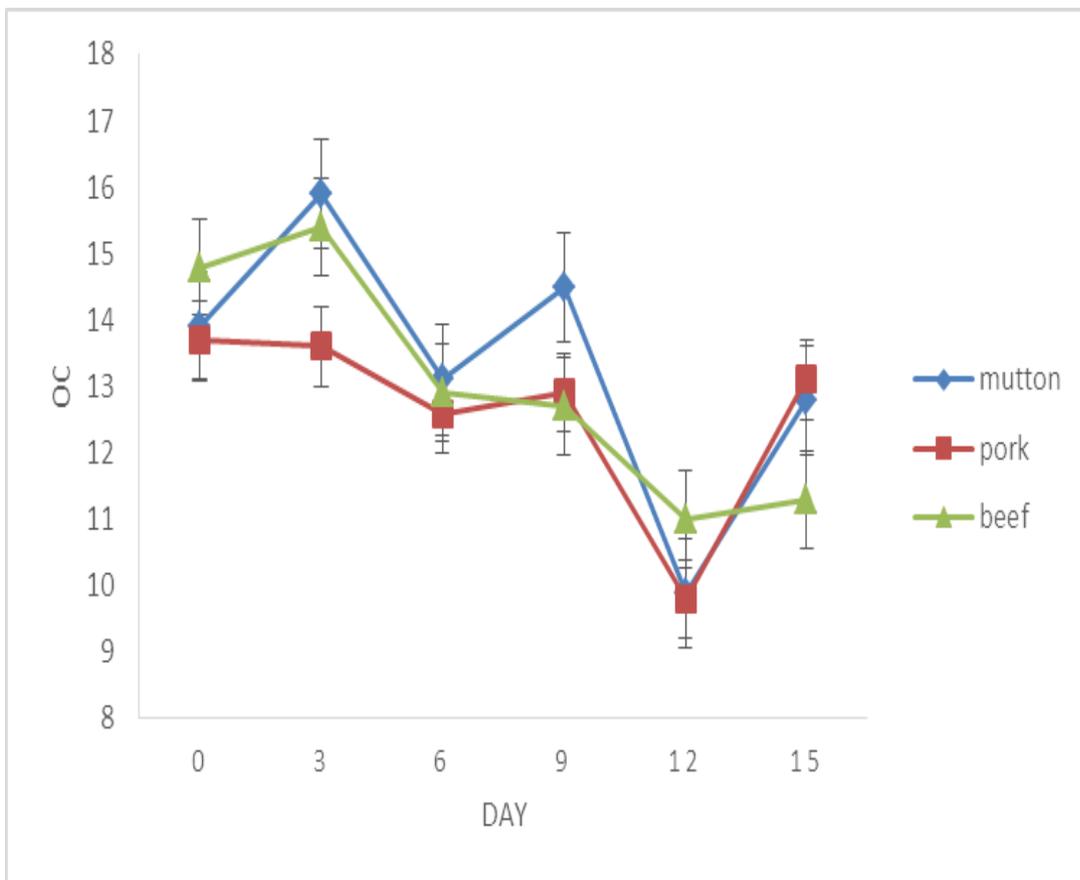
Figure 6.5: Changes in meat temperature (Tm) for beef, pork and mutton during a 15 days storage period at 4 °C

Microbial load on beef, pork and mutton loin cuts stored under the same conditions using different packaging methods for a period of 15 days is presented in Figure 6.6. The results of the microbiological analyses on the meat samples on the day of delivery to the laboratory revealed a normal microbiological situation, the acceptable limits were not exceeded. On the day of purchase TBC were above 5.5 log CFU/cm^2. The higher levels on the day of purchase could be linked to the fact that, on the day of purchase carcasses or meat that was sold was already kept for an extended period in the butcher storage/ refrigerator room. This implied that the meat which is sold to the consumers at is already spoiled and may not be kept for extended periods by the consumers in their homesteads. TBC, CC (Figure 6.7) and *E.coli* (Figure 6.8) increased progressively with storage period. This means, the longer the samples were kept, the greater are chances of susceptibility to spoilage and growth of pathogenic micro-organisms (Zerdin and Scully, 2010).
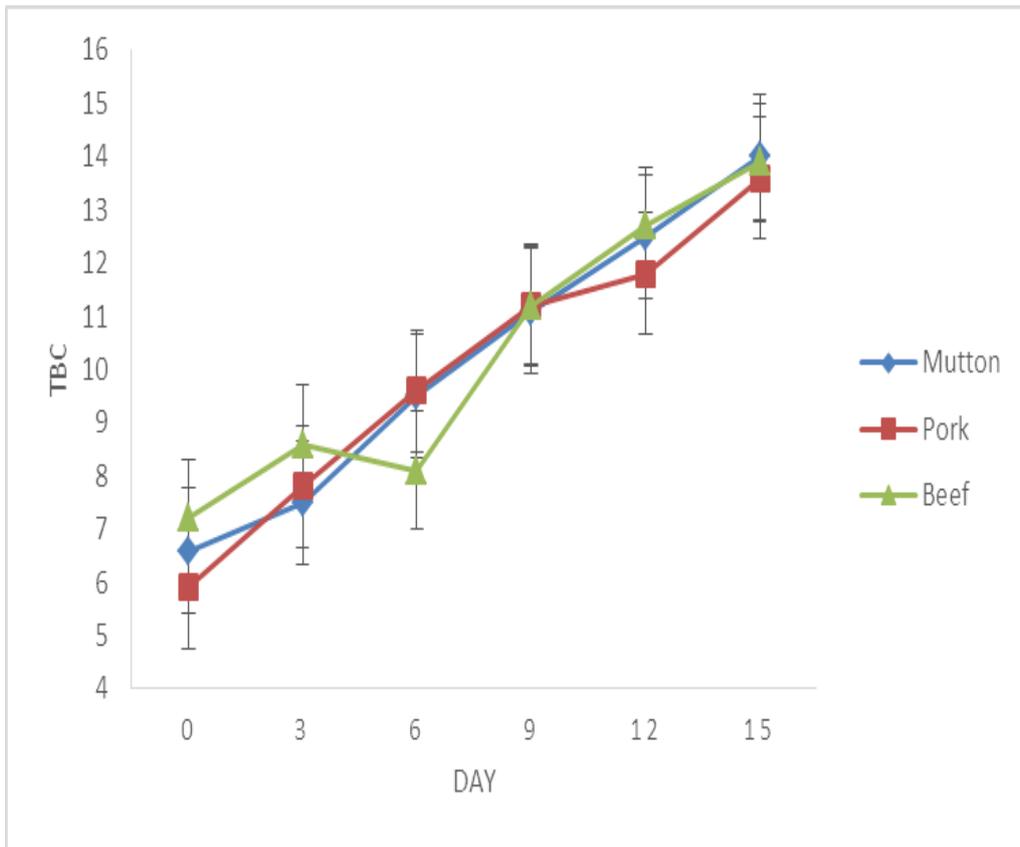
Figure 6.6: Total bacteria counts (log CFU/cm^2) in beef, pork and mutton during a 15 days storage period at 4 °C
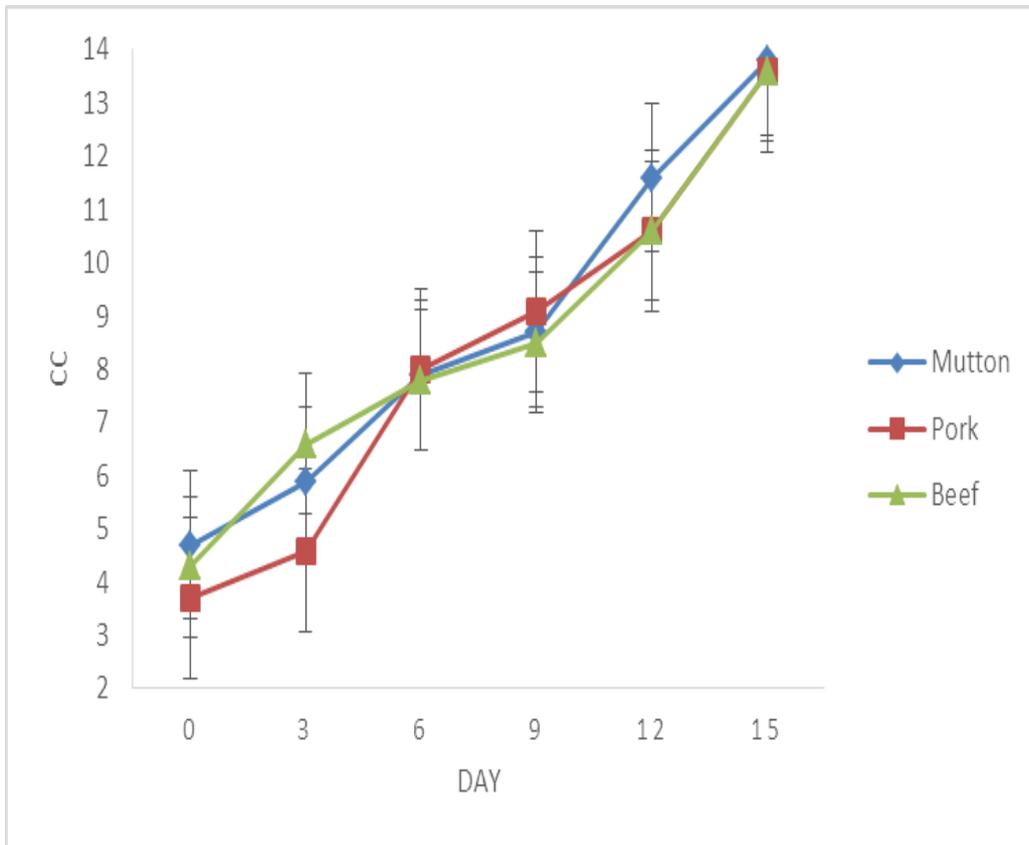
Figure 6.7: Total coliform counts (log CFU/cm^2) in beef, pork and mutton during a 15 days storage period at 4 °C
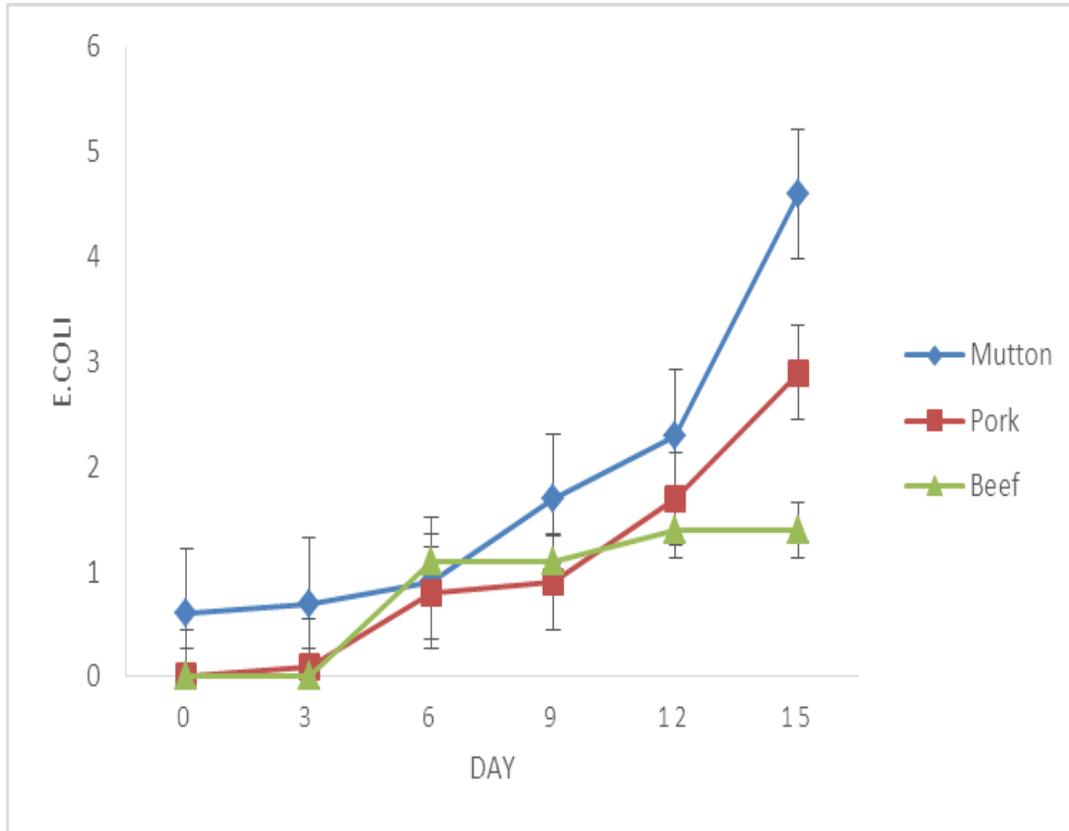
Figure 6.8: *Escherichia coli* levels (log CFU/cm^2) in beef, pork and mutton during a 15 days storage period at 4 °C

6.3.3 Effect of packaging on colour (L*, a*, b*), pHu, temperature and microbial counts over a storage duration of 15 days

Changes in microbial counts and physico-chemical traits of red meat stored under two different types of packaging systems are shown in Figure 6.9. The colour of fresh meat is considered to be the most important sensory attribute affecting the consumer's purchasing decision because consumers use discolouration as an indicator of freshness and wholesomeness (Mancini and Hunt, 2005). The effect of packaging type on the colour of red meat over a storage duration of 15 days is shown in Figure 6.9, Figure 6.10 and Figure 6.11. Lightness (L*), redness (a*) and yellowness (b*) showed significant differences ($p < 0.05$) due to storage time and packaging conditions. The initial mean lightness (CIE L*) value for overwrapped packaging (41.1 ± 1.49) and vacuum packaging (38.4±1.49) were similar to those reported by Vergara and Gallego (2001) and Berruga *et al.* (2005) who found L* values of 38.8 - 47.15.

The changes in the L* values throughout the entire storage period were different among vacuum and overwrapped packaging. Greater colour stability of samples was found in overwrapped packaging than in vacuum packaging. This contradicts with the observations that were made by several authors who reported vacuum packaging as the best packaging type which can maintain a blooming colour in meat (Cayuela *et al*., 2004; Brewer *et al*., 2001). The L* values increased during the first three days of storage in overwrapped packaging whilst it maintained the same trend in vacuum packaging. However, a gradual decrease in overwrapped packaging between day 6 (40.9±1.49) and day 12 (39.8±1.49) was observed whilst the trend continued to fluctuate by increasing and decreasing in the vacuum packed samples as the storage duration progressed. Some authors reported an increase in lightness during the storage time (Fernández-López *et al*., 2006) although other studies showed a decrease at the end of storage (Bingol and Ergun, 2011). The lowest L* values towards the end of the storage period (day 15) for vacuum packaging were 36.8 ±1.49.
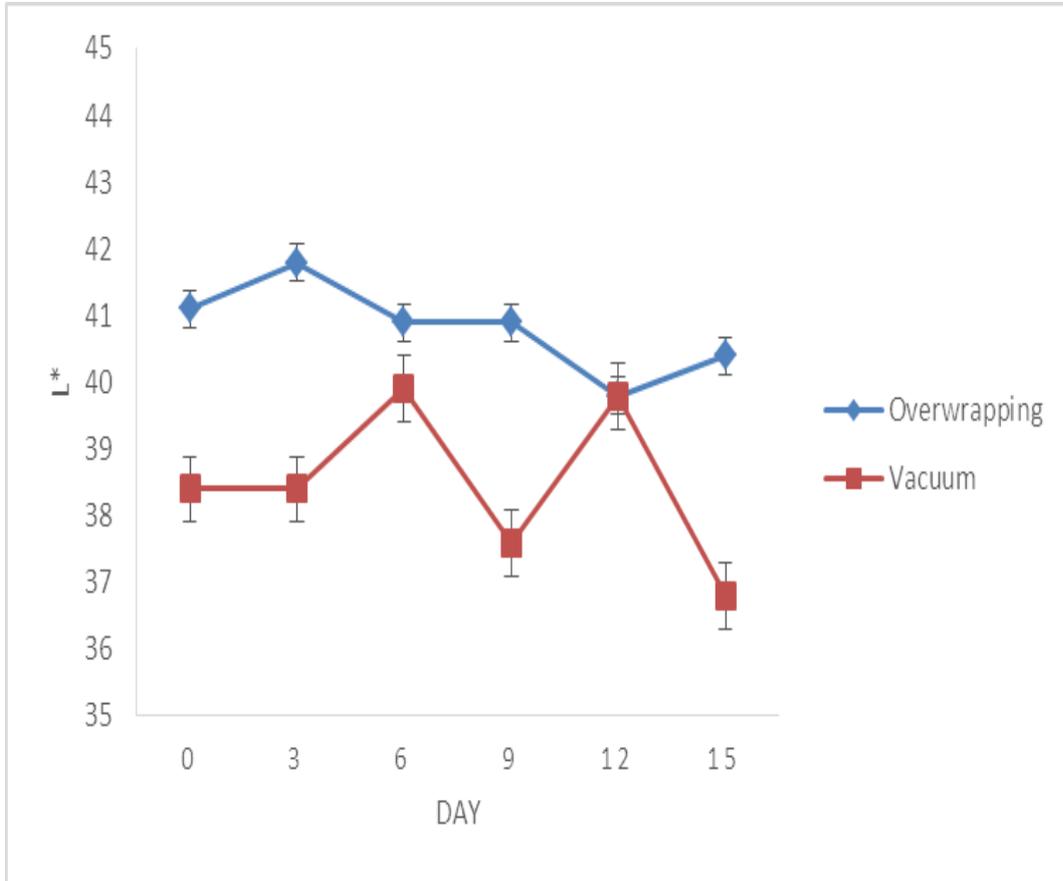
Figure 6.9: Lightness (L*) values for overwrapping and vacuum packaging during a 15 days storage period at 4 °C
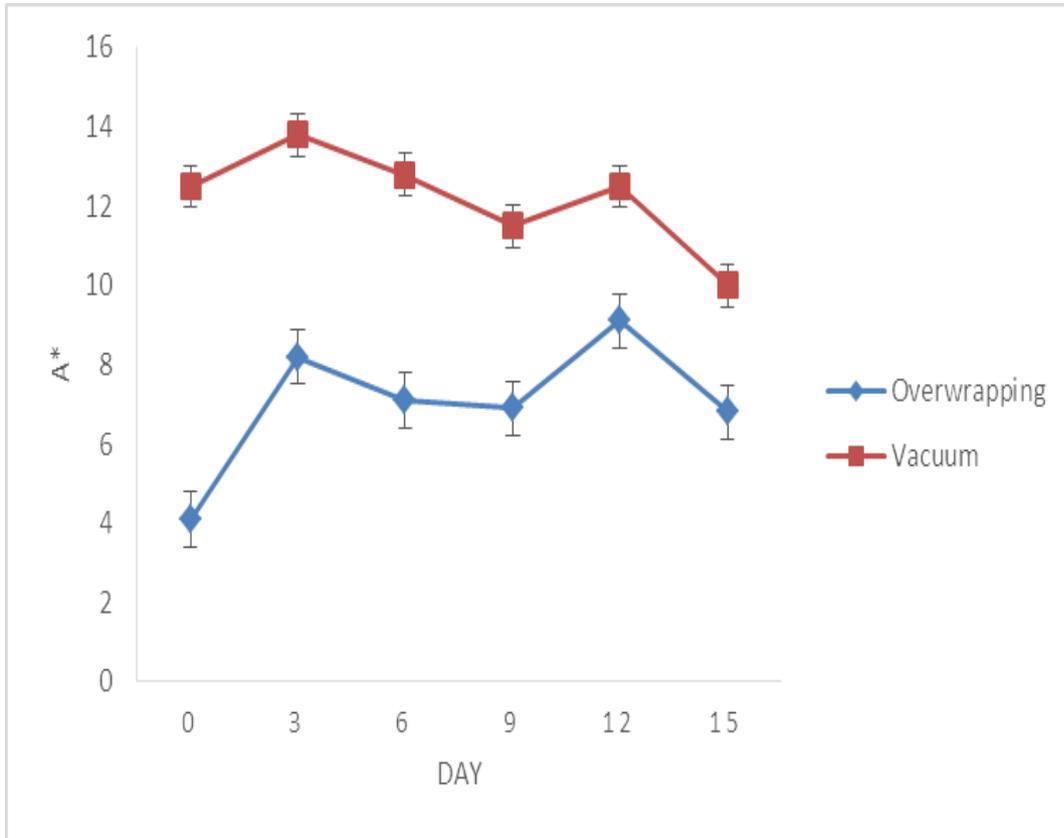
Figure 6.10: Redness (a*) values for overwrapping and vacuum packaging during a 15 days storage period at 4 °C
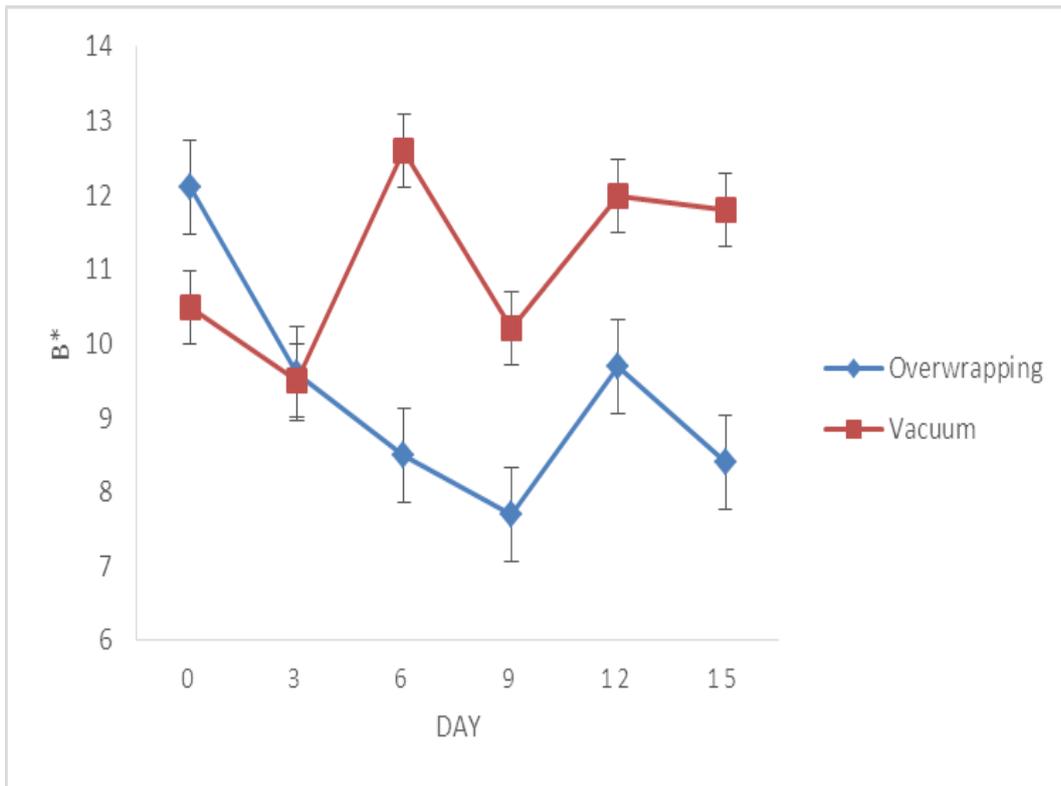
Figure 6.11: Yellowness (b*) values for overwrapping and vacuum packaging during a 15 days storage period at 4 °C

The b* and a* values showed significant differences (p<0.05) over time and among the packaging conditions. The initial redness values in overwrapped samples were 11.4 ± 0.56 and vacuum packed samples were 12.5± 0.56. The redness values increased between day 0 and day 3, whereas a gradual decrease to day 9 occurred in both vacuum and overwrapping packages. Initial CIE b* values for overwrapped samples were 12.1 ± 0.56 and vacuum packed were observed at 10.5 ±0.56. However, from day three significant changes were observed. Changes in b* values were more significant for vacuum packs (p <0.005) than in overwrap (P < 0.05). The b* values increased between day 3 and day nine in vacuum packed samples whilst a gradual decrease in overwrapped packaging occurred. Jeremiah (2001) associated the increase in b* with the transformation of the meat pigment and the formation of metmyoglobin, which is faster at relatively low oxygen concentrations.

The observed significant increase in the b* values between day 9 and day 15 for overwrapped samples and vacuum packed samples are in disagreement with those reported by Bingol and Ergun (2011) and Esmer *et al*. (2011), who found a decreasing trend throughout the whole storage period. The mean value of temperature and pH for overwrapped and vacuum packaging during a storage period of 15 days are presented in Figure 6.12 and Figure 6.13. Temperature ranged between 13.5 to 13.1 on day 0 to day 9 in vacuum packed samples, and at day 12 a gradual decrease was observed. The pH values increased with storage duration in both packages. The pH values at day 15 increased to 7.5 in both packages. This value is un-acceptable as it indicates dark coloured meat with off-odours. These results are due to the initial TBC counts that were observed in the samples on the day of purchase.
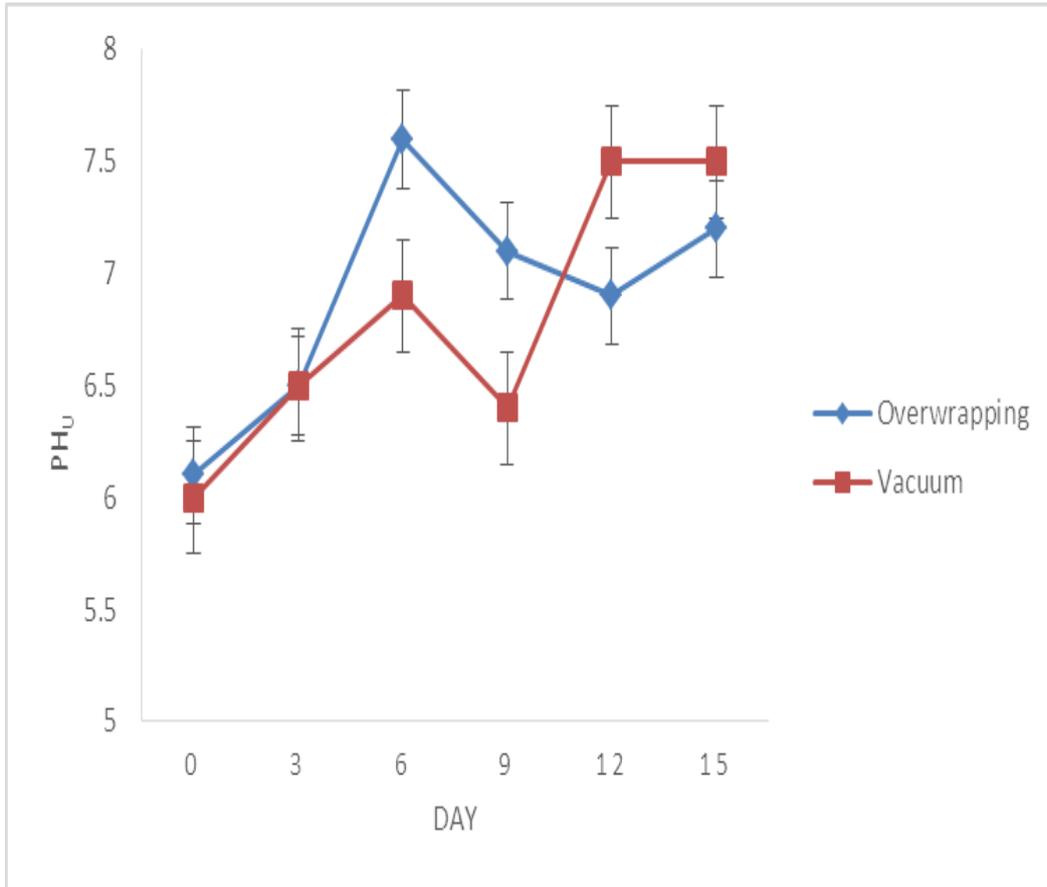
Figure 6.12: **Ultimate pH (pH$_u$) values for overwrapping and vacuum packaging during a 15 days storage period at 4 °C**
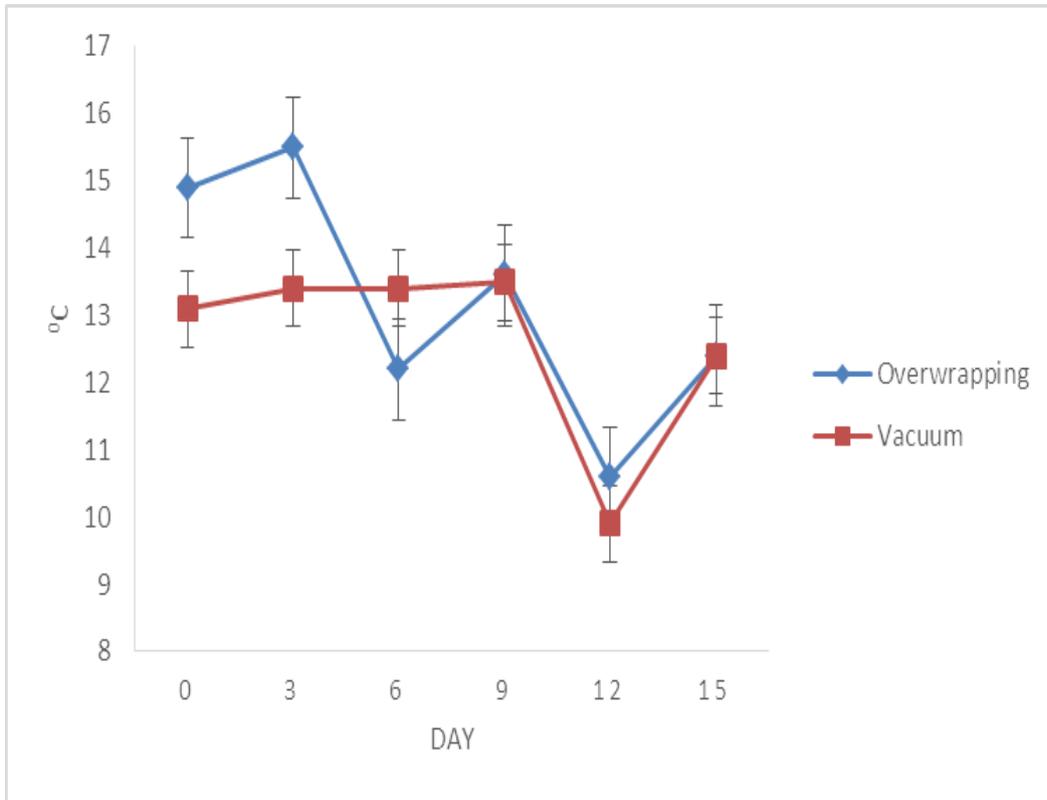
Figure 6.13: **Microbial changes (log C/g) of TBC in meat packed under overwrapping and vacuum packaging during a 15 days storage at 4 °C**

Figure 6.14 to Figure 6.16 demonstrate a comparison of the microbial load between vacuum and overwrapping packaging. In general, microbial counts showed differences (p< 0.05) during storage time and among packaging conditions. Initial TBC at day 0 were 6.7 and 6.3 log CFU/cm^2 for overwrapped and vacuum packed samples, respectively. Kraft (1986) stated that shelf life is inversely proportional to initial microbial load. The initial levels for TBC were high in the current study compared to those reported by several authors (Skandamis and Nychas, 2002; Chouliara *et al*., 2007; Lorenzo and Gomez, 2012). The initial total bacteria counts reported by these authors ranged between 4.2 log CFU/cm^2 to 4.9 logCFU/cm^2. Therefore, the observed levels in the current study (above 6.2 log CFU/cm^2) exceeded the expected limits. According to the Spanish legislation (Regulation EC 2073/05, DOUE L338/1, 2005) the limit established for bacterial counts is 10^6 CFU/g, but the spoilage can be detected, mainly due to odour, in most foods with more than 6 logCFU/g (Dainty and Mackey, 1992). However, it should be noted that even though the initial levels for TBC in the current study were higher than 6 logCFU/g, spoilage of the meat samples or non-acceptable off odours were detected in the first few days of the experiment (from day 0 to day 6).

The overwrap packed samples showed higher TBC than vacuum packaging (p < 0.05) between day 0 and day 3 of the storage period. However, a gradual increase in the levels of TBC in vacuum packed samples from day 9 till the end of the storage duration was observed compared to overwrapped packed samples. The observed results were not expected as vacuum packed meat is expected to have lower levels of TBC than overwrapped samples. This is due to the fact that vacuum packaging conditions have very low moisture and oxygen transmission rates. With the elimination of oxygen, the growth of typical spoilage organisms is significantly reduced, thereby extending product
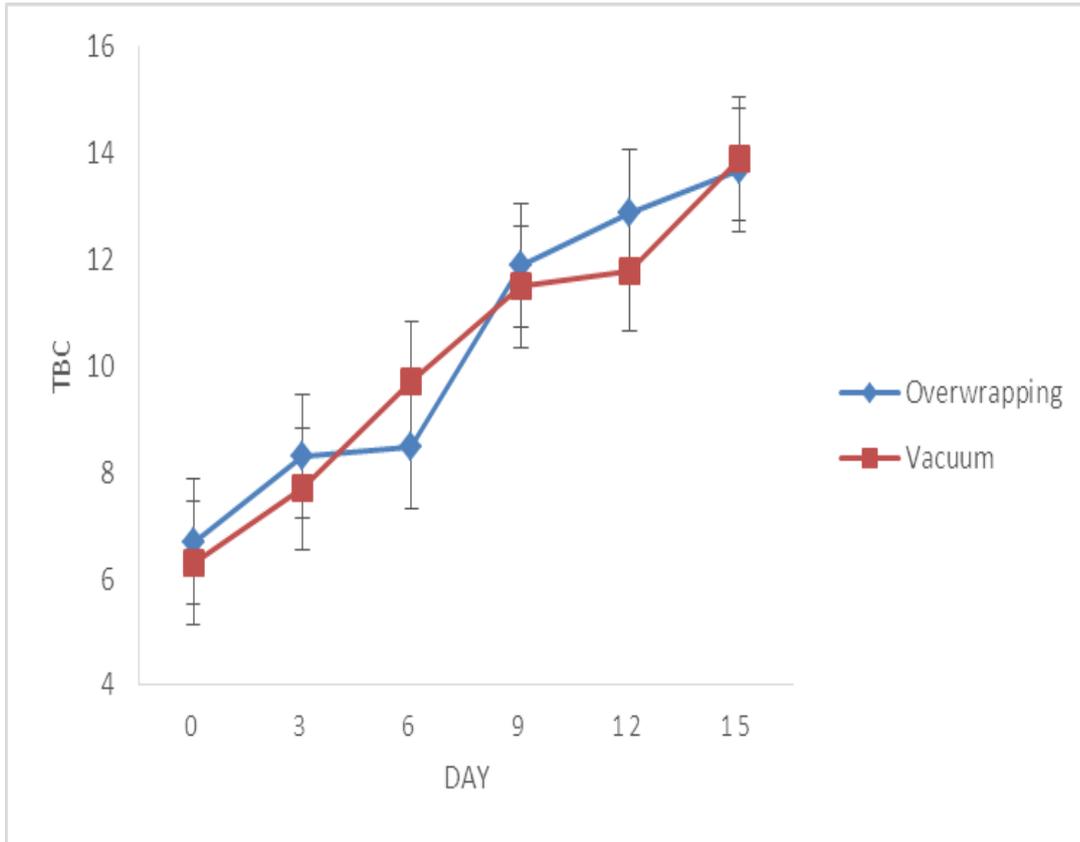
Figure 6.14: Total bacteria counts (log CFU/cm^2) in meat packed under overwrapping and vacuum packaging during a 15 days storage period at 4 °C
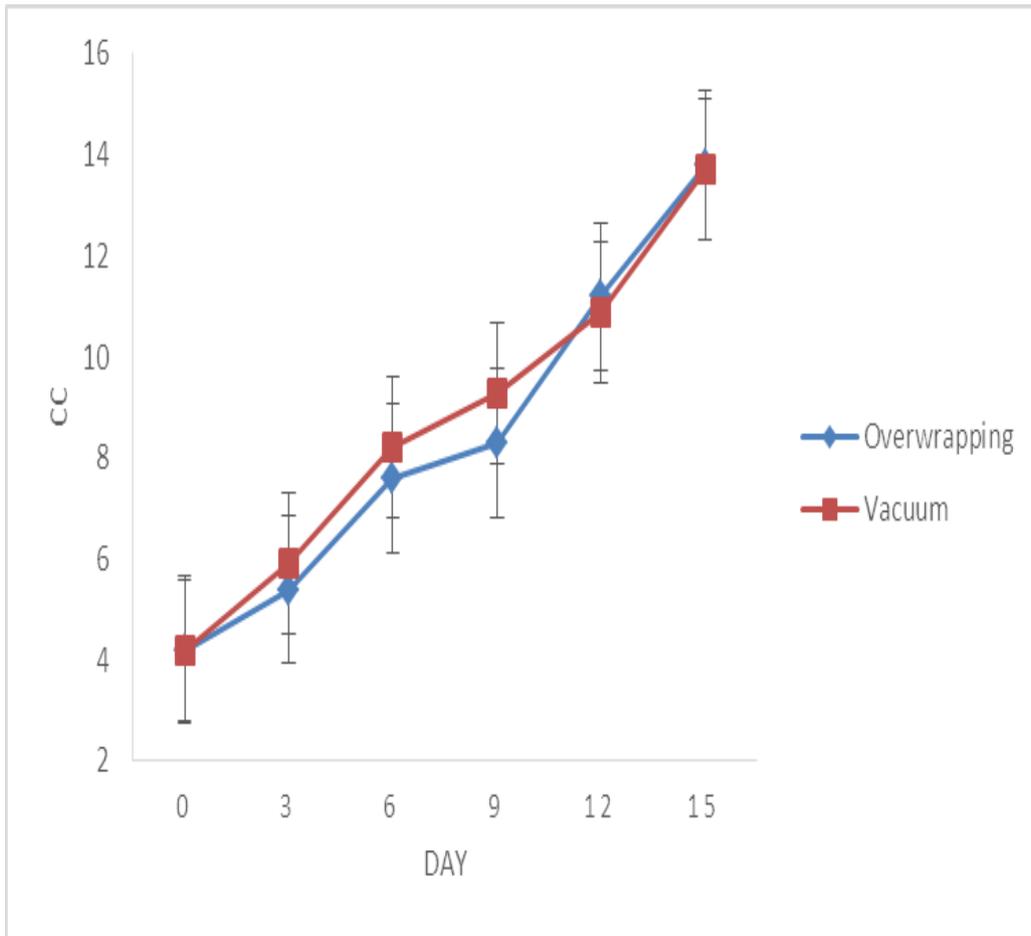
Figure 6.15: Coliform Counts (log CFU/cm^2) in meat packed under overwrapping and vacuum packaging during a 15 days storage period at 4 °C
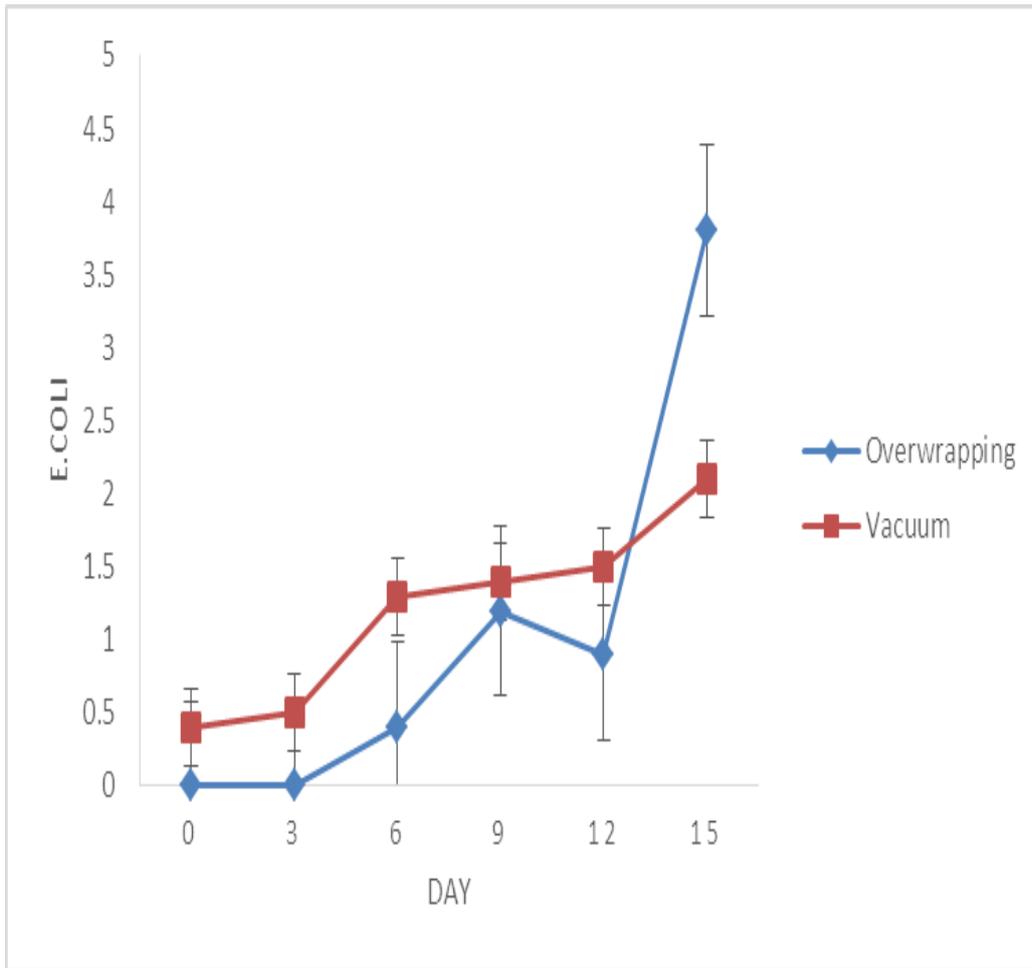
Figure 6.16: *Escherichia coli (E.coli)* (log CFU/cm^2) in meat packed under overwrapping and vacuum packaging during a 15 days storage period at 4 °C

shelf-life. This is confirmed by the results from previous studies by Lorenzo and Gomez (2012) and Egan *et al*. (1998) who reported that overwrap packed samples showed higher total viable counts than vacuum packed samples during the entire storage period, reaching at day 14 an average value of 7.11 logCFU/g. Nonetheless, contradicting observations were made by Sheridan *et al.* (1997) and Berruga *et al*. (2005) who reported larger bacterial numbers in vacuum packed samples compared to other packaging types.

In the current study, higher levels of TBC on day 6 in both packaging types were observed. At day 6, TBC on overwrapped samples increased to 8.5 log CFU/cm^2 and vacuum packed samples were observed with 9.7 log CFU/cm^2. Similar observations were made by Berruga *et al*. (2005) where the total viable counts increased faster in vacuum packaged meat samples, in comparison with modified atmospheric groups. Some authors reported that microbial spoilage of meat occurs with TVC at levels of 7–8 log CFU/cm^2 or g (Insausti *et al.,* 2001; Jeremiah, 2001). This could mean that the red meat which was purchased by the consumers from the chosen butcher of the current study coming from the same carcasses could have been susceptible to spoilage. However judging from the colour of the meat at the point of purchase, the cuts appeared to be having an excellent quality. The only challenge could be that, after purchase consumers will have to keep the meat for a shorter period if not consumed at the same day hence it's shelf-life had already been extended at the butcher's storage facilities. The butcher manager confirmed that the meat was stored in their storage rooms for several days after it was delivered from the abattoir. Judging from the results, it could mean that the butcher manager should be encouraged to reduce or minimise the number of storage days for the carcasses at the chiller rooms before display.

6.4 Conclusion

From the current results it can be concluded that both physico-chemical and microbiological shelf life of red meat, either vacuum packed or overwrapped during marketing, was reduced over time. Both used package systems could not sustain the meat quality traits and the meat was no longer in a good consumable state by the end of the trial. However, regardless of the superior reputation vacuum packaging has attained over the other wrapping systems, the current vacuum packed samples were observed to have low lightness values and significantly high levels of TBC, CC, and *E. coli* compared to overwrap packaging. Though the reason for this is not fully understood, the present results show overwrapping as an ideal option for the retailers. It should be prioritized that meat which reaches the consumer has as low microbial levels as possible.

6.5 References

Aymerich, T., Picouet, P. A. and Monfort, J. M. 2008. Decontamination technologies for meat products. *Meat Science*, **78:** 114−129.

Belcher, J.N. 2006. Industrial packaging developments for the global meat market. *Meat Science*. **74**: 143-148.

Berruga, M. I., Vergara, H. and Gallego, L. 2005. Influence of packaging conditions on microbial and lipid oxidation in lamb meat. *Small Ruminant Research*, **57:** 257-264.

Bingol, E. B. and Ergun, O. 2011. Effects of modified atmosphere packaging (MAP) on the microbiological quality and shelf life of ostrich meat. *Meat Science,* **88:** 774–785.

Borch, E. and Arinder, P. 2002. Bacteriological safety issues in red meat and ready-to-eat meat products, as well as control measures. *Meat Science*, **62:** 381-390.

Brewer, M. S., Zhu, L. G., Bidner, B., Meisinger, D. J. and McKeith, F. K. 2001. Measuring pork colour: effects of bloom time, muscle, pH and relationship to instrumental parameters. *Meat Science,* **57:** 169–176.

Brooks, J. C., Alvarado, M., Stephens, T. P., Kellermeier, J. D., Tittor, A. W., Miller, M. F., and Brashears, M. M. 2008. Spoilage and safety characteristics of ground beef packaged in traditional and modified atmosphere packages. *Journal of Food Protection*, **71:** 293-301.

Brito, G. W. 2003. Segregating Uruguayan beef carcasses by tenderness under commercial conditions using postmortem carcass traits, pH, temperature and color. *PhD Diss. The University of Georgia, Athens*.

Cardello, A. V. 1995. Food quality: relativity, context and consumer expectations. *Food Quality and Preference*, **6:** 163-170.

Cayuela, J. M., Gil, M. D., Bañón, S. and Garrido, M. D. 2004. Effect of vacuum and modified atmosphere packaging on the quality of pork loin. *European Food Research and Technology*, **219:** 316–320.

Commission International De I'Eclairage (CIE). 1976. Colorimetry. 2nd edition. Vienna, Switzerland.

Coles, R., McDowell, D. and Kirwan, M. J. (Eds.) 2003. *Food packaging technology* (Vol. 5). CRC Press.

Chouliara, E., Karatapanis, A., Savvaidis, I. N. and Kontominas, M. G. 2007. Combined effect of oregano essential oil and modified atmosphere packaging on shelf-life extension of fresh chicken breast meat, stored at 4 °C. *Food Microbiology,* **24:** 607–617.

Dainty, R. H. and Mackey, B. M. 1992. The relationship between the phenotypic properties of bacteria from chill-stored meat and spoilage processes. *The Journal of Applied Bacteriology,* **73:** 103–114.

Dave, D. and Ghaly A. E. 2011. Meat spoilage mechanisms and preservation techniques: A critical review*. American Journal of Agricultural and Biological Sciences,* **6:** 486-510.

Deumier, F. 2006. Decontamination of deboned chicken legs by vacuum-tumbling in lactic acid solution. *International Journal of Food Science and Technology*, **41:** 23-32.

Dickson, J. S. and Anderson, M. E. 1992. Microbiological decontamination of food animal carcasses by washing and sanitizing systems: a review. *Journal of Food Protection*, **55:** 133-140.

Dixon, Z. R., Acuff, G. R., Lucia, L. M., Vanderzant, C., Morgan, J. B., May, S. G. and Savell, J. W. 1991. Effect of degree of sanitation from slaughter through fabrication

on the microbiological and sensory characteristics of beef. *Journal of Food Protection*, **54:** 200-207.

Dransfield, E. and Sosnicki, A. A. 1999. Relationship between muscle growth and poultry meat quality. *Poultry Science*, **78:** 743-746.

Esmer, O. K., Irkin, R., Degirmencioglu, N. and Degirmencioglu, A. 2011. The effects of modified atmosphere gas composition on microbiological criteria, colour and oxidation values of minced beef meat. *Meat Science,* **88:** 221–226.

Egan, A. F., Eustace, I. J. and Shay, B. J. 1988. Meat packaging–maintaining the quality and prolonging the storage life of chilled beef, pork and lamb. *Meat 88: Proceedings of Industry Day*, 68-75.

Falowo, A. B., Fayemi, P. O. and Muchenje V. 2014. Natural antioxidants against lipid-protein oxidative deterioration in meat and meat products: A review. *Food Research International*, **64**: 171- 181.

Fernández-López, J., Jiménez, S., Sayas-Barberá, E., Sendra, E. and Pérez-Alvarez, J. A. 2006. Quality characteristics of ostrich (Struthio camelus) burgers. *Meat Science*, **73:** 295-303.

Fregonesi, R. P., Portes, R. G., Aguiar, A. M. M., Figueira, L. C., Gonçalves, C. B., Arthur, V., and Trindade, M. A. 2014. Irradiated vacuum-packed lamb meat stored under refrigeration: Microbiology, physicochemical stability and sensory acceptance. *Meat science*, **97:** 151-155.

Gispert, M., Faucitano, L., Oliver, M. A., Guàrdia, M. D., Coll, C., Siggens, K., and Diestre, A. 2000. A survey of pre-slaughter conditions, halothane gene frequency, and carcass and meat quality in five Spanish pig commercial abattoirs. *Meat Science*, **55:** 97-106.

Global Salm-Surv, 2003. A global Salmonella surveillance and laboratory support project of the World Health Organization. Edited: Rene S. Hendriksen (DFVF), Laboratory Protocols. "MIC determination by broth dilution using Sensititre. 4th Ed.

Greig, J. D. and Ravel, A. 2009. Analysis of foodborne outbreak data reported internationally for source attribution. *International Journal of Food Microbiology*, 130: 77-87.

Gregory, N. G. 2008. Animal welfare at markets and during transport and slaughter. Meat Science**, 80:** 2-11.

Guinane, C. M., Cotter, P. D., Hill, C. and Ross, R. P. 2005. Microbial solutions to microbial problems; lactococcal bacteriocins for the control of undesirable biota in food. *Journal of Applied Microbiology*, **98 :** 1316-1325.

ICMSF, 1986. Microorganisms in Foods. 2. Sampling for Microbiological Analysis: Principles and Specific Applications, 2nd ed. University of Toronto Press, Toronto.

INE. 1997. Quinta encuesta de presupuestos familiars (Agosto, 1996-Julio, 1997). Ministerio de Economía, Santiago, Chile. Available in http://www.ine.cl/ine/canales/chile_estadistico/estadisticas_laborales/vencuesta/volumen1/xls/cuunvoun.xls Accessed 10 January 2007.

Insausti, K., Beriain, M. J., Purroy, A., Alberti, P., Gorraiz, C. and Alzueta, M. J., 2001. Shelf life of beef from local Spanish cattle breeds stored under modified atmosphere. *Meat Science*, **57:** 273–281.

Jeremiah, L. E., 2001. Packaging alternatives to deliver fresh meats using short- or long-term distribution. *Food Research International*, **34:** 749–772.

Karabagias, I., Badeka, A. and Kontominas, M. G. 2011. Shelf life extension of lamb meat using thyme or oregano essential oils and modified atmosphere packaging. *Meat Science*, **88:** 109-116.

Koutsoumanis, K. P. and Taoukis, P. 2005. Meat safety, refrigerated storage and transport: Modeling and management. In: J.N. Sofos, Editor, Improving the Safety of Fresh Meat. Woodhead/Publishing, Ltd., Cambridge, UK, pp. 503–561.

Kraft, A. A. 1986. Meat microbiology. In P. J. Bechtel (Ed.), *Muscle as food* (pp. 239–278). London: Academic Press.

Kusmider, E. A., Sebranek, J. G., Lonergan, S. M. and Honeyman, M. S. 2002. Effects of carbon monoxide packaging on color and lipid stability of irradiated ground beef. *Journal of Food Science-Chicago-*, **67:** 3463-3468.

Lee, K. T. 2010. Quality and safety aspects of meat products as affected by various physical manipulations of packaging materials. *Meat Science,* **86:** 138 – 160.

Lorenzo, J. M. and Gómez, M. 2012. Shelf life of fresh foal meat under MAP, overwrap and vacuum packaging conditions. *Meat Science*, **92:** 610-618.

Lücke, F. K. 2000. Utilization of microbes to process and preserve meat. *Meat Science*, *56***:** 105-115.

Mancini, R. A. and Hunt, M. C. 2005. Current research in meat colour. *Meat Science,* **71:** 100–121.

McMillin, K.W. 2008. Where is MAP going? A review and future potential of modified atmosphere packaging for meat. *Meat Science.* **80:** 43-65.

McMillin, K. W., Huang, N. Y., Ho, C. P. and Smith, B. S. 1999. Quality and shelf-life of meat in case-ready modified atmosphere packaging. In *Quality attributes of muscle foods* (pp. 73-93). Springer US.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P. E. and Raats, J. G. 2008. Meat quality of Nguni, Bonsmara and Aberdeen Angus steers raised on a natural pasture in the Eastern Cape, South Africa. *Meat Science*, **79:** 20-28.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P. E., Hugo A. and Raats, J. G. 2009. Some biochemical aspects pertaining to beef eating quality and consumer health: A review. *Food Chemistry,* **112:** 279-289.

Ntanga, P. D. 2013. Assessment of microbial contamination in beef from abattoir to retail meat outlets in Morogoro municipality, Tanzania (Doctoral dissertation, Sokoine University of Agriculture).

Nkukwana, T. T., Muchenje, V., Masika, P. J., Pieterse, E., Hoffman, L. C. and Dzama, K. 2015. Proximate composition and variation in colour, drip loss and pH of breast meat from broilers supplemented with Moringa oleifera leaf meal over time. *Animal Production Science*.

Niyonzima, E., Bora, D. and Ongol., M. P. 2013. Assessment of beef meat microbial contamination during skinning, dressing, transportation and marketing at a commercial abattoir in Kigali city, Rwanda. *Pakistan Journal of Food Science*, **23:** 133–138.

Parlapani, F. F., Haroutounian, S. A., Nychas, G. J. E. and Boziaris, I. S. 2015. Microbiological spoilage and volatiles production of gutted European sea bass stored under air and commercial modified atmosphere package at 2° C. *Food Microbiology*, **50:** 44-53.

Pothakos, V., Devlieghere, F., Villani, F., Björkroth, J. and Ercolini, D. 2015. Lactic acid bacteria and their controversial role in fresh meat spoilage. *Meat Science*. **109:** 66- 74.

Pereira, P. M. C. C. and Vincente, A. F. R. B. 2013. Meat nutritional composition and nutritive role in the human diet. *Meat Science*, **93:** 586-592.

Priolo, A., Micol, D. and Agabriel, J. 2001. Effects of grass feeding systems on ruminant meat colour and flavour: A review. *Animal Research*, *50*: 185–200.

Qwele, K., Muchenje, V., Oyedemi, S.O., Moyo, B. and Masika, P.J. 2013. Effect of dietary mixtures of Moringa *(Moringa oleifera)* leaves, broiler finisher and crushed maizeon anti-oxidative potential and physico-chemical characteristics of breast meat from broilers. *African Journal of Biotechnology*: **12:** 290-298**.**

Rousset, S. and Renerre, M. 1990. Comparison of different packaging systems for the storage of fresh beef meat in carbon dioxide atmosphere with or without residual oxygen. *Sciences des aliments,* **10:** 737-747.

SAS. 2011. Users Guide, Version 9. Statistical Analysis System Institute Inc., Cary, NC, USA.

Sebranek, J. G. and Bacus, J. N. 2007. Cured meat products without direct addition of nitrate or nitrite: what are the issues? *Meat science*, *77*: 136-147.

Sheridan, J.J., Doherty, A.M., Allen, P., McDowell, D.A., Blair, I.S., and Harrington, D., 1997. The effect of vacuum and modified atmosphere packaging on the shelf-life of lamb primals, stored at different temperatures. *Meat Science,* **45:** 107–117.

Skandamis, P. N. and Nychas, G. E. 2002. Preservation of fresh meat with active and modified atmosphere packaging conditions. *International Journal of Food Microbiology,* **79:** 35–45.

Simopoulus, A. P. 2006. Evolutionary aspects of diet, the omega-6/omega-3 ratio and genetic variation: Nutritional implications for chronic diseases. *Biomed. Pharmacother.* **60:** 502-507.

Singh, R. K. and Singh, N. 2005. 3 Quality of packaged foods. *Innovations in food packaging*, 24-44.

Smolander, M., Alakomi, H. L., Ritvanen, T., Vainionpää, J. and Ahvenainen, R. 2004. Monitoring of the quality of modified atmosphere packaged broiler chicken cuts stored in different temperature conditions. A. Time–temperature indicators as quality-indicating tools. *Food Control*, **15:** 217-229.

Suman, S. P., Mancini, R. A., Joseph, P., Ramanathan, R., Konda, M. K. R., Dady, G. and López-López, I. 2010. Color-stabilizing effect of lactate on ground beef is packaging-dependent. *Meat Science*, **84:** 329-333.

Tauxe, R. V., Doyle, M. P., Kuchenmüller, T., Schlundt, J. and Stein, C. E. 2010. Evolving public health approaches to the global challenge of foodborne infections. *International Journal of Food Microbiology*, **139:** S16-S28.

Véronique, C. O. M. A. 2008. Bioactive packaging technologies for extended shelf life of meat-based products. *Meat science*, **78:** 90-103.

Vergara, H. and Gallego, L. 2001. Effects of gas composition in modified atmosphere packaging on the meat quality of Spanish Manchega lamb. *Journal of the Science of Food and Agriculture*, **81:** 1353-1357.

Werner, M., Hepp, C., Soto, C., Gallardo, P., Bustamante, H. and Gallo, C. 2013. Effects of long distance transport and subsequent recovery in recently weaned crossbred beef calves in Southern Chile. *Livestock Science,* **152**: 42-46.

Wong, D. L. F., Hald, T., Van Der Wolf, P. J. and Swanenburg, M. 2002. Epidemiology and control measures for Salmonella in pigs and pork. *Livestock Production Science*, **76:** 215-222.

Zakrys, P. I., Hogan, S. A., O'Sullivan, M. G., Allen, P. and Kerry, J. P. 2008. Effects of oxygen concentration on the sensory evaluation and quality indicators of beef muscle packed under modified atmosphere. *Meat Science,* **79:** 648–655.

Zerdin, K., and Scully, A. D. 2010. Inactivation of Food-borne Spoilage and Pathogenic Micro-organisms on the Surface of a Photoactive Polymer. *Photochemistry and photobiology*, **86:** 1109-1117.

Zhang, S. X., Farouk, M. M., Young, O. A., Wieliczko, K. J. and Podmore, C. 2005. Functional stability of frozen normal and high pH beef. *Meat Science*, **69:** 765–772.

Zhou, G. H., Xu, X. L. and Liu, Y. 2010. Preservation technologies for fresh meat–A review. *Meat Science*, **86:** 119-128.

Chapter 7: General Discussion, Conclusions and Recommendations

7.1 General Discussion

Meat is the first-choice of animal protein for human and consumption of meat is continuously increasing worldwide. On the other hand, the rich nutrient matrix of meat is subject to various types of spoilage depending on handling and storage conditions. Significant portions (3.5 billion kg) of meat and meat products are spoiled every year at the consumer, retailer and food service levels which have a substantial economic and environmental impact. Meat spoilage leads to the development of off flavours, off-odours and often slime formation due to the breakdown of valuable contents (fat, protein and carbohydrates) which make the product undesirable for human consumption. Worldwide population growth and globalization of the food supply, the control of meat spoilage and pathogenic micro-organisms becomes essential in order to increase meat shelf life and maintain its nutritional value, texture and flavour (Manios *et al.*, 2015). Continued efforts to promote proper handling, pre-treatment and preservation techniques, can improve the quality of meat, promote meat safety and increase its shelf life.

The safety of meat should be ensured by controlling the food chain from the farm of origin, inspection of the carcass before and after slaughter, handling and storage of meat and by protecting the product until it is time for consumption (FAO, 2015).

Therefore, the objective of this research was to assess the effect of post-slaughter handling in the meat distribution chain on meat quality and safety in the Eastern Cape Province, South Africa. Becker *et al.* (2000) identified a knowledge gap where he found that most consumers have little knowledge or lack information on the importance of food safety and only consider quality when making their purchasing decisions. This also applies to the consumers in South

Africa as it has been identified that there is scarcity of research related to food safety knowledge on both consumers and the meat handlers. In Chapter 3, consumer and handlers' perceptions on meat quality and safety along the distribution chain were determined. Consumers had shown lack of knowledge on some of the pathogenic diseases which arise from consuming bad meat. Most of the consumers perceived that quality goes beyond safety, such that 35.6% of the respondents indicated that they do not have a problem with consuming spoiled meat. Hence a strong significant association ($p < 0.05$) between educational status and awareness on meat safety was observed. Meat handlers generally believed that the distribution chain has an effect on meat quality since they believed that some of the important meat quality attributes like colour are affected by transportation and that retailers do not have an influence on meat quality. However, consumers perceived that there is a difference in the quality of meat that is purchased from different shops. They further stated that meat purchased from high class shops indicate high quality in meat, whilst according to the instrumental measurements in Chapter 5, this was proven not to be the case.

In Chapter 5, the physico-chemical quality of meat along the distribution chain was observed. The results revelead that the retailer class does not have a significant effect on the majority of the meat quality attributes but rather the storage duration and storage temperatures play a significant role on the quality of the meat produced. The perception of the meat handlers were that they believed that the distribution chain affects meat quality which corresponded with results from the instrumental measurements. In chapter 5, it was found that the distribution chain affects the physico-chemical quality of red meat especially during the offloading of the carcasses. Also in chapter 4, it was proven that the distribution chain does not only affect the physico-chemical quality of meat but the microbiological quality is also affected. The results showed significant ($p < 0.05$) microbial contamination of carcasses with all bacterial groups

investigated in the current research. An increase in microbial load between the distribution stages was observed. Total bacterial count, coliform count and the levels of *E. coli* contamination increased progressively between the loading and the off-loading points (5.1 to 7.9 log CFU/cm^2; 5.0 to 5.6 log CFU/cm^2 and 2.7 to 3.7 log CFU/cm^2, respectively). Furthermore, as the storage duration at the abattoir and retail shops increased, the levels of microbial counts also increased.

Ntanga (2013) and Adhikari *et al.* (2014) stated that the extent to which contamination occurs and the type of bacteria present reflects the standard of hygiene in an abattoir. According to the current results in chapter 4, samples from the commercial abattoir were found with significantly ($p < 0.05$) higher levels of microbial contaminants than in those from the communal abattoir. Compared to the European microbiological standards for meat, levels of contamination observed in the current study by TBC and CC at all stages were found to be above the acceptable range (CE , 2005). However, it was of importance to assess the levels of microbial counts in meat during marketing points and see if the meat which is sold to the consumers is safe enough for consumption, therefore its levels should range below the acceptable range. Therefore in chapter 6, a study which investigated the shelf life of meat sold to the consumers was conducted. Microbial analysis showed that the initial levels for TBC, CC, *and E.coli* in beef, pork and mutton samples were exceeding the acceptable range. Meaning that the possibility of selling or purchasing meat which is susceptible to spoilage or pathogens in the South African retail shops are high.

7.2 Conclusion

It was concluded that the levels of microbial counts in meat delivered from the South African abattoirs and retail shops are high. Hence some control measures to improve handling of meat along the supply chain are encouraged. Introducing a microbial assessment approach in the

South African abattoirs and retail shops could be a proper way of safe- guarding consumer's health. The distribution chain has scientifically proven to have an effect on both physico-chemical and microbiological quality of meat. Storage duration and storage temperatures have been shown to have a significant effect on meat quality traits and developments of microbial counts in meat. Furthermore, compared to other studies by Gregory (2008) and the current results, it was concluded that the pHμ at the point of purchase ranges above 6.0.

7.3 Recommendations

Based on these findings, there are challenges of unhygienic meat handling and processing practices in abattoirs and retail meat outlets which could result in production of low quality meat and hence, putting consumers at risk. The following recommendations were put forward so as to alleviate the observed prevailing situation:

- More effective meat inspection programs that will cater for the microbiological meat inspection in both abattoirs and retail shops should be developed as a way to prevent contamination and food-borne illnesses. Microbiological analyses of red meat through the supply chain, from abattoir to retail point will help identify possible modes of contamination. This will help the responsible authorities to take appropriate steps to improve meat safety in abattoirs

- Also, the findings on microbial counts were compared to the European microbiological standards for meat. It should be borne in mind that these levels were crafted based on the European environmental conditions which may differ from temperatures in South Africa. Therefore, findings from this study can also act as a foundation for the development of acceptable microbiological standards or guidelines for abattoirs in South Africa and other developing countries as well as help in the development of more effective meat inspection programs.

- It is also recommended that producers when labelling packaging at the point of purchase are urged to also include the background information such as the sex and the age of animal at slaughter and the breed type. This can assist consumers to be able to predict meat quality traits like tenderness when purchasing meat in a shop.

- Information guidelines on food safety and its implications for the meat handlers and the consumers should be compiled and distributed.

- The health of the South African public is the heart of the Meat Safety act of 2000. Assessing the extent to which this act is implemented by abattoirs and shops, will assist relevant stakeholders identify constraints with a view to providing panacea's. In addition, finding a model that will deal with reducing the number of bacteria developing on meat can improve meat safety and reduce chances of food-borne diseases. This model will be used by the meat traders in order to reduce spoilage and ultimate economic losses. This proposed research will help generate a model of bacteria contamination and growth from slaughter to the point of purchase which will help researchers in solving meat safety and shelf-life issues.

7.4 References

Adhikari, B. M., Subedi, R. P. and Subba, D. 2014. A Study on standard of buffalo meat

hygiene in Dharan. *Journal of Food Science and Technology Nepal,* **7:** 99-101

Becker, T., Bennerr, E. and Glitsch, K. 2000. Consumer perception of fresh meat quality in

Germany. *British Food Journal*, **102:** 246- 266.

Brooks, J. C., Alvarado, M., Stephens, T. P., Kellermeier, J. D., Tittor, A. W., Miller, M.

F., and Brashears, M. M. 2008. Spoilage and safety characteristics of ground beef

packaged in traditional and modified atmosphere packages. *Journal of Food*

Protection, **71:** 293-301.

Commission International De I'Eclairage (CIE). 1976. Colorimetry. 2nd edition. Vienna,

Switzerland.

Gregory, N. G. 2008. Animal welfare at markets and during transport and slaughter. *Meat*

*Science, 80***:** 2–11.

Manios, S. G., Grivokostopoulos, N. C., Bikouli, V. C., Doultsos, D. A., Zilelidou, E. A.,

Gialitaki, M. A. and Skandamis, P. N. 2015. A 3- year hygiene and safety

monitoring of a meat processing plant which uses materials of global origin.

International Journal of Food Microbiology, **209**: 60-69.

Ntanga, P. D. 2013. Assessment of microbial contamination in beef from abattoir to retail

meat outlets in Morogoro Municipality, Tanzania. MSc Thesis, Sokoine University of

Agriculture, Tanzania.

Appendix 1: Consumer's perceptions on meat quality and safety along the distribution chain

University of Fort Hare
Together in Excellence

Ethics research Confidentiality and Consent Form

Please note:

This form is to be completed by the researcher(s) as well as by the interviewee before the commencement of the research. Copies of signed form must be filed and kept on record

(To be adapted for individual circumstances/needs)

Our University of Fort Hare are asking people from your community/ sample/group to answer some questions, which we hope will benefit your community and possibly other communities in the future.

The University of Fort Hare is conducting a research regarding the rural and urban consumer's perception on meat distribution chain and how they perceive meat of acceptable quality.We are interested in finding out more about the perceptions of meat traders/ distributors on how they maintain quality of meat till at point of purchase and challenges that they face. We are carrying out this research to increase consumer in rural communities to be awareness of health issues associated with meat consumption and hence transform consumer meat consumption behaviour. We also anticipate having data base created on resources found in this community.

Please understand that you are not being forced to take part in this and the choice whether to participate or not is yours alone. However, we would really appreciate it if you do share your thoughts with us. If you choose not take part in answering these questions, you will not be affected in anyway. If you agree to participate, you may stop me at any time and tell me that you don't want to go on with interview. If you do this there will also be no penalties and will NOT be prejudiced in ANY way. Confidentiality will be observed professionally.

I will not be recording your name anywhere on the questionnaire and no one will be able to link you to the answers you give. Only researchers will have access to the unlinked

information. The information will remain confidential and there will be no "come-backs" from answers you give.

The interview will last around **(20) minutes** at the most. I will be asking you questions and ask that you as open and honest as possible in answering these questions. Some questions may be of personal and/ or sensitive nature. I will be asking some questions that you may not have thought about before, and which also involve thinking about the past or the future. We know that you cannot be absolutely certain about the answers to these questions but we ask that you try to think about these questions. When it comes to answering questions there are no right and wrong answers. When we ask questions about the future we are not interested in what you think the best thing would be to do, but what you think would actually happen.

If possible, our organization would like to come back to this area once we have completed our study to inform you and your community of what the results are and discuss our findings and proposals around the research and what this means for people in this area.

I hereby agree to participate in research regarding ……………………….. I understand that I am participating freely and without being forced in any way to do so. I also understand that I can stop this interview at any point should I not want to continue and that this decision will not in any way affect me negatively.

I understand that this is a research project whose purpose is not necessarily to benefit me personally.

I have received the telephone number of a person to contact should I need to speak about any issues which may arise in this interview.

I understand that this consent form will not be linked to the questionnaire, and that my answers will remain confidential.

I understand that if at all possible, feedback will be given to my community on the results of the completed research.

………………………..
Signature of participant   **Date**:………………..

I hereby agree to the tape recording of my participation in the study

………………………..
Signature of participant   **Date**:………………..

University of Fort Hare
Together in Excellence

Important information

This survey is designed to gather information about the perception of consumers and meat traders on mutton, beef and pork quality during the distribution chain. It is not meant to implicate anyone but rather, to gather data for academic purpose <u>only</u>. Your response and cooperation will be immensely appreciated.

Enumerator name :	
Name of respondent :........................	Municipality: ………………….....................
Place of preference for purchasing meat	Date: ……………………
Occupation / position .... Location : Urban ☐ Rural ☐	

Part 1: Demographic information of the respondents

1.1 Please indicate your age group: >20yrs   ☐   21-30yrs☐
31-40yrs ☐ 41-50yrs ☐   41-50yrs   ☐   >50 yrs ☐

1.2 Educational status of the respondent:

 No formal education☐   Grade1-7☐   Grade8-12 ☐   Tertiary☐

1.3 Are your qualifications linked to meat sector? 1. Yes   ☐   2. No   ☐

1.4 If yes, state experience in meat sector: 1- 3 years ☐   4-6 years ☐   6- 10 ☐   > 10 years ☐

1.5 Race: Black   ☐   White ☐   Coloured   ☐   Indians ☐ Other   ☐

Part 2: Consumers

4.1 Which type of meat do you purchase the most and why?

   Beef   ☐   Pork   ☐   Mutton   ☐

…………………………………………………………………………………………………

4.2 How do you think the meat gets to the shelves for you to purchase?

……………………………………………………………………………………………..

4.3 How long do you think it takes after the meat has been slaughtered from the abattoir to reach the shelves in a shop?

………………………………………………………………………………………………….

4.4 How do you know when the quality of meat has been affected?

……………………………………………………………………………………………..

4.5 How do the meat traders maintain meat quality for it to reach you in acceptable quality?

……………………………………………………………………………………………..

4.6 Do you check the expiry date when purchasing meat in a shop? Yes ☐ No ☐

4.7 Do you trust the expiry dates that are written in meat packages or you judge the quality of meat by just looking at it ?

....

4.8 What does the expiry date on meat packages mean to you?

....

4.8 Which type of meat do you think is much healthier?

   Beef   ☐   Pork   ☐   Mutton   ☐

4.9 Where do you prefer to purchase your meat ?

   Shop ☐   Butcher   ☐

Give a reason for your answer

....

 4.10 Is there a difference in meat purchased from a butcher and shop?

 Yes ☐ No ☐

If yes, what is the difference?

....

 4.11 Do you rank shops into classes when purchasing meat ? Yes ☐ No ☐

If yes how do you judge them……………………………………………. ………….

4.12 When purchasing meat do you consider the type of packaging used? Yes ☐ No ☐

If yes, what is your preferred packaging and why?

…………………………………………………………………………………………….

4.13 Do you think that it's important to know the background information of where the meat comes from or you only consider what you are purchasing and taking home? Yes ☐ No ☐

………………………………………………………………………………………………….

4.14 How do you measure meat quality at display?

……………………………………………………………………………………………

4.15 Which meat part do you prefer to purchase the most and why?

…………………………………………………………………………………………..

4.16 If meat is sold at a cheaper price do you purchase it?

Immediately   ☐   Think twice about it ☐   Will never purchase it   ☐

Why? ....

4.16 Which type of meat can you keep for a longer period?

Mutton ☐   Beef ☐   Pork ☐

4.17 Which method do you use to keep the meat longer

....

4.18 What do you do to meat that is going bad?

....

4.19 What makes beef superior? Colour ☐   Tenderness ☐ Fatness ☐ Taste Juiceness ☐

4.20 What makes mutton superior ? Colour ☐ Tenderness ☐ Fatness ☐ Taste Juiceness ☐

4.21 What makes pork superior ? Colour ☐ Tenderness ☐ Fatness ☐ Taste Juiceness ☐

4.20 Meat quality attributes

How important are the following aspects in defining meat of an acceptable quality to consumers? Each aspect should be ranked on a scale of 1-5: **1-Totally un- important; 2-Not important; 3- Either important or un-important; 4-Important; 5-Very important**

5.1 Colour of the meat…………………………………………………………………

5.2 Leanness of the meat……………………………………………………………………

5.3 Presence of fat/ marbling…………………………………………………………………

5.4 Smell of the raw meat………………………………………………………………

5.5 Freshness of the meat …………………………………….......................................

5.6 Texture of the meat …………………………………….......................................

5.7 Flavour…………………………………………………….

5.8 Type of packaging used……………………………………………………

5.9 The price of meat ……………………………………………………………………

5.10 Tenderness/softness of the meat……………………………………………………

5.11 Juiciness of the meat…………………………………………………………………..

5.12   Visual   look   at display……………………………………………………………………………

Part 5: Contamination

5.1 Are you aware that raw meat that you purchase can carry bacteria which can cause diaseses to your family?

    Yes ☐ No ☐

5.2 Have you ever purchased meat that has caused diseases to your family, e.g. diarrhea

   Yes ☐ No ☐ Not sure ☐

5.2 Which meat was that?

....

5.3 For how long did the disease last and how was it cured?

....

5.4 Whom do you put the bame to ?

Yourself ☐   place from where you purchased the meat ☐   Other ☐

Thank you for your time.

Appendix 2: Retailers perceptions on meat quality and safety

Ethics research Confidentiality and Consent Form

Please note:

This form is to be completed by the researcher(s) as well as by the interviewee before the commencement of the research. Copies of signed form must be filed and kept on record

(To be adapted for individual circumstances/needs)

Our University of Fort Hare are asking people from your community/ sample/group to answer some questions, which we hope will benefit your community and possibly other communities in the future.

The University of Fort Hare is conducting a research regarding the rural and urban consumer's perception on meat distribution chain and how they perceive meat of acceptable quality.We are interested in finding out more about the perceptions of meat traders/ distributors on how they maintain quality of meat till at point of purchase and challenges that they face. We are carrying out this research to increase consumer in rural communities to be awareness of health issues associated with meat consumption and hence transform consumer meat consumption behaviour. We also anticipate having data base created on resources found in this community.

Please understand that you are not being forced to take part in this and the choice whether to participate or not is yours alone. However, we would really appreciate it if you do share your thoughts with us. If you choose not take part in answering these questions, you will not be affected in anyway. If you agree to participate, you may stop me at any time and tell me that you don't want to go on with interview. If you do this there will also be no penalties and will NOT be prejudiced in ANY way. Confidentiality will be observed professionally.

I will not be recording your name anywhere on the questionnaire and no one will be able to link you to the answers you give. Only researchers will have access to the unlinked information. The information will remain confidential and there will be no ''come-backs'' from answers you give.

The interview will last around (20) minutes at the most. I will be asking you questions and ask that you as open and honest as possible in answering these questions. Some questions may be of personal and/ or sensitive nature. I will be asking some questions that you may not have thought about before, and which also involve thinking about the past or the future. We know that you cannot be absolutely certain about the answers to these questions but we ask that you try to think about these questions. When it comes to answering questions there are no right and wrong answers. When we ask questions about the future we are not interested in what you think the best thing would be to do, but what you think would actually happen.

If possible, our organization would like to come back to this area once we have completed our study to inform you and your community of what the results are and discuss our findings and proposals around the research and what this means for people in this area.

INFORMED CONSENT

I hereby agree to participate in research regarding ……………………….. I understand that I am participating freely and without being forced in any way to do so. I also understand that I can stop this interview at any point should I not want to continue and that this decision will not in any way affect me negatively.

I understand that this is a research project whose purpose is not necessarily to benefit me personally.

I have received the telephone number of a person to contact should I need to speak about any issues which may arise in this interview.

I understand that this consent form will not be linked to the questionnaire, and that my answers will remain confidential.

I understand that if at all possible, feedback will be given to my community on the results of the completed research.

…………………………..
Signature of participant   **Date**:…………………..

I hereby agree to the tape recording of my participation in the study

…………………………..
Signature of participant   **Date**:…………………..

University of Fort Hare
Together in Excellence

Important information

This survey is designed to gather information about the perception of consumers and meat traders on mutton, beef and pork quality during the distribution chain. It is not meant to implicate anyone but rather, to gather data for academic purpose <u>only</u>. Your response and cooperation will be immensely appreciated.

Enumerator name :	
Name of respondent :..........................	Municipality: ……………….....................
Name of shop/butchery	Date: ……………………
Occupation / position .... Location : Urban ☐ Rural ☐	

Part 1: Demographic information of the respondents

1.1Please indicate your age group: >20yrs   ☐   21-30yrs☐
31-40yrs ☐ 41-50yrs ☐ 41-50yrs   ☐   >50 yrs   ☐

1.2 Educational status of the respondent:

 No formal education☐   Grade1-7☐   Grade8-12 ☐   Tertiary☐

1.3 Are your qualifications linked to meat sector? 1. Yes   ☐   2. No   ☐

1.4 If yes, state experience in meat sector: 1- 3 years ☐   4-6 years ☐   6- 10 ☐   > 10 years ☐

1.5 Race: Black   ☐   White ☐   Coloured   ☐   Indians ☐ Other   ☐

 Part 2: Retailers

3.1 Which type of meat is purchased the most?

Beef   ☐   Pork   ☐   Mutton   ☐

…………………………………………………………………………………………………

3.2 What do you understand about shelf life ?

…………………………………………………………………………………………………

3.3 Do different meat have the same shelf - life?

Yes ☐ No ☐

Give a reason for your answer …………………………………………………………………

3.4 Which type of meat among the three (beef, pork and mutton) do you think has got a
    prolonged shelf life and why?

…………………………………………………………………………………………………..

3.5 Who determines the expiry date of meat in your shop and how is it determined ?

....

3.6 At what temperatures is the meat stored on display?

....

3.9 Who is responsible for monitoring the storage and display temperatures?

....

3.10 For how long is the meat kept in storage before it can be displayed in shelves?

....

3.11 At what temperature is the meat kept before it can be displayed in shelves?

....

3.12 How / who determines prices for meat in your shop ?

....

3.13 How do you grade your meat?

....

3.14 Do you think that consumers care about where the meat comes from ?

Care   □   Do not care □   Do not know □

 3.15 Which type of packaging do you use?

   Modified atmosphere packaging (MAP) □   Vacuum packaging □

    Overwrapping   □   Display it with no packaging □

  3.16 Do packaging used differ according to the type of meat/ they are the same?

    (a)   Yes □ No □ They are the same   □

(b) What effect does packaging have on meat quality ?
....

  3.15 How do you ensure that adualteration does not take place in your shop?

....

3.16 What do you use the meat for which has passed its best before date?

....

3.17 What are some of the challenges you are faced with when the meat is still at storage?

....

3.18 What are some of the challenges you are faced with at display?

....

3.19 How do you maintain meat quality for it to reach consumers in acceptable quality?

……………………………………………………………………………………………….

3.20 *Please rank the following factors according how much influence they have on meat quality. Each aspect should be rank;8ed on a scale of 1-5:* Totally un- important; 2-Not important; 3- Not sure; 4-Important; 5-Very important

Class of retailer…………………………………………………………………………………

Storage facilities………………………………………………………………………………..

Hygiene at storage rooms……………………………………………………………………….

Storage temperatures……………………………………………………………………………

Duration at storage……………………………………………………………………………...

Size of storage…………………………………………………………………………………..

Packaging type used……………………………………………………………………………

Visual look at display…………………………………………………………………………...

Hygiene at display………………………………………………………………………………

Duration at display……………………………………………………………………………...

3.21 Meat quality attributes

How important are the following aspects in defining meat of an acceptable quality to consumers? Each aspect should be ranked on a scale of 1-5: **1-Totally un- important; 2-Not important; 3-Not sure; 4-Important; 5-Very important**

5.1 Colour of the meat……………………………………………………………………

5.2 Leanness of the meat…………………………………………………………………

5.3 Presence of fat/ marbling……………………………………………………………

5.4 Smell of the raw meat…………………………………………………………………

5.5 Freshness of the meat …………………………………...

5.6 Texture of the meat ……………………………………...

5.7 Flavour…………………………………………………….

5.8 Type of packaging used…………………………………………………………

5.9 The price of meat ……………………………………………………………………

5.10 Tenderness/softness of the meat……………………………………………………

5.11 Juiciness of the meat………………………………………………………………..

5.12 Visual look at display………………………………………………………………

Appendix 3: Meat handler's/ Abattoir workers questionnaire

Ethics research Confidentiality and Consent Form

Please note:

This form is to be completed by the researcher(s) as well as by the interviewee before the commencement of the research. Copies of signed form must be filed and kept on record

(To be adapted for individual circumstances/needs)

Our University of Fort Hare are asking people from your community/ sample/group to answer some questions, which we hope will benefit your community and possibly other communities in the future.

The University of Fort Hare is conducting a research regarding the rural and urban consumer's perception on meat distribution chain and how they perceive meat of acceptable quality. We are interested in finding out more about the perceptions of meat traders/ distributors on how they maintain quality of meat till at point of purchase and challenges that they face. We are carrying out this research to increase consumer in rural communities to be awareness of health issues associated with meat consumption and hence transform consumer meat consumption behaviour. We also anticipate having data base created on resources found in this community.

Please understand that you are not being forced to take part in this and the choice whether to participate or not is yours alone. However, we would really appreciate it if you do share your thoughts with us. If you choose not take part in answering these questions, you will not be affected in anyway. If you agree to participate, you may stop me at any time and tell me that you don't want to go on with interview. If you do this there will also be no penalties and will NOT be prejudiced in ANY way. Confidentiality will be observed professionally.

I will not be recording your name anywhere on the questionnaire and no one will be able to link you to the answers you give. Only researchers will have access to the unlinked information. The information will remain confidential and there will be no "come-backs" from answers you give.

The interview will last around **(20) minutes at the most**. I will be asking you questions and ask that you as open and honest as possible in answering these questions. Some questions may be of personal and/ or sensitive nature. I will be asking some questions that you may not have thought about before, and which also involve thinking about the past or the future. We

know that you cannot be absolutely certain about the answers to these questions but we ask that you try to think about these questions. When it comes to answering questions there are no right and wrong answers. When we ask questions about the future we are not interested in what you think the best thing would be to do, but what you think would actually happen.

If possible, our organization would like to come back to this area once we have completed our study to inform you and your community of what the results are and discuss our findings and proposals around the research and what this means for people in this area.

INFORMED CONSENT

I hereby agree to participate in research regarding ……………………….. I understand that I am participating freely and without being forced in any way to do so. I also understand that I can stop this interview at any point should I not want to continue and that this decision will not in any way affect me negatively.

I understand that this is a research project whose purpose is not necessarily to benefit me personally.

I have received the telephone number of a person to contact should I need to speak about any issues which may arise in this interview.

I understand that this consent form will not be linked to the questionnaire, and that my answers will remain confidential.

I understand that if at all possible, feedback will be given to my community on the results of the completed research.

………………………………..
Signature of participant   **Date**:…………………..

I hereby agree to the tape recording of my participation in the study

………………………………..
Signature of participant   **Date**:…………………..

University of Fort Hare
Together in Excellence

Important information

This survey is designed to gather information about the perception of consumers and meat traders on mutton, beef and pork quality during the distribution chain. It is not meant to implicate anyone but rather, to gather data for academic purpose only. Your response and cooperation will be immensely appreciated.

Enumerator name :	
Name of respondent :.........................	Municipality: ………………….....................
Name of Abattoir	Date: ……………………
Occupation / position .... Location : Urban ☐ Rural ☐	

Part 1: Demographic information of the respondents

1.1 Please indicate your age group: >20yrs ☐   21-30yrs☐

31-40yrs ☐ 41-50yrs ☐   41-50yrs ☐   >50 yrs ☐

1.2 Educational status of the respondent:

 No formal education☐   Grade1-7☐   Grade8-12 ☐   Tertiary☐

1.3 Are your qualifications linked to meat sector? 1. Yes ☐   2. No ☐

216

1.4 If yes, state experience in meat sector: 1- 3 years ☐   4-6 years ☐   6- 10 ☐   > 10 years ☐

1.5 Race: Black   ☐   White ☐   Coloured   ☐   Indians ☐ Other   ☐

Part 2: Abattoirs

2.1 Who do you supply in the course of meat chain distribution?

  Retailers ☐ Shops ☐ Butcheries ☐ Consumers ☐   Institutions ☐ Other

…………………………………………………………………………………………………

2.2 Has any of them ever rejected/ returned the meat that you have supplied?

  Yes ☐ No ☐

2.3 If yes, what was the reason of rejecting?

  ………………………………………………………………………………………….

2.4 Do you think that the quality of meat differs according to suppliers? Yes ☐ No ☐

2.5 If yes what do you think causes the difference?

  Handling ☐   Storage temperatures ☐   Storage days ☐   State other reason

. ……………………………………………...

2.6 Which meat quality characteristic do you think is affected the most by the reason stated above?

Colour ☐ Juiciness ☐   Tenderness ☐ Fatness ☐ Taste ☐ Do not know ☐

2.7 What do you think causes the difference in meat quality once it reaches the supply points?

  Transportation ☐   Handling ☐   Type of storage conditions ☐   State other reason

…………………………………………………………………………………………………

2.8 At what temperature is the meat stored before delivery?

....

 2.9 For how long is the meat kept in an abattoir before it can be transported to retailers?

Few hours ☐   1-3 days ☐ 3-5 days ☐   A week ☐ More than a week ☐

State the reason

....

2.10 (a) Do you mix different types of meat when transporting to the supply points?

Yes ☐ No ☐

2.10 (b) Give a reason for your answer in (a)

....

2.11 (a) Do you think that distance is a problem when transporting meat to distribution centres?

;8 Yes ☐ No ☐

2.11 (b) If yes to (a), specify the problem caused by distance

……………………………………………………………………………………………….

2.12 What are some of the challenges that are faced during transportation which could affect meat quality?

....

2.13 What is the shortest distance you cover when transporting meat to the distribution centers?

....

2.13 When using the shortest distance, do you use refrigerated trucks or just vehicles?

....

2.14 What is the longest distance you cover when transporting meat to the distribution centers?

....

2.15 At what temperature is the meat stored under during transportation?

....

2.16 How is the temperature monitored/ maintained during transportation to distribution centers?

....

2.17 Is colour of the meat affected during transportation?

Yes ☐ No ☐

2.18 If the meat gets spoiled during transportation what do you do with it and what could be the cause for it to be spoiled ?

…………………………………………………………………………………………..

2.19 ow many times does spoilage of meat during transportation likely to happen in a year? Not often ☐ Many times ☐ Never ☐

2.20 What are some of the challenges faced during packaging of meat which could affect it's ability?

…………………………………………………………………………………………..

2.21 What are some of the challenges / problems that you are faced with during displaying?

....

2.22 Which stage of the distribution chain do you think is most critical?

Transportation ☐ Packaging ☐ Storage ☐ Displaying

Give a reason for your answer …………………………………………………………..

2.23 How do you maintain meat quality for it to reach the retailers in acceptable quality?

………………………………………………………………………………………….

2.24 (a) What makes beef superior? Colour ☐ Tenderness ☐ Fatness ☐ Taste Juiceness ☐

(b) What makes mutton superior? Colour ☐ Tenderness ☐ Fatness ☐ Taste Juiceness ☐

(c) What makes pork superior? Colour ☐ Tenderness ☐ Fatness ☐ Taste Juiceness ☐

2.25 Please rank the following factors according how much influence they have on meat quality. Each aspect should be ranked on a scale of 1-5: 1-Totally un- important; 2-Not important; 3- Not sure; 4-Important; 5-Very important

Class of abattoir…………………………………………………………………………..

Carcass handling in abattoir………………………………………………………………

Storage temperatures…………………………………………………………………………

Storage facilities…………………………………………………………………………….

Distance covered when transporting meat…………………………………………………

Hygiene…………………………………………………………………………………….

Storage days/ duration……………………………………………………………………

Appendix 4: Physico-chemical parameters indicating the shelf life of meat

University of Fort Hare
Together in Excellence

Meat type (mutton,beef,pork)	Retailer name/ class	Municipality	COLOUR AT POINT OF PURCHASE			Meat part	T˚C	pHµ	Type of packaging	Shelf life (Colour measurements in 7 days)							pHµ
			L*	a*	b*					Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	

Appendix 5: Physico-chemical meat quality attributes during distribution

Meat part	LOADING					OFFLOADING					DISPLAY					Distance
	L*	a*	b*	pH	T˚c	L*	a*	b*	pH	T˚c	L*	a*	b*	pH	T˚c	