UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Beef carcass quality, yield and causes of condemnations in Ethiopia

By
Yesihak Y Mummed
Dip. Animal Health, BSc Animal Science, MSc Animal Breeding

Thesis submitted in partial fulfillment of the requirements for the degree of PhD
(Animal Science)

In the faculty of Natural and Agricultural Science
University of Pretoria
Pretoria

February 2015

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Abstract

Beef carcass quality, yield and causes of condemnations in Ethiopia were investigated in this study. Data was collected from Abergelle, Adama, Elfora Bishoftu, Elfora Kombolcha, Elfora Melgawendo, Hawassa, and Mekelle local and export abattoirs which include a total of 88,299 cattle. The study indicated that management practices at the abattoirs contribute to the poor quality of carcasses. The average carcass weight at the local abattoirs was 135.90 $\pm$ 0.69 kg. Carcass weight was significantly ($p<0.001$) different between abattoirs, season, conformation grades, fat grades and categories of cattle. Superior conformation and fat grades were lower for cows and castrated bulls compared to other categories of cattle. The average live weight, carcass weight and dressing percentage at the export abattoirs were 241.41 $\pm$ 0.37 kg, 106.93 $\pm$ 0.21 kg and 44.21 $\pm$ 0.05 %, respectively. Live weight, carcass weight and dressing percentage were significantly ($p<0.001$) differ between abattoirs, season and breeds. Average meat yield and yield percentage were 61.56 $\pm$ 0.94 kg and 67.81 $\pm$ 0.33%, respectively. Meat yield and weight of primal meat cuts were significantly ($p<0.001$) different between breeds of cattle. Only 31.13% of total carcasses sampled had an acceptable ultimate pH of 5.4-5.7. 170 whole carcasses, 52,437 partial carcasses and a number of organs were condemned out of a total of 62,917 cattle slaughtered. The main causes of condemnations of carcasses and organs were poor bleeding, bruising, contamination, abscess, hydatid cyst, pneumonia, nephritis, pericarditis and cysticercus bovis. The financial loss due to condemnation of carcasses and organs at one of the abattoirs was about 771,666.9 ETB (38,953.40 USD). From this study it was concluded that main factors that affected carcass quality of cattle in Ethiopia were poor management practices at the abattoirs, very low level of carcass fat, low proportion of carcass with desired pH for acceptable conversion of muscle to meat and higher level of condemnations of carcasses and organs. It is therefore recommended that developing law governing abattoirs operation, implementing good management program at abattoirs, proper feeding of cattle before slaughter and proper handling of cattle during transport will improve the quality of carcasses in Ethiopia.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Declaration

I declare that this thesis for the PhD (Animal Science) degree at the University of Pretoria has not been submitted by me for a degree at any other university.

Signed……………………………………….
Yesihak Y Mummed

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Summary

Beef carcass quality, yield and causes of condemnations in Ethiopia
By
Yesihak Y Mummed
Promoter: Prof E.C. Webb

Department of Animal and Wildlife Science
Faculty of Natural and Agricultural Science
University of Pretoria
For the degree of PhD

Carcass quality, yield and causes of condemnations of carcasses at local and export abattoirs in Ethiopia were investigated in this study. In the first and second parts of the study, general abattoir operation, facilities and management systems, factors affecting carcass yield, conformation and fat grades were evaluated. In the third part of the study factors affecting the live weight, carcass weight, dressing percentage, meat yield and meat cuts of cattle slaughtered at export abattoirs were investigated. In the fourth part of the study the causes of condemnations of carcasses and organs and economic loss were investigated.

The result of the study indicated that the management of public and private abattoirs was one of the causes of poor quality carcasses. The average carcass weight at local abattoirs was 135.90 $\pm$ 0.69 kg. Carcass weight was significantly ($p<0.001$) different between abattoirs, season, conformation grades, fat grades and categories of cattle slaughtered. Conformation grade 1, 2 and 3 accounted for 30%, 34.29% and 35.71% of carcasses evaluated, respectively. Fat grade1, 2 and 3 accounted for 67.5%, 23.57% and 8.93% of carcasses evaluated, respectively. The proportion of intact bulls, castrated bulls, growing bulls and cows accounted for 26.07%, 64.64%, 3.95% and 5.36% of carcasses evaluated, respectively. The average live weight, carcass weight and dressing percentage of cattle slaughtered at export abattoirs were 241.41 $\pm$ 0.37 kg, 106.93 $\pm$ 0.21 kg and 44.21 $\pm$ 0.05%, respectively. These parameters were significantly ($p<0.001$) different between abattoirs, season and breeds. The overall meat yield and yield percentage were 61.56 $\pm$ 0.94 kg and 67.81 $\pm$ 0.33%, respectively. Meat yield and yield percentage were significantly ($p<0.05$) different between breeds. The forequarter, hindquarter and meat cuts were significantly ($p<0.001$) different between breeds. All meat cuts significantly ($p<0.001$) predicted the meat yield. Based on the carcass pH measurement made on 151 samples, only 31.13% of the total sample had a pH of 5.4-5.7 which can be considere as carcasses from unstressed cattle. The study conducted on condemnations of carcasses and organs revealed that a total of 170 whole carcasses, 52,437 partial carcasses and a number of organs were condemned out of 62,917 cattle slaughtered during the study period. The financial loss due to condemnation of carcasses and organs in one of the abttoir between July 2010 and June 2013 was about 771,666.90 ETB (38,953.40 USD).
From the study it was concluded that major factors which affected carcass qualities of cattle in Ethiopia were absence of law governing abattoirs oprations, good management practice at abattoirs, very low level of fat, low proportion of carcasses with desired pH for acceptable conversion of muscle to meat and higher level of condemnations of carcasses and organs. It is therefore recommended that developing law governing abattoirs operation, implementing good

managemet program and hazard analysis and critical control points (HACCP) at the abattoirs, proper feeding management before slaughter and proper handling of cattle during transport will improve the quality of carcasses of cattle in Ethiopia.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Acknowledgements

I like to thank the following individuals and institutions for their indispenceble contribution to the successful completion of my study:

- Prof. E.C. Webb for his support, encouragement and guidance in my research work.
- University of Pretoria and Haramaya University for their financial support of my research work.
- Beef exports unite of Ministry of Agriculture of Ethiopia for coordinating data colletion at export abattoirs in Ethiopia.
- Supervisors and staffs of Abergelle, Elfora Kombolcha and Elfora Melgawendo export abattoir for facilitating data collection.
- Supervisors at Hawassa, Adama and Mekelle local abattoirs for their coordinating data collection.
- Federal meat inspectors at Mekelle, Kombolcha and Bishoftu abattoirs for their well recorded information on condemnations of carcasses and organs.
- My wife Aminata Dawud, my childrens Salih, Ne’ema, Ayub, my mother Shega Issa, my father Yusuf Mummed, my brothers and sisters for standing by me all the time.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

List of acronyms

AHDB	Agriculture and horticulture development board
AUS-MEAT	Australia meat
CWE	Carcass weight equivalent
DFD	Dark firm dry
ES	Ethiopian Standard
EMA	Eye muscle area
EU	European Union
GDP	Gross Domestic Product
GMPs	Good management programs
HACCP	Hazard analysis and critical control point
KPH	Kidney, pelvic and heart fat
MGA	Melengestrol acetate
MT	Metric tone
MSA	Meat standard Australia
PSE	Pale soft exudes
REA	Rib eye area
SA	South Africa
SPNN	Southern People National and Nationalities
SPS	Sanitory phytosaniotry
USDA	United State Department of Agriculture

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Table of Contents

Abstract i

Declaration ii

Summary iii

Acknowledgements v

List of acronyms vi

List of tables xii

List of figures xiv

1 INTRODUCTION 1

1.1 Project theme 1

1.2 Project title 1

1.3 Aim 1

1.4 Motivation 2

2 LITRATURE REVIEW 6

2.1 Beef industry and constraints in Ethiopia 6

2.1.1 Role of cattle in the economy of Ethiopia 6

2.1.2 Cattle production system 7

2.1.3 Oppertunities and constraints for beef market 10

2.2 Carcass quality 14

2.2.1 Factors affecting carcass quality 19

2.2.2 Improving carcass quality through breeding and management 42

2.3 Live, carcass weight and dressing percentage 48

2.4 Phenotypic characterstics of cattle in Ethiopia 50

2.5 Sanitatary condition of the hide 52

2.6 Design and equipment recommendations for small- to medium-sized abattoirs 53

2.7 Responsibility of governments to develop laws governing abattoir operations 54

2.8 Good manufacturing practice for abattoir 58

2.9 Hazard analysis at critical control points (HACCP) 59

2.10 Summary 63

3 MATERIALS AND METHODS 64

3.1. Study abattoirs 64

3.2 Data collection 65

3.2.1 Data collected on abattoirs operations, facilities and management system practiced 65

3.2.2 Data on carcass quality and yield at local abattoirs 65

3.2 .3 Data on carcass, meat yield, meat cuts and quality from selected cattle breeds at export abattoirs 66

3.2.4 Data on condemnations of carcasses and organs at local and export abattoirs 67

3.3 Statistical analysis 68

4 ABATTOIRS OPERATIONS, FACILITIES AND MANAGEMENT IN ETHIOPIA 70

4.1 Introduction 70

4.2 Results 71

4.2.1 Capacity, end product and working time of public and private abattoirs 71

4.2.2 Facilities available at public and private abattoirs 72

4.2.3 Inspection, recording, weighting and grading practices at public and private abattoirs 74

4.2.4 Bleeding, evisceration, flaying hides, processing and transport of carcass 75

4.3 Discussion 77

4.4 Summary 83

5 SURVEY ON BEEF CARCASS PRODUCTION AND QUALITY IN ETHIOPIA 84

5.1 Introduction 84

5.2 Results ... 85

5.2.1 Carcass yield difference between abattoirs, season, conformation, fat grades and categories of cattle ... 85

5.2.2 Percentage of different conformation, fat grades and categories of cattle ... 87

5.2.3 Conformation and fat grades of carcasses at local abattoirs ... 89

5.2.4 Conformation and fat grades of carcasses in wet and dry seasons ... 91

5.2.5 Conformation and fat grades in different categories of cattle ... 93

5.2.6 Correlation and regression between conformation, fat and carcasses weight ... 95

5.2.7 Heart girth, backbone weight, estimated live weight and dressing percentage ... 96

5.2.8 Mud contamination score of cattle slaughtered at local abattoirs ... 97

5.2.9 Length of horns of cattle slaughtered local abattoirs ... 98

5.2.10 Coat color of cattle slaughtered in Adama, Hawassa and Mekelle abattoirs ... 98

5.3 Discussion ... 99

5.4 Summary ... 106

6 CARCASS YIELD TRAITS OF SELECTED CATTLE BREEDS IN ETHIOPIA ... 107

6.1 Introduction ... 107

6.2 Results ... 108

6.2.1 Factors affecting live weight, carcass weight and dressing percentage ... 108

6.2.2 Prediction of warm carcass weight from live weigh of cattle ... 111

6.2.3 Meat yield and yield percentage ... 112

6.2.4 Prediction of meat yield from carcass and live weight ... 113

6.2.5 The weight of primal meat cuts ... 113

6.2.6 Meat yield predicted from meat cuts ... 114

6.2.7 Carcass pH of cattle slaughtered at Abergelle export abattoir ... 115

6.3 Discussions ... 116

6.4 Summary ... 122

7 CAUSES OF CONDEMNATIONS OF CARCASSES AND ORGANS OF CATTLE SLAUGHTERED AT LOCAL AND EXPORT ABATTOIRS IN ETHIOPIA ... 123

7.1 Introduction ... 123

7.2 Result ... 124

7.2.1 Causes of condemnations whole carcasses ... 124

7.2.2 Causes of condemnations of partial carcasses ... 127

7.2.3 Causes of condemnations of livers ... 127

7.2.4 Causes of condemnations of lungs ... 129

7.2.5 Causes of condemnations of kidneys ... 132

7.2.6 Causes of condemnations of hearts ... 132

7.2.7 Causes of condemnations of tongues ... 133

7.2.8 Causes of condemnations of spleens ... 133

7.2.9 Causes of condemnations of heads ... 134

7.2.10 Causes of condemnations of intestine ... 134

7.2.11 Economic analysis of condemned organs ... 134

7.3 Discussion ... 136

7.3.1 Condemnations of whole carcasses ... 136

7.3.2 Condemnations of partial carcasses ... 136

7.3.3 Condemnations of livers ... 137

7.3.4 Condemnations of lungs ... 138

7.3.5 Condemnations of kidneys ... 139

7.3.6 Condemnations of hearts ... 139

7.3.7 Strategies to minimize commen causes of condemnations of carcasses and organs ... 140

7.4 Summary ... 144

8 CARCASS QUALITY AUDIT - A STRATEGY TO IMPROVE THE BEEF SECTOR IN ETHIOPIA 145

8.1 Introduction 145

8.2 Establishing beef carcass quality audit in Ethiopia 145

8.3 Summary 149

9 CONCLUSIONS AND RECOMMENDATIONS 150

9.1 Conclusions 150

9.2 Recommendations 154

LIST OF REFERENCES 156

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

List of tables

Table 2.1 Principal component of selected beef classification and grading schemes in selected countries around the world 16
Table 2.2 Characteristics and description beef carcass classification system in Ethiopian 19
Table 2.3. The control points, requirements and inspections for good manufacture practice 60
Table 2.4 Principles of Hazard analysis and critical control points (HACCP) 61
Table 3.1 Description of study abattoirs 65
Table 4.1 Capacity, end product and working time of public and private abattoirs 72
Table 4.2 Facilities available at public and private abattoirs 72
Table 4.3 Inspection, recording, weighting and grading practices at public and private abattoirs74
Table 5.1 Carcass yield difference between abattoirs, season, conformation grades, fat grades and categories of cattle 86
Table 5.2 Conformations grades of carcasses at local abattoirs 90
Table 5.3 Fat grades of carcasses at local abattoirs 91
Table 5.4 Conformation of carcasses in the wet and the dry season 92
Table 5.5 Fat grades of carcasses in the wet and the dry seasons 93
Table 5.6 Conformation grades of different categories of cattle 94
Table 5.7 Fat grades of different categories of cattle 95
Table 5.8 Correlation between conformation, fat grade and carcass weight 95
Table 5.9 Prediction of carcasses weight from conformation and fat grades 96
Table 5.10 Heart girth, backbone weight, estimated live weight and dressing percentage 96
Table 5.11 Pearson correlation between heart girth, backbone and carcass weight 97
Table 5.12 Prediction of carcass weight from backbone weight and heart girth 97
Table 5.13 Mud contamination score of cattle slaughtered at local abattoirs 98
Table 5.14 Length of horns of cattle slaughtered at local abattoirs 98
Table 5.15 Coat color of cattle slaughtered at local abattoirs 99
Table 6.1 Live weight, carcass weight and dressing percentage of cattle slaughtered at Abergelle and Melgawendo abattoirs 108
Table 6.2 Regression equation of warm carcass weight on live weigh of cattle 112
Table 6.3 Effects of breeds and season on meat yield and meat yield percentage 112
Table 6.4 Meat yield prediction from carcass and live weight of cattle 113

Table 6.5 Weight of major primal meat cuts of Arado, Barka, Raya and nondescript breeds ... 114
Table 6.6 Predicting meat yield from meat cuts of cattle 115
Table 6.7 The pH of beef at Abergelle export abattoir 115
Table 6.8 Effect of year and season on pH of beef at Abergelle export abattoir 116
Table 7.1 Causes of condemnation of whole, partial carcass and organs of cattle during the study period 125
Table 7.2 Chi-square test for causes of condemnations of carcasses and organs by years, abattoirs and season 128
Table 7.3 Condemnations of whole, partial carcasses and organs at abattoirs studied in the dry and the wet seasons 130
Table 7.4 Financial loss due to condemnations of carcass and organs at ElforaKombolcha abattoir 135

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

List of figures

Figure 2.1 Loading cattle on ISUZU truck at Harobake market, Borana 24
Figure 2.2 Bull jamping from ISUZU truck at Harobake market, Borana 25
Figure 2.3 Transporting cattle using ISUZU truck 26
Figure 2.4 Pictures of some cattle breeds in Ethiopian.. 51
Figure 2.5 Mini slaughterhouses for cattle with space 8 x 6 m 53
Figure 2.6 Lay-out plan for medium-scale cattle slaughter line 54
Figure 2.7 Medium size cattle abattoir including refrigeration section 55
Figure 3.1 Physical locations of study abattoirs 64
Figure 4.1 Lairrage: Elfora-Kombolcha(left), Adam (middle) and Hawassa (right).................. 73
Figure 4.2 Stunning box at ElforaKombolcha (left), Mekelle (middle) and Adama (right)......... 73
Figure 4.3 Stunning using sharp knife at atlanto-occipital space at Kombolcha (left) and Adama (right) abattoirs 74
Figure 4.4 Sticking of cattle at Kombolcha (left) and Adama (right) abattoir 75
Figure 4.5 Carcass processing at Mekelle (left), Kombolcha (middle) and Adama (right) abattoir 76
Figure 4.6 Vehicle (left) and carcass suspended in the vehicle for transport to butcheries (middle and right) 76
Figure 4.7 Dehorning using axe 76
Figure 5.1 Percentage and carcass weights in different conformation grades 87
Figure 5.2 Percentage and carcass weight in different fat grades 87
Figure 5.3 Carcass weight affected by fat and conformation with in fat grade 88
Figure 5.4 Conformation by fat with in carcass weight 89
Figure 5.5 Precentage and carcass weight of different categories of cattle 89
Figure 5.6 Pictures on cattle slaughtered at Adama abattoir 99
Figure 5.7 Pictures on cattle slaughtered in Hawassa abattoir.. 100
Figure 5.8 Pictures on cattle slaughtered at Kombolcha abattoir 101
Figure 6.1 Frequencies of live weight of cattle slaughtered at Abergelle and Melgawendo abattoirs 109
Figure 6.2 Propotion of breeds of cattle slaughtered at Abergelle and Melgawendo abattoirs .. 110

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Figure 6.3 Frequencies of dressing percentage of cattle slaughtered at Abergelle and Melgawendo abattoirs 111

Figure 7.1 Trend in organs condemntion in Elfora Kombolcha abattoir from 2010-2013......... 135

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

CHAPTER 1

1 INTRODUCTION

1.1 Project theme

Quality, yield and condemnations of carcasses

1.2 Project title

Beef carcass quality, yield and causes of condemnations of carcasses in Ethiopia

1.3 Aim

The aims of this study were to:

- Evaluate abattoir operations, facilities and management in public and private abattoirs
- Evaluate carcasses yield and quality of cattle slaughtered at local abattoirs in Ethiopia
- Evaluate the carcass, meat yield and meat cuts of cattle slaughtered at export abattoirs in Ethiopia.
- Determine the causes of condemnations of carcasses and organs at local and export abattoirs in Ethiopia and analyse economic loss due to condemnations
- Suggest possible improvement strategy to sustain the quality, consistency and competitiveness of the country in beef industry.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

The following objectives were investigated, namely whether or not:

1) operations, facilities and management differ between abattoirs.
2) conformation and fat grades differ between abattoirs, season and categories of cattle slaughtered at local abattoirs in Ethiopia.
3) live weights, carcass weights, dressing percentage and meat yield differ between abattoirs, season and breeds of cattle slaughtered at export abattoirs in Ethiopia.
4) primal meat cuts of cattle differ between breeds.
5) causes of condemnations of carcasses differ between years, abattoirs and season.

1.4 Motivation

Livestock plays an important role in the agriculture of Ethiopia. It contributes 15 to17 % of GDP and 35 to 49 % of agricultural GDP, and 37 to 87 % of the household incomes (CSA, 2008). Cattle contribute about 80% of GDP that come from livestock (Tefera, 2011). The meat and livestock sector in Ethiopia contribute 14 % to national exports (Jan Nell, 2006).

The population of cattle in Ethiopia was about 53.4 million (CSA, 2010/11). The majority (99.26 %) of the cattle population are local breeds. Cross-bred and pure exotic cattle account for about 0.64 and 0.1 %, respectively (CSA, 2010/11). There are 33 recognized indigenous cattle breeds in the country (DAGRIS, 2011). Although Ethiopia owns large numbers of cattle population, its potential has not been fully utilized. Meat consumption was about 8 kg per capita per year (Sebisbe, 2008) of which about 4.3 kg comes from beef. Beef consumption has been growing at a rate of 2.25 % per year. Beef production per head of cattle was about 108 kg. The total quantity of beef produced in 2004 and 2008 was estimated at 294,336 and 380, 000 tons, respectively (Negassa *et al.,* 2011).

Middle East and North African countries are potential market to export livestock and meat product (NEPAD–CAADP, 2005). Geographical proximity to Egypt and the Gulf region compared to major meat suppliers to the region such as Brazil, India, Pakistan, Australia and New Zealand is one of the advantages (SPS and LMMP, 2010). The annual demand of meat by these regions was estimated about 206,846 tones. However, Ethiopia has exported only 16, 877 MT of meat to this region in 2010/11 (SPS-LMM, 2011). Feedback from importing countries revealed that they were not satisfied with the quality of meat imported from Ethiopia (Farmer, 2010). Contamination, dark cutting, sanitation, careless packing, post slaughter carcass handling, lack of continuous supply were reported as some of the problems (Anon, 2006). Farmer (2010) reported the unreliable continuous supply and low quality of meat as key factors hindering Ethiopia's competitiveness in the region.

Ethiopia has imported significant amount of meat from USA, United Arab Emirates, Italy, Netherlands, China and South Africa. One of the main reasons given by meat importing firms in Ethiopia for importing meat from other countries was the unavailability of higher quality meat in domestic markets (SPS and LMMP, 2010). This indicated that the meat produced in Ethiopia was not guaranteed the quality requirement of domestic consumers. The level of condemnations of carcasses and organs affect the quality and monetary value of carcasses directly or indirectly. Some studies conducted in Ethiopia indicated that large number of organs of cattle were condemened during slaughter (Asseged *et al.,* 2004; Megersa *et al.,* 2010; Abunna *et al.,* 2012;

Aragaw *et al.,* 2012; Mesele *et al.,* 2012; Terefe *et al.,* 2012; Assefa and Tesfay, 2013; Mulatu *et al.,* 2013).

Very little research has been done concerning carcass quality of beef in Ethiopia (Negash *et al.,* 2008). Moreover, few carcass traits were evaluated separately in different studies. Rib eye area of Boran and Kereyu breeds were reported as 223.17 and 173.50 mm^2, respectively. Fat thicknesses for the two breeds were reported as 4.25 and 3.25 mm, respectively (Negash *et al.,* 2008). In a study in the Northern part of Ethiopia, 43.37% of carcass sample contained slight marbling, 42.17% had moderate marbling and 14.46% had moderately abundant marbling which corresponded to the select, choice and prime categories of USDA beef grades (Kumar *et al.,* 2010). Most studies done on carcass quality used USDA grading system. However, USDA grading system was developed for cattle finished on feedlot. Steers and heifers are the only type of animals considered for top quality beef in this system. Most countries in Africa, Asia and Europe use classification system. Taking in to account these entire situations Ethiopia has developed a beef carcass classification system in 2012 (ES, 2012). The classification system is structured per animal categories, conformations and fat grades. Even though Ethiopia has developed beef carcass classification system recently (ES, 2012), the system was not used to characterize the carcass quality to date. Little information available on carcass quality and yield was based on slaughter of cattle at research station after fattening experiments. There was no documented information on carcass yield traits of cattle slaughtered at abattoirs in Ethiopia. Moreover, meat yield and meat cuts of cattle breeds were not evaluated in the country before. Eventhough a number of studies were conducted on the causes of condemnations of organs (Asseged *et al.,* 2004; Megersa *et al.,* 2010; Abunna *et al.,* 2012; Aragaw *et al.,* 2012; Mesele *et*

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

al., 2012; Terefe *et al.,* 2012; Assefa and Tesfay, 2013; Mulatu *et al.,* 2013), little work was done on causes of condemnations of whole and partial carcasses at abattoirs in Ethiopia. Moreover, most research conducted on condemnations of organs used data collected for few numbers of months on specific abattoir.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

CHAPTER 2

2 LITRATURE REVIEW

2.1 Beef industry and constraints in Ethiopia

2.1.1 Role of cattle in the economy of Ethiopia

Ethiopia ranks first in Africa and tenth in the world with respect to livestock population (Tolera, 2006). Livestock plays an important role in the agriculture of Ethiopia. It contributes 15 to17 % of GDP and 35 to 49 % of agricultural GDP, and 37 to 87 % of the household incomes (CSA, 2008). Cattle contribute about 80% of GDP that come from livestock (Tefera, 2011). The meat and livestock sector in Ethiopia contribute 14 % to national exports (Jan Nell, 2006). Ethiopia has 53.4 million cattle (CSA, 2010/11). The majority (99.26 %) of the cattle population are local breeds. Cross-bred and pure exotic cattle account for about 0.64 and 0.1 %, respectively (CSA, 2010/11). There are 33 recognized indigenous cattle breeds in the country (DAGRIS, 2011). Although Ethiopia owns large numbers of cattle population, its potential has not been fully utilized. Meat consumption was about 8 kg per capita per year (Sebisbe, 2008) of which about 4.3 kg comes from beef. Beef consumption has been growing at a rate of 2.25 % per year. Beef production per head of cattle was about 108 kg. The total quantity of beef produced in 2004 and 2008 was estimated 294,336 and 380, 000 tons, respectively (Negassa *et al.,* 2011).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

2.1.2 Cattle production system

Livestock is produced under two major production systems in Ethiopia.These are sedentary mixed crop-livestock production system and the nomadic pastoral or agro-pastoral production system (Negassa *et al.,* 2011). The highland crop- livestock mixed farming system covers about 40 % of the total land surface of the country and is located 1500 m above sea level. Pastoral and agro pastoral area account for 60% of the total surface area and is located below 1500 m above see level (Halderman, 2004). Livestock are kept for multiple purposes such as draft power, milk, meat, skin and hides. They are also the main sources of income and are closely linked to the social and cultural lives of the community. The highland area is characterized by a mixed farming system where crop cultivation and livestock production are undertaken side-by-side complementing each other. In this system, livestock is primarily kept by small holders where it provides draught power for crop production, manure for soil fertility, animal product for family consumption and source of cash income. Livestock production is a means to accumulate assets aimed for protection against risk serving the role of a bank. It is a means of investment in traditional security system by which bride price would be paid with. The majority of the animals sold for beef purpose are old draft cattle and barren cows. Beef is a by –product in the mixed crop-livestock producton system since cattle are primarily kept for traction purposes. Cattle are usually sold when they are too old for draft purpose, due to scarcity of feed or shortages of cash. Oxen are usually sold after finishing with ploughing service when they are old and in poor condition. The exception in this traditional system is the “Hararghe highland fattening system” where cattle are profitably fattened using forages and crop residues. The fattening system in Hararghe highland indicates a scope for improvement of the traditional production system. In lowland area cattle are primarily used for milk purpose. This area has great potential for meat animals. Most of the cattle used for beef purpose come from pastoral and agro-pastoral production system. The presences of diverse agro-ecologies in the country allow different production systems. The presence of different production system will be an opportunity to produce different quality of beef that can answer the different preference of global market (NABC, 2010). These different production systems usually depend up on one another. Pastoral and agro-pastoral system in the lowland areas are source of draft and fattening cattle to the highlands.

The population dynamics of cattle shows that most of cattle were in the age category between 3 and 10 years. Out of 49.3 million cattle population in the country in 2008, 9.4% were under 6 months of age, 8.2% are between 6 months and 1 year, 16.3% are between 1 and 3 years, 62.8% between 3 and 10 years and 3.3% are 10 years and older. Out of the total cattle population, the female cattle constituted about 55.48 % and the remaining 44.52 % were male cattle (Negassa *et al.,* 2011).

The cattle population is primarily indigenous types and have not been adequately characterized. Cattle breed in the country are categorized under tropical Zebu breed. The Boran breed is one of popular breed found in the southern and eastern parts of the country. European breeds, especially Friesian and Jersey, have been imported to urban and peri-urban areas and crossed with the indigenous cattle breeds for dairy purpose. Boran breed from pastoral area and highland oxen are the main source of beef in the country. Livestock holding differ from highland to pastoral areas. On average in the highland, households own 3.7 head of cattle where as pastoral household owns 13 head of cattle (Negassa *et al.,* 2011). Although most livestock found in the highland of

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Ethiopia, 95 % of the livestock supplied for export was supplied by the pastoral and agro-pastoral areas of Afar Regional State, Somali Regional State and Borena area of Oromiya Regional State. A large percentage of live cattle and beef are exported from Borena area (Legese *et al.,* 2008).

In 2007, there were 180 feedlot centers in Oromiya. The centers contain about 20,500 fattening cattle which were mainly introduced from Borena region (Little *et al.,* 2010). Boran cattle are poplar in Ethiopia and the majorities managed in feedlots vary in age between 3 and 4 years of age. They are muscular and capable of producing beef of consistently high quality (Hutcheson, 2006). In most feed lot, older Boran bulls are fattened for domestic consumption. However, the younger bulls are fattened for live export.

The other source of beef is the highland oxen. The Oxen are usually castrated and are used for draft purpose. However, after finishing with the draft purpose, they are marketed for beef purpose at the age of 5-7 years (Hutcheson, 2006).

Feed shortages are often reported as a major constraint to livestock production in Ethiopia. In the highlad part of the country, natural pasture is the main source of feed for most livestock, complemented by fodder and crop residues during the dry season. Cattle graze on natural meadows, fallow, marginal lands and crop residue. Grazing area is very limited in this part of the country. In pastoral area the main source of feed are natural pastures which are affected by rainfall (Tolera and Abebe, 2007). Productivity of the range land was about 0.15 ton per hectare (Halderman, 2004). The land in the pastoral areas usually belongs to community as a whole and

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

utilized according to the long-standing tradition. Over exploitations of land has left sparse vegetations, shrubs and trees on the ground for the livestock. In pastoral areas, lack of feed and water during the dry season and occasional drought were the main constraint affecting livestock production. Shortage of rain and recurring drought were commen phenomenon. Moreover, shortage of feed, water and the harsh climatic condition seriously affect the health and productivity of animals in the region (Tolera and Abebe, 2007).

2.1.3 Oppertunities and constraints for beef market

The world demand for beef is expected about 316 million metric tons in 2015. In 2005, the Gulf region including Egypt imported 72,000 MT carcass weight equivalents (cwe) of fresh and chilled beef valued at over $186 million. Moreover, they have imported 230,000 MT cwe of frozen bone-in and boneless beef valued at over $332 million. Ethiopia's share of boneless chilled beef to this region was equivalent to 720 MT cwe at a value of $2,583 and 2,300 MT cwe of frozen beef at a value of $1,442/MT). Egypt is by far the largest market for beef in the region. It imported more than 250,000 MT of beef from different countries in 2007. From July 2005 to April 2006, Ethiopia exported 864 MT of meat (valued at $1.49 million) to Egypt. This represents 12 % of Ethiopia's meat exports, but less than 1 % of Egypt's meat imports. Saudi Arabia also imports about 74,000 MT in year 2005-2007 from different countries and is also an important target market (Farmer, 2010). From 2000 to 2004, Dubai imported livestock and livestock products worth $2.24 billion. However, only 0.01- 0.12 % of this import came from Ethiopia (Anon, 2006). A significant proportion of the beef sold in Bahrain comes from cattle imported from Djibouti and Berbera port in Somalia (Sullivan, 2007).

The domestic demand for beef in Ethiopia has been rising due to population growth, urbanization and income growth. Total consumption of beef is estimated at 298,000 MT in 2002. Consumption has been growing at a rate of 2.6% per year from 1993 to 2000. Ethiopia imported about 100 tons of meat paying around 5 millions ETB during the years of 2005-2009. Beef was the most imported meat type (31%) followed by offal (25%), pork (21%), poultry meat (15%) and mutton (3%). USA was the leading meat exporter to Ethiopia (28%) followed by UAE (25%) and Italy (10%; Sullivan, 2007).

Ethiopia has good opportunity to increase its market share to the Gulf region. Even though the country has the comparative advantage due to geographical proximity to Middle East beef market, the high rate of carcass rejection by the region because of low quality of the product was implicated in impairing competitiveness of the country (Farmer, 2010).

The other major constraint in marketing livestock product was the absence of market oriented production system with the majority of small holder farmers. Farmers do not sell their product based on the demand of the market. About 75 % of farmers in mixed crop-livestock production system sale oxen because of old age. In pastoral society, owning large number of animal give individuals prestige in the society. Hence pastorals prefer to manage large size of herd irrespective of their productive. Farmers sale animals when needs for cash arise, fear of theft and scarcity of feed. A significant proportion of smallholder farmers in the highland and pastoralists in the lowland do not participate in livestock markets. For those who participate, the volume of transactions was very low (Legese, *et al.,* 2008).

Absence of uniform market chain was the other constraints which affect marketing of livestock in Ethiopia. The market system can be generally classified as primary, secondary and terminal markets. Those markets can be categorized based on the number of animals marketed per a day. In these markets less than 500, 500-1000, and greater than 1000 cattle are presented per day, respectively. In terms of market participant, primary markets are those in which the main sellers are producers and the main buyers are local assemblers. Secondary markets are those in which the main sellers are local assemblers and main buyers are big traders. In terminal market the main sellers are traders and main buyers are butcheries and restaurants (Legese *et al.,* 2008). Most of the pastoralists and highland farmers sell their livestock to small traders in primary markets. Animals are traded based on estimated weight by visual observation. Weight scales are not in used for the transaction.The small traders trek the livestock to larger traders (CARE International Kenya, 2010). Brokers are major actors in many livestock markets in Ethiopia. They act as intermediary price negotiators between buyer and seller. They offer services of holding grounds for animals of small farmers that are not sold on the market day. Livestock marketing cooperatives and Trade Share Company such as Utuba Gumi International (UGITSC) is becoming important trade rout in the country these days (Hurrissa, 2009). Feedlots, abattoirs and live animal exporters purchase livestock in secondary markets either through their agents or from traders and occasionally from cooperatives (Saperstein and Farmer, 2006). Some times agents from importing countries were seen buying live animal from primary and secondary markets directly (Legese, *et al.,* 2008).

Feedlot owners fatten young animals and sale to export abattoirs. Old animals were usually marketed for the domestic slaughter. Feedlot owners show a strong preference for Boran cattle due to its large size, efficient feed conversion ability and superior meat quality (Legese *et al.,* 2008). The prices paid by feedlots to pastoralists/traders is low in opposite to the market in developed country, where the producer obtains a price premium per kg for the young animal and the feedlot makes its profit on the cost of gain (Farmer, 2010).

Seasonality of demand for livestock and livestock product was observed in the Middle East market. Each year 1-2 million head of animals slaughtered during the three-day Eid al-Adha celebration in Islamic month Hajj. The Hajj period therefore corresponds to a dramatic peak in demand. The domestic market is also affected by fasting and feasting period of Orthodox Christian and Muslim religion followers in the country. In the Orthodox calendar, there are 207 days of fasting per year where the followers of the religion fast from all animal products. During this period, the demand for meat decreases significantly and many butcheries are closed. During celebration of festival for Muslims and Christians, the demand for the meat reach peak in the country (Legese, *et al.,* 2008).

The policy of the Government of the Federal Democratic Republic of Ethiopia support livestock development and export of meat. The policy recognized livestock as one of the key economic resources of the country. The policy encourages meat and live animal export (Rich *et al.,* 2008). In 2006, 12,000 tons of meat was exported, primarily as chilled sheep and goat carcasses. The goal was to increase the export of ruminant meat to 30,000 metric tons by 2008 which was not achieved. This increase in ruminant meat exports cannot be sustained from sheep and goats only. Therefore, to meet the goal, more beef will have to be exported. It is estimated that the beef exports need to increase as much as 20,000 metric tons per year (Hutcheson, 2006).

2.2 Carcass quality

Evaluation of carcass and meat quality is an important practice in the meat marketing at national and international level (Lazzaroni, 2007). Interest and question about quality of beef are on the rise due to increase in awareness about the marketing of beef, from procurement and processing to consumer acceptance. Producers are now beginning to receive information about quality of beef they produce. Consolidation among beef market resulted in better communication between marketers and producers on carcass quality. This has made the producers to get monetary incentives for improving beef quality. New marketing structures such as vertical integration and value based marketing provided direct financial rewards to cow-calf producers who offer more desirable carcasses (Drake, 2004). Improving quality of carcasses begins with understanding the targets of industry for carcass traits. These target includes increasing/decreasing the degree of fatness, increasing degree of conformation, elimination of bruises, injection site lesions, dark cutter, and condemnations of organs. The USDA and EU grading scheme are two predominant schemes to evaluate qualities of carcasses globally. USDA grading scheme evaluate carcass based on class of animals (steer bullock, bull, heifer, cow), maturity (meat color and texture), quality grade (Prime, choice, Select, Standard, Commercial, Utility, Cutter, Canner) and yield grade. EU grading system (SEUROP) evaluate carcass based on class (calf, young bull, bull, steer, heifer, cow), conformation grade (six levels), fat grade (five levels) and meat color for veal (Fisher, 2007).

In general, key parameters in grading carcass included carcass weight, age or maturity of the animal (often using dentition or ossification as a proxy for age), sex, fat cover and color, conformation and freedom from bruising and blemishes. Depending upon the country, marbling and lean color and/or texture have often been added as quality traits. Those schemes with a yield component also included other measurements of fatness (internal fat scores, rib or rump fat thickness) or muscling (rib eye area, carcass conformation). These parameters remain relevant and are in use today in most beef grading schemes. The uptake of grading by sectors of the industry depends on accuracy, simplicity, ease of application, cost and ease for monitoring or verification (Strydom, 2011).

The grading method practiced in different countries varies depending on the objectives of the system and on the degree of uniformity that exists among types and species of animals. The USA and Australia use a grading system based on marbling, age and sex of slaughter animals. In South Africa, the grading system is based on external fat covering and age of the animal. EU carcass classification scheme have focused more on yield (AHDB Industry Consulting, 2008). AUS-MEAT and MSA are the only systems using pre-slaughter criteria, while the other grading performs measurements on the slaughter floor. Chiller assessments are used by all but the SEUROP and SA systems. The MSA system performs post-chiller assessments. Conformation, shape or rib eye area (REA), some form of fat measurement, carcass weight and sex are common criteria for all systems and are recorded on the slaughter floor and/or during chiller assessment (Table 2.1).

In South Africa beef description systems have evolved over a long period. Carcass grading system was used from 1932 to 1985. The grading system was replaced by carcass classification system in 1992. The change in the system was aimed to describe carcasses in more objective terms which allowed buyers to select their ideal article for a purpose rather than impose a universal hierarchical grade structure (Anon, 2005). The South African system classifies carcasses into four age categories derived from dentition denoted as A (no permanent incisors), AB (1–2 permanent incisors), B (1–6 permanent incisors) and C (greater than six permanent incisors). Bulls in age category B or C are noted and denoted MD. Seven fat classes denoted as numerals from 0 (no visible fat) to 6 (excessively fat) are added to the age cypers and the combination applied as a colored roller brand to carcasses after classification. Colors (purple for A, green for AB, brown for B, red for C and black for MD) represent the age in classification. Five numerical conformation classes - 1 (very flat), 2 (flat), 3 (medium), 4 (round) and 5 (very round) are also designated together with three damage codes of 1 (slight), 2 (moderate) and 3 (serious) where applicable (Anon, 2006b).

Table 2.1 Principal component of selected beef classification and grading schemes in selected countries around the world

Scheme	**Canada**	**SUROP**	**Japan**	**Korea**	**S. Africa**	**USDA**	**Aust-Meat**	**Meat Standard**
Grade Unite	Carcass	Carcass	Carcass	Carcass	Carcass	Carcass	Carcass	Cut
Classification	--	Yes	--	--	Yes	--	Yes	--
Quality grade	Yes	--	Yes	Yes	--	Yes	--	Yes
Yield grade	Yes	--	Yes	Yes	--	Yes	--	--
Pre-slaughter	--	--	--	--	--	--	Grain fed	Bos indicus % HGP implant
Slaughter floor	Carcass wt Sex Conformation	Carcass wt Sex Fat cover Conformation.	Carcass wt Sex	Carcass wt Sex	Carcass wt Dentition Fat cover Conformation Sex	Carcass wt Sex	Carcass wt Sex Dentition But shape P8 fat	Carcass wt Sex Electric stimulation Hang
Chiller	Marbling score Meat core Meat texture Fat color Fat thickness Skeletal development	--	Marbling Meat color Meat brightness Fat color Fat lust Fat texture Fat firm EMA Rib thickness Fat thickness	Marbling score Meat color Fat color Firmness Meat texture Lean maturity EMA Fat thickness	--	Marbling Ossification Meat color Meat texture Rib fat EMA Kidney and perennial fat	Marbling Meat color Fat color	Marbling Ossification Meat color Hump height Ultimate pH
Post chiller	--	--	--	--	--	--	--	Aging time Cooking method

(Strydom, 2011)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Classification is a set of descriptive terms describing features of the carcass that are useful as guidelines to those involved in the production, trading and consumption of carcasses, whereas grading is the placing of different values on carcasses for pricing purposes, depending on the market and requirements of traders and consumers. Criteria used in grading systems rank carcasses fairly accurately according to expected eating experience of muscles. Criteria used in classification systems give limited descriptions of the quality related characteristics of the carcass (Strydom, 2011).

USDA grading system was developed for cattle finished in feedlots. Marbling and age of cattle are the major parameters used to determine quality of carcass. Steers and heifers are the only type of animals considered for top quality beef in the system (ZoBell *et al.,* 2005).

Most Asian and European countries use classification systems instead of grading system. Middle East countries are the potential market for meat produced in Ethiopia. Hence the development of a carcass classification system instead of grading by the Ethiopian standard agency was the appropriate choice. Ethiopia has developed a beef carcass classification system in 2012 which is a modification of the SEUROP classification system (ES, 2012). The Ethiopian classification system is structured per animal categories, conformation and fat grade (ES, 2012; Table 2.2).

Carcass quality of beef cattle was evaluated at interval of years in USA, Canada and Europe. The national beef quality audit in USA in 2011 revealed that 25.0% carcasses were yield grade 1, 46.5% of carcasses were yield grade 2, 23.0% of carcasses were yield grade 3, 4.6% carcasses were yield grade 4 and 0.9% of carcasses were yield grade 5. The quality grade was reported as

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

2.1% of carcasses were prime, 58.9% of carcasses were choice, 32.6% of carcasses were select, 5.1% of carcasses were standard, 0.9% of carcasses were commercial and 0.3% carcasses were utility (Savell *et al.,* 2011). The Canadian national beef quality audit conducted in 2010/2011 revealed that 52.4% of carcasses were yield grade 1, 33.5% carcasess were yield grade 2 and 14.2% of carcasses were yield grade 3. The quality grades of cattle were 1.2% Prime, 52.5% AAA, 43.4% AA, and 2.8% A (NBQA, 2010/2011). Survey on beef carcass quality in Mexico revealed that 82% of the carcasses varied from poor to good in conformation and only 17.8% carcasses was the excellent in conformation. The KPH (kidney, pelvic and heart fat) was about 2%, the subcutaneous fat depth was 1 cm, longissmus muscle area (LMA) was 80 cm^2, carcass maturity score was USDA B100, 93.6% of the sample had marbling scores of slight, practically devoid, or traces, 87.1% the fat coverwas white or beige. The backfat layer was uniform in43.2% of the carcasses, where as 55.9% had an uneven fat cover (Mendez *et al.,* 2009). National grading of quality of carcasses of beef and veal in Romania revealed 48.56% and 48.97 carcasses were class O and P conformation grades based on EUROP classification system. Only 2.40% carcasses accounted for conformation grade R. The 1^{st}, 2^{nd},3^{rd}, 4^{th} and 5^{th}fat subclass accounted for 60%, 28.77% , 9%, 1.87% and 0.72% carcasses with a mean weight of 180.95, 224.71, 270.66, 298.11and 311.35 kg/carcass, respectively. In these subclasses the class O represents the major proportion of carcasses (Petroman *et al.,* 2009). In Italy, conformation class U, E and Prepresent 38.37%, 28.92% and 18.15% of carcasses evaluated. The rest conformation class R, O and S were 6.34%, 5.03% and 3.22%, respectively. Moreover, fat class 2 represents majority of carcasses evaluated (86.35%; Lazzaroni and Biagini, 2009).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Few carcass traits evaluated in Ethiopia revealed that rib eye area of Boran and Kereyu cattle were 223.17 and 173.50 mm^2, respectively. Moreover, the fat thicknesses for the two breeds were 4.25 and 3.25 mm, respectively (Negash *et al.,* 2008). Rib eye area of Borana bulls was in the range of 155.7 to 265 mm^2 (Lemma *et al.,* 2007). In a study in the Northern part of Ethiopia, 43.37% of carcass sample contained slight marbling, 42.17% had moderate marbling and 14.46% had moderately abundant marbling which corresponded to the select, choice and prime categories of USDA beef grades (Kumar *et al.,* 2010).

Table 2.2 Characteristics and description beef carcass classification system in Ethiopia

Conformation		**Grade**
	Carcasses with convex profiles and very well developed muscle	1
	Carcasses with straight profiles and good muscle development	2
	Carcasses with concave profiles and moderate muscle development	3
Fat		**Grade**
	Carcasses with little or no fat coverage	1
	Carcasses with visible fat on the whole body except the hind leg and shoulder	2
	Whole carcasses covered with fat and fat deposited in the thoracic cavity	3
Descriptions		**Categories**
	Carcass of young bull or heifers that weight less than 70 kg	JB
	Carcasses of growning bulls (cartilage of the spine up to four thoracic vertebras show no sign of ossification and from fifth to ninth show sign of ossification; discs of inter-vertebral of sacral vertebrae show sign of ossification)	JM
	Carcasses of mature intact bulls	M
	Carcasses of castrated bulls	O
	Carcasses of heifers	JF
	Carcasses of cows	F

(ES, 2012)

2.2.1 Factors affecting carcass quality

Carcass quality can be affected by many factors such as pre-slaughter animal handling, methods of slaughtering and post carcasses handling. Poor carcass quality will be reflected in poor meat quality and possibly poor appearance. Improper handlings of animals yield poor quality meat.

Poor quality meat will have poor processing properties, functional quality, eating quality and less likely to be accepted by consumers (Adzitey and Nurul, 2012).

2.2.1.1 Pre-slaughter animal handling

Pre-slaughter animal handling starts from the farm (medication, veterinary inspection, feeding, provision of water, loading), then to marketing (transportation, selling) and end up in the abattoir (off loading, lairaging, veterinary inspection and slaughtering). During these processes, animals can be exposed to stimuli like human contact, transport, unfamiliar environments, food and water deprivation, changes in social structure and changes in climatic conditions (Ferguson and Warner, 2008). These stimuli disturb homeostasis and trigger animal response. The perceptions of stress and degree of response varied from individual to individuals (Moberg, 2001). They are modulated by several intrinsic factors such as genetics, sex, age and physiological state, and extrinsic factors such as past experiences and acquired learning (Hemsworth and Barnett, 2001; Moberg, 2001). Because of stress created from farm to abattoirs, animals may experience fear, dehydration, hunger, hyper activation, fatigue and physical injury. The inability to adequately stabilize these states may invoke further psychological distress. All these consequences of stress end up in affecting quality of meat. Females and young animals are more susceptible to stress compared to males and older animals (Ferguson and Warner, 2008). Stress is the inevitable consequence in the process of transferring animals from farm to slaughter. The effects of chronic stress on muscle glycogen depletion and the consequent dark cutting condition have been well documented (Ferguson and Warner, 2008). All meat animals experience some level of stress prior to slaughter and this in turn, may have significant effects on meat quality. The effects of stress on the quality of meat depend on the type, duration and intensity of stress (Ferguson *et al.,* 2001). Reduction in the live weight and carcass yield of animals are the other effect of pre-slaughter animal handling. Reduction in live weight might be due to deprivation of food and water. Deprivation of food and water reduce the gut fill there by increasing breakdown of muscle glycogen for energy. Of all the pre-slaughtering stress, transportation stress appeared the most common. During transportation, animals can do little to help themselves to be free from discomfort compared to freedom of movement in farms, markets and lairage (Warriss, 2000). Conditions such as dehydration, injury, suffocation, heat or cold stress, overcrowding and death can result from transportation.

One of the most effective means of minimizing stress is to ensure that the animal handling facilities enable smooth and efficient movement of animal (Grandin, 2003). Selection for cool temperament of animal reduce stress based defect of meat quality creating safe condition for handlers. There is evidence that temperament is correlated with physiological measures of stress and incidence of dark cutting in cattle (Fell *et al.,* 1999; King *et al.,* 2006). This leads to the conclusion that selection for improved temperament reduces magnitude of the stress. This in turn reduces stress-mediated losses of meat quality (Voisinet *et al.,* 1997).

Improper pre-slaughter handling can result in mortality, low carcass yields, bloodsplash, bruises, broken bones, skin blemishes, contamination by pathogens, pale soft exudes (PSE) and dry firm dry (DFD) meat. Death of animals is the worst effect of pre-slaughter animal handling. Bruising, haemorrhages, skin blemishes, bloodsplash and broken bones are common phenomenon due to improper handling. The skin and the blood vessels of animal affected with these defect accumulate excessive blood which need to be trimmed off during processing. If not trimmed, it will be reflected in poor appearance of the meat and can serve as substrates for microbial growth. Trimming part of the carcass will reduce yield and value of meat. Moreover, it increases processing time and labour cost. Broken bones may cause bone splinters in meat. If split of bone is not detected during deboning, consumer acceptance of the product will reduce (Warriss, 2000). PSE meat looks pale, lean, has soft texture, low water holding capacity and poor functional attributes. DFD meat looks dark, tender, poor functional attributes and prone to spoilage (Adzitey and Nurul, 2011). DFD problem is observed in all species. DFD can be caused by exposing animals for long hours of transportation, deprivation of food and water and overcrowding in the lairage. DFD meats are unattractive and lack acceptability by consumers (Viljoena *et al.,* 2002).

2.2.1.1.1 Marketing of animals

Meat quality is also affected by method of marketing in pre-slaughter handling chain. Animals are either sold at the markets or sent directly from farms to abattoirs. In the markets, they may be kept in groups and in open pens. They might be exposed directly to the sun or cold stimuli. They may encounter stresses such as noise, unfamiliar environment and social regrouping. They can also be starved or dehydrated. Cattle sold through saleyards are typically exposed to longer transport and consequently, longer periods of deprivation of feed before slaughter. Moreover, they are exposed to more size of unfamiliar noise in market place. This might increase the chance of reduction in meat quality. Higher incidence of dark cutting and bruising were reported in saleyard marketing compared to cattle consigned directly to abattoir (Eldridge *et al.,* 1986; Shorthose, 1988). Various degrees of bruising can occur on their skin at the market depending on the way they are handled. McNally and Warriss (1996) reported that the prevalence of bruising varies between 2% and 8% in markets.

2.2.1.1.2 Transportation

Transportation of animal was another factor which affects meat quality. Transportation begins with loading and ends with unloading of animals. Both ought to be done in a gentle manner and under a quiet environmental condition. Careful loading and unloading is suggested for good quality of meat. Over speeding, sudden stops, rapid acceleration and long journey times without appropriate rest should be avoided. Efforts should be made to reduce stress to the minimum. Cattle transported a short distance and slaughtered within 4 hours of leaving feedlot had more acceptable consumer panel scores for tenderness, flavor and juiciness than those traveled long distance and slaughtered after 24 h (Jeremiah *et al.,* 1988). Duration of transport affects quality of meat. Cattle and sheep destined for slaughter should not transported over 10 hours continuously. The influence of transport stress in cattle varies depending on the type of animal and prevailing condition during the journey (Tarrant, 1990). Some reports indicated that transport of cattle less than 400 km is unlikely to affect pH of the meat (Eldridge & Winfield, 1988; Tarrant, 1989). However, when cattle are transported over 2000 km or over 24 h, an increase in pH from 0.1–0.2 units might occur (Tarrant, 1989; Wythes *et al.,* 1981). Knowles et al. (1999) reported small reductions in glycogen concentration in muscles of cattle transported for 14, 21, 26, and 31 hours. Feeding and watering within recommended period during transportation prevent the animals from starvation and dehydration. Overfeeding and watering should also be avoided. Area assigned for each animal during transport affect degree of bruising. Eldridge et al. (1988) reported higher incidence of bruising at space of 0.89 m^2 per animal and lower level of bruising at 1.39 m^2 per animals. Reducing the space allowance per animal resulted in increased heart rate and movement scores (Eldridge *et al.,* 1988). Loading and the initial stages of transport are the most stressful. Once cattle were habituated to transport, their heart rates were only 15% greater than those observed during grazing. After initial stage of loading, animals adapt to the conditions (Pettiford *et al.,* 2008; Warriss *et al.,* 1995).

In many parts of Africa, trekking is the primary means of moving livestock to consumer markets (ILRI, 1995). This makes the level of stress of animals higher. In Ethiopia animals are transported along all the supply chain by trucks that is used to transport goods or by trekking (Dirbaba and Hurrissa, 2009). These trucks are not convenient for loading and unloading animals (Fig. 2.1), they lack shade to protect animals from extreme sun and rains, difficult to provide rest, feed and water during transport (Dirbaba and Hurrissa, 2009).

Figure 2.1 Loading cattle on ISUZU truck at Harobake market, Borana

Loading was carried out without a loading ramp. Beating animals with a stick was common phenomenon during loading on trucks. During transport there have been instance where animals jumping down from the truck (Fig.2.2). Trucking was carried out without maintaining proper space for animals (Fig. 2.3). Once the animals were loaded, they travel long distance without rest, feed and water. The animals were loaded without keeping proper space between animals. This exposed animals to stress, loss of weight, injury and sometimes death. Truck drivers and attendants have no training in animal handling during transport (Dirbaba and Hurrissa, 2009).

Figure 2.2 Bull jamping from ISUZU truck at Harobake market, Borana

In some places in Ethiopia, the producers trek animals for 1-3 hours to arrive at the primary markets. The distance animals were trekked were longer in pastoral region. For instance in Somali, Oromia, and SNNP regions, the pastoralists find markets after traveling 100-300 or more kilometers (LMA, 2001). Interval of the distance at which the producers provide rest, feed and water is determined by availability of feed and water in the premises of trekking routes, which is affected by seasons in which trekking is carried out. Usually, sufficient grass and water is available during wet season, while there is shortage of both during the dry season.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Figure 2.3 Transporting cattle using ISUZU truck

2.2.1.1.2 Lairage

Inspection of the live animal prior to slaughter is an important step in the production of wholesome meat for human consumption. Only in the live animal can abnormalities of posture, movement and behavior be detected. Ante-mortem inspection can improve the efficiency of the operation by screening out a number of animals that would be unfit for consumption. Ante-mortem inspection should include all relevant information from the level of primary production on an ongoing basis, e.g. declarations from the primary producers relating to the use of veterinary drugs and information from official hazard control programs. Ante-mortem inspection should ideally be carried out at the time of the animals' arrival at the slaughterhouse. If it is not possible to carry out inspection at the time of the animals' arrival, an inspection should be carried out within 24 hours after arrival, again to prevent further suffering in the event of a welfare problem. The ante-mortem inspection should also be carried out within the 24-hour period prior to slaughter, as signs of disease may become manifest as time progresses. Where animals remain in the lairage for longer periods of time, they may be inspected more than once. The length of time animals spend in the lairage awaiting slaughter should not exceed 72 hours (FAO, 2004).

Animal welfare can be ensured only if the personnel engaged in slaughterhouses have been correctly trained. Workers should be experienced in the unloading, moving, lairaging, restraining, stunning and bleeding of animals. Correct training must be based on scientific principles and must enable workers to learn and understand the problems of the slaughter process, so that they become fully aware of their duties. Workers should also be instructed on the meaning and importance of the principles of animal welfare on which international and domestic legislation is based. Local authorities should grant a licence to workers who have attained the required qualifications (Cortesi, 1994).

Animals are held temporarily in the lairage prior to slaughter. It serves as a collection point for different animals just before slaughter. It is also a means to provide animals with recovery from transport stress. During this holding time, animal should be observed for any injury or infection. Lairage can be a major source bruise and injury as the animal can fight during this time. It can also act as a source of infection for animal kept for longer period of time (Warriss, 2003). Improper use of electrical goads and beating in the Lairage adversely affect carcass and meat quality (Adzitey, 2011). The application of electric goads to cattle 15 min pre-slaughter was reported to affect the water-holding capacity and the consumer acceptability of the loin muscle (Warner *et al.,* 2007). Cattle and sheep are often washed in lairage to prevent contamination of carcass. Washing elicit a sympatho-adrenal stress response. This in turn was reported as the cause for dark cutting. Exposing lambs to a swim wash for 3 h before slaughter increased the incidence of dark cutting and toughness of the loin muscle (Geesink *et al.,* 2001). In many European countries and in North America it is common to slaughter animals on the day of

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

arrival. In Australia and New Zealand, animals are slaughtered the day after arrival. In the latter countries, the time in the lairage give the animal an opportunity to rehydrate, rest and recover from transport stress. In such circumstance lairage facilities and conditions are expected to be conducive for this to occur. Cattle situated near a noisy environment exhibited more movement than cattle held in quieter locations (Eldridge *et al.,* 1989). Cattle from the ‘‘noisy” pens had higher carcass bruise scores. The time spent in lairage tends to increase the incidence of dark cutting in beef cattle (Warner *et al.,* 1998). But there is little evidence for the duration of lairage having any influence on eating quality or tenderness (Ferguson and Warner, 2008).

Lairages which do not provide an environment adequate to the needs of the species cause stress in the animals and affect the meat quality. A certain number of lairages should be present in every slaughterhouse, so that slaughter animals should be separated based on sex and type. Mixing different types and sex of animals will cause physical and psychological stress (Gracey, 1981; Moning, 1988). If it is necessary to mix unfamiliar bulls, this should be done towards dusk and immediately before feeding, so as to reduce stress (Kenny and Tarrant, 1982).

Harsh lights, as well as strange and loud noises, frighten the animals and should therefore be avoided. Floors should be drained and should not be slippery. Suitable bedding material should be available if animals are kept overnight. Troughs should be placed along the walls and should be adequate in number and design. Drinking water must be constantly available. Feed must also be provided if slaughter does not take place within twelve hours. Each animal should have sufficient space to stand up, lie down and turn around. Heightened activity, hindrance of free movements and bruising were more frequently observed among horned cattle than among dehorned animals. Accidental horning (injury caused to an animal by the horns of another animal) was noted as well. Dehorning is therefore important in order to reduce stress (Kenny and Tarrant, 1982). The conditions of lairage should include: facilities are operated in a way that soiling and cross-contamination of animals with food-borne pathogens is minimized to the greatest extent practicable; holding of animals so that their physiological condition is not compromised and ante-mortem inspection can be effectively carried out, e.g. animals should be adequately rested and not overcrowded and protected from weather where necessary; separation of different classes and types of slaughter animals as appropriate, e.g. sorting of animals by age so as to facilitate the efficiency of routine dressing, separation of animals with special dressing requirements, and separation of "suspects" that have been identified as having the potential to transfer specific food-borne pathogens to other animals; systems to ensure that only animals that are sufficiently clean are slaughtered; systems to ensure that feed has been appropriately withdrawn before slaughter; maintenance of identification of animals (either individually, or as lots, e.g. poultry) until the time of slaughter and dressing; and conveying of relevant information on individual animals or lots of animals to facilitate ante- and post-mortem inspection (FAO, 2004).

2.2.1.2 Methods of slaughter

Animals have to be transferred from the lairage pens either directly or through a race into an area where stunning and slaughter are carried out. The race design should take into account animals' natural instincts and normal behavior. Race designs incorporating solid, smooth sides and walls, and non-slip flooring work well. In order to facilitate stunning and to protect the operators, some kind of restraint is necessary. Restraint should allow correct application of stunning equipment and protect animal welfare, as well as protecting operators from potential injury, especially from large animals (FAO 2004).

Slaughtering techniques and methods of handling slaughter animals vary greatly throughout the world. Regardless of the way in which slaughter is performed, this is a stressful process for the animals and must therefore be efficient, ensuring the best possible conditions for the animals. Each country should establish regulations to secure humane conditions of slaughter for the different animal species. The duties and responsibilities of slaughterhouse managers should be clearly established (Cortesi, 1994). It is well accepted that stress and handling of animals during slaughter influence the degree of lipid oxidation in meat. Lipid oxidation in muscle starts immediately after death, following the failure of the circulatory system and the cessation of metabolic activities. This has been associated with deterioration in the quality of meat (MLA, 2011).

In many parts of the world, animals are still slaughtered while conscious (Gracey, 1981). However, in the developed countries, all animals (except those slaughtered by the Judaic) are stunned before slaughter. The duty to avoid all forms of cruelty to animals and the necessity of adopting efficient stunning methods are well defined in European Union (formerly Economic Community, EEC), Directive 74/577 (6). According to this Directive, "stunning means a process effected by a mechanically operated instrument, electricity, or gas anaesthesia without adverse effects on the condition of the meat or the offal, which when applied to the animal puts it into a state of insensibility which lasts until it is slaughtered, thus sparing it in any event needless suffering."

Stunning methods must be simple, quick and safe, and must suit the practical conditions of the slaughterhouse. Stunning procedures in cattle include the use of electrical and mechanical stunning. Mechanical stunning can be penetrating and non-penetrating. With mechanical stunning method the intent is to cause concussion with or without penetration. The means most commonly used for stunning are the captive bolt and free bullet pistols, electricity and carbon dioxide (CO_2). Enervation (i.e. thrusting a knife into the atlanto-occipital space) should be banned, as it has been demonstrated to be the least effective of six methods examined (Gracey, 1981). Enervation paralyses the animal but does not produce loss of consciousness, as blood supply to the brain is not stopping (Leach, 1978). Since the bovine spongiform encephalopathy (BSE) outbreak, captive bolt stunning (CBGs) method has been questioned and considered for the potential risk of contaminating edible parts of the carcass with central nervous system (CNS) material. Research has shown that captive bolt stunning can cause brain tissue to become dislodged and disseminated into the blood circulation in cattle and sheep. Since, in a BSE-infected animal, brain and spinal cord tissue contain the highest number of infective units, carcasses may be contaminated with the BSE agent. In addition, there is a possibility of contaminating the brain with pathogenic bacteria through the use of captive bolt stunning. Consequently, there are now concerns and discussions about the use and future of CBGs and alternative stunning methods are being considered. One alternative is the use of electrical stunning. However, this method is expensive, and incorrect use may result in welfare problems. Electrical stunning in cattle, however, has been associated with blood speckle and blood splash in the carcass. Nevertheless, an automated system of electrical stunning is successfully used in New Zealand (FAO 2004).

Sticking must only be carried out on animals that are stunned. The knife that is used must be clean and sharp and of sufficient length for the species and size of the animal. Both carotid arteries and the vessels (close to the heart) should be severed. Following sticking, the animal must be allowed to bleed to death before any further dressing procedure or any electrical stimulation is carried out. The minimum times between sticking and dressing for cattle is 60 seconds (FAO, 2004).

The bleeding position may have a considerable influence on meat quality (Aalhus et al., 1991; Holscher et al., 1989; Lambooy, 1990; Troeger, 1991). Rapid bleeding is highly desirable because it reduces the probability of the animal recovering and ensures early brain death. According to Recommendation R(91)7 of the Council of Europe (Council of Europe, 1991), bleeding must start within 20 sec if electricity or a percussion stunner is used, or within 60 sec in the case of the captive bolt, free bullet or Co_2 stunning methods. Approximately 40-60% of the total blood is lost at bleeding, and the rate of loss is very similar in the different species for which this has been measured (Warris, 1984). Bleeding is influenced by the vasoconstrictive action of catecholamines, which are released during stunning and bleeding. Complete and early bleeding is desirable for meat quality (Gracey, 1981; Ring and Kortmann, 1988, Troeger, 1991) and hygienic reasons.

2.2.1.3 Post-slaughter carcass handling

Post-slaughter carcass handling involves all the activities the carcass is subjected to after sticking of the animal. It contributes significantly to the quality of meat produced. It can be categorized into carcass condemnation, cutting of meats into parts, electrical stimulation, storage, processing into different meat products, marketing and cooking (Adzitey and Huda, 2012).

2.2.1.3.1 Condemantions of carcasses and organs

Carcasses unfit for human consumption are condemned. Condemnation may be partial or total. Trimming due to DFD, blood splash and bruises result in partial condemnation. In extreme cases, the carcasses can be totally condemned. In Canada, out of 1,162,410 cattle, a total of 6875 carcasses were rejected because of septicemia and/or toxemia from 2001-2007 (Alton *et al.,* 2010). Cutting of carcasses into parts is the other post slaughter activity. For easy handling, transportation and processing, carcasses can be cut into primer parts. During this process some meats may fall off and do not enter the food chain. This can be significant loss in large processing plants.

The main causes of whole carcasses condemnations in Ontario, Zambia and Tanzania were reported as cysticercus bovis, TB and Hydatid cyst, abscess, emaciation, odour, jaundice, bruising, contamination, inadequate bleeding and lymphadenitis (Phiria, 2006; Alton *et al.,* 2010; Mellau *et al.,* 2011). Bruising was observed at a rate of 2.0 % from the total cattle examined at slaughter in Northern part of Ethiopia (Mesele *et al.,* 2012). Loss due to bruising is more apparent in partially and totally condemned carcasses. Apart from affecting carcass value, bruising has also an implication for animal welfare as excessive use of sticks while driving animals to the abattoir is greatly responsible for this phenomenon (Cadmus *et al.,* 2009.) Bruising of animals during transport is the major source of economic loss in African and Asian countries. Up to 50% of all bruising was caused by rough treatment of animals during handling

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

and transport (Grandin, 1980). Moreover, fighting between animals in the lairage can be a major cause of bruising (Warriss, 2003). About 40% and 34% of bruising of carcasses was reported in USA and Canada, respectively (Boleman *et al.,* 1998; McKenna *et al.,* 2002; NBQA, 2010/2011; Savell *et al.,* 2011).

Fasciolosis, hydatid cyst, Cysticercus bovis, pneumonia, emphysema, hydronephrosis, cirrhosis, hepatitis, calcification, and abscess were the major causes of organs condemnation in cattle slaughtered at Adigrat municipal abattoir (Assefa and Tesfay, 2013). The two researchers reported condemnations of liver, lungs, kidneys and hearts at the rate of 17.58%, 8.19%,1.21% and 0.27%, respectively, in Northern Ethiopia The condemnation rate of liver in Gondar , Kombolcha and Jimma municipalities of Ethiopia were 31.1%, 66.5% and 64.4%, respectively (Yifat *et al.,* 2011; Nurit *et al.,* 2012; Amene *et al.,* 2012).

Fasciolosis (9.26%) was the main cause of liver condemnation in Ethiopia (Assefa and Tesfay, 2013). Fasciolosis is an economically important disease of domestic livestock, in particular cattle and sheep. The disease is caused by trematodes of the genus *Fasciola*, commonly referred to as liver flukes. The two species most commonly implicated as the etiological agents of fasciolosis are *F. hepatica* and *F. gigantica*. *F. hepatica* has a worldwide distribution but predominates in temperate zones while *F. gigantica* is found in tropical regions (Andrews, 1999). A high number of livers were condemned due fasciolosis and hydatidosis from local market in Ethiopia (Mesele *et al.,* 2012). The prevalence rate of fasciolosis was reported 16.64% ,14.04 %, 46 % and 46.2% in Gonder, Wolaita Sodo, Mekelle and Jimma, respectively, in Ethiopia (Abunna *et al.,* 2010; Tadelle and Worku, 2007; and Berhe *et al.,* 2009; Mesele *et al.,* 2012). Moreover, prevalence rate of 14%, 8%, 8.2 % and 37% were reported in Tanzania, Nigeria, Kenya, and Zambia, respectively (Okoli *et al.,* 2000; Kithuka *et al.,* 2002; Phiria, 2006; Swai and Ulicky, 2009).

Hydetidosis have been recognized as a zoonotic disease which has significant livestock and public health importance in developing countries (Eckert and Deplazes 2004). The adult tapeworm is found in the small intestine of carnivores, particularly the dog. The metacestode (hydatid cyst) is found in a wide variety of ungulate animals and man (Soulsby, 1982; Urguhart et al. 1988). Dogs are primary hosts for the parasite with livestock acting as intermediate host. The outcome of infection in livestock and humans is the development of hydatid cyst mainly in liver, lung and other organs. Hydatid cyst causes severe disease and death in humans. It causes unnecessary expense of cost for treatment and reduction in livestock production (Budke et al. 2006). Hydatidosis affected most of the visceral organs such as lungs, liver, heart and kidney (Mesele *et al.,* 2012). The prevalence of hydatidosis was reported 19.87%, 15.2%, 46.8%, 48.5% and 52.7% in Gonder, Wolaita Sodo, Debre-Markos, Adama, and Hawassa, respectively, in Ethiopia (Kebede *et al.,* 2009; Getaw *et al.,* 2010; Kebede *et al.,* 2010; Regassa *et al.,* 2010; Mesele *et al.,* 2012).

Bovine cysticercosis has livestock and public health importance. Economic losses can occur due to the condemnation of heavily infected carcasses and the necessity to freeze or boil infected meat. Bovine cysticercosis is a parasitic disease of cattle caused by the larval stage (*Cysticercus bovis*) of the human tapeworm *Taenia saginata*. The indirect life cycle of this parasite involves only humans as the primary host and bovines as the intermediate host. Infection of humans with the adult tapeworm occurs via the consumption of beef which has been insufficiently cooked or

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

frozen to kill the cysticerci (WHO/FAO/OIE, 2005; OIE, 2012). *Taenia saginata* is most prevalent in sub-Saharan Africa, Latin America, Asia, and some Mediterranean countries. Tens of millions of people are likely infected with *T. saginata* taeniosis worldwide (Craig, 2007). Cysticercosis was reported as 26.3%, 13.3%, 17%, 20.5%, 28.3%, 46.5%, 25.7% in Hawassa, Wolaita, Kombolcha, Eastern Ethiopia, Kombolcha, Debre Zeit and South Omo in Ethiopia (Mersie, 1993; Asrat, 1996; Jobre *et al.,* 1996; Abunna *et al.,* 2008; Abunna *et al., 2012;* Regassa *et al.,* 2009).

The condemnation rate of lung at Gondar, Bahir Dar and Jimma municipal abattoirs were 19.68 %, 25.8% and 46.2%, respectivley (Amene *et al.,* 2012; Asmare *et al.,* 2012; Mesele *et al.,* 2012). Pneumonia was the other important problem of lungs. Pneumonia is the second important disease for lung condemnation in Northern Ethiopia (Mesele *et al.,* 2012). Pneumonia is a complex condition, involving interaction among host, pathogens and environmental factors. A number of factors can explain the high prevalence of pneumonia in lungs. Exposure to dust from the environment, exhaustion during long trekking in search of feed and water, long trekking to markets and abattoirs, and parasites of lungs are some of the factors. Poor housing condition might expose the cattle to various stresses like cold, wind, rain and dust. Consequently, opportunistic bacteria like Pasteurella spp. and Arcanobacterium pyogenes would get a chance to attack the lungs (Brodgen *et al.,* 1998). The prevalence rate of pneumonia was 2.45% and 4.8% in North Ethiopia and Northern Nigeria (Raji *et al.,* 2010; Mesele *et al.,* 2012).

The condemnations of kidneys were 18% and 5.77% in Jimma and Mekelle municipality of Ethiopia, respectively (Shagaw *et al.,* 2009; Amene *et al.,* 2012). Hydronephrosis was the main causes of condemnation of kidneys (Yifat *et al.,* 2011; Amene *et al.,* 2012; Assefa and Tesfay, 2013).

The condemnations of hearts were 11% and 3.71% in Jimma and Mekelle municipality of Ethiopia, respectively (Shagaw *et al.,* 2009; Amene *et al.,* 2012). The main cause of condemnations of heart was cysticercus bovis, pericarditis, abscess and hydatid cyst (Ashwani and Gebretsadik, 2008; Bekelle *et al.,* 2010; Amene *et al.,* 2012; Mesele *et al.,* 2012; Assefa and Tesfay, 2013). Prevalence of Cysticercus bovis in Adigrat and Jimma were 0.27% and 0.8%, respectively (Megersa *et al.,* 2010; Assefa and Tesfay, 2013).

Enteritis and pimply guts were the main cause of condemnations of intestine in Tanzania (Mellau *et al.,* 2011) while tape worms was the main cause in Zambia (Phiria, 2006). Abscess, cysticercus cyst and TB were the main causes of condemnations of head while contamination, splenomegaly, hydatidosis, haematoma and abscess were reported as the main causes of condemnations of spleen in Zambian and Tanzania (Phiria, 2006; Mellau *et al.,* 2011).

2.2.1.3.2 Meat yield, percentage and meat cuts

The carcass cutting yield is the percentage of the carcass that actually ends up as meat. The carcass cutting yield is calculated as a ration of pounds of meat over carcass weight multiplied by 100. Cutting yields can vary significantly depending upon cutting specifications; cuts that are bone-in or boneless, will produce very different cutting yields. If the animal is excessively fat, then the cutting yield will be lower because the fat is removed and discarded. A more muscular animal will have a higher cutting yield. Aging and leaving the carcass to hang for an extended period of time will also impact cutting yields as the carcass tends to shrink during the process. Cutting losses on a side of beef may range from 20 to 40 %, and average around 28% (Cornell University, 2014).

Breed and feeding conditions are some of the factors which affect the meat yield of cattle (Graham *et al.,* 2009). The meat yield percentage of Nguni and Tuli cattle in South Africa were reported 72.5% and 73%, respectively (Strydom, 2009). The yield percentage of Angus, limousine and Wagyu breeds were in the range from 67.7-69.9% in Australia (Graham *et al.,* 2005). Higher meat yield from hind quarter compared to fore quarter was reported for Piemontese and Belgian blue breeds (Biagini and Lazzaroni, 2005). The effect of breed on meat cut was reported for Piemontese and Belgian Blue cattle breeds. However, feeding system was not as significant as breeds for retail cut weights (Biagini and Lazzaroni, 2005).

2.2.1.3.3 Electrical stimulation, deboning, chilling, improving tender of meat, packing, marketing and cooking

Microbial load on Caracas can be reduced using water spray, physical and chemical treatment. Portable water or hot water with temperature below 75°C with high pressure can be used to spray the carcass. In physical decontamination method ultraviolet light, ionizing radiation and ultrasound are used. In chemical decontamination method chlorine, hydrogen peroxide, trisodium phosphate and organic acids are used (Warriss, 2000).

Electrical stimulation initiates the contraction of muscles. Lowers pH speeds up offset of rigor mortis, reduces the risk of cold shortening and improves tenderization of meats (Zocchi and Sams, 1999). However, it can result in broken bones, hemorrhages and reduced bleeding defect

(Wilkens *et al.,* 1999). Hanging carcasses by hooking the hind legs puts many muscles into tension and stretches the sarcomere lengths which may produce meats that are more tender (Warriss, 2000).

Hot processing or boning is the removal or cutting of carcasses into parts while it is still hot about 37- 39 °C. It can increase yield, promote uniform color and better water holding capacity. However, it can reduce tenderness; promote abnormal shape of joints and difficulty in handling (Warriss, 2000; Fletcher, 2002). Li et al. (2009) compared different boning methods and reported that cold-boning at 36 h post-mortem had the advantages of giving muscles a better color, lower cooking loss, better tenderness, juiciness and flavor.

The rate at which carcasses are chilled affect meat quality. Speeding up the rate of chilling will help reduce microbial growth. Besides, fast chilling reduces evaporative weight loss, manifestation of PSE, improve lean color and water holding capacity (Warriss, 2000; Adzitey and Nurul, 2012). Furthermore, cooling rates affects pH of the product, the disappearance of adenosine triphosphate (ATP) and fasten occurrence of rigor mortis (Warriss, 2000). When muscles are cooled below 10°C before the onset of rigor mortis, cold shortening occur which makes the meat tough upon cooking. Slow freezing may produce cold shortening while rapid freezing may results in thaw rigor (Warriss, 2000). Meat losses large amount of drip or water during thawing and are tough upon cooking. A condition known as heat ring characterized by darker band muscle forming can occur in beef carcasses subjected to relatively fast chilling (Warriss, 2000). Heat ring and thaw rigor meat will have poor appearance. Freeze drying ensures

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

that water is sublimated from meat enabling the meat to be stored for a longer period (Warriss, 2000).

Package can be done by limiting amount of oxygen, carbon dioxide and nitrogen gases to the desired level. Packaging is done to protect meat from contamination, inhibiting microbial growth, reducing or eliminating evaporative weight loss and surface drying, and enhancing the color of the product (Warriss, 2000). Pseudomonas which is the most common spoilage microorganism can grow below 5°C under aerobic condition. Adding high concentration of carbon dioxide in the pack restricts their growth and promotes the growth of lactic acid bacteria. Consumers also associate meat color to its freshness. Oxygenated meat has bright red color (Warriss, 2000).

Aging or conditioning carcasses are done by keeping meat in refrigerated temperatures for extended periods of time (2 to 4 weeks) after initial chill. This helps to improve tenderness and flavor. Aging 8 days was reported enough to obtain an acceptable sensory attributes (Forrest, 2010b; Li *et al.,* 2009). Comminution is the grinding, mincing, chopping or flaking of meats into particulate sizes. Comminution improves the texture of low value meats and increases it economic values. However, such meats are prone to spoilage and loss of some vitamins (Warriss, 2000; Adzitey *et al.,* 2011). Tumbling increase meat weight as the meats knocks against each other and absorbing water. This may also improve meat tenderness and juiciness when cooked (Adzitey and Huda, 2012).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Marination using salt, vinegar or wine and injection using calcium chloride solution tenderizes meat and improves its juiciness. It break muscle structure making the myofibrils swell to hold more water (McFarlane and Unruh, 1996). In beef, injection of calcium chloride solutions may produce unfavorable effects on taste and flavor if the optimum amount is not used. It turns surfaces of the meat can be changed to brown due to fast oxidation of heme pigments. Higher concentrations of calcium chloride reduce the shelf life of the meat (Warriss, 2000). Nonetheless, this problem can be overcome by the combined effect of calcium chloride and ascorbic acid (Wheeler *et al.,* 1996). Antioxidants such as Vitamin C (ascorbic acid), Vitamin E (α-tocopherol), propyl gallate, butylated hydroxyanisole and butylated hydroxytoluene are used in meats to reduce the effects oxidation during storage (Warriss, 2000). Calcium chloride improved tenderness in the rounds of *Bos indicus* bulls and late castrate steers when injected within 1 h postmortem (Wheeler *et al.,* 1991) and when used as a marinade applied to steaks several days postmortem (Whipple and Koohmaraie*.,* 1993). Because older animals have less tender meat (Reagan *et al.,* 1976), increasing the acceptability of loin and rib cuts from mature cows by improving tenderness could significantly improve the supply of steaks for the institutional food service industry.

Cooking procedures affect meat quality. The essence of cooking is to improve sensory characteristics so that it becomes more palatable and edible. Cooking to adequate temperature destroys both spoilage and pathogenic microorganisms. This makes meat safer for consumption and increase the shelf life. Cooking can improve the quality of meat by making it tender. Cooking temperatures also affect meat appearance. Beef cooked to 60°C is quite red inside, at 70°C pink brown and at 80°C brown (Warriss, 2000). Nonetheless, cooking beyond or below recommended temperatures can make meat inedible and unpalatable. Grilling reduced water and fats contents from 66.7 to 59.3% and 13.5 to 12.1%, respectively. This increase the relative energy content from 821 to 912 kJ 100g^{-1} and concentrat the protein content from 18.9 to 27.3% (McCance and Widdowson 1997). Sheard et al. (1998) also reported a percentage reduction of fat in minced ground beef content to be 62% through grilling. Cooking melts fats and some volatiles fatty acids from the meat (Adzitey and Huda, 2012).

2.2.2 Improving carcass quality through breeding and management

Quality grade, yield grade, and carcass weight are the min carcass traists of economic interest. These traists can be imporoved through improvement of genetics and managements (Drake, 2004).

2.2.2.1 Improving carcass quality through genetics

The greates and most practical opportunities to improve carcass traits are through genetics (Drake, 2004). There is a widerange of difference in carcass quality between individuals with in a breed. Efforts to improve the genetics associated with carcass quality must be based on individual animals' performance, not the reputation of a breed or general trends for a breed. Selection of individuals with superior carcasst raits within the breeding program should be considered. The best method for evaluating the genetics of individuals for selection is through expected progeny differences (EPDs), determined either by carcass evaluation or ultra-sound, or throughs pecific gene testing (Drake and Forero, 2001).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Quality grade is determined on the amount of marbling or intramuscular fat. Intramuscular fat is found in fatcells (adipocytes), and the marblings core is more closely related to the number of fat cells per gram of tissue than to the size of those fat cells (Cianzio *et al.,* 1985). There are also genetic differences between breeds in the number of fat cells and thus the potential for marbling. In one study, the rate of fat cell development was twice as high inWagyu cattle compared to Angus cattle (May *et al.,* 1994). Efforts to increase the number of fat cells in muscle tissue should lead to increases in marbling, the marbling score and consumer acceptance. Both genetic and management methods may be effective inincreasing the number of intramuscular fat cells (Drake, 2004).

Approaches to improve the cattle's genetic disposition for marbling may include traditional EPDs and newer specific genetic tests (Drake, 2004). Carcass EPDs are used in the same way as other EPDs to estimate the differences in progeny between compared individuals (usually sires). Because carcass traits are moderately heritable, management decisions based on EPDs are effective in effecting changes. Vieselmeyer et al. (1996) compared high-marbling EPD Angus sires to low-marbling Angus sires and showed an increase in the number of choice-graded carcasses among animals sired by high-marbling EPD Angus bulls. Carcass EPDs are developed and provided by breed associations whose methodologies and terminology vary (Drake, 2004).

Vieselmeyer et al. (1996) reported that marbling could be increased without increasing the yield grade. Sires selected on the basis of ultrasound intramuscular fat and EPDs have also shown improvements in marbling and quality grades among their calves (Sapp *et al.,*

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

2002). These studied showed that quality grades were improved with more intramuscular fat deposition but without any increase in external fat thickness and yield grade. This shows the possibility of increasing marbling fat without increasing fat cover.

A specific gene such as thyroglobulin or Gene STAR marbling gene has been identified with increased marbling and choice grade. This gene controls thyroglobulin, a precursor molecule to thyroid hormone. The gene or genotypes called 2 stars, 1star, or no star was identified three forms of genes that affect carcass quality (Drake, 2004). Cattle with 2 stars was reported that produced more marbling and higher quality grades compared to cattle with fewer stars when maintained under the same conditions (Anon, 2002).

2.2.2.1 Improving carcass quality through management

Carcass quality is affected by management of animal at the pre-weaning, post-weaning or feedlot phases. Days on feed, weight and age are three most important factors that can affect carcass quality. Among these factors, days on feed are the single most important factor affecting carcass quality (Drake, 2004). Increasing the days on feed will increase marbling (improving quality grade), increase numerical yield grade (decreasing lean meat yield) and increase carcass weight (Short *et al.,* 1999). Date of slaughter is generally determined when there is adequate fat thickness over the ribs to achieve corresponding marbling for a low Choice grade. By increasing days on feed, it is possible to increases marbling, quality grade, external fat cover, carcass weight and yield grade. As days on feed increase, weight gain, fatness and marbling will increase with the crospponding increase in carcass weights, quality grade and numerical yield grade. It would be easy to attain sufficient marbling and

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

quality grade merely by increasing the number of days on feed. But with an increase in the number of days on feed comes increases in carcass size and external fat cover. As carcass weights approach the upper limits of desirability (which vary depending on market, but generally run about 800 pounds, with discounts for heavier weights), cattle should be slaughtered even if they lack adequate fat cover and quality grade to keep them from attaining excessive weight (Drake, 2004).

Age at feedlot entry is determined by age at weaning and whether the calves are placed directly in to the feedlot or backgrounded. Carcass weights may be 200 to 300 pounds heavier for backgrounded cattle. Backgrounding may be better suited for medium to smaller frame cattle. Large-frame cattle that are subjected to backgrounding and then fed to acceptable levels of fat thickness will often end up with excessive carcass weights. Similarly, smaller frame cattle placed directly in to the feedlot after weaning may have unacceptably low carcass weights. The rate of gain during backgrounding did not impact the carcass quality grade when the cattle were fed to the same fat thick-ness (Klopfenstein *et al.,* 2000). Older calves that were kept on feed long enough to achieve high marblings coressondingly had increasingly heavier carcass weights (Drake, 2004).

The practice of sorting feeder cattle by weight, fat thickness, and marblings improves feedlot performance and carcass quality. Particularly sorting based on ultrasound readings has resulted in improved feedlot performance and carcass quality (Basarab *et al.,* 1997). Sorting does not actually improve carcass characteristics. It does, however, permit increased uniformity and a greater number of cattle fed to the correct end point, and in this way improves feedlot performance and carcass quality.

The effects of creep feeding during the pre-weaning phase depend on the amount of nutrition available to attain potential growth. When nutrition is sufficient for cattle to attain their potential growth, creep feeds usually will not enhance their performance.When nutrition is limiting growth, however, creep feeding will be beneficial. Starch-based creep feeds fed for at least 80 days may be more effective than other types (Drake, 2004).

It is always best to test for the presence of adequate trace minirals in the feed of cattle. Zinc supplements given to steers that were already receiving marginal to adequate amounts of zinc in their diets during the growing and finishing phases were shown to increase quality grade, yield grade, marbling and back fat (NRC, 1996; Spears and Kegley, 2002).

Health of animal is the other factor which affects the carcass quality. The effects of sickness on final carcass quality depend on the severity and timing of the sickness. Heifers that were sick with bovine respiratory disease during the receiving phase in to the feedlot but were not treated during the finishing phase haves hown carry over effect in the form of reduced quality grades (Stovall *et al.,* 2000). Heifers that were never treated, were treated once, or were treated more than once during the receiving phase had reduced marbling scores, lower percentages grading Choice, and tended to have leaner carcasses (McNeill *et al.,* 2000). Heifers treated once compared to those that received no treatment for respiratory disease during the receiving phase had similar carcass quality levels (McBeth *et al.,* 2001).

Pre and post weaning nutrition are the other factors which affect quality of carcasses.

Marbling score is more closely associated with the number of fat cells than with their size. Besides breeding cattle to increase the number of intramuscular fat cells, producers may also be able to influence intramuscular fat through nutritional regimens that are conducive to increases in intramuscular fat cells. Similarly, yield grade is most strongly influenced by external fat cover, which again involves fat cells, this time located subcutaneously (Drake, 2004).

The types of feed used for the cattle affect the quality of carcasses. The VFAs and their usual proportions from forage based diets are 65-70% acetate, 15-25% propionate, and 5-10% butyrate. High-energy rations composed of grains produce less acetate and more propionate: 50-60% acetate, 35-45% propionate, and 5-10% butyrate. When the mechanisms for fat deposition is observed, it appears that forage-based diets lead to acetate production that favors external fat deposition and little intramuscular fat, while grain-rich diets increase propionate, which favors intramuscular fat deposition and not external fat covering (Smith *et al.,* 1984, Smith and Crouse, 1984, Fluharty, 2003). This would mean that even very high-quality forage diets that result in rapid weight gain would not result in the degree of intramuscular fat deposition found in diets in which grains support more moderate weight gains. The specific application of pre-and post-weaning nutrition manipulation to enhance carcass characteristics has not been explored in detail, but potential management alternatives are apparent. Supplements that contain some grain may be beneficial for enhanced marbling if administered prior to or near weaning. These could include grains in creep feeds or supplements or forages from mature grain hays that include significant amounts of filled grain (Drake, 2004).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

2.3 Live, carcass weight and dressing percentage

Slaughter weight of known beef European breeds such as Hereford, Angus, Brahman and Belgian blue was reported as 577 kg, 580 kg, 539 kg and 567 kg, respectively (Aynalem *et al.,* 2011). The performance of local cattle breeds in Ethiopia such as Horro, Barka and unimproved Boran were 250 kg, 360 kg and 268 kg, respectively while the adult weight of African cattle such as Kuri, N'Dama, Shorthorn Ghana and Butan were reported as 480 kg, 246 kg, 204 kg and 356 kg, respectively (Aynalem *et al.,* 2011). The slaughter weight of Zebu, WASH and Sanga cattle at local abattoirs in Ghana were reported as 309 kg, 202 kg and 162 kg, respectively (Teye and Sunkwa, 2010). The slaughter weights of Bonsmara and Drakens-berger at commercial farmers were 434 kg and 454 kg, respectively while the slaughter weight of Bonsmara, Brahman and Nguni cattle managed at emerging farmers were 434 kg, 413 kg and 391 kg, respectively in South Africa. However, the slaughter weight of Nguni managed at communal farmer and Tuli cattle were reported 324 kg and 418 kg, respectivley (Strydom, 2009). The slaughter weight of White Fulani cattle in west and central Africa under improved system of management was in the range from 350-665 kg (Tawah and Rege, 1996). About 32% of cattle slaughtered in North-West of Italy had live weight between 200-300 kg (Lazzaroni and Biagini, 2009). The slaughter weight of un-supplemented Ogaden bull was 297.4 kg while the supplemented bulls have finishing weight ranging from 302.7-318.2 kg under experimental condition in Ethiopia (Mekasha *et al.,* 2011).

The average carcass weight of Boran and Ogaden cattle under experimental condition in Ethiopia were in the range from 98.2-135.2 kg and 163-182 kg, respectively (Lemma *et al.,* 2007; Mekasha *et al.,* 2011). The average carcass weigh of Kuri, N'Dama and Butana cattle were

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

reported as 191 kg, 105 kg and 155 kg, respectively (Aynalem *et al.,* 2011). The carcass weights of Zebu, WASH and Sanga breed in Ghana were reported as 155.9 kg, 74.1 kg and 95.3 kg, respectively, (Teye and Sunkwa, 2010). The carcass weights of Nguni and Tuli cattle in South Africa were 181 kg and 241 kg, respectively (Strydom, 2009). The carcass weights of Bonsmara and Drakens-berger at commercial farmers were 256 kg and 265 kg while for Bonsmara, Brahman and Nguni cattle managed at emerging farmers were 256 kg, 235 kg and 227 kg in South Africa. However, the carcass weights of Nguni managed at communal farmer and Tuli cattle were reported 181 kg and 241 kg (Strydom, 2008).

Dressing percentage reflects the proportion of a live animal's weight, which will result in carcass weight. Some major factors that affect dressing percentage are stage of maturity of animal, degree of muscling; hide weight, stomach fill and amount of fatness. Moreover, feeding condition, breeds, age and sex affect the dressing percentage. Breed and sex of cattle was shown significant effect on the dressed percentage of Zebu cattle in Peshawar (Rahman *et al.,* 2012). It has been reported that *Bos Taurus* heifers have 1.5 to 2% lower dressing percentage than the steers at the similar age (Harris, 2006). Moreover, dressing percentage of Zebu cattle was reported to be 5-6 % lower than the beef breeds of Europe and America (Harris, 2006). The average dressing percentage of Zebu cattle slaughtered at Peshwar abattoir in Pakistan was 50% (Rahman *et al.,* 2012). The average dressing percentage of improved Boran cattle breed 55.7% in Ethiopia (Aynalem *et al.,* 2011). The dressing percentage of N'Dama breed was reported 42% in West Africa (DAGRIS, 2006). The dressing percentage of WASH, Sanga and Zebu cattle were 45.9%, 47.6% and 52.1%, respectively, in Ghana (Teye and Sunkwa, 2010).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

2.4 Phenotypic characterstics of cattle in Ethiopia

Indigenous cattle breed types in Ethiopia fall into 5 distinct breed groups. These groups are Small East African Zebu, Sanga, Large East African Zebu, Zenga and Humpless Shorthorn. Nearly half of cattle breeds are Small East African Zebu. Boran, Murle and Arsi breeds are Large East African Zebu. Danakil, Raya Azebo, Anuak and Aliab Dinka are Sanga breeds. Horro, Fogera and Arado are Zenga (sanga-zebu interbreeds) breeds. The Sheko breed is the Humpless Shorthorn cattle breed (Ayalew *et al.,* 2003). The breeds of cattle in Ethiopia have differetn coat colour, horn orientation, ear orientation, dewlap size, rump size, facial profile, colour pattern and hump shape (Fig. 2.4). Horn length is the best discriminating quantitative variables between breeds of cattle (Tadesse *et al.,* 2008).

Borana cattle is physically described as white, light gray, fawn or light brown with gray, black or dark brown shading on head, neck, shoulders and hindquarters. The horns are thick at the base, very short, erect and pointing forward. The hump is well developed in the male, is of pyramidal shape and overhanging to the rear or to one side. The dewlap is well developed. In the male, the preputial sheath is pendulous while in the female, the udder is well developed. Average wither height is 118 to 124 cm in males and 116 to 120 cm in females. Body weight ranges from 318 to 680 kg in males and 225 to 454 kg in females (Tegegne, 2004). Horro cattle are classified in Zenga breed group (DAGRIS, 2006). They are of medium to large size, with small and finely shaped head, a straight profile and medium to large horns. The hump is small to medium in size.

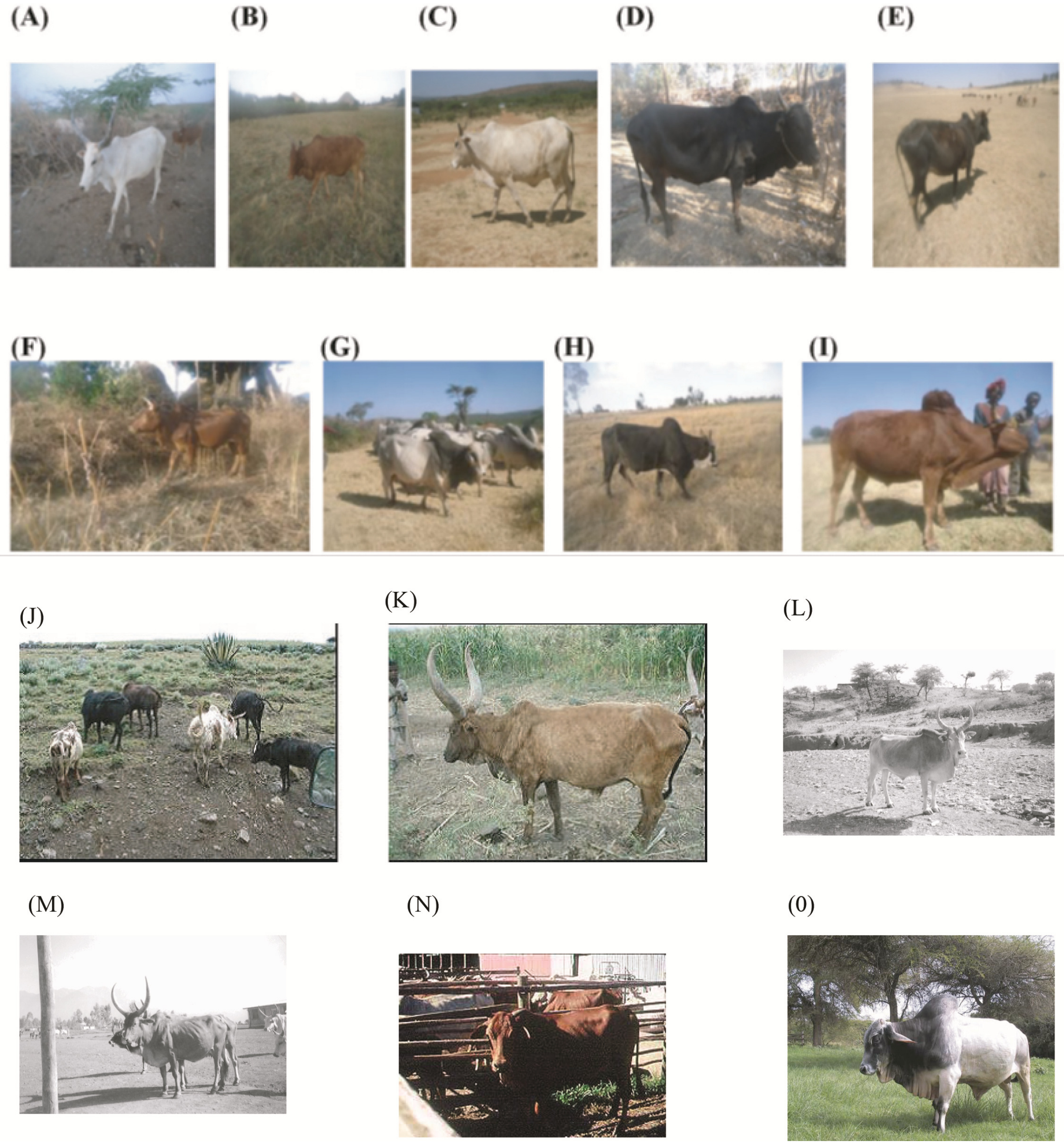


Figure 2.4 Pictures of some cattle breeds in Ethiopian
(A) Danakil adult female. (B) Horro adult female. (C) Borana adult female. (D) Arsi adult female. (E) Ambo adult female. (F) Horro adult male. (G) Borana adult males. (H) Arsi adult male. (I) Ambo adult male.(J) Wollo highland Zebu. (K) Raya Sanga. (L) Arado bull. (M) Raya cow. (N) Barka breed. (O) Improved Boran (Hassen et al., 2007; Zerabruk et al., 2007; Tadesse et al., 2008; Edea et al., 2012)

The Horro cattle have a uniform brown color which is slightly lighter around the muzzle and on the flank. The Sheko cattle are humpless shorthorn taurine cattle. They have small horns and many are polled. Their color is brown or black and white. Guraghe cattle are small-sized, usually with red, chestnut or roan coat color. The coats of Gamo cattle breed are dominated by red color. The heart girth and horn length of this breed ranges between 141.27-149.27 cm and 15.98-17.86 cm, respectively (Chebo *et al.,* 2013). The heart girth and horn length of cattle in North West part of Ethiopia was in the range between 135.47 - 146.44 cm and 16.40 – 19.30 cm, respectively (Tadesse *et al.,* 2008).

2.5 Sanitatary condition of the hide

Mud or manure is of great concern regarding the contamination of carcasses, especially when it is present on the legs and belly of the animal, particularly when there is a hide opening which may introduce this contamination to the carcass inadvertently (Hanson, 2000). Differen methods reducing microbial contamination are used on the beef carcasses. Contamination of carcasses of beef is one of quality problems that may occur during slaughter (Bogh-Sorensen, 1980).

The national beef quality audit conducted in 1995 in USA revealed that 61.6% of cattle had no mud, 18.8% had mud on legs, 14.5% had mud on legs and belly, and 5.1% had mud on legs, belly, and side (Boleman *et al.,* 1998). The presence of horns and (or) mud lower the dressing percentage. Furthermore, the presence of mud could influence the safety of beef. During slaughtering/dressing, especially as the hide is removed, mud and (or) feaces can contaminate the carcass.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

2.6 Design and equipment recommendations for small- to medium-sized abattoirs

According to the FAO (2008), the ideal abattoir operations uses the line-slaughter system. “Line slaughter” entails hoisting up the carcass at an early stage, preferably beginning with the bleeding. All subsequent slaughtering and dressing procedures are carried out with the carcass suspended on and moving along an overhead rail (or line). Line slaughter is suitable for bovines, small ruminants and pigs. One of the principles of hygienic slaughtering is the lifting of carcasses off the floor at the earliest possible stage. Bovines, mainly cattle and buffaloes and in some areas also yaks, have to be lifted up mechanically. The design for small- to medium-sized abattoirs by FAO (2008) is shown in Fig. 2.5, 2.6 and 2.7

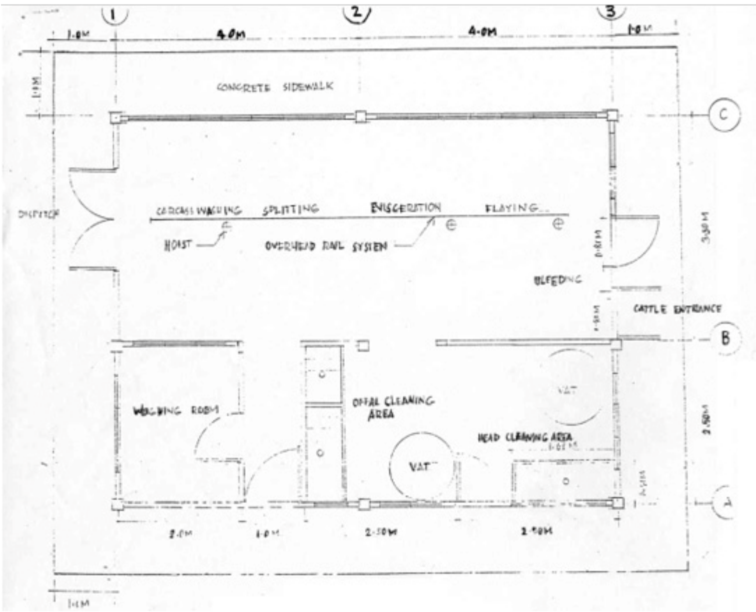


Figure 2.5 Mini slaughterhouses for cattle with space 8 x 6 m

Accoding to FAO (2008) low-capacity, partly mechanized installation that allows for the efficient line slaughter of bovines contains the following facilities: stunning box, captive bolt pistol, rodding equipment, hock cutter, electrical hoists, platforms (galvanized, stationary),

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

overhead rails (galvanized), breastbone saw, splitting saw, head-washing cabinet, carcass-washing cabinet, chutes, viscera carts, racks, tables, hooks and small tools.

2.7 Responsibility of governments to develop laws governing abattoir operations

Rapidly growing livestock production in response to increasing meat demand, particularly in developing countries, is associated with environmental pressures and problems. Some of these can be mitigated through appropriate measures, but many of them are unavoidable and difficult to address. The conversion of livestock into meat at the abattoir stage can be linked to various health and environmental hazards. These hazards can be contained if abattoirs function properly and produce meat according to stringent hygiene and environmental rules and regulations. In this context, one key responsibility of governments is to develop and provide for abattoirs and for the meat sector as a whole the necessary hygiene and environmental legislative frameworks. These need to be supplemented by regulatory systems ("directives") to be issued by governments and designed to implement and strictly enforce the laws (FAO, 2008).

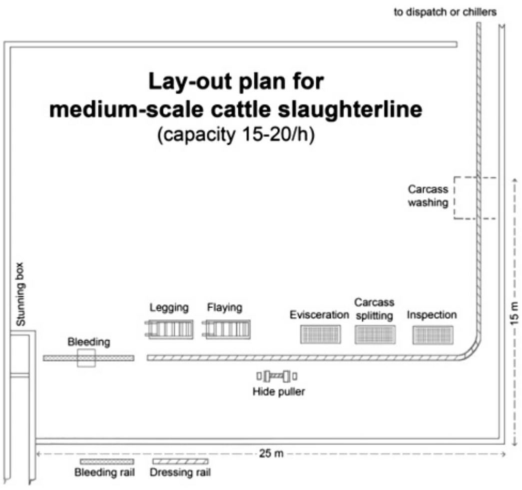
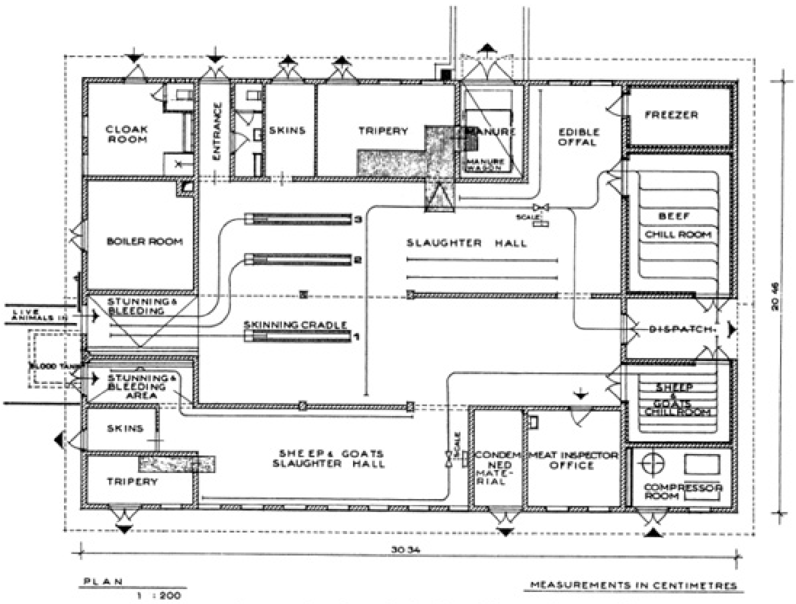


Figure 2.6 Lay-out plan for medium-scale cattle slaughter line

One principle of modern meat hygiene is the sharing of responsibilities for consumer protection between the meat business operator and the government official health and hygiene control entities. Meat business operators must be prepared to accept the primary responsibility for the hygienic quality and safety of meat and meat products. They are supervised in this task by the official government control authorities. In order to enhance the viability and safety of current consumer protection systems, a significant increase of investment by abattoir/meat business operators in suitable equipment for hygienic slaughtering and proper meat inspection as well as in waste treatment facilities is an urgent requirement (FAO, 2008). According to FAO (2008) governments must participate in complementary investments focused on capacity building in Good Hygiene Practices and sanitary control of meat.



Medium-size cattle abattoir incl. refrigeration section
(ground view drawing)

Figure 2.7 Medium size cattle abattoir including refrigeration section

1. Improved meat inspection practices

Consumer protection can only be assured by the implementation of internationally accepted meat inspection practices required to prevent the spread of zoonotic and/or food-borne diseases. It is the role and responsibility of governments to provide sufficient inspection personnel. Governments must also invest in human capacity by laying more emphasis on improving the proficiency of meat inspection personnel. Supporting the meat inspection services includes ensuring the availability of laboratory facilities in each country for diagnosing parasitic or infectious diseases. Concurrently the hygienic status of meat and meat products produced for the markets as well as the hygiene of equipment and premises used in the meat chain should be tested in such laboratories (FAO, 2008).

2. Promote local abattoir engineering companies/equipment manufacturers

The poor functioning and hygiene of many abattoirs in developing countries is linked to the fact that efficient and good quality slaughter equipment is practically only available from developed countries, at costs not readily affordable by local meat business operators. The majority of most locally produced abattoir equipments are typically deficient in terms of material quality and functionality. This results in difficulties in operating such equipment properly, breakdowns, corrosion and short productive life. Local companies engaged in the manufacture of abattoir equipment should be promoted by technical assistance programmes. Their access to internationally developed technologies should be facilitated; this could include the import of locally not available machinery and materials. Regional technical cooperation in this sector should also be promoted, thus enabling specialized manufacturers to benefit from the economies of scale generated by larger distribution networks throughout the region. It fosters the availability of more profitable and possibly cheaper manufacturing through higher output numbers of individual equipment (FAO, 2008).

3. Set up a representative range of pilot equipment for abattoir operations

The establishment of pilot and demonstration facilities, featuring recommended equipment for small to medium-scale abattoirs for replication in the individual countries, would be one initial step in technically and hygienically upgrading abattoirs. Preferably the demonstration units should be built in connection with an existing meat training institution where also routine slaughtering at a daily basis is carried out to support practical demonstrations/training. The demonstration equipment should not only be limited to genuine slaughter facilities but also include equipment for humane killing of slaughter animals as well as treatment plants for solid abattoir wastes and abattoir effluents in order to address the much needed improvement of the environmental impact of abattoirs (FAO, 2008).

4. Abattoir sector training

According to FAO (2008) yraining in the abattoir sector is needed for personnel at abattoirs carrying out sanitary, meat hygiene and technical operations:

4.1 Training in Meat Inspection

Insufficient skills and knowledge in meat inspection routine practices are a key constrain to ensuring food safety of animal products. This includes deficiencies in judgment from the food safety aspect of suspicious or diseased animals or meat. National Veterinary Authorities should make all efforts possible and practicable to start training programmes in meat inspection.

Therefore efforts should be undertakento set up regional training in meat inspection (FAO, 2008).

4.2 Training in Abattoir Technology and Hygiene

Training in abattoir technology and hygiene should primarily be conducted at the national level, with the assistance of national and possibly international experts. In this case the principle of "training of trainers" could be applied, but also the slaughter personnel in individual abattoirs directly be targeted. The training should not only refer to correct slaughter techniques but should always be linked with practices indispensable for efficient slaughter hygiene. In addition, training on these subjects on a regional level could materialize if the demonstration center for abattoir equipment could be made available (FAO, 2008).

2.8 Good manufacturing practice for abattoir

Good Manufacturing Practices for Abattoir is the general requirements of abattoir practices. This standard covers the processes of the hygienic slaughtering including the animal welfare and good manufacturing practices. In addition, the standard shall be used in establishing the abattoir, including the management in order to produce good quality and safe meat products for both domestic consumption and export. It is the practical guidelines for abattoir in order to provide safe and quality products that fit for consumption and are acceptable domestically and internationally (Thai Agricultural Standard, 2005). The control points, requirements and inspections for good manufacturing practices for abattoir of meat and animal products are defined in Table 2.3.

2.9 Hazard analysis at critical control points (HACCP)

HACCP is science based and systematic, identifies specific hazards and measures for their control to ensure the safety of food. HACCP is a tool to assess hazards and establish control systems that focus on prevention rather than relying mainly on end-product testing. Any HACCP system is capable of accommodating change, such as advances in equipment design, processing procedures or technological developments. HACCP can be applied throughout the food chain from primary production to final consumption and its implementation should be guided by scientific evidence of risks to human health (FAO, 2004).

As well as enhancing food safety, implementation of HACCP can provide other significant benefits, such as the application of HACCP can aid inspection by regulatory authorities and promote international trade by increasing confidence in food safety (EC, 2005). However, HACCP implementation is time-consuming and creates extra work for staff.

Thus a HACCP system is not easy to accommodate, particularly for small, multispecies operators. Nevertheless, HACCP is currently the meat safety management system of choice; no better alternative is presently available (FAO, 2004).The main goal of applying HACCP plans in abattoirs is to ensure that animals are slaughtered and dressed under conditions that mean the meat will carry minimal public health risk (FAO, 2004). General hygiene principles known as good hygienic practice (GHP) or good manufacturing practice (GMP) are the foundations on which a more specific HACCP system is built. Therefore, GHP is a prerequisite and there can be no effective implementation of a HACCP plan without pre-existing, effective GHP (FAO, 2004). The principle of HACCP is shown in Table 2.4.

Table 2.3. The control points, requirements and inspections for good manufacture practice

Control Points	Requirements
1. License for establishment of abattoir, lairage and slaughtering.	Abattoir, lairage and slaughtering shall be registered and permitted by the Department of Livestock Development (DLD).
2. Location	2.1 Do not locate nearby the community 2.2 Prevent contamination of hazardous substances from agriculture and manufacturing industry.
3. Lairage	3.1 Lairage area shall have adequate space for all animals held for slaughtering. 3.2 There is a separated area for sick or suspected sick animal. 3.3 Construction materials shall be strong and can protect the animals from unsuitable environment. 3.4 Lairage area shall have the waste water drainage.
4. The building of abattoir	4.1 Construction materials for both indoor and outdoor shall be strong and durable, not harmful to animals, easy for cleaning and can protect the animals from unsuitable environment. 4.2 The area for live animals shall be separated from the operating area 4.3 The dirty and clean zones shall be separated. 4.4 The edible products operating area shall be separated from the area of inedible products. 4.5 There shall be systems in place for public utility cleaning and waste water drainage. 4.6 The temperature for specific operation room can be controlled.
5.Equipment, machinery and utensils	5.1 They shall be able to be cleaned and disinfected 5.2 They shall not be contaminated with the heavy metal and other hazards.
6. Chilling room	The temperature of carcass shall be controlled to maintain core temperature between 4 and 10 ^{0}C.
7. Waste water treatment system	Waste water treatment system shall be in place in compliance with relevant laws.
8. Transportation and movement of live animals	8.1 The practices are considered with the animal welfare. 8.2 Transportation and movement of animal shall be approved by Department of Livestock Development. 8.3 The report of farm animal examination shall be available.
9. Transportation vehicle for carcass and meat	9.1 The vehicle shall be specially designed for meat transportation. 9.2 The container shall have temperature control system. 9.3 The inside and outside of container shall be washable.
10. Slaughtering	10.1 Humane slaughtering 10.2 Animal shall be rendered completely unconscious prior to slaughtering. The suitable method shall be applied to each animal species in accordance with animal welfare, except the religious practices.
11. Ante-mortem and post-mortem inspections	There are assigned officers who have the responsibility to examine the animals before and after slaughtering.
12. Management and hygienic control	12.1 There shall be systems in place for pest control and management of waste products. 12.2 Workers shall have physical examination at least once a year.
13. Recording	13.1 Animal health status before and after slaughtering shall be recorded 13.2 The hygienic status shall be verified and reported before the operation.

A hazard is any biological, chemical or physical agent present in, or condition of, food that can cause harmful effects on human health. Biological hazards are probably of greatest concern in abattoirs, and they include pathogenic micro-organisms (bacteria, fungi, and viruses), microbial toxins and/or toxic metabolites, parasites and prions. Chemical hazards include residues (e.g. pesticides, polychlorinated biphenyls [PCBs], heavy metals, mycotoxins), veterinary medicines, growth promoters, cleaning/sanitation chemicals, lubricants/solvents, and pest baits. Physical hazards can include glass, plastic, metal, wood, rubber bands, string, hair, buttons, jewellery, bone splinters and insects. Although CCP allocation can differ among abattoirs depending on the specifics of the production process, including the technologies used, some generic CCPs are common to all abattoirs. For both large and small ruminant abattoirs, CCPs may include acceptance of animals for slaughter, skinning, evisceration, chilling and dispatch. Critical limits are applicable only at CCPs. They represent a measurable and/or observable indicator of whether previously identified hazards have reached unacceptable levels of risk. Critical limits can differ

Table 2.4 Principles of Hazard analysis and critical control points (HACCP)

Principle	General scope
1. Hazard analysis	Identification of all likely public health hazards associated with the operation, assessment of the risk of their occurring, identification of related control measures.
2. Identification of critical control points (CCPs)	Identification of the process steps where hazards pose a high-level risk and so must be controlled.
3. Establishing critical limits at each CCP	Defining the line between acceptable and unacceptable hazard-related values, from the safety aspect, at individual CCPs.
4. Monitoring of each CCP	Establishing the system for monitoring whether hazards are effectively controlled at all the CCPs.
5. Corrective actions at each CCP	Development of actions/procedures to prevent transfer of hazards posing unacceptable risk to consumers if CCPs get out of control.
6. HACCP verification/validation	Proving that all the measures are working and that all hazards are controlled.
7. HACCP documentation	Practical, record-based proof that the checking/action activities are carried out and are effective.

in their nature and how they are measured. For example, chilling temperature (e.g. 4°C) is a critical limit because it prevents the growth of some pathogenic bacteria; exceeding that temperature would pose a high risk from multiplication of the pathogens. The temperature can be measured by thermometer. Another example of a critical limit is the absence of meat contamination by digesta during evisceration because it can contain enteric pathogens; the contaminated meat would pose too high a risk. Such meat contamination can be detected by either visual or instrument-aided observation, or both. For each CCP, regular monitoring procedures have to be established, to ensure that the CCP is controlled effectively and to detect proactively any danger from exceeding critical limits. The monitoring should include established parameters such as the methods used (e.g. sampling plans and temperature recording checks are meaningful), the frequency, the allocation of related responsibilities and recording. Although regular, monitoring is not always a continuous activity. Ideally, CCP monitoring should provide an early warning of the danger of losing control, before critical limits are exceeded. Immediately when there is an indication that for any CCP the critical limit has been exceeded and the process is getting out of control, a specific, pre-planned corrective action must be taken (FAO, 2004).

2.10 Summary

Ethiopia has large number of cattle. However, annual meat production, per capita consumption and meat production per head of cattle was low. The potential of cattle has not been fully utilized. Many factors contribute for low level of production of cattle. Cattle are kept for multiple purposes such as draft power, milk and meat. Beef is a by –product in the mixed crop-livestock and pastoral production system since cattle are primarily kept for traction and milk purpose, respectively. Shortage of feed characterized both production systems. Feedlots practice concentrated mainly in the central part, not in other parts of the country. The absence of market oriented production system with the majority of small holder farmers was the other constraints. The cattle population is primarily indigenous types and has not been characterized. The higher demand for meat in the Middle East and North African countries and geographical proximity to the region is one of the advantages. Moreover, the demand for beef in domestic market is rising due to growth in population, income and urbanization. Meat exported form Ethiopia was reported had poor quality due to contamination, dark cutting and poor carcass handling problems. Carcass quality can be affected by many factors such as pre-slaughter animal handling, methods of slaughtering and post-slaughter carcasses handling. Skin and intestinal content are the main source of carcass contamination. In this study the main reason for poor quality of carcass of cattle will be investigate and possible improvement strategy will be suggested.

CHAPTER 3

3 MATERIALS AND METHODS

3.1. Study abattoirs

This study was conducted at local and export abattoirs in Ethiopia. The physical locations and description of the study abattoirs are shown in Fig. 3.1 and Table 3.1, respectively.

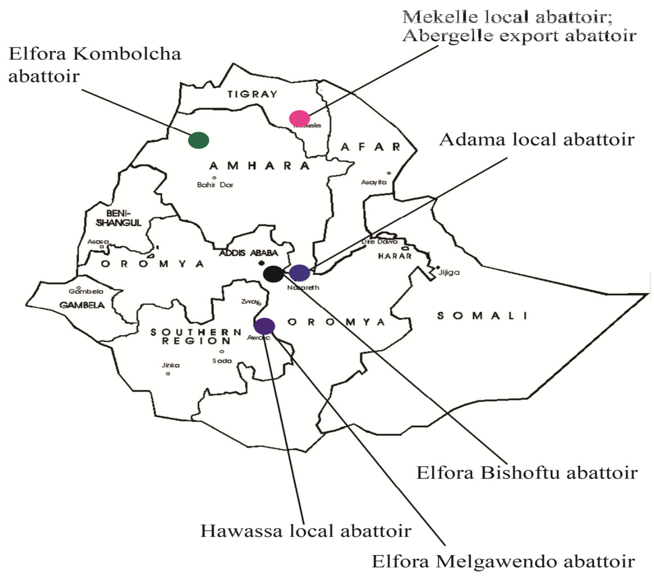


Figure 3.1 Physical locations of study abattoirs

Adama, Hawassa, and Mekelle are public abattoirs slaughtering animal for local consumption. Abergelle, Elfora Bishoftu, Elfora Kombolcha and Melgawendo abattoirs are private abattoirs. Abergelle and Melagawendo slaughter animal for export purpose while Elfora Bishoftu and Kombolcha slaughter animals for local and export purpose. These abattoirs are located in Oromiya, Southern People National and Nationalities (SPNN), Amhara and Tigry regional states which account for more than 95% of cattle population in the country. The local abattoirs slaughter about 150 cattle per a day for about 200 days a year while the export abattoirs slaughter more than 250 cattle per a day as per the demand of the market.

Table 3.1 Description of study abattoirs

Abattior	Service	City	Region	Distance from Addis (km)	Location	Altitude (m.a.s)	T°C	RF mm
Adama	Local	Adama	Oromiya	99 east	8°32'N39°16E	1712	13-27	809
Hawassa	Local	Hawassa	SPNN	250 south	7°03'N38°28E	1500-2000	20-25	800-1000
Kombolcha	Local, export	Kombolcha	Amhara	375 north east	11°4'N39°44E	1842 - 1915	11 - 26	750 - 900
Mekelle	Local	Mekelle	Tigray	783 north	7°13'N 35°52E	2000-2200	11- 24	579-650
Abergelle	Export	Mekelle	Tigray	783 north	7°13'N 35°52E	2000-2200	11- 24	579-650
Melgawond	Export	Hawassa	SPNN	270 south	7°37'N 38°37'E	1800	10-29	1372
Bishoftu	Local	Bishoftu	Oromiya	47 east	8°45'N 38°59'E	1880	9-23	1151.6

3.2 Data collection

3.2.1 Data collected on abattoirs operations, facilities and management system practiced

Information on Lairage management, stunning method, bleeding, carcass processing and transporting was collected by direct observation, photograph and discussion with workers from public (Adama, Hawassa and Mekelle) and private (Elfora Kombolcha) abattoirs in Ethiopia between August 2013 and January 2014. To identify the causes of inferior quality of carcasses, the presence/absence of basic slaughter facilities, equipment and slaughter procedure were compared between abattoirs.

3.2.2 Data on carcass quality and yield at local abattoirs

Data collected from Adama, Hawassa, Elfora Kombolcha and Mekelle abattoirs were used to evaluate carcass quality and yield of cattle slaughtered at local abattoirs. A total of 3080 data was collected from 10% cattle slaughtered in each abattoir in the dry and the wet season between August 2013 and January 2014. Data was collected from 7-10 days from each abattoir in each season during slaughtering of cattle.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Information on wither circumference, categories of cattle slaughtered, gender, hot carcass weight, weight of back bone, conformation and fat grade were collected from the study abattoirs. Conformation and fat scores were recorded by an inspector at all abattoirs studied to avoid subjective difference between evaluators. Half right side of whole carcasses were weight randomly using weighing scale sensitive at 100 gm. The weight of half right side was multiplied by two to estimate whole carcass weight. The back bone of each animal was weighted during data collection. The back bone (vertebral column) is comprises of bones from the first cervical vertebrae to coccygeal vertebrae that make up the base of the tail. Carcasses were categorized in to cows, growing bulls, intact bulls and castrated bulls based on Ethiopian beef classification system (Table 2.2). Moreover, data was collected on sanitary conditions of the hide of the cattle using mud score technique (Boleman *et al.,* 1998). For the purpose, mud score 0 was given for cattle with no mud; mud score 1 for cattle with mud on legs and mud score 2 for cattle with mud on legs and belly. The lengths of horns were measured using measuring tap. Data was collected on the hide color of cattle. Hide color were classified based on primary color (>50% total hide surface area) in to black, white, red, gray or Holstein.

3.2 .3 Data on carcass, meat yield, meat cuts and quality from selected cattle breeds at export abattoirs

This study was conducted from Abergelle and Melgawondo export abattoirs. Information recorded on source of cattle, breeds, live weight and carcass weight from 22,302 cattle slaughtered from September 2010 to July 2011 was used for the study. Boran, Barka, Arado, Raya and nondescript cattle breeds were slaughtered in the abattoirs. Boran breed was slaughtered at Melgawendo abattoir while Arado, Barka, Raya and nondescript breeds

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

slaughtered in Abegelle abattoir. In addition to carcass traits mentioned above, data was collected on meat yield, yield percentage and weights of primal meat cuts from 93 carcasses of cattle slaughtered at Abergelle abattoir. This information was obtained from 23 Arado, 16 Barka, 16 Raya and 37 nondescript cattle breeds. All cattle supplied to Melgawendo abattoir were intact male while those supplied to Abergelle abattoir was mix of castrated and intact bulls. The cattle slaughtered in the study abattoirs were in the age between 3-5 years old. Boran catte was produced in pastoral production system and finished in the feedlot while other breeds in the study were produced in mixed crop-livestock production system. pH data was collected from November 2011 to August 2012 from 151 carcasses chilled at 4 °C for 24 h using pH paper strips.

3.2.4 Data on condemnations of carcasses and organs at local and export abattoirs

Daily condemnation records for cattle slaughtered at Abergelle, Elfora Bishoftu and Elfora Kombolcha abattoirs were used as the sources of the data. Daily meat inspection was carried out by qualified federal veterinary inspectors. Routine ante-mortem examinations of all animals were carried out for slaughtered cattle a day before or shortly prior to slaughter. This is followed by postmortem meat inspection involving visual examination, palpation, and systematic incision of carcasses and visceral organs, particularly lungs, livers, kidneys, hearts, spleens, tongues, heads and intestine according to procedures described Meat Inspection Guideline of Ethiopia, 2010. Organs were grossly diagnosed based on pathological changes such as colour, size, morphology, consistence, presence of lesions or parasites. At the end of meat inspection, all partial and whole condemned carcasses and organs were taken to the laboratory at each respective abattoir for further examination and identification of the lesions and parasites. In case causes of diseases

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

were not confirmed in each respective laboratory, samples were submitted to the regional/ national animal health laboratory for further diagnosis.

A total numbers of 62,917 cattle slaughtered at Abergelle, Elfora Bishoftu and Elfora Kombolcha abattoirs from February 2010 to November 2013 were used for the study. The number of cattle slaughtered in these abattoirs were 39098, 9227 and 14592, respectively. The number of cattle slaughtered in 2010, 2011, 2012 and 2013 were 12708, 34674, 10363 and 5172, respectively. Almost all cattle slaughtered came from mixed crop livestock and agro-pastoral production systems.

The economic loss due to condemnations of carcass and organs were analyzed for Elfora Kobmolcha abattoir based on the annul report of condemned carcass and organs from July 2010 to June 2013. Economic loss due to condemned organs was estimated based on the retailed market price of average size of organs (liver, kidney, lung, heart, tongue, head and spleen). Morover, economic loss due to condemnation of carcasses was calculated based on data analysed in the second part of the study i.e average carcass weight at the Kobmolcha abattoir (95.67 kg), average meat yield percent at the studied abattoirs (67.81%) and the current price of kg of meat (150 ETB).

3.3 Statistical analysis

Data was analyzed using procedure of GLM of SAS 2011 and JMP version of the SAS software. Factors showing significant difference at probability level of $p<0.05$ were compared using Tukey pairwise comparison procedure. In the first part of the study, carcass weight was analyzed using conformation grade, fat grade, categories of cattle and abattoirs as fixed effects. The percentage of different grades of conformation and fat of carcasses was calculated as a ratio of carcasses in each category to the total carcasses evaluated. Dressing percentage was estimated as the ratio of carcass weight and estimated live weight multiplied by 100. In the second part of the study, standard linear model was used to estimate meat yield from live weight and carcass weight, viz. $Y=a+bx_1+cx_2$, where y represent meat yield (kg), b and c are regression coefficients for fixed effect of live weight (x_1) and carcass weight (x_2). ANOVA was used to analyze fixed effects of breeds on meat cuts. The Bonferroni correction method was used for unequal number of observation. Moreover, meat yield was estimated from meat cuts of fore- and hindquarters. Cold carcass weight was calculated by multiplying warm carcass weight by 0.98 (Anon, 2004). Meat yield percentage was calculated as the ratio of kg of meat yield and cold carcass weight multiplied by 100. In the third part of the study, prevalence of disease was calculated as a ratio of number of cattle positive for specific disease condition to the total number of cattle slaughtered during the day and further compared using chi-square test at critical probability of $p<0.05$. Presence (value = 1) and absence (value = 2) of diseases condition was used to test the significant difference between abattoirs, years and season.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

CHAPTER 4

4 ABATTOIRS OPERATIONS, FACILITIES AND MANAGEMENT IN ETHIOPIA

4.1 Introduction

Proper handling of animals is not only a matter of welfare but also it is about a quality of meat. Improper handlings of animals yield poor quality meat. Poor quality meat will have poor processing properties, functional quality, eating quality and less likely to be accepted by consumers (Ferguson and Warner, 2008). Carcass and meat quality defects such as pale soft exudates, dark firm dry, skin blemish, blood splash, bruising, cyanosis, high microbial load, spoilage of meat, broken bones and death may occur from improper animal handling (Warriss 2000; Forrest 2010; Adzitey et al 2011; Adzitey and Nurul 2011). Pre-slaughter animal handling starts from the farm, through marketing and end at the abattoir activities (offloading, lairaging, veterinary inspection and slaughtering; Adzitey 2011). Moreover, handling of animals during slaughter can also influence the quality of meat (MLA, 2011). Imperfect bleeding affects the quality of meat as more blood in the meat makes it more prone to microbial multiplication which ultimately reduces the quality of meat. Moreover, stunning methods affects the bleeding process (Gracey et al., 1999). Carcass handling can also contribute significantly to the quality of meat (Adzitey and Huda, 2012). During processing of carcasses contamination can occur from slaughter facilities, equipment, workers, and environmental (Jay 1992). Different abattoirs have different facilities and management system which can affect the quality of meat differently. Commercial abattoirs have sophisticated machinery (Gregory, 2005) while most municipal abattoirs have poor handling facilities (Ndou *et al.*, 2011). These differences are thought to have an effect on animal behavior at slaughter and the quality of the product. Animals' reactions differ with different handling techniques and systems (Grandin, 1999). Slaughtering technology is becoming important as it had a large influence on meat quality (Swatland, 2000). Animal welfare problems are related to inadequate facilities and equipment, lack of training of personnel and improper animal handling (Grandin, 1996). It is the responsibility of the abattoirs to ensure the stress and welfare of animals from the time the animals arrive at the abattoir until the time of slaughter (RMAA, 2011). Animals which are well looked at slaughter provide good quality meat products. In less commercial abattoirs with little machinery available there is high human-animal interaction which can be a cause of stress to the animals due to fear of humans (Breuer et al., 2000; Hemsworth, 2003; Waiblinger et al., 2006). Research has shown that a better quality meat with a longer shelf life can be produced if animals are handled with greater patience, understanding and care at slaughter (RMAA, 2011). Hence it is important to asses the level of facilities and management in public/municipal abattoirs to identify the impact of operation on quality of meat. There was no documented information on operation, facilities and managements in public and private abattoirs in Ethiopia. This study was therefore conducted to assess the level of operation; facilities and management at public and private abattoirs in Ethiopia and suggest possible improvement strategy.

4.2 Results

4.2.1 Capacity, end product and working time of public and private abattoirs

Capacity, end product and working time of public and private abattoirs is presented in Table 4.1. The public and private abattoirs studied had a capacity of slaughtering from 100-300 cattle per a day. Adama, Hawasa and Mekelle abattoirs are public abattoirs while Elfora Kombolcha was private abattoir. Public abattoirs gave slaughter service to butcheries. They distribute quartered carcasses to their clients. The private abattoir purchased cattle, process and distribute meat to clients. Moreover, the abattoir process corned beef for local and international market. Public abattoir worked during the night, early in the morning and late in the afternoon. However, the private abattoir worked during the day time.

Table 4.1 Capacity, end product and working time of public and private abattoirs

Abattoir	Capacity	Ownership	Location	Out put	Working time
Adama	100-300	Public	Outside city	Carcass	20:30-06:00
Hawasa	100-150	Public	Outside city	Carcass	20:30-06:00
Elfora Kombolcha	250-300	Private	Inside city	Meat and corn beef	06:00-16:00
Mekelle	100-150	Public	Inside city	Carcass	05:00-09:00, 14:00-20:00

4.2.2 Facilities available at public and private abattoirs

Facilities available at public and private abattoirs are presented in Table 4.2. All abattoirs have Lairage, stunning boxes, hoisting facilities and vehicle to transport carcass and meat. However, it was only at Adama and Elfora Kombolcha abattoirs that Lairage was divided in to compartments to accommodate different classes and types of animals. In the other abattoirs, the Lairage was constructed as a unit to accommodate all classes and types of cattle together (Fig. 4.1).

Table 4.2 Facilities available at public and private abattoirs

Abattoirs	Lairage	Stunning box	Stunning	Hoisting	Knife and axes sharpening facilities	Sterilization facilities	Hot water	Referigtor	Deboning room	carcass quartering	Lab	Vehicle
Adama	Yes	Yes	knife	Electrical	No	No	Yes	No	No	Manual axe	No	2
Hawasa	Yes	Yes	knife	Electrical	No	No	Yes	No	No	Manual axe	No	2
Elfora Kombolcha	Yes	Yes	knife	Electrical	Yes	No	Yes	Yes	Yes	Electrical saw	Yes	2
Mekelle	Yes	Yes	Hammer and Knife	Manual	Yes	No	No	No	No	Manual axe	No	2

Watering trough was available only at the Lairage at Kombolcha abattoir. Information obtained from the workers in public abattoirs revealed that cattle were slaughtered in 2-3 hours after arrival at the Lairage while private abattoir cattle were required to stay in the Lairage for 12-24 hrs before slaughter. During this time cattle had an access to water but not to feed.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Figure 4.1 Lairage facilities at Elfora-Kombolcha(left), Adam (middle) and Hawassa (right)

Stunning boxes were available in each abattoir (Fig. 4.2). The boxes were properly designed in all but Mekelle abattoir. However, in all abattoirs, boxes were not on use as cattle were not willing to enter in to the boxes (based on information from the workers). In all abattoirs enervation method of stunning was practice. This method was conducted by thrusting sharp knife to the atlanto-occipital space of the cattle (Fig. 4.3).

Figure 4.2 Stunning box at ElforaKombolcha (left), Mekelle (middle) and Adama (right)

There were no Knife and axe sharpening machine in Adama and Hawasa abattoirs (Table 4.2). In these abattoirs, workers sharpen these equipments out side the abattoir by their own means. There were no means of sterilizing equipment in all abattoirs visited. Hot water was available during working time in all but Mekelle abattoir. Carcasses were quartered using axe, manually, in the public abattoirs while electrical saw was used in the private abattoir. Vehicle to transport carcasses were available in all abattoirs visited (Table 4.2).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Figure 4.3 Stunning using sharp knife at atlanto-occipital space at Kombolcha (left) and Adama (right) abattoirs

4.2.3 Inspection, recording, weighting and grading practices at public and private abattoirs

Inspection, recording, weighing and grading practices at public and private abattoirs is presented in Table 4.3. In all abattoir visited, veterinarian inspect live animals some hours or a day before slaughter. Based on anti-mortem inspection, animals were accepted, condemned and remained for some more days of observation in the Lairage. Similarly, there were good practices of inspecting carcasses in all abattoirs visited. However, recording of anti- and post mortem finding was regularly conducted only in Kombolcha abattoir. Moreover, this abattoir reports the causes of condemnations of live animals and carcasses every 3, 6 and 12 months to regional agricultural bureau. This practice of reporting causes of condemnations to responsible offices was not practiced by public abattoirs.

Table 4.3 Inspection, recording, weighing and grading practices at public and private abattoirs

Abattoir	Anti- and postmortem inspection	Recording disease finding	Live and carcass weight	Record source of cattle	Report of causes of condemnation to regional office	Classification of carcasses
Adama	Yes	occasional	No	No	No	No
Hawasa	Yes	occasional	No	Yes	No	No
Kombolcha	Yes	Always	Yes	No	Yes	No
Mekelle	Yes	occasional	No	No	No	No

Weighing scale for live animals and carcasses were available only in Kombolcha abattoir. In this abattoir live weight, carcass weight and meat yield were measured every working days. This facility was not available in the public abattoirs and hence there was no practice of recording live and carcass weight of cattle. Recording the origins of cattle was practiced by Hawasa abattoir. This experience was not available in other abattoirs visited. Classifying carcasses was not practiced in all abattoirs (Table 4.3).

4.2.4 Bleeding, evisceration, flaying hides, processing and transport of carcass

Bleeding was conducted on the floor at all public abattoirs. In these abattoirs, evisceration was conducted on horizontal position on the floor by incising the hide at the bottom of the abdomen with out flaying the skin. At Kombocha abattoir both bleeding and evisceration was conducted on vertical position after hoisting the carcasses (Fig.4.4).

Figure 4.4 Sticking of cattle at Kombolcha (left) and Adama (right) abattoir

Carcasses were hoisted using mechanized hoisting system in all except Mekelle abattoir where workers hoisted carcass manually using chained pulley system after flaying the skin and evisceration on the floor (Table 4.2). The hides were flied after hoisting the carcasses at Adama, Hawassa and Kombolcha abattoirs. In these abattoirs, carcasses were hoisted higher above the ground creating less chance of contamination of carcasses by filth and blood on the floor. At Mekelle abattoir, carcasses were not raised high enough from the ground and they touch the floor during processing (Fig. 4.5).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Figure 4.5 Carcass processing at Mekelle (left), Kombolcha (middle) and Adama (right) abattoir

Carcasses were quartered immediately before being loaded on the vehicles. The distance between conveyer bar and the vehicle was 1-10 meters. The distance between conveyer bar and the vehicle were relatively longer at Hawassa abattoir and relatively shorter at Adama abattoir. Between the two points, workers transport carcasses on their shoulder. Carcasses were suspended in the vehicle to be transported to butcheries. In most cases, carcasses were toughing the floor of the vehicle during transport (Fig. 4.6)

Figure 4.6 Vehicle (left) and carcass suspended in the vehicle for transport to butcheries (middle and right)

In all abattoirs visited, dehorning was conducted using an axe (Fig. 4.7). At Kombolcha abattoir horns were removed at hoisted position while in the public abattoirs the head removed from the body was taken in to separate rooms for dehorning.

Figure 4.7 Dehorning using an axe

Separate rooms from the carcasses were used to process rumen and intestine in all abattoirs. Bones, hoofs and hides were semi-processed to supply for respective companies in the private abattoirs while only hides were considered as valuable product in public abattoirs. Horns and hoof were wasted with out being marketed in the latter abattoirs.

4.3 Discussion

All meat animals suffer from stress following transport. Therefore it is important that lairage should provide comfortable environment to relief animals from stress. Among the abattoir visited during the study period, Adama and Elfora Kombolcha abattoirs had well designed Lairage which are well ventilated and have accommodations for different classes and types of slaughter animals. The Lairage in the other abattoirs were constructed as a unit to accommodate all class and types of slaughtered cattle together. Lairages should be well ventilated and provided with adequate day and night lighting (Cortesi, 1994). Animals need to be separated based on their sex, ages and origin. Mixing different class and type of animals is a source of physical and psychological stress (Gracey 1981). In all abattoirs visited, there were no feeding troughs in the Lairage. Watering trough was available only in the private abattoir. Well designed watering and feeding troughs should be placed along the walls of the Lairage in adequate number (Cortesi, 1994). Drinking water must be constantly available throughout the waiting period till slaughter (Grandin, 2003). Feed must also be provided if slaughter does not take place within twelve hours (Ledger and Payne, 1990). Availability of water at all times in the Lairage will make processing of rumen and intestine easier; it promotes proper bleeding and makes flaying very easy. At Kombolcha abattoir slaughter cattle were required to spend at least 12 hours in the Lairage to make sure that they do not take any solid feed before slaughter. In the public abattoirs animals reach abattoirs 2-3 hours before slaughter. This makes it difficult to know whether cattle were starved for at least 12 hours before slaughter. FAO (1991) specifies the withdrawal of feed 12-24 hours before slaughter. This will reduce the risk of contaminating the carcass with the gut content during evisceration, and reduce processing time and cost. Cattle were slaughtered in most public abattoirs during the night and early in the morning. This was to provide fresh meat early in the morning to the consumers.

Anti-mortem examination of animals and post mortem inspection of carcasses and organs were conducted in all abattoirs visited. However, the causes of condemnations were regularly recorded in the private abattoir. The record book in the public abattoirs revealed that there was no practice of daily recording on causes of condemnations of live cattle. Moreover, the private abattoir provides quarter, semi-annual and annuls reports on causes of condemnations of live animals, carcasses and organs to regional Berea of Agriculture. This practice was not observed at public abattoirs. All abattoirs should be able to report their finding to the responsible sector in the Ministry of Agriculture so that the latter body will develop integrated preventive and control strategy on major animal and public health important diseases.

Recording the origin of slaughter animals were not practiced in all but Hawassa abattoir. This experience must be shared by other abattoir so that quality, yield and disease problems can be traced to the origin there by taking appropriate measure to improve the situations.

Slaughtering is a stressful process and hence must be efficient that minimize fear, excitement, pain or suffering of animals before slaughter. Unstressed animals before slaughter make

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

slaughter operations easier and safer (Cortesi, 1994). However, what was practiced at the abattoirs was different from this reality. A group of cattle were allowed to inter in to slaughter floor at a time. In this part of the slaughter house, they wait for their turn for stunning and sticking watching all activities of slaughter. The stunning boxes in each abattoir were not on use. Information from the workers reveled that cattle were not willing to inter in to this box. The causes of this problem must be sorted out and appropriate measure must be taken in the future. Cattle were stunned by workers by holding their horns and/or tying on any available poles. Stunning cattle with out stunning boxes would compromise the safety of the worker. Moreover, it increases the level of stress on animals. Enervation method of stunning method was practiced in all abattoirs. Enervation was reported the least effective methods of stunning known to date (Gracey 1981). This method was reported paralyses the animal but does not produce loss of consciousness, as blood supply to the brain is not stopped (Leach, 1978). This method was banned from European community long ago. Efficient stunning methods are well defined in European Union (formerly Economic Community, EEC), Directive 74/577 (Council of Europe, 1974). According to this Directive, "stunning means a process effected by a mechanically operated instrument, electricity, or gas anaesthesia without adverse effects on the condition of the meat or the offal, which when applied to the animal puts it into a state of insensibility which lasts until it is slaughtered, thus sparing it in any event needless suffering." Similarly, for abattoirs in Ethiopia, stunning methods should be defined that minimize suffering of animals, maximize safety of workers and improve quality of meat product.

It is important that each abattoir should have its own sharpening machine and sterilizers to avoid the use of blunt knife and unhygienic equipments. Giving the responsibility of sharpening knife for each worker will compromise the sharpness of the knife and hygiene equipment. The knife that is used for slaughter purpose must be clean and sharp (FAO, 2004).

Even though proper equipment for hanging carcasses was found in the abattoirs, it was not properly used. Proper equipment for handling carcasses includes manual or electric hoists for lifting up the carcass – getting it off the floor for flaying, eviscerating and splitting (FAO, 2008). In all public abattoirs, bleeding was conducted on the floor on horizontal position. Even though horizontal bleeding promotes faster bleeding rates (RMAA, 2011), it is not as hygienic as vertical bleeding. Moreover, in the pubic abattoirs evisceration was made on the filthy floor without flaying the skin. This might expose carcasses for contamination by blood and mud from the skin. At one of the public abattoir, it was observed that flaying of the skin was conducted on the floor. This would further contaminate the carcasses and compromise the quality of meat. This might be the reason for poor quality of beef reported at local markets in Ethiopia (Kumar et al., 2010).

At public abattoirs, workers transported carcasses from conveyer bar to the vehicle on their shoulder. They used plastic gown which covered their head and their back. However, the hygienic condition of these clothing was not up to the standard require for abattoir personnel. Personnel at the abattoirs didnt wear clean aprons, clothing, boots, mesh gloves and hair cap during meat processing. This might be the reason for high aerobic plate count (APC) in beef sold at local markets in Ethiopia (Kumar et al., 2010). For good hygienic practices and production of high quality meat, workers should maintain their hands clean; wear clean protective clothing to cover both their body and hair.

During transporting carcasses to butchery, quartered carcasses were suspended in the vehicle touching the floor of the vehicle. The rumen, intestines and head were placed on the floor under suspended carcasses. This might further increase the chance of contact between carcasses and rumen exposing the former for microbial contamination.

In most abattoirs studied, horns were removed mechanically using an axe. Moreover, in one of the abattoir it was observed that stunning was made with hammer in addition to enervation method practiced. This might increase the chance of bruising the head their by lowering its market value.

The tendency to pay beef producers based on carcass yield and quality traits is increasing (Lazzaroni, 2007). Hence it is important to measure the live weight, carcass weight and evaluate quality of beef slaughtered in each abattoir. The absence of weighing scale in all public abattoirs needs considerable attention. Live and carcass weight of cattle slaughtered in public abattoirs should be identified. Beef carcass classification system developed by the country (ES, 2012) must be implemented in each abattoir. Implementing this program will help to identify the quality and yield problems of beef in the country and develop improvement strategy in the future.

A country like South Africa has developed the laws governing abattoir operations which include The Meat Act, 2000, and the Animal Protection Act, 1962 and 1935 for animal welfare maintenance (RMAA, 2011). This kind of law should be developed for public and private abattoirs in Ethiopia to ensure public health safety, the welfare of animals, maximize efficiency and quality of meat. A hazard analysis at critical control points (HACCP) system is strongly recommended in all abattoirs. By making regular measurements at critical control points (CCPs), various critical operations that are carried out by workers, handling and slaughtering animals can be monitored to ensure that they are done properly, leading to steady improvements in welfare and operational quality. Monitoring and evaluation of the CCPs should be conducted on a regular basis (FAO, 2004).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

4.4 Summary

There was significant difference in operation, facilities and management system practiced at public and private abattoirs in Ethiopia. Moreover, difference in facilities and management were observed within public abattoirs. Howevere, the management practiced in all abattoirs contributes to poor qualities of carcasses in one way or the other. Lairages were not divided in to compartment to accommodate different class and types of slaughter cattle in two of the four abattoirs visited. In all abattoirs, stunning boxes were not used, enervation method of stunning was practiced and there were no means of sterilizing cutting equipments. Even though anti- and post mortem inspection was conducted properly in all abattoirs, findings were not regularly recorded in public abattoirs. Weighing scales were not available at the public abattoirs while live and carcasses weights were regularly measured in the private abattoir. In all public abattoirs, bleeding was conducted on the floor at horizontal position while it was performed in vertical position in private abattoir. Carcasses were exposed for contamination either during processing and/or during transport in the public abattoirs. Classifications of carcasses were not practiced in both public and private abattoirs. Hence it is important that the country should develop law governing abattoirs operations. Moreover, hazard analysis at critical control point (HACCP) should be established in all abattoirs to maintain welfare of animals, maximum efficiency and a quality of beef product.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

CHAPTER 5

5 SURVEY ON BEEF CARCASS PRODUCTION AND QUALITY IN ETHIOPIA

5.1 Introduction

Livestock plays an important role in the agriculture of Ethiopia. It contributes 15 to17% of GDP and 35 to 49 % of agricultural GDP (CSA, 2008). Cattle contribute about 80% of GDP that come from livestock (Tefera, 2011). Ethiopia has 53.4 million cattle (CSA, 2011) which represent the largest cattle population in Africa (Negassa *et al.,* 2011). However, the potential has not been fully utilized. Cattle in Ethiopia produced about 3.2 billion liters of milk and 0.331 million tones of meat annually (CSA, 2008). Average carcass weight of cattle was 108 kg per head (Negassa *et al.,* 2011), while Ethiopians consume about 8 kg of meat per capita annually which is far less than what is consumed in developing countries (Betru and Kawashima, 2009). Very little research has been done concerning meat production in Ethiopia (Avery, 2004), and in particular, on carcass quality of beef cattle (Negassa *et al.,* 2008). Carcass qualities are mainly determined by age, sex, conformation and fat cover of carcasses (Lazzaroni and Biagini, 2009). Different proportion of categories of cattle, conformation grade and fat grade were reported for different abattoirs in different countries. In USA 87.3% bulls and heifers slaughtered were less than 2 years of age (Savell *et al.,* 2011). In Italy the proportion intact bulls, cows, veal calves and other females were reported as 46.46%, 24.69%, 15.16% and 13.04%, respectively (Lazzaroni and Biagini, 2009). In Poland the proportion of intact bulls was about 47% (Weglarz, 2010). The proportion of conformation grade 1 (superior conformation) in Mexico was reported about 17.8% (Mendez *et al.,* 2009). However, in North-West of Italy it was reported as 28.92% (Lazzaroni and Biagini, 2009). The proportion of fat grade 1, 2 and 3 in North-West of Italy was

8.43%, 86.35% and 5.23%, respectively (Lazzaroni and Biagini, 2009). Even though Ethiopia has developed beef carcass classification system recently (ES, 2012), the system was not used to characterize the carcass quality to date. Characterizing carcass traits of cattle is one of the important means to develop an appropriate improvement strategy of the sector. Moreover, the tendency to pay beef producers based on carcasses quality and weight is increasing. Weighing scale is one of the problems in determining the live and carcass weight of cattle slaughtered in local abattoirs in many developing countries (Abdelhadi *et al.,* 2011). The same is true for local abattoirs in Ethiopia. Hence, it is important to investigate the relationship between different carcasses measurements and carcass weight so that prediction equations will be developed to estimate the weight of carcasses. Different carcasses measurement has been studied as a useful predictor of carcass weight, grading and dressing percentage (Abdelhadi *et al.,* 2011).

The objective of this study was therefore to evaluate carcasses yield and quality of cattle slaughtered at local abattoirs in Ethiopia and investigate the relation between carcasses measurement and carcass weight.

5.2 Results

5.2.1 Carcass yield difference between abattoirs, season, conformation, fat grades and categories of cattle

Carcass yield difference between abattoirs, season, conformation grades, fat grades and categories of cattle are presented in Table 5.1. The average carcass weight at local abattoirs was 135.90 $\pm$ 0.69 kg. Carcass weight was significantly ($p<0.001$) different between abattoirs, season, conformation grades, fat grades and categories of cattle slaughtered. A higher carcass

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

weight was observed in Adama abattoir (161.26 ± 1.05 kg) compared to Hawassa (142.46 ± 1.10 kg) and Mekelle (136.15 ± 1.17 kg) abattoirs. Cattle slaughtered in Kombolcha abattoir had lower carcass weight which was 95.63 ± 0.46 kg.

Table 5.1 Carcass yield difference between abattoirs, season, conformation grades, fat grades and categories of cattle

Variables	Number of observation	Mean (kg)	Se
Overall mean	3080	135.90	0.69
Abattoir			
Adama	1122	161.26[a]	1.05
Hawassa	429	142.46[b]	1.10
Kombolcha	781	95.63[d]	0.46
Mekelle	748	136.15[c]	1.17
Season			
Dry	1661	119.56[b]	0.89
Wet	1419	155.02[a]	0.83
Conformation grade			
1	924	171.24[a]	1.04
2	1056	130.39[b]	0.85
3	1100	111.51[c]	0.89
Fat grade			
1	2079	120.69[c]	0.70
2	726	162.59[b]	1.09
3	275	180.44[a]	1.80
Category			
Cow (F)	165	103.10[c]	2.24
Growing bull (JM)	121	132.36[b]	2.57
Intact bull (M)	803	150.90[a]	1.34
Castrated bull (O)	1991	132.78[b]	0.83

Means in the same column with different superscript letters differ ($p<0.001$)

A higher carcasses weight in the wet season (155.02 ±0.83 kg) was higher than the weight in the dry season (119.56 ±0.89 kg). Conformation grade 1 had higher ($p<0.001$) carcass weight (171.24 ±1.04 kg) than conformation grade 2 (130. 39±0.85 kg) and conformation grade 3 (111.51 ±0.89 kg). Conformation grade 1, 2 and 3 accounted for 30%, 34.29% and 35.71% of carcasses evaluated, respectively (Fig. 5.1).

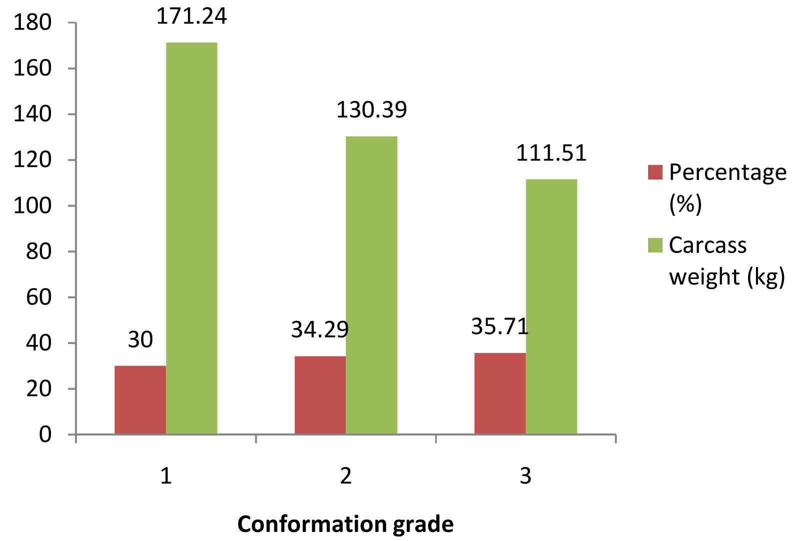


Figure 5.1 Percentage and carcass weights in different conformation grades

5.2.2 Percentage of different conformation, fat grades and categories of cattle

Fat grade 3 carcasses had higher ($p<0.001$) weight (180.44 $\pm$1.80 kg) compared to fat grade 2 carcasses (162.59 $\pm$ 1.09 kg) and fat grade 1 carcasses (120.69 $\pm$ 0.70 kg). Fat grade1, 2 and 3 accounted for 67.5%, 23.57% and 8.93% of carcasses evaluated, respectively (Fig. 5.2).

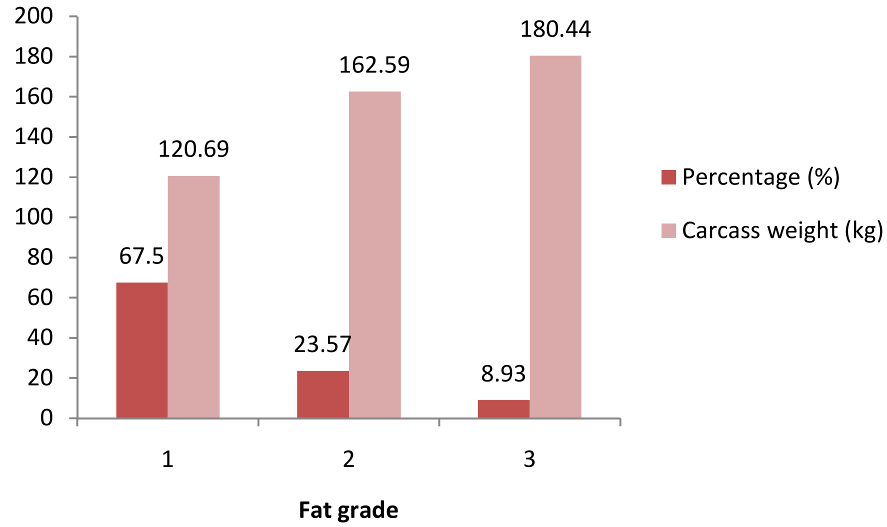


Figure 5.2 Percentage and carcass weight in different fat grades

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Figure 5.3 further illiterate the effect of conformation with in fat categories on carcass weight of cattle. With in each fat category, as the level of conformation carcasses decrease from 1 to 3 the carcass weight also decreases. The carcass weights increased as fat grade increased from 1 to 3 in all categories of conformations.

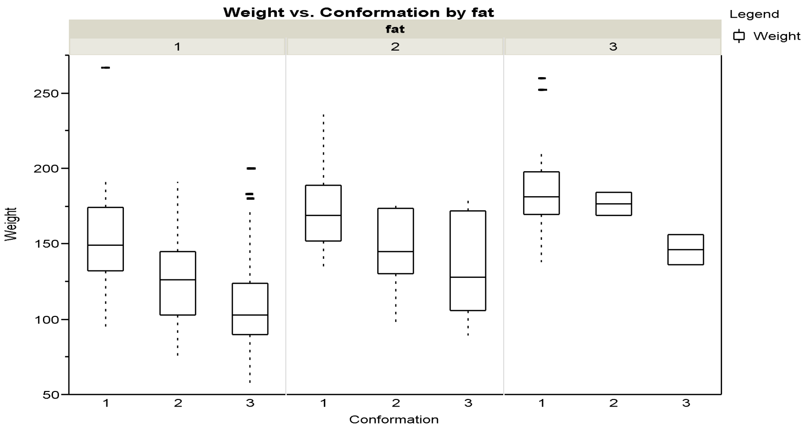


Figure 5.3 Carcass weight affected by fat and conformation with in fat grade

Figure 5.4 illustrates the proportion of carcass weights with in fat and conformation grades. Carcasses with a lower weight generally had a lower carcass fat content. There was no carcass with fat grade 3 with in the weight categories between 57 and 124 kg. Most of these carcasses in this category were in fat grade 1 and few in fat grade 2. Fat grade 3 carcasses were observed in categories of carcass weight between 124 and 267 kg.

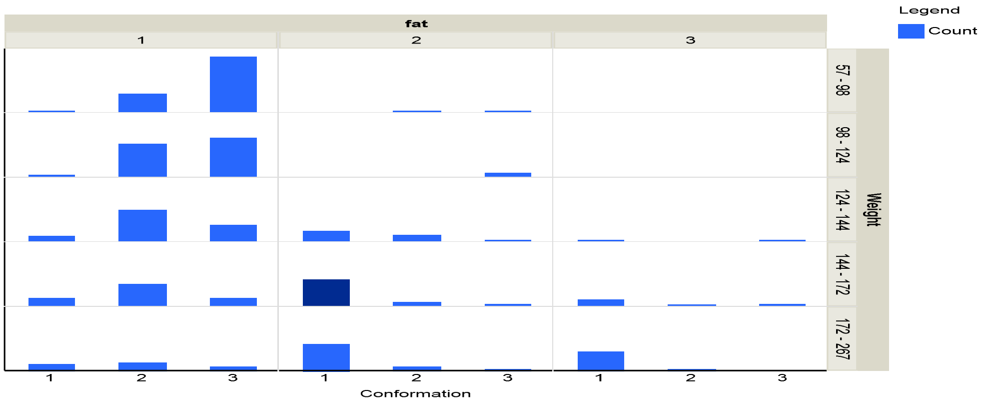


Figure 5.4 Conformation by fat with in carcass weight

The proportion of intact bulls, castrated bulls, growing bulls and cows accounted for 26.07%, 64.64%, 3.95% and 5.36% of carcasses evaluated, respectively (Fig. 5.5). Intact bulls had higher mean carcass weight (150.90+1.34 kg) compared to castrated bulls (132.78 +0.83 kg), growing bulls (132.36 +2.57 kg) and cows (103.10 +2.24 kg; Table 5.1).

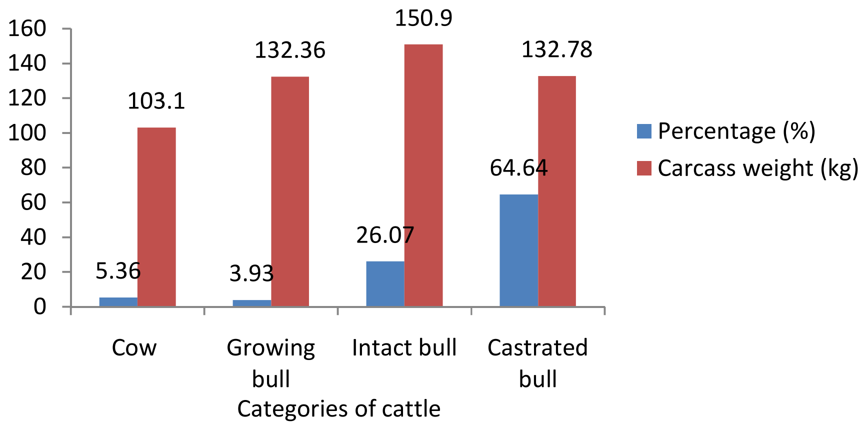


Figure 5.5 Precentage and carcass weight of different categories of cattle

5.2.3 Conformation and fat grades of carcasses at local abattoirs

Carcass conformations of cattle slaughtered in Adama, Hawassa, Mekelle and Kombolcha abattoirs is presented in Table 5.2. A higher proportion conformation grade 1 carcass (superior conformation) was observed in Adama local abattoirs (57.84%) compared to Hawassa (35.90%)

and Mekelle (16. 04%) with mean carcass weights of 176.32 + 1.19, 157.79+ 1.31 and 161.09 + 3.95 kg, respectively. No carcass with conformation grade 1 was observed at Kombolcha abattoir. Conformation grade 2 carcasses were higher at Hawassa (45.92%) and Mekelle (44.25%) abattoirs compared to Kombolcha (33.80%) abattoir with carcass weights of 138.14 + 1.42 kg, 137.60 + 1.29 kg and 100.29 + 0.70 kg, respectively. This conformation grade was lower at Adama abattoir (22.46%) with carcass weight of 151.89 + 1.50 kg. Conformation grade 3 carcasses (inferior conformation) were relatively lower at Adama (19.70%) and Hawassa (18.18%) abattoirs compared to Mekelle (39.71%) abattoir with carcass weight of 127.58 + 2.23 kg, 138.14 + 2.94 kg and 124.37 + 1.65 kg , respectively. This conformation grade was higher at Kombolcha abattoir (66.20%) with carcass weight of 93.26 + 0.57 kg.

Table 5.2 Conformations grades of carcasses at local abattoirs

Abattoir	Conformation Grade*	Carcass number	Percentage**	Mean weight (kg/ carcass)	SEM
	1	649	57.84	176.32^{a}	1.19
Adama	2	252	22.46	151.89^{b}	1.50
	3	221	19.70	127.58^{c}	2.23
	1	154	35.90	157.79^{a}	1.31
Hawassa	2	197	45.92	138.14^{ab}	1.42
	3	78	18.18	131.06^{b}	2.94
	1	120	16.04	161.09^{a}	3.95
Mekelle	2	331	44.25	137.60^{ab}	1.29
	3	297	39.71	124.37^{b}	1.65
	1	0	0.00	-	-
Kombolcha	2	264	33.80	100.29^{a}	0.70
	3	517	66.20	93.26^{b}	0.57

*1-superior conformation, 2- moderate conformation, 3- inferior conformation;
** Proportion of carcasses in each conformation categories
Means in the same column with different superscript letters differ ($p<0.001$)

Fat grades of carcasses at Adama, Hawassa, Mekelle and Kombolcha abattoirs are presented in Table 5.3. A lower proportion of fat grade 1 carcasses were observed at Adama (28.43%) compared to Hawassa (61.54%) abattoir with the mean carcass weights of 139.48 + 1.91 and 133.83 + 1.21 kg, respectively. However, almost all carcasses evaluated at Mekelle (95.59%) and Kombolcha (100.00%) abattoirs were fat grade 1 with the mean carcass weights of 134.49+ 1.19

and 95.63 ± 0.46 kg, respectively. The proportion of fat grade 2 carcasses at Adama was higher (51.96%) compared to Hawassa abattoir (28.44%) with mean carcass weights of 165.29 ± 1.26 kg and 148.27 ± 1.98 kg, respectively. The proportion of the same fat grade was very low at Mekelle abattoirs (2.81%) with mean carcass weights of 170.00 ± 0.44 kg. The proportion of fat grade 3 carcasses at Adama and Hawassa were 19.61% and 10.02% with mean carcass weights of 182.15 ± 2.19 and 173.00 ± 2.20 kg, respectively. The proportion of this fat grade was very low at Mekelle abattoirs (1.60%) abattoir with mean carcass weights of 176.00 ± 1.23 kg. No fat grade 2 and 3 carcasses were observed at Kombolcha abattoir during the study period.

Table 5.3 Fat grades of carcasses at local abattoirs

Abattoir	Fat grade*	Carcass number	Percentage**	Mean weight (kg/ carcass)	SEM
Adama	1	319	28.43	139.48^{c}	1.91
	2	583	51.96	165.29^{b}	1.26
	3	220	19.61	182.15^{a}	2.19
Hawassa	1	264	61.54	133.83^{c}	1.21
	2	122	28.44	148.27^{b}	1.98
	3	43	10.02	173.00^{a}	2.20
Mekelle	1	715	95.59	134.49^{b}	1.19
	2	21	2.81	170.00^{a}	0.44
	3	12	1.60	176.00^{a}	1.23
Kombolcha	1	781	100.00	95.63	0.46
	2	0	0.00	-	-
	3	0	0.00	-	-

* 1- carcass with little/no fat; 2- fat cover whole body except hind leg and shoulder; 3- fat cover the whole body;
** Proportion of carcasses in each fat categories
Means in the same column with different superscript letters differ (p<0.001)

5.2.4 Conformation and fat grades of carcasses in wet and dry seasons

Conformation of carcasses in the wet and dry season is presented in Table 5.4. Conformation grade 1 (superior conformation) was higher in the wet season (43.41%) with heavier carcass weight of 173.91 ± 1.20 kg compared to the dry season (18.60%) with carcass weight of 165.90 ± 1.96 kg. The proportion of conformation grade 2 was comparable in the wet (34.81%) and dry season (33.05%) with carcass weights of 143.04 ± 1.49kg and 122.67 ± 1.28 kg, respectively.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Conformation grade 3 carcasses (inferior conformation) were higher in the dry season (48.34%) with the average carcass weight of 99.38 ± 0.70 kg compared to the wet season (21.78%) with the average carcass weight of 138.98 ± 1.01 kg.

Table 5.4 Conformation of carcasses in the wet and the dry season

Seasons	Conformation grade*	Carcass number	Percentage**	Mean weight (kg/ carcass)	SEM
Wet	1	616	43.41	173.91^{a}	1.20
	2	494	34.81	143.04^{b}	1.49
	3	309	21.78	138.98^{b}	1.01
Dry	1	309	18.60	165.90^{a}	1.96
	2	549	33.05	122.67^{b}	1.28
	3	803	48.34	99.38^{c}	0.70

*1-superior conformation, 2- moderate conformation, 3- inferior conformation;
** Proportion of carcasses in each conformation categories
Means in the same column with different superscript letters differ (p<0.001)

Fat grades of carcasses in the wet and dry season are presented in Table 5.5. A smaller proportion of fat grade 1 carcasses were observed in the wet season (48.06%) with a mean carcass weight of 143.31 ± 1.08 kg compared to the dry season (84.11%) with a mean carcass weight of 109.48 ± 0.73 kg. A higher proportion of fat grade 2 carcasses were observed in the wet season (33.33%) compared to the dry season (15.05%) with carcass weights of 157.63 ± 1.24 kg and 171.87 ± 1.98 kg, respectively. A higher proportion of fat grade 3 carcass was observed in the wet season (18.60%) compared to the dry season (0.84%) with mean carcass weights of 180.63 ± 1.87 and 176.00 ± 2.10 kg, respectively.

Table 5.5 Fat grades of carcasses in the wet and the dry seasons

Season	Fat grade*	Carcass number	Percentage**	Mean weight (kg/ carcass)	SEM
Wet	1	682	48.06	143.31[c]	1.08
	2	473	33.33	157.63[b]	1.24
	3	264	18.60	180.63[a]	1.87
Dry	1	1397	84.11	109.48[b]	0.73
	2	250	15.05	171.87[a]	1.98
	3	14	0.84	176.00[a]	2.10

* 1- carcass with little/no fat; 2- fat cover whole body except hind leg and shoulder; 3- fat cover the whole body;
** Proportion of carcasses in each fat categories
Means in the same column with different superscript letters differ ($p<0.001$)

5.2.5 Conformation and fat grades in different categories of cattle

The conformation grades of different categories of cattle are presented in Table 5.6. A higher proportion of conformation grade 3 carcasses (inferior conformation) was observed in cows (80.00%) with carcass weight of 95.00 ± 2.24 kg compared to conformation grade 1 (12.73%) and conformation grade 2 (7.27%) with carcass weights of 140.25 ± 3.00 kg and 126.00 ± 2.50 kg, respectively. A higher proportion of conformation grade 3 (37.57%) was observed in castrated bulls compared to the conformation grade 1 (27.07%) with carcass weights of 109.40 ± 0.87 kg and 171.35 ± 1.31 kg, respectively. However, the proportion of conformation grade 1 were higher in growing bulls (46.28%) and intact bulls (38.36%) with carcass weights of 150.40 ± 2.53 kg and 176.98 ± 1.89 kg, respectively, compared to the proportion of conformation grade 3 which were 19.01% and 26.03% with carcass weights of 115.25 ± 1.96 kg and 128.29 ± 2.62 kg, respectively.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Table 5.6 Conformation grades of different categories of cattle

Categories*	Conformation grade**	Number	Percentage***	Mean carcass weight (kg/ carcass)	SEM
	1	21	12.73	140.25[a]	3.00
F	2	12	7.27	126.00[a]	2.50
	3	132	80.00	95.00[b]	2.24
	1	56	46.28	150.40[a]	2.53
JM	2	42	34.71	121.50[b]	2.84
	3	23	19.01	115.25[b]	1.96
	1	308	38.36	176.98[a]	1.89
M	2	285	35.49	139.35[b]	1.45
	3	210	26.15	128.29[c]	2.62
	1	540	27.12	171.35[a]	1.31
O	2	703	35.31	127.77[b]	1.10
	3	748	37.57	109.40[c]	0.87

*JM -carcass of grown up bull, M-carcass of mature intact bulls, O-carcass of castrated bulls, F-carcass of cows;
**1-superior conformation, 2- moderate conformation, 3- inferior conformation;
*** Proportion of carcasses in each conformation categories;
Means in the same column with different superscript letters differ ($p<0.001$)

Fat grades of different categories of cattle are presented in Table 5.7. The proportion of fat grade 1 carcasses were higher in all categories of cattle i.e. 84.42% of cows, 65.66% of growing bulls, 62.50% of intact bulls and 67.96% of castrated bulls with carcass weights of 96.37 ± 2.30, 126.25 ± 3.12, 136.40 ± 1.46 and 116.77 ± 0.80 kg, respectively. Fat grade 2 carcasses produced from 15.58% cows, 24.24% growing bulls, 29.04% intact bulls and 22.15% castrated bulls with mean carcass weights 130.00 ± 3.79, 154.00 ± 3.93, 172.45 ± 2.04 and 160.29 ± 1.29 kg, respectively. Fat grade 3 carcasses were produced from 10.10% growing bulls, 8.46% intact bulls and 9.89% castrated bulls with mean carcass weights of 154.00 ± 3.93, 189.17 ± 4.32 and 179.89 ± 1.88 kg, respectively. Fat grade 3 carcass was not observed in the category of cows during the study period.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Table 5.7 Fat grades of different categories of cattle

Category*	Fat grade**	Number	Percentage***	Carcass weight (kg)	SEM
F	1	130	84.42	96.37[b]	2.30
	2	24	15.58	130.00[a]	3.79
	3	0	0.00	-	-
JM	1	65	65.66	126.25[b]	3.12
	2	24	24.24	138.00[ab]	3.70
	3	10	10.10	154.00[a]	3.93
M	1	495	62.50	136.40[c]	1.46
	2	230	29.04	172.45[b]	2.04
	3	67	8.46	189.17[a]	4.32
O	1	1353	67.96	116.77[c]	0.80
	2	441	22.15	160.29[b]	1.29
	3	197	9.89	179.89[a]	1.88

*JM- carcass of grown up bull, M- carcass of mature intact bulls, O- carcass of castrated bulls, F- carcass of cows
** 1- carcass with little/no fat; 2- fat cover whole body except hind leg and shoulder; 3- fat cover the whole body;
*** Proportion of carcasses in each fat categories
Means in the same column with different superscript letters differ ($p<0.001$)

5.2.6 Correlation and regression between conformation, fat and carcasses weight

The correlation between conformation grade, fat grade and carcass weight is presented in Table 5.8. The correlations between these factors were moderate and significant. As the conformation and fat grades of carcasses progress, the weight of carcasses had increased from lighter to heavier.

Table 5.8 Correlation between conformation, fat grade and carcass weight

	Conformation grade	Fat grade
Carcass weight	-0.624 **	0.573 **

** $p<0.001$

The prediction of carcass weight from conformation and fat grade is presented in Table 5.9. Carcass weight was significantly predicted from conformation grade, fat grade and the combination of the two. The coefficient of determination (R^2) was higher when the carcass weight was determined from combination of conformation and fat grade (46.9%) compared to conformation grade (38.9%) and fat grade (32.8%) separetly.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Table 5.9 Prediction of carcasses weight from conformation and fat grades

Equations	R^2	P-value	
		Conformation	Fat
$y = 151 - 21.0\ x_1 + 19.8\ x_2$	46.9%	**	**
$y = 197 - 29.5\ x_1$	38.9%	**	-
$y = 88.1 + 33.8\ x_2$	32.8%	-	**

** p<0.001, y- carcass weight, x_1-comformation grade, x_2- fat grade

5.2.7 Heart girth, backbone weight, estimated live weight and dressing percentage

Heart girth, backbone weight, estimated live weight and dressing percentage are presented in Table 5.10. The average heart girth of cattle slaughtered in Adama, Hawassa and Mekelle abattoirs was 157.62 ± 0.28 cm. The minimum and maximum lengths of circumferences were 122 and 190 cm, respectively. Average live weight estimated from heart girth was 328.35 ± 1.70 kg. The average dressing percentage was 46.78 ± 0.18%. The weight of backbone was in the range between 5 and 14 kg with the mean weight of 9.31± 0.05 kg.

Table 5.10 Heart girth, backbone weight, estimated live weight and dressing percentage

Variable	N	Mean	SE	Minimum	Maximum
Backbone (kg)	1067	9.31	0.05	5	14
Heart girth (cm)	2168	157.62	0.28	122	190
Carcass weight (kg)	2168	150.45	0.71	81	267
Estimated live weight (kg)	2168	328.35	1.70	153	557
Dressing percentage (%)	2168	46.78	0.18	30.38	74.46

The correlation between heart girth, backbone and carcasses weight is presented in Table 5.11. Significant (p<0.001) moderate to high correlation were observed between these parameters. The correlation between backbone and carcass weight was high (0.879) and the correlation between heart girth and carcass weight was moderate (0.617). Similarly, moderate correlation of 0.654 was observed between heart girth and backbone weight.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Table 5.11 Pearson correlation between heart girth, backbone and carcass weight

	Backbone	Heart girth
Heart girth	0.654 **	
Carcass weight	0.879 **	0.617 **

** $p<0.001$

Prediction of carcass weight from weight of backbone and heart girth is presented inTable 5.12. The carcasses weight was significantly predicted from weight of backbone, heart girth and combination of the two. Coefficient of determination (R^2) was higher when carcasses weight was predicted from combination of backbone weight and heart girth (83.2%) compared to predicting from backbone alone (77.3%). The coefficient of determination was low (38.1%) when carcasses weight was estimated from heart girth.

Table 5.12 Prediction of carcass weight from backbone weight and heart girth

Equation	R^2	Backbone		Wither circumference	
		SE	p-value	SE	p-value
$y = 2.04 + 17.2\ x_1$	77.3%	0.28	**		-
$y = -97.7 + 1.57\ x_2$	38.1%		-	0.04	**
$y = -97.1 + 13.1\ x_1 + 0.842\ x_2$	83.2%	0.32	**	0.04	**

** $p<0.001$, y- carcass weight, x_1-weight of backbone, x_2- heart girth

5.2.8 Mud contamination score of cattle slaughtered at local abattoirs

Mud contamination score of cattle slaughtered at local abattoirs is presented in Table 5.13. Of all the cattle scored for contamination of mud, 82.78% had score of 0 (no mud), 14.83% had score of 1 (mud on leg) and 2.39% had sore 2 (mud on leg and belly). Mud conataminaton score 1 and 2 were higher in Hawassa (43.59%, 12.82%) compared to cattle slaughtered at Adama (11.76%, 0.00%) and Mekelle (2.94%, 0.00%) abattoirs. Mud contamination score 1 and 2 were higher in wet season (23.26%, 3.88%) compared to the dry season (1.25%, 0.00%).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Table 5.13 Mud contamination score of cattle slaughtered at local abattoirs

Factors	Mud score*			Total	$\chi2$	p-value
	0	1	2			
Over all mean	1903 (82.78%)	341 (14.83%)	55 (2.39%)	2299		
Abattoir					573.247	<.0001
Adama	990 (88.24%)	132 (11.76%)	0 (0.00%)	1122		
Hawassa	187 (43.59%)	187 (43.59%)	55 (12.82%)	429		
Mekelle	726 (97.06%)	22 (2.94%)	0 (0.00%)	748		
Season					338.556	<.0001
Dry	869 (98.75%)	11 (1.25%)	0 (0.00%)	880		
Wet	1034 (72.87%)	330 (23.26%)	55 (3.88%)	1419		

*0 -no mud; 1-mud on leg; 2- mud on leg and belly

5.2.9 Length of horns of cattle slaughtered local abattoirs

The length of horns of cattle slaughtered at local abattoirs is presented in Table 5.14. The average length of horn of cattle slaughtered during the study period was 26.32 ± 0.34 cm. Cattle slaughtered in Kombolcha and Mekelle abattoir (33.04 ± 0.29; 31.14 ± 0.82 cm) had longer horn compared to cattle slaughtered in Adama (26.11 ± 0.33cm) and Hawassa (19.50 ± 0.34 cm) abattoirs (Fig. 5.8).

Table 5.14 Length of horns of cattle slaughtered at local abattoirs

Abattoir	Number	Mean (cm)	SE
Overall mean	2522	26.32	0.34
Adama	1078	26.11^{b}	0.33
Hawassa	418	19.50^{c}	0.34
Kombolcha	388	33.04^{a}	0.29
Mekelle	638	31.14^{a}	0.82

Means in the same column with different superscript letters differ (p<0.001)

5.2.10 Coat color of cattle slaughtered in Adama, Hawassa and Mekelle abattoirs

The coat color of cattle slaughtered at local abattoirs is presented in table 5.15. The coat colors of cattle slaughtered during the study period were black, gray, red and white. Holstein Frisian cattle account for 1.44% of cattle slaughtered. The dominant coat colors were black (32.54%) and red (32.06%) followed by gray (19.62%) and white (14.35%). In all abattoirs studied red and black

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

coat color cattle dominated. No Holstein Friesian cattle were slaughtered in Hawassa abattoir while small proportion of this breed was slaughtered in the other abattoirs.

Table 5.15 Coat color of cattle slaughtered at local abattoirs

Abattoirs	Coat color					Total
	>50% Black	>50% Gray	Holstein Frisian	>50% Red	>50% White	
Overall	748 (32.54%)	451 (19.62%)	33 (1.44%)	737 (32.06%)	330 (14.35%)	2299
Adama	330 (29.41%)	275 (24.51%)	11 (0.98%)	341 (30.39%)	165 (14.71%)	1122
Hawassa	176 (41.03%)	99 (23.08%)	0 (0.00%)	132 (30.77%)	22 (5.13%)	429
Mekelle	242 (32.35%)	77 (10.29%)	22 (2.94%)	264 (35.29%)	143 (19.12%)	748

$\chi2= 138.99$; $p<.0001$

In Adama abattoir cattle with red coat color dominated during the study period (Table 5.15; Fig. 5.6). The dominant coat color in Hawass abattoir was red (Table 5.15; Fig. 5.7). The dominant coat color at Kombolcha abattoir was gray (Fig. 5.8).

Figure 5.6 Pictures on cattle slaughtered at Adama abattoir

5.3 Discussion

The average carcass weight in the present study was comparable to the carcass weight of Boran breed (98.2-135.2 kg) reported under experimental condition in Ethiopia (Lemma *et al.,* 2007), relatively lower than the carcass weight reported for Ogaden bulls (163-182 kg) at fattening center in Ethiopia (Mekasha *et al.,* 2011) and relatively higher than the carcass weight of WASH (74.1 kg) and Sanga (95.3 kg) breed in Gana (Teye and Sunkwa, 2010). The difference in carcasses weight, conformation and fat grade between Adama, Hawassa, Mekelle and Kombolcha abattoirs in present study might be due to the difference in breed and environment in which cattle was managed prior to slaughter. Large proportions of fattening center are found in and around the city Adama (Little *et al.,* 2010) which serve as source of cattle for the Adama abattoir. Most cattle slaughtered at Hawassa abattoir comes from agro-pastoral production systems. Most of cattle used in Mekelle and Kombolcha abattoirs come from mixed production system after serving draft purpose for long period of time. All these environmental factors might have contributed to the difference in weights of carcasses, conformation and fat grades between abattoirs studied.

Figure 5.7 Pictures on cattle slaughtered in Hawassa abattoir

The better carcasses weight, conformation and fat grades in the wet season compared to the dry season might be due to the availability of feed and water which made the cattle finished in good body condition and relatively better slaughter weight.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

The proportion of conformation grade 1 (superior conformation) in the present study was higher than 17.8% reported in Mexico (Mendez *et al.,* 2009). However, it was comparable to excellent conformation (28.92%) reported in north-west Italy (Lazzaroni and Biagini, 2009). The proportion of conformation grade 3 (inferior conformation) in the present study was lower than conformation grade reported for carcasses in Romania which was 96% (Petroman *et al.,* 2009).


Figure 5.8 Pictures on cattle slaughtered at Kombolcha abattoir

The higher carcass weight for fat grade 3 compared to fat grade 2 and 1 indicate the importance of fat in determining the carcass weight of cattle. The proportion of fat grade 1 and 2 in the present study was higher than fat grade 1 (8.43%) and lower than fat grade 2(86.35%) reported in north-west of Italy (Lazzaroni and Biagini, 2009). However, the proportion of fat grade 3 in the present study was similar to the finding by Lazzaroni and Biagini (2009) which was 5.23%. The higher proportion of carcasses in fat grade 1 in present study might be associated with poor body condition of cattle prior slaughter. Feed shortage was often reported as a major constraint to livestock production in Ethiopia. Natural pasture is the main source of feed for most livestock, complemented by fodder and crop residues during the dry season. Productivity of the rangeland was about 0.15 ton per hectare (Halderman, 2004). Moreover, there is no specialized production system rearing cattle specifically for beef purpose in Ethiopia. Beef is a by-product in the mixed crop-livestock production system as cattle are primarily kept for traction purposes. Cattle are usually sold when they are too old for draft purpose and in a poor body condition. Moreover, beef is a by product of dairy in pastoral production system as the cattle are primarily kept for milk purpose. In this stytem, cattle are usually sold when they are culled from dairy service usually at old age and poor body condition. This two production systems account for more than 99% of cattle production system practiced in the country (Negassa *et al.,* 2011).

The reason for lower carcass weight of castrated bulls and cows compared to intact bulls in the present study might be the old age and poor body conditions of these cattle at time of slaughter as they have been serving for the draft and milking purpose, respectively, before they were used for meat purpose. Intact bulls were usually slaughtered at a young age. Higher carcass weights from intact bulls compared to castrated bulls and cows in present study were similar to that reported for Hanwoo cattle in Korean (Park *et al.,* 2002). The higher proportion of carcasses from castrated and intact bulls might be due to the higher proportion of cattle between 3 and 10 years of age which accounted for 62.8% of cattle population in Ethiopia (Negassa *et al.,* 2011). The proportion of intact bulls slaughtered at local abattoirs in the present study was less than the proportion reported in Poland which was about 47% (Weglarz, 2010). No carcasses from immature bulls and heifers were encountered during the study period. This is in contrast to the carcasses produced in USA namely 87.3% bulls and heifers less than 2 years of age (Savell *et al.,* 2011). In contrary to the present finding about 46.46%, 24.69%, 15.16% and 13.04% of intact bulls, cows, veal calves and other females, respectively, were slaughtered in north-west Italy (Lazzaroni and Biagini, 2009).

Growing bulls and intact bulls had relatively higher conformation grade 1 compared to castrated bulls and cows. Castrated bulls and cows served for long period as draft animals and milking cows, respectively. They were culled from the former services usually in old age and in a very poor body conditions. This might be the reason for castrated bulls yielding lower carcass weight and conformation grade compared to the intact bulls which were usually slaughtered at a young age. The degree of fatness of growing bulls, intact bulls and castrated bulls were similar. However, these categories of cattle had deposited better fat compared to cows. This further confirms the fact that the culled cows were in a very poor condition when they were slaughtered. Higher age at slaughter was reported as one of the reason for poor quality of carcass from cows (Zaujec *et al.,* 2012).

Conformation significantly affected the carcass weight of cattle in the present study. Moreover, significant correlation was observed between the two parameters. Similar to the present study, significant correlation of 0.34 and 0.58 were reported between conformation and carcass weight in Brazil and Spain (Medizabal, 2006; Cancian *et al.,* 2013).

The heart girth of cattle in the present study was comparable to the heart girth of cattle reported in south-west Ethiopia which was in the range between 141.27 and 149.27 cm (Chebo *et al.,*

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

2013) and in Sudan which was 163 cm (Abdelhadi *et al.,* 2011). Moreover, the estimated average live weight of cattle in the present study was comparable to the weight of Zebu (309 kg) cattle slaughtered in local abattoirs in Ghana (Teye and Sunkwa, 2010) and Nguni (324 kg) cattle slaughtered in South Africa (Strydom, 2009). Average dressing percentage of cattle slaughtered in the present study was comparable to the average dressing percentage of WASHA (45.9%) and Sanga (47.65%) cattle in Ghana (Teye and Sunkwa, 2010) but relatively lower than the dressing percentage of Zebu cattle (50%) slaughtered in Pakistan (Rahman *et al.,* 2012). The correlation between the heart girth and carcasses weight in the present study was comparable to the correlation reported for cattle slaughtered in local abattoirs in Sudan which was 0.66 (Abdelhadi *et al.,* 2011). The coefficient of determination (R^2) to estimate carcasses weight from heart girth in the present study was lower than the estimate between carcasses weight and heart girth around the hump in Sudan which was 0.62 (Abdelhadi *et al.,* 2011). The researchers didn't come across prediction of carcasses weight estimated from weight of backbone and combination of backbone and heart girth which was found to have high coefficient of determination. It is possible that the weight of backbone can estimate carcass weight as the longissmus muscle was used to evaluate the quality of carcasses.

The proportion of cattle with no mud and mud on legs in the present study was comparable to the reported in USA which was 61.6% and 18.8%, respectively. However, the proportion of cattle with mud on leg and belly was relatively lower than the report in USA which was 14.5% (Boleman *et al.,* 1998). Mud or manure on the skin of animal are the main sources of contamination of carcasses, especially when it is present on the legs and belly of the animal and when there is a hide opening which may introduce this contamination to the carcass (Hanson,

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

2000). The relatively higher mud score in wet season compared to the dry season in the present study might be the soiling of the skin of animal in the former than the latter season because of the wet ground.

Almost all cattle in the present study had horns. The average length of horn in the present study was longer than 75% cattle slaughtered in USA which have 2.54 -12.7 cm (McKenna *et al.,* 2002). The presence of horn was reported one of the factors which affect the bruising of carcasses (Anderson and Horder, 1979). Moreover, the presence of horns and/or mud can lower the dressing percentage. The difference in the length of the horn of cattle slaughtered at the abattoirs might be due to the difference in the breed of cattle used for slaughtered. Among quantitative traits, horns were reported the most variable traits between breeds of cattle (Tadesse *et al.,* 2008)

In the present study, most of cattle slaughtered at the abattoirs were indigenous local cattle. The proportion of exotic cattle (Holstein Friesian) used for beef purpose was very low. This shows the opportunity to explaoit dairy beef in the future. The dairy industry is a rapidly growing in Ethiopia. The present study further confirmed the report by Hutcheson (2006) which suggested the need to exploit dairy beef in Ethiopia. Majority of cattle slaughtered at the abattoirs studied had >50% black or red color. The percentage of cattle which had >50% gray or white color was relatively lower. The difference in the proportion of coat color between abattoirs further confirms the slaughter of different breeds of cattle in the abattoirs studied.

5.4 Summary

The average carcass weight at local abattoirs was 135.90 ± 0.69 kg. Carcass weight was significantly ($p<0.001$) different between abattoirs, season, conformation grades, fat grades and categories of cattle slaughtered. Cattle slaughtered at Adama abattoir had relatively superior conformation and fat grade while cattle slaughtered at Kombolcha abattoir had relatively inferior conformation and fat grades during the study period. A higher carcasses weight, superior conformation and fat grade were observed in the wet season compared to the dry season. Carcass weight was significantly predicted from combination of conformation and fat grade (46.9%), and combination of backbone weight and heart girth (83.2%). Relatively higher proportions of castrated bulls (64.64%) were slaughtered during the study period. Among categories of cattle slaughtered, cows exhibited higher proportion of inferior conformation grade (80%) during the study period. The proportion of inferior fat grade was more than 60% in all categories of cattle slaughtered. However, cows had higher proportion of inferior fat grades (84.42%) compared to other categories of cattle slaughtered. The average heart girth of cattle slaughtered at the studied abattoirs was 157.62 ± 0.28 cm. Average live weight estimated from heart girth was 328.35 ± 1.70 kg. The average dressing percentage was 46.78 ± 0.18%. Holstein Frisian cattle accounted for 1.44% of cattle slaughtered. The dominant coat colors of cattle slaughtered during the study period were black (32.54%) and red (32.06%).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

CHAPTER 6

6 CARCASS YIELD TRAITS OF SELECTED CATTLE BREEDS IN ETHIOPIA

6.1 Introduction

Ethiopia has 53.4 million cattle (CSA, 2010/11) and about 33 cattle breed (DAGRIS, 2011). However, the potential of these breeds for meat was not properly studied. Understanding the carcass traits and meat yield of a breed is a prerequisite to identify the potential of a breed for meat production. Moreover, it is important to evaluate the amount of meat that can be marketed and available as a food for the consumers. Consumers place high emphasis on food quality, and their decision on purchasing a product is mainly based on color (Marenčić et al., 2012). The pH value has a significant impact on the color, shelf life, taste, microbiological stability, yield andtexture of meat and meat products and is, therefore, important for meat quality evaluation (Feiner, 2006).

Some studies were conducted at experimental station on Boran, Kereyu and Ogaden cattle carcass characteristics (Lemma et al., 2007; Mekasha et al., 2011). However, no work was conducted to characterized carcass characteristics of cattle slaughtered at abattoirs in Ethiopia. Moreover, no work was conducted on meat yield, yield percentage and meat cut of Ethiopian cattle. Furthermore, little information was available on quality of meat produced in Ethiopia. The aim of this study was therefore to characterize the carcass traits, meat yield, primal meat cut and quality of Boran, Barka, Arado, Raya and nondescript cattle breeds slaughtered at export abattoirs in Ethiopia.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

6.2 Results

6.2.1 Factors affecting live weight, carcass weight and dressing percentage

Live weight, carcass weight and dressing percentage are presented in Table 6.1. The average live weight of cattle slaughtered was 241.41 $\pm$ 0.37 kg. Live weight differed significantly between ($p<0.001$) abattoirs, season and breeds of cattle. Live weight of cattle slaughtered at Melgawendo abattoir (284.02 $\pm$ 0.92) was significantly higher ($p<0.001$) than cattle slaughtered at Abergelle abattoir (238.16 $\pm$ 0.27).

Table 6.1 Live weight, carcass weight and dressing percentage of cattle slaughtered at Abergelle and Melgawendo abattoirs

Variable	No.	Live wt.		Warm carcass wt.		Cold carcass wt.		Warm Dressing %		Cold dressing %	
		Mean	SE	Mean	SE	Mean	SE	%	SE	%	SE
Overall	22302	241.41	0.37	106.93	0.21	101.19	0.18	44.21	0.05	42.53	0.03
Abattoir		**		**				**			
Abergelle	20720	238.16^{b}	0.27	103.27^{b}	0.14	101.19	0.13	43.40^{b}	0.03	42.53	0.03
Melgawend	1582	284.02^{a}	0.92	154.86^{a}	0.60			54.78^{a}	0.15		
Season		**		**		**		**		*	
Wet	11585	243.05^{a}	0.35	108.12^{a}	0.20	103.48	0.16	44.49^{a}	0.05	42.79^{a}	0.03
Dry	10717	238.81^{b}	0.43	104.04^{b}	0.25	100.89	0.22	43.57^{b}	0.06	42.26^{b}	0.04
Breed		**		**		**		**		*	
Arado	2115	230.46^{d}	0.99	102.12^{c}	0.61	100.08^{b}	0.60	44.24^{b}	0.11	43.36^{a}	0.11
Barka	3051	241.11^{b}	0.84	105.49^{b}	0.44	103.33^{a}	0.43	43.68^{c}	0.07	42.79^{c}	0.07
Boran	1582	284.06^{a}	0.97	154.86^{a}	0.60			54.78^{a}	0.15		
Raya	5383	238.76^{bc}	0.44	104.86^{b}	0.21	102.85^{a}	0.21	43.99^{b}	0.05	43.14^{b}	0.05
Nondescript	10171	238.56^{c}	0.35	101.99^{c}	0.17	99.91^{b}	0.16	42.84^{d}	0.04	41.96^{d}	0.04

* $P<0.05$, ** $p<0.001$

Live weights of cattle slaughtered in Abergelle and Melagawendo abattoirs are presented in Figure 6.1. More than 50% of cattle slaughtered in Melgawondo abattoir were weighted between 251 and 300 kg while those slaughtered in Abergelle abattoir was between 201 and 250 kg. Furthermore, about 25% of cattle slaughtered at Melgawondo abattoir were between 301 and 350 kg while those slaughtered in Abegelle abattoir were between 251 and 300 kg.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

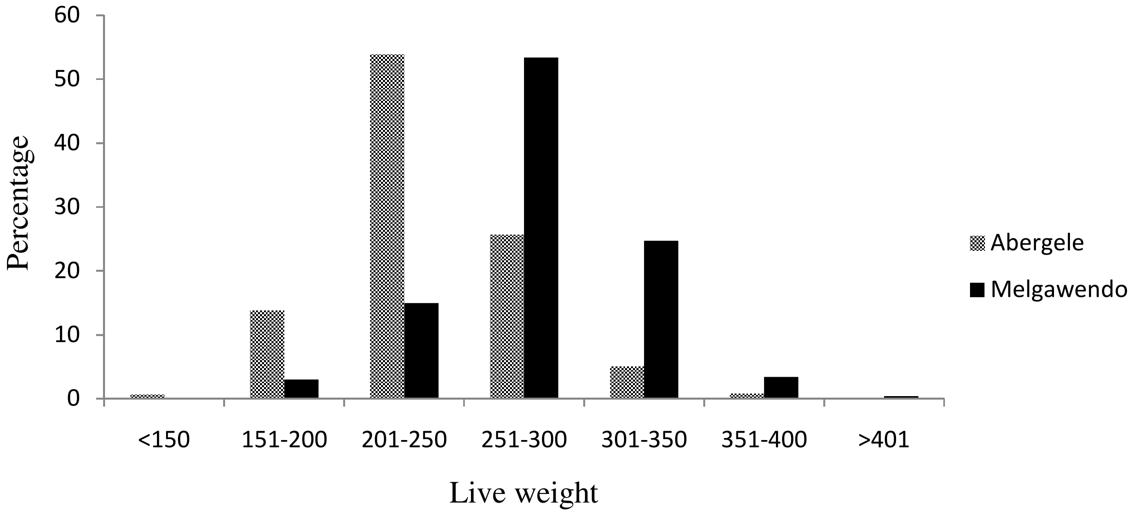


Figure 6.1 Frequencies of live weight of cattle slaughtered at Abergelle and Melgawendo abattoirs

Cattle slaughtered in the wet season had a higher ($p<0.001$) live weight (243.05 $\pm$ 0.35 kg) compared to those slaughtered in the dry season (238.81 $\pm$ 0.43 kg). Boran cattle had a higher slaughter weight (284.06 $\pm$ 0.97 kg) while Arado cattle (230.46 $\pm$ 0.99 kg) had lower weight compared to other breeds studied. Proportion of different breeds of cattle slaughtered at Abergelle and Melgawendo abattoirs are shown in Fig. 6.2. About 45% of cattle slaughtered in export abattoirs were nondescript breeds. The Raya cattle accounted for 24% followed by Barka (13.68%). Arado and Boran cattle were the least in number during the study period.

The average warm carcass weight of cattle during the study period was 106.93 $\pm$ 0.21 kg. Warm carcass weight was significantly different ($p<0.001$) between abattoirs, season and breeds of cattle slaughtered. Warm carcass weight of cattle slaughtered at Melgawando abattoir (154.86 $\pm$ 0.60 kg) was higher ($p<0.001$) than carcass weight of cattle slaughtered at Abergelle abattoir (103.27 $\pm$ 0.14 kg). A higher ($p<0.001$) carcass weight was observed in the wet season (108.12

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

± 0.20 kg) compared to the dry season (104.04 ± 0.25 kg). Boran cattle breed (154.86 ± 0.60 kg) had a higher carcass weight while nondescript (101.99 ± 0.17 kg) and Arado cattle (102.12 ± 0.61 kg) had lower weight. Barka (105.49 ± 0.44 kg) and Raya (104.86 ± 0.21 kg) cattle had heavier carcass weight compared to Arado cattle and nondescript breeds.

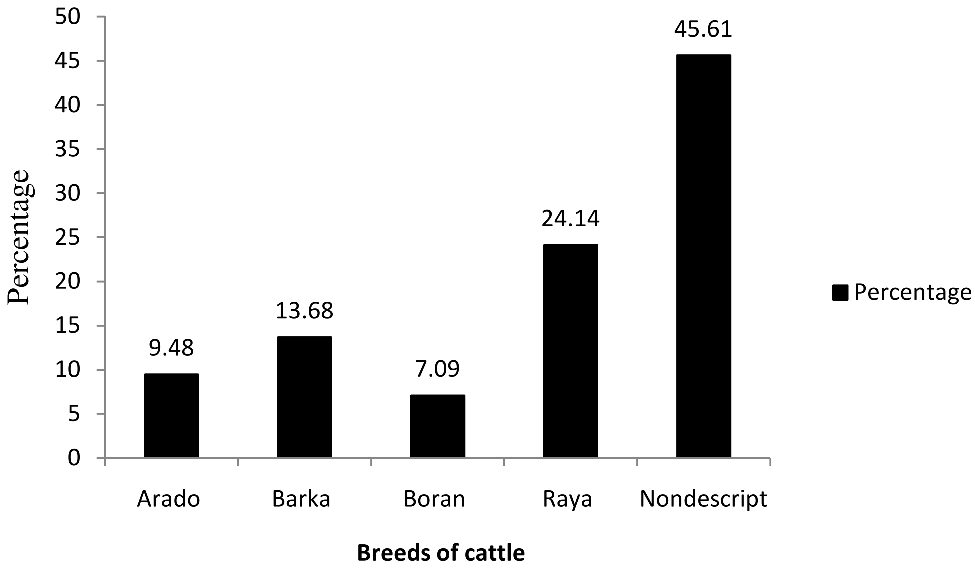


Figure 6.2 Propotion of breeds of cattle slaughtered at Abergelle and Melgawendo abattoirs

The average warm dressing percentage of cattle during the study period was 44.21 ± 0.05 %. Dressing percentage was significantly different ($p<0.001$) between abattoirs, season and breeds of cattle slaughtered. Cattle slaughtered at Melgawendo abattoir had a higher ($p<0.001$) dressing percentage (54.78 ± 0.15 %) compared to cattle slaughtered at Abergelle abattoir (43.40 ± 0.03 %). A higher ($p<0.001$) dressing percentage was observed in the wet season (44.49 ± 0.05 %) compared to the dry season (43.57 ± 0.06 %). A higher dressing percentage was observed for Boran cattle (54.78 ± 0.15 %) while a lower dressing percentage was observed for nondescript breeds (42.84 + 0.04 %). Arado (44.24 + 0.11%) and Raya (43.99 + 0.05%) cattle had higher dressing percentage compared to Barka (43.68 + 0.07%) cattle.

The dressing percentage of cattle slaughtered during the study period is shown in Fig. 6.3. About 40% of dressing percentage of Boran cattle was between 51 and 55% while more than 50% of dressing percentage of Arado, Barka, Raya and nondescript breeds were between 41 and 45%.

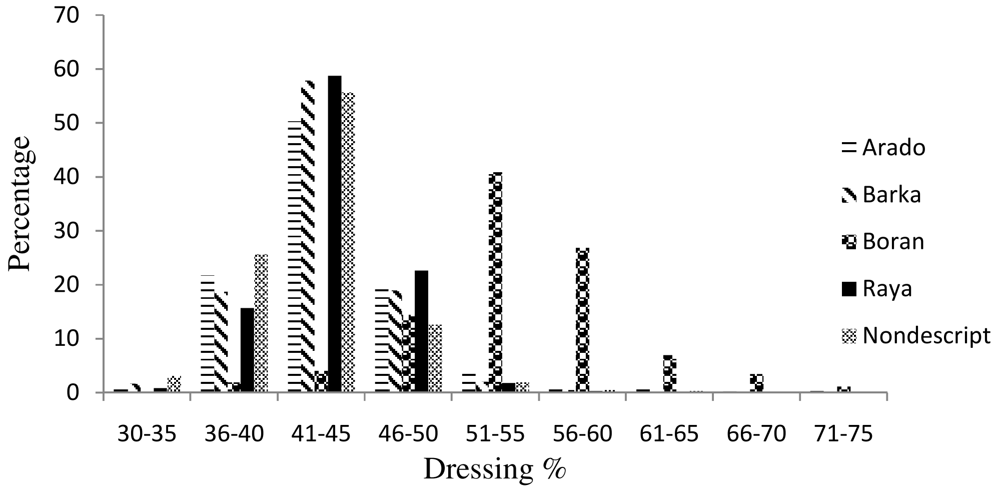


Figure 6.3 Frequencies of dressing percentage of cattle slaughtered at Abergelle and Melgawendo abattoirs

6.2.2 Prediction of warm carcass weight from live weigh of cattle

Regression equation of warm carcass weight on live weigh of cattle is presented in Table 6.2. Overall coefficient of determination (R^2) for all cattle was highly significant ($p<0.001$) and was 71.3%. About 71% of the warm carcass weight was estimated from live weight of cattle. The coefficients of determination were significant for all breeds. It was higher for Arado (86%), Barka (85%), Raya (73.2%) and nondescript breeds (69.5%). However, it was moderate for Boran (55.6%) cattle breed.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Table 6.2 Regression equation of warm carcass weight on live weigh of cattle

Breed	Equation	R^2	SE	P-value
All	y = 0.489x - 11.2	71.3%	0.002	<.0001
Arado (11)	y = 0.477x - 7.77	86.0%	0.004	<.0001
Barka (12)	y = 0.479x - 10.1	85.0%	0.004	<.0001
Boran (13)	y = 0.437x +30.6	55.6%	0.01	<.0001
Undiff (14)	y = 0.397x +7.34	69.5%	0.003	<.0001
Raya (15)	y = 0.405x +8.16	73.2%	0.003	<.0001

y-estimate of warm carcasses weight (kg); x- live weight; S.E –standard error of observation

6.2.3 Meat yield and yield percentage

Effect of breeds and season on meat yield and yield percentage are presented in Table 6.3. The overall meat yield and yield percentage were 61.56 ± 0.94 kg and 67.81 ± 0.33%, respectively. Meat yield and yield percentage were significantly (p<0.05) effected by breeds of cattle slaughtered. Barka cattle had relatively higher meat yield (73.16 ± 1.54 kg) while Arado cattle (50.28 ± 1.48 kg) had lower yield. Raya breed (66.17 ± 0.46 kg) had relatively higher meat yield compared to nondescript breed (61.82 ± 0.42 kg).

The meat yield percentage between breeds studied was similar (67.35- 68.38%). A higher (p<0.05) meat yield percentage was observed in the wet season (68.65 ± 0.44%) compared to the dry season (66.03 ± 0.22%).

Table 6.3 Effects of breeds and season on meat yield and meat yield percentage

Variable	Meat yield (kg)		Meat yield%	
	Mean	SEM	Mean	SEM
Overall meat yield	61.56	0.94	67.81	0.33
Breed	**		ns	
Arado	50.28[d]	1.48	67.35	0.89
Barka	73.16[a]	1.54	68.38	0.67
Raya	66.17[b]	0.46	67.89	0.54
Nondescript	61.82[c]	0.42	67.82	0.47
Season	ns		*	
Dry	59.59	1.01	66.03[b]	0.22
Wet	62.46	1.30	68.65[a]	0.44

** p<0.001, *p<0.05, ns non-significant

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

6.2.4 Prediction of meat yield from carcass and live weight

Meat yield predicted from carcasses and live weights of cattle is presented in Table 6.4. Meat yield was accurately predicted from carcasses and live weight with coefficient of determination R^2=94.0%. As expected, the effect of live weight became non-significant in most cases when both parameters were used as predictors.

Table 6.4 Meat yield prediction from carcass and live weight of cattle

Breed	Equation	R^2	P-value	
			x_1	x_2
All	$y = -8.53 - 0.0475x_1 + 0.854x_2$	94.0%	ns	**
	$y = -27.3 + 0.402x_1$	88.1%	**	-
Barka	$y = -7.9 - 0.170x_1 + 1.13x_2$	92.5%	ns	*
	$y = -31.8 + 0.425x_1$	82.9%	*	-
Raya	$y = -8.83 - 0.208x_1 + 1.22x_2$	98.3%	*	**
	$y = -20.1 + 0.386x_1$	90.7%	**	-
Nondescript	$y = -8.09 - 0.0092x_1 + 0.760x_2$	93.0%	ns	**
	$y = -26.9 + 0.398x_1$	87.4%	**	

y-meat yield, x_1- live weight, x_2- warm carcass weight, ** p<0.001, *p<0.05, ns non-significant

6.2.5 The weight of primal meat cuts

The weights of major primal meat cuts are presented in Table 6.5. The average meat yields from the fore- and hindquarter were 28.05 ± 0.50 kg and 33.50 ± 0.48 kg, respectively. The forequarter, hindquarter and meat cuts were significantly affected (p<0.001) by breeds of cattle. The fore- and hindquarter weight of Barka breed (34.28 ± 1.28 kg, 38.88 ± 0.33 kg) was heavier than Raya, Arado and nondescript breeds. The fore- and hindquarter weight of Arado breed (22.93 ± 0.75 kg, 27.34 ± 0.78 kg) was the lower compared to other breeds studied. The average weight of meat cuts of brisket, chuck, shine, neck, blade, topside, silverside, rump, flank, knuckle, striploin, tenderloin, shank, and rump cup were 4.26 ± 0.17, 7.36 ± 0.14, 3.05 ± 0.12, 5.53 ± 0.14, 8.45 ± 0.11, 5.96 ± 0.09, 5.90 ± 0.08, 4.25 ± 0.07, 5.71 ± 0.12, 3.97 ± 0.05, 4.54 ± 0.10, 1.63 ± 0.03, 1.45 ± 0.02 and 1.43 ± 0.03 kg, respectively. The meat cuts from the fore- and hindquarter of Barka cattle were relatively heavier than the Arado cattle. The weight of meat cuts

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

from Raya cattle was relatively heavier than the meat cuts from Arado cattle except for shine and rump. The weight of meat cuts form Raya and nondescript breeds was not significantly different. All the meat cuts from nondescript cattle was heavier than the meat cuts from Arado cattle except meat cuts from chuck and shine.

Table 6.5 Weight of major primal meat cuts of Arado, Barka, Raya and nondescript breeds

Breed	Arado		Barka		Raya		Nondescript		Overall	
Meat cut	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**
Fore quarter (kg)	22.93[c]	0.75	34.28[a]	1.28	29.78[b]	0.31	27.91[b]	0.23	28.05	0.50
Brisket (kg)	3.10[c]	0.15	5.93[a]	0.67	4.34[b]	0.09	4.08[b]	0.05	4.26	0.17
Chuck (kg)	6.54[c]	0.35	8.44[a]	0.21	7.68[ab]	0.19	7.26[bc]	0.18	7.36	0.14
Shine (kg)	2.45[b]	0.09	4.18[a]	0.53	3.18[b]	0.22	2.88[b]	0.03	3.05	0.12
Neck (kg)	4.40[b]	0.32	6.45[a]	0.16	6.01[a]	0.27	5.65[a]	0.17	5.53	0.14
Blade (kg)	7.39 [b]	0.28	9.28[a]	0.14	8.84[a]	0.24	8.60[a]	0.08	8.45	0.11
Hind quarter (kg)	27.34[d]	0.78	38.88[a]	0.33	36.39[b]	0.30	33.90[c]	0.23	33.50	0.48
Topside (kg)	5.07[c]	0.19	6.79[a]	0.12	6.29[ab]	0.08	6.04[b]	0.06	5.96	0.09
Silverside (kg)	5.09[c]	0.18	6.67[a]	0.12	6.28[ab]	0.10	5.92[b]	0.07	5.90	0.08
Rump (kg)	3.82[b]	0.16	4.38[a]	0.11	4.25[ab]	0.15	4.46[a]	0.11	4.25	0.07
Flank (kg)	4.57[b]	0.22	5.99[a]	0.37	6.38[a]	0.20	5.92[a]	0.07	5.71	0.12
Knuckle (kg)	3.44[c]	0.13	4.42[a]	0.08	4.14[ab]	0.06	4.05[b]	0.04	3.97	0.05
strip loin (kg)	3.58[c]	0.18	5.61[a]	0.14	5.00[a]	0.11	4.47[b]	0.11	4.54	0.10
Tenderloin (kg)	1.41[c]	0.06	1.86[a]	0.03	1.74[ab]	0.03	1.62[b]	0.03	1.63	0.03
Shank (kg)	1.22[c]	0.05	1.65[a]	0.03	1.52[ab]	0.03	1.48[b]	0.02	1.45	0.02
Rump cup (kg)	1.10[c]	0.09	1.64[a]	0.05	1.48[ab]	0.02	1.40[b]	0.05	1.43	0.03

Similar letter in the same raw are not significantly different

6.2.6 Meat yield predicted from meat cuts

Meat yield predicted from meat cuts are presented in Table 6.6. All meat cuts can significantly ($p<0.001$) predicted the meat yield. However, the model variances (R^2) differ between meat cuts. The accuracy of prediction (R^2) of meat yield from the forequarter was between 30.36 and 59.62%. The accuracy of prediction (R^2) of meat yield from hindquarters was between 19.72 and 77.86%. The accuracy of prediction (R^2) of meat yield from brisket and blade were 58.27% and

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

59.62%, respectively. The accuracy of prediction (R^2) of meat yield from topside and silverside were 77.86% and 75.64%, respectively.

Table 6.6 Predicting meat yield from meat cuts of cattle

Cut	Model	R^2 (%)	SE (kg)	P
Forequarter				
Brisket	y = 42.34 + 4.62*Brisket	58.27	0.437	<.0001
Chuck	y = 27.55 + 4.65*chuck	47.07	0.519	<.0001
Shine	y = 45.10 + 5.40*Shine	43.81	0.641	<.0001
Neck	y = 41.21 + 3.68*Neck	30.36	0.584	<.0001
Blade	y = 7.43 + 6.41*Blade	59.62	0.553	<.0001
Hind quarter				
Flank	y = 40.32 + 3.80*Flank	19.72	0.857	<.0001
Topside	y = 3.79 + 9.69*Topside	77.86	0.542	<.0001
Silverside	y = 3.01 + 9.92*Silverside	75.64	0.590	<.0001
Rump	y = 36.62 + 5.87*Rump	19.83	1.237	<.0001
Knuckle	y = 3.64 + 14.59*Nuckle	70.13	0.998	<.0001
Striploin	y = 25.51 + 7.99*Striploin	70.73	0.542	<.0001
Tenderloin	y = 13.42 + 29.55*Tenderloin	61.33	2.487	<.0001
Shank	y = 11.83 + 34.34*Shank	64.55	2.682	<.0001
Rumpcap	y = 19.79 + 30.73*Rumpcap	64.48	3.076	<.0001

y-estimate of meat yield (kg); SE – estimated standard error of observation

6.2.7 Carcass pH of cattle slaughtered at Abergelle export abattoir

Carcass pH of beef at Abergelle export abattoir is presented in Table 6.7. Based on the carcass pH measurement made on 151 samples, only 31.13% of the total sample had a pH of 5.4-5.7. About 23.18% of the samples had a pH of 5.9-6.4, 7.28% of sample had the less than 5.4 and 38.41% had the pH 5.7-5.9.

Table 6.7 The pH of beef at Abergelle export abattoir

pH	No.	Percentage
<5.4	11	7.28
5.4-5.7	47	31.13
5.7-5.9	58	38.41
5.9-6.4	35	23.18
Total	151	100.00

The effect of years and season is presented in Table 6.8. The average carcass pH in 2011 (6.01 ± 0.04) was higher ($p<0.001$) than the pH in 2012 (5.78 ± 0.02). The carcass pH in the dry season (5.86 ± 0.02) was higher ($p<0.05$) than the pH in the wet season (5.73± 0.04).

Table 6.8 Effect of year and season on pH of beef at Abergelle export abattoir

Level		Number	Mean	SEM
Year			**	
	2011	55	6.01[a]	0.04
	2012	96	5.78[b]	0.02
Season			*	
	Dry	88	5.86[a]	0.02
	Wet	63	5.73[b]	0.04

* p<0.05, ** p<0.001, similar letter in the same raw are not significantly different

6.3 Discussions

The average live weight of cattle slaughtered in the abattoirs studied was comparable to the weight of Zebu (309 kg), Sanga (202 kg) and WASH (162 kg) cattle slaughtered at local abattoirs in Ghana (Teye and Sunkwa, 2010). However, live weight was lower than Nguni (324 kg) and Tuli (418 kg) cattle slaughtered in South Africa (Strydom, 2008). The higher live weights of cattle slaughtered at Melgawendo compared to Abergelle abattoir can be due to difference in breeds and body condition of cattle prior to slaughter. Cattle supplied to Melgawendo abattoir was mostly from the Boran breed. This breed was managed in pastoral and agro-pastoral production system. Moreover, a long term improvement program has been going on for the breed since 1960 (Aynalem *et al.,* 2011). However, most cattle slaughtered at Abergelle abattoir were of the Arado, Barka, Raya and nondescript breeds but no Boran cattle. These breeds were managed in mixed crop livestock production system. More than 50% of cattle slaughtered at Melgawendo had an average live weight of 251 to 300 kg while those slaughtered in Abergelle abattoir had an average live weight of 201 to 250 kg. Similar to the present study, Lazzaroni and Biagini (2009) reported a higher proportion (32%) of cattle slaughtered in the north-west of Italy had live weight between 200-300 kg. The relatively higher live weight of

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

cattle slaughtered in the wet season compared to the dry season might be due to the availability of feed and water which allowed the cattle to be finished in good body condition and higher slaughter weight. A marked difference in live weights between seasons was reported for livestock in Ethiopia (Tolera and Abebe, 2007). The slaughter weight differences between breeds were similarly reported in some other studies (Biagini and Lazzaroni, 2005; Strydom, 2008; Teye and Sunkwa, 2010). A slaughter weight of 268 kg was reported for Boran cattle in Ethiopian similar to the present finding (Aynalem *et al.,* 2011). Moreover, the slaughter weight of Boran cattle in the present study was comparable to the weight of Ogaden bull with out supplement (297.4 kg) and the weight of Zebu cattle in Ghana (Teye and Sunkwa, 2010; Mekasha *et al.,* 2011). The slaughter weights of Barka, Raya and Arado cattle were relatively higher than the weight of Sanga and WASHA cattle in Ghana (Teye and Sunkwa, 2010).

The average carcass weight in the present study was comparable to the carcass weight of Boran cattle (98.2-135.2 kg) managed under experimental condition in Ethiopia and Zebu breed (155.9 kg) in Ghana (Lemma *et al.,* 2007; Teye and Sunkwa, 2010). However, it was lower than carcass weight of Ogaden cattle (163-182 kg) managed under experimental condition in Ethiopia and Nguni (181 kg) and Tuli (241 kg) cattle in South Africa (Strydom, 2008; Mekasha *et al.,* 2011). However, it was higher than the carcass weight of WASH (74.1 kg) and Sanga cattle (95.3 kg) in Ghana (Teye and Sunkwa, 2010). The difference in carcass weights between the present study and other studies reported might be due to differences in breeds and environment.

More numbers of cattle slaughtered in the present study were nondescript breeds. According to the report from one of the abattoir, most of nondescript cattle were purchased from terminal market in the region. Cattle purchased from market could be exposed for different kinds of stress as they reached to the market after travelling long distance, most of the time through trekking. In the market places, cattle are kept in open pens. This can exposed them to the sun or cold stimuli. They might encounter some more stresses such as unfamiliar noise, environment and social regrouping. They might also be starved, dehydrated and exposed to longer periods of deprivation. This might be the reason for lower carcass weight and dressing percentage of nondescript cattle in the present study. The effect of market on the carcass traits was similarly reported in some other studies (Eldridge *et al.,* 1986; McNally and Warriss, 1996; Shorthose, 1988).

Average warm dressing percentage of cattle slaughtered in the present study was lower than the dressing percentage of Zebu cattle (50%) slaughtered at Peshwar abattoir in Pakistan (Rahman *et al.,* 2012). The difference in dressing percentage between abattoirs, season and breeds can be expected as there were already differences in live weigh and carcass weight between these factors. Similar to the dressing percentage of Boran cattle in the present study, Aynalem et al. (2011) has reported a dressing percentage of 55.7% for improved Boran cattle in Ethiopia. The dressing percentages of Barka, Raya and Arado cattle were comparable to the dressing percentage of N'Dama breed (42%) in West Africa and WASH breed in Ghana (DAGRIS, 2006; Teye and Sunkwa, 2010). The variability in dressing percentage of Boran cattle (36-70%) and other breed studied (30-55%) indicate good opportunity for selection and improvement of local breeds in the future.

The over all meat yield percentage of cattle in the present study was less than the yield reported for Nguni (72.5%) and Tuli (73%) cattle in South Africa (Strydom, 2008). The difference between breeds on meat yield was similarly reported for Angus, limousine and Wagyu cattle in Australia (Graham *et al.,* 2005). Higher meat yield of Barka cattle compared to Arado cattle could be due to the relative heavier live weight and carcass weights of the former breed. The yield percent of cattle in the present study was comparable to Angus, limousine and Wagyu (67.7-69.9%) cattle in Australia (Graham *et al.,* 2009). Higher percent yield in the wet season compared to the dry season can be due to the heavier live and carcass weight of cattle in the former season. A higher meat yield from hindquarter compared to forquarter was similarly reported for Piemontese and Belgian blue breeds (Biagini and Lazzaroni, 2005). The heavier fore- and hindquarter of Barka cattle compared to Raya and Arado cattle could be due to the heavier live and carcass weight of the former breed. A heavier live and carcass weights was reflected in heavier primal cuts. The difference between breeds on weight of meat cuts was similarly reported for Piemontese and Belgian Blue cattle (Biagini and Lazzaroni, 2005).

The weight of knuckles and topsides in present study were relatively lower while the weight of striploins, rumps and tenderloins were compared to the temperate and tropical cattle in Australia (Reverter *et al.,* 2001). The weight of meat cuts from hindquarters predicted the meat yield with higher accuracy compared to the weight of meat cuts from forequarters. The weigh of topsides, knuckles and striploins predicted the meat yield with higher accuracy among the weight of all meat cuts.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Carcass pH has a significant impact on the color, shelf life, taste, microbiological stability, yield andtexture of meat and meat products and is, therefore, important for meat quality evaluation (Feiner, 2006). Optimum carcass pH is also essential for the conversion of muscle to meat. The pH range of normal meat of an unstressed animal is 5.4-5.7. DFD meat will have a much higher pH of 5.9-6.5, with some meat being as high as a pH of 6.8 (Miller, 2007). In the present study, only 31.13% of the total sample had a desired carcass pH which can be considered as normal meat of unstressed cattle. This was comparable to the report at Mekelle local abattoir which was 38.55% (Kumar et al., 2010). About 23.18% of the samples in the present study can be considered as DFD meat. About 38.41% of the sample had pH of 5.7-5.9. pH higher than 5.6 indicate susceptibility of the meat to microbial attackaffecting the shelf life and indicates animals might be under stress and might not have beengiven adequate restbefore slaughter (Kumar et al., 2010). Meat from stressed animals with high pH spoils faster while meat from well restedanimals generally has better keeping quality due todesirable low pH. To enhance the keeping quality ofmeat, it is always suggested that animals should beprovided rest of atleast 24 hours before slaughter (Sherikar et al., 2004). The DFD meat observed in the present study was higher than the report by National Beef Quality Audit in1992 and 2000 in USA which was 5% and 2.3%, respectively (Lorenzen et al., 1992; Miller, 2007). This indicates the possibility of reducing the level DFD at export abattoirs in Ethiopia by taking appropriate measures to minimize the causes of the incidence.

Higher level of pH in 2011 compared to 2012 in the present study was a reflection of the effect of season. The entire samples evaluated in 2011 were collected in the dry season (November-December) while those collected in 2012 comprises of both wet and dry seasons. Moreover, the difference can be explained by measures taken by the abattoirs to minimize the level of DFD meat. A relatively higher pH was observed in the dry season compared to the wet season in the present study. This can be explained by stress created due to long trekking of cattle in the dry season compared to the wet season in search of feed and water as these resources are scarce in the dry season.When cattle are stressed, there is a rapid release of catecholamines (norepinephrine, epinephrine, dopamine), which results in glycogen depletion (Lacourt and Tarrant, 1985) causing a lower rate of *post mortem* lactic acid synthesis and high ultimate pH.Moreover, adverse seasonal conditions can potentially stress meat animals and consequently influence carcass and meat quality characteristics. Cattle are considered more sensitive to hot than to cool temperatures (Baker *et al.,* 1981). During warm weather, cattle show signs of stressful behavior and impaired physiological functions (Hahn and Mader, 1997), while cold weather combined with precipitation increases the rate of body-heat loss (Smith *et al.,* 1993). Similar to the present study higher level of pH was observed in the summer (5.61) compared to the winter (5.58) season (Marenčić et al., 2012).

6.4 Summary

The result of the study revealed that the average live weight, warm carcass weight, cold carcass weight and warm dressing percentage of cattle slaughtered were 241.41 $\pm$ 0.37 kg, 106.93 $\pm$ 0.21 kg, 101.19 $\pm$ 0.18 kg and 44.21 $\pm$ 0.05 %, respectively. Live weight, carcass weight and dressing percentage were significantly ($p<0.001$) differ between abattoirs, season and breeds of cattle slaughtered. Boran cattle had a higher slaughter weight, carcass weight and dressing percentage. About 45% of cattle slaughtered in export abattoirs were nondescript breeds. The overall meat yield and yield percentage was 61.56 $\pm$ 0.94 kg and 67.81 $\pm$ 0.33%, respectively. Meat yield and yield percentage was significantly ($p<0.05$) different between breeds of cattle slaughtered. Meat yield was accurately predicted (R^2=94.0%) from carcasses and live weight. The meat cuts from the forequarters and hindquarter of Barka cattle were relatively higher than the Arado cattle. All meat cuts were accurate predictor of the meat yield at highly significant level ($p<0.001$). Particularly, topside (R^2>77.86%), silverside (R^2>75.64%), striploin (R^2>70.73%) and knuckle (R^2>70.13%) had predicted meat yield with higher accuracy. Based on the carcass pH measurement made on 151 samples, only 31.13% of the total sample had a desigred pH of 5.4-5.7 for acceptable conversion of musle to meat. About 23.18% of the samples had a pH of 5.9-6.4 which can be considred as DFD. Moreover, 7.28% of sample had the less than 5.4 and 38.41% had the pH 5.7-5.9 which can be considred as meat pron to DFD. The pH in the dry season (5.86 $\pm$ 0.02) was higher ($p<0.05$) than the pH in the wet season (5.73$\pm$ 0.04).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

CHAPTER 7

7 CAUSES OF CONDEMNATIONS OF CARCASSES AND ORGANS OF CATTLE SLAUGHTERED AT LOCAL AND EXPORT ABATTOIRS IN ETHIOPIA

7.1 Introduction

Abattoirs and slaughterhouses are good sources of valuable information on the incidence of animal diseases and conditions. Prevalence of less acute, chronic and mild diseases with no clinical signs can be detected at slaughterhouses. An abattoir is a focal point to detect diseases of importance for public health such as TB, cysticercosis, hydatidosis and faciola (Cadmus and Adesokan, 2009). As a result, if such information is well documented, it will aid in developing strategies to control animal and public health important disease in a country.

Cattle population in Ethiopia was estimated about 53.4 million (CSA, 2011). However, the potential has not been fully utilized. The annual meat productions, carcass weight per head of cattle and per capita meat consumption were low (CSA, 2008; Negassa *et al.,* 2011; Betru and Kawashima, 2009). Ethiopia has exported about 16, 877 MT of meat to Middle East and North African countries in 2010/11 despite the huge demand in the region (SPS-LMM, 2011). Feedback from importing countries revealed that contamination and dark cutting were some of the problems observed on meat exported from Ethiopia (Anon, 2006).

The level of condemnations of carcasses and organs affect the quality and monetary value of carcasses directly or indirectly. Most studies conducted to date concentrated on condemnations

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

of offal based on data collected for few number of months at specific abattoir (Asseged *et al.,* 2004; Megersa *et al.,* 2010; Abunna *et al.,* 2012; Aragaw *et al.,* 2012; Mesele *et al.,* 2012; Terefe *et al.,* 2012; Assefa and Tesfay, 2013; Mulatu *et al.,* 2013). Causes of partial and whole carcasses condemnations were not extensively studied in Ethiopia.

The purpose of the present study was therefore to determine the causes of whole, partial carcasses and organs condemnations at local and export abattoirs in Ethiopia.

7.2 Result

7.2.1 Causes of condemnations whole carcasses

A total of 170 whole carcasses were condemned out of 62,917 cattle slaughtered during the study period (Table 7.1). The main causes of whole carcasses condemnation were poor bleeding (0.11%), abscess (0.06%), adhesion (0.04%), TB (0.03%), pneumonia (0.01%), Cysticercus bovis (0.01%) and bruising (0.01%). The prevalence of abscess was significantly different (P<0.0001) between years and abattoirs (Table 7.2). A higher prevalence of abscess was observed in 2010 which was 0.20%. The prevalence of TB, C. *bovis* and bruising significantly differed (P<0.0001) between abattoirs. TB and C. *bovis* were higher in Elfora Kombolcha. Condemnations due to bruising were observed at Kombolcha and Bishoftu abattoirs (Table 7.3).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Table 7.1 Causes of condemnation of whole, partial carcass and organs of cattle during the study period

Organ	Conditions	Number (%) of carcasses condemned 2010 (n=12708)	2011 (n=34674)	2012 (n=10363)	2013 (n=5172)	Total (n=62917)
Whole carcass condemnation	Poor bleeding	0 (0.00)	69 (0.20)	0 (0.00)	0 (0.00)	69 (0.11)
	Abscess	25 (0.20)	7 (0.02)	3 (0.03)	5 (0.10)	40 (0.06)
	Adhesion	0 (0.00)	28 (0.08)	0 (0.00)	0 (0.00)	28 (0.04)
	TB	3 (0.02)	6 (0.02)	5 (0.05)	5 (0.10)	19 (0.03)
	Pneumonia	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.10)	5 (0.01)
	Cysticercusbovis	0 (0.00)	1 (0.00)	2 (0.02)	1 (0.02)	4 (0.01)
	Bruising	0 (0.00)	0 (0.00)	1 (0.01)	3 (0.06)	4 (0.01)
	Hydatid cyst	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)	1 (0.00)
Partial carcasses condemnation	Bruising	6854 (53.93)	13626 (39.30)	977 (9.43)	1 (0.02)	21458 (34.11)
	Poor bleeding	2275 (17.90)	12727 (36.70)	1101 (10.62)	0 (0.00)	16103 (25.59)
	Contamination	2168 (17.06	5271 (15.20)	479 (4.62)	0 (0.00)	7918 (12.58)
	Adhesion	395 (3.11)	5100 (14.71)	402 (3.88)	0 (0.00)	5897 (9.37)
	Abscess	112 (0.88)	792 (2.28)	71 (0.69)	1 (0.02)	976 (1.55)
	Calcified cyst	72 (0.57)	0 (0.00)	0 (0.00)	0 (0.00)	72 (0.11)
	Cysticercusbovis	0 (0.00)	6 (0.02)	1 (0.01)	1 (0.02)	8 (0.01)
	Hydatid cyst	0 (0.00)	3 (0.01)	0 (0.00)	0 (0.00)	3 (0.00)
	edema	2 (0.02)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.00)
Liver	Faciola	1622 (12.76)	6968 (20.10)	2285 (22.05)	1280 (24.75)	12155 (19.32)
	Hydatid cyst	1259 (9.91)	5065 (14.61)	2389 (23.05)	1000 (19.33)	9713 (15.44)
	Calcified cyst	1555 (12.24)	4651 (13.41)	424 (4.09)	14 (0.27)	6644 (10.56)
	Cirrhosis	585 (4.60)	4134 (11.92)	1091 (10.53)	748 (14.46)	6558 (10.42)
	Hepaitis	732 (5.76)	4041 (11.65)	1109 (10.70)	368 (7.12)	6250 (9.93)
	Contamination	1993 (15.68)	2305 (6.65)	244 (2.35)	87 (1.68)	4629 (7.36)
	Cysticercusbovis	598 (4.71)	2466 (7.11)	286 (2.76)	75 (1.45)	3425 (5.44)
	Poor bleeding	319 (2.51)	2548 (7.35)	283 (2.73)	0 (0.00)	3150 (5.01)
	Abscess	184 (1.45)	525 (1.51)	123 (1.19)	112 (2.17)	944 (1.50)
	Other*	327 (2.57)	1023 (2.95)	359 (3.46)	348 (6.73)	2057 (3.27)
Lung	Hydatid cyst	2815 (22.15)	7267 (20.96)	3213 (31.00)	1182 (22.85)	14477 (23.01)
	Pleumonia	1755 (13.81)	8794 (25.36)	1683 (16.24)	602 (11.64)	12834 (20.40)
	Emphysema	2269 (17.85)	7978 (23.01)	1358 (13.10)	305 (5.90)	11910 (18.93)
	Poor bleeding	2158 (16.98)	8434 (24.32)	662 (6.39)	4 (0.08)	11258 (17.89)
	Contamina	869 (6.84)	1816 (5.24)	244 (2.35)	98 (1.89)	3027 (4.81)
	Calcified cyst	233 (1.83)	1553 (4.48)	168 (1.62)	1 (0.02)	1955 (3.11)
	Pleurisis	414 (3.26)	634 (1.83)	214 (2.07)	173 (3.34)	1435 (2.28)
	Abscess	162 (1.27)	318 (0.92)	42 (0.41)	24 (0.46)	546 (0.87)
	Other*	4 (0.03)	42 (0.12)	12 (0.12)	7 (0.14)	65 (0.10)
Kidney	Nephritis	859 (6.76)	2470 (7.12)	2513 (24.25)	1021 (19.74)	6863 (10.91)
	edema	201 (1.58)	667 (1.92)	166 (1.60)	134 (2.59)	1168 (1.86)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

	Hydronephrosis	49 (0.39)	344 (0.99)	470 (4.54)	257 (4.97)	1120 (1.78)
	Hemorrage	211 (1.66)	592 (1.71)	160 (1.54)	140 (2.71)	1103 (1.75)
	Contamination	446 (3.51)	368 (1.06)	6 (0.06)	4 (0.08)	824 (1.31)
	Congenital cyst	121 (0.95)	351 (1.01)	190 (1.83)	140 (2.71)	802 (1.27)
	Infracts	62 (0.49)	193 (0.56)	96 (0.93)	49 (0.95)	400 (0.64)
	Calcified cyst	32 (0.25)	157 (0.45)	84 (0.81)	80 (1.55)	353 (0.56)
	Poor bleeding	259 (2.04)	38 (0.11)	0 (0.00)	0 (0.00)	297 (0.47)
	Hydatid cyst	10 (0.08)	125 (0.36)	67 (0.65)	45 (0.87)	247 (0.39)
	Other*	6 (0.05)	97 (0.28)	20 (0.19)	15 (0.29)	138 (0.22)
Heart	Poor bleeding	2698 (21.23)	9330 (26.91)	1075 (10.37)	2 (0.04)	13105 (20.83)
	Pericarditis	666 (5.24)	1473 (4.25)	500 (4.82)	249 (4.81)	2888 (4.59)
	Cysticercusbovis	33 (0.26)	554 (1.60)	299 (2.89)	88 (1.70)	974 (1.55)
	Contamination	204 (1.61)	553 (1.59)	132 (1.27)	77 (1.49)	966 (1.54)
	oedema	109 (0.86)	409 (1.18)	147 (1.42)	93 (1.80)	758 (1.20)
	Other*	253 (1.99)	834 (2.41)	169 (1.63)	90 (1.74)	1346 (2.14)
Tongue	Abscess	689 (5.42)	1902 (5.49)	232 (2.24)	142 (2.75)	2965 (4.71)
	Cysticercusbovis	36 (0.28)	188 (0.54)	194 (1.87)	77 (1.49)	495 (0.79)
	Contamination	59 (0.46)	361 (1.04)	22 (0.21)	14 (0.27)	456 (0.72)
	edema	44 (0.35)	83 (0.24)	10 (0.10)	28 (0.54)	165 (0.26)
	Others*	65 (0.51)	58 (0.17)	10 (0.10)	29 (0.56)	162 (0.26)
Spleen	Splenities	198 (1.56)	730 (2.11)	409 (3.95)	389 (7.52)	1726 (2.74)
	Hematoma	105 (0.83)	395 (1.14)	258 (2.49)	281 (5.43)	1039 (1.65)
	Contamination	79 (0.62)	182 (0.52)	111 (1.07)	78 (1.51)	450 (0.72)
	Splenomegaly	58 (0.46)	158 (0.46)	57 (0.55)	71 (1.37)	344 (0.55)
	Hydatid cyst	32 (0.25)	89 (0.26)	73 (0.70)	81 (1.57)	275 (0.44)
	Abscess	5 (0.04)	74 (0.21)	13 (0.13)	7 (0.14)	99 (0.16)
	Other*	5 (0.04)	12 (0.03)	2 (0.02)	11 (0.21)	30 (0.05)
Head	Poor bleeding	1811 (14.25)	9336 (26.93)	665 (6.42)	0 (0.00)	11812 (18.77)
	Bruising	2009 (15.81)	8043 (23.20)	593 (5.72)	81 (1.57)	10726 (17.05)
	Abscess	608 (4.78)	1266 (3.65)	201 (1.94)	105 (2.03)	2180 (3.46)
	Contamination	77 (0.61)	1091 (3.15)	307 (2.96)	37 (0.72)	1512 (2.40)
	Cysticercusbovis	2 (0.02)	37 (0.11)	20 (0.19)	4 (0.08)	63 (0.10)
	Other*	28 (0.22)	68 (0.20)	2 (0.02)	5 (0.10)	103 (0.16)
Intestine	Abscess	0 (0.00)	13 (0.04)	39 (0.38)	0 (0.00)	52 (0.08)
	Cysticercusbovis	0 (0.00)	7 (0.02)	1 (0.01)	1 (0.02)	9 (0.01)
	Hydatid cyst	0 (0.00)	10 (0.03)	0 (0.00)	0 (0.00)	10 (0.02)

*Other on liver (oedema, adhession, pleurisis, hemorrage, hematoma, tumer, peritonities, TB, Bruice, Jaundice); On lung (hemorrage, tumer, adhesion, c.bovis, TB) ;On kidney (tumer, abscess, c.bovis, bruising,); On heart (hemmorhage, calcified cyst, abscess, Hydatid cyst, tumer,); On tongue (hemorrhage, tumer, ulcer); on spleen (oedema, calcified cyst, hemorrhage, c.bovise, tumer); on head (Hydatid cyst, edema, adhesion)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

7.2.2 Causes of condemnations of partial carcasses

About 52,437 carcasses were partially condemned out of 62,917 cattle slaughtered during the study period (Table 7.1). Main causes of partial condemnations were bruising (34.11%), poor bleeding (25.59%), contamination (12.58%), adhesion (9.37%), abscess (1.55%) and calcification of cysts (0.11%). The prevalence of bruising, poor bleeding, contamination, adhesion, abscess and calcified cyst were significantly different ($P<0.0001$) between years, abattoirs and season. The prevalence of C. *bovis*, H. *cyst* and edema was significantly different ($P<0.0001$) between abattoirs (Table 7.2). Bruising and contamination were higher ($P<0.0001$) in 2010 (53.93%, 17.06%) while poor bleeding and adhesion were higher ($P<0.0001$) in 2011 (36.70%, 14.71%). The prevalence of all disease conditions was the lower in 2013 compared to other years of study (Table 7.1). Most partial condemnation was observed at Abergelle abattoir. The prevalence of bruising, poor bleeding and contaminations were higher in dry season while the prevalence of adhesion, abscess and calcified cysts were higher in wet season (Table 7.3).

7.2.3 Causes of condemnations of livers

The main causes of condemnations of livers were faciola (19.32%), H. *cyst* (15.44%), Calcified cyst (10.56%), Cirrhosis (10.42%), Hepatitis (9.93%), contamination (7.36%), C. *bovis* (5.44%) and poor bleeding (5.01%; Table 7.1). The prevalence of these problems was significantly different ($P<0.0001$) between years and abattoirs (Table 7.2). All these problems except faciola, contamination and C. *bovis* were significantly different ($P<0.05$) between seasons (Table 7.2). Condemnations of livers due to fasciola and H. *cyst* were lower in 2010 (12.76%, 9.91%) compared the prevalence of these problems in 2011 (20.10%, 14.61%), 2012 (22.05%,

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Table 7.2 Chi-square test for causes of condemnations of carcasses and organs by years, abattoirs and season

Condemnations	Causes	Year		Abattoir		Season	
		χ2	P-value	χ2	P-value	χ2	P-value
Whole carcasses	Poor bleeding	1.91	0.59	2.09	0.352	1.76	0.184
	Abscess	46.8	<.0001*	73.87	<.0001*	1.88	0.17
	Adhesion	1.91	0.59	2.09	0.352	1.76	0.184
	TB	0.49	0.921	86.89	<.0001*	0.28	0.6
	Pneumonia	3.18	0.365	2.09	0.352	1.07	0.301
	C.bovis	1.87	0.599	20.33	<.0001*	0.48	0.49
	Bruise	5.1	0.165	5.9	0.052	0.78	0.378
	H.cyst	3.18	0.365	2.09	0.352	1.07	0.301
Partial carcasses	Bruise	356.07	<.0001*	1218.18	<.0001*	4.81	0.0284*
	Poor bleeding	281.28	<.0001*	1030.83	<.0001*	14.07	0.0002*
	Contamination	310.83	<.0001*	1115.55	<.0001*	6.17	0.0130*
	Adhesion	264.29	<.0001*	825.26	<.0001*	5.31	0.0212*
	Abscess	234.53	<.0001*	842.26	<.0001*	5.15	0.0232*
	C.calcification	16.32	0.0010*	11.22	0.0037*	4.07	0.0437*
	C.bovis	5.62	0.132	11.13	0.0038*	2.93	0.087
	H.cyst	3.92	0.271	5.6	0.061	2.03	0.154
	edema	8.14	0.0432*	5.6	0.061	2.03	0.154
Liver	Faciola	16.97	0.0007*	10.33	0.0057*	1.45	0.229
	H. cyst	7.68	0.053	279.15	<.0001*	3.77	0.052
	Calcified cyst	273.23	<.0001*	982.41	<.0001*	6.57	0.0104*
	Cirrhosis	53.39	<.0001*	156.8	<.0001*	4.66	0.0308*
	Hepaitis	22.07	<.0001*	640.63	<.0001*	9.1	0.0026*
	Contamination	280.33	<.0001*	1082.55	<.0001*	0.37	0.545
	C.bovis	239.54	<.0001*	795.07	<.0001*	3.54	0.06
	Poor bleeding	191.14	<.0001*	707.38	<.0001*	17.86	<.0001*
	Abscess	83.31	<.0001*	573.41	<.0001*	0.32	0.575
Lung	H. cyst	2.32	0.509	99.67	<.0001*	0.87	0.352
	Pleumonia	45.04	<.0001*	99.56	<.0001*	0.09	0.76
	Emphysema	123.33	<.0001*	589.9	<.0001*	0.3	0.583
	Poor bleeding	276.87	<.0001*	1023.48	<.0001*	16.11	<.0001*
	Contamination	152.81	<.0001*	815.39	<.0001*	1.29	0.256
	Calcified cyst	242.88	<.0001*	753	<.0001*	1.18	0.277
	Pleurisis	10.71	0.0134*	709.14	<.0001*	5.77	0.0163*
	Abscess	72.34	<.0001*	327.58	<.0001*	1.7	0.192
Kidney	Nephritis	59	<.0001*	207.42	<.0001*	0.63	0.428
	Edema	5.96	0.114	542.63	<.0001*	6.18	0.0129*
	Hydronephrosis	40.24	<.0001*	277.05	<.0001*	0.9	0.343
	Hemorrage	8.66	0.0341*	634.21	<.0001*	6.58	0.0103*
	Contamination	156.64	<.0001*	219.19	<.0001*	2.55	0.111
	Co. Cyst	7.43	0.06	660.92	<.0001*	9	0.0027*
	Infracts	6.12	0.106	400.63	<.0001*	0.77	0.381
	Calcified cyst	1.51	0.68	331.69	<.0001*	0.2	0.655
	Poor bleeding	212.36	<.0001*	153.2	<.0001*	30.63	<.0001*
	H. cyst	11.51	0.0093*	72.96	<.0001*	4.4	0.0360*
Heart	Poor bleeding	309.33	<.0001*	1045.31	<.0001*	10.47	0.0012*
	Pericarditis	104.13	<.0001*	207.74	<.0001*	0.03	0.872
	C. bovis	112.14	<.0001*	94.78	<.0001*	1.97	0.161
	Contamination	82.4	<.0001*	505.09	<.0001*	0	0.95
	Edema	3.9	0.273	621.02	<.0001*	4.18	0.0409*
Tongue	Abscess	178.69	<.0001*	555.99	<.0001*	0.41	0.522
	C. bovis	23.47	<.0001*	133.6	<.0001*	27.82	<.0001*
	Contamination	102.87	<.0001*	206.13	<.0001*	1.67	0.197
	Edema	33.39	<.0001*	259.56	<.0001*	18.71	<.0001*
Spleen	Splinities	5.72	0.126	802.97	<.0001*	5.68	0.0172*
	Hematoma	6.69	0.082	634.39	<.0001*	7.31	0.0068*
	Contamination	2	0.572	431.26	<.0001*	2.45	0.118
	Splinomegalia	5.08	0.166	363.24	<.0001*	3.17	0.075
	H. cyst	3.29	0.348	312	<.0001*	1.02	0.314
	Abscess	2.35	0.504	30.7	<.0001*	1.41	0.235
Head	Poor bleeding	260.84	<.0001*	930.82	<.0001*	13.09	0.0003*
	Bruise	104.38	<.0001*	725.62	<.0001*	2.22	0.137
	Abscess	134.01	<.0001*	727.23	<.0001*	0	0.956
	Contamination	20.73	0.0001*	257.09	<.0001*	0.24	0.628
	C. bovis	15.58	0.0014*	8.97	0.0113*	0.02	0.896
Intestine	Abscess	28.83	<.0001*	0	-	6.81	0.0091*
	C. bovis	2.65	0.265	0	-	1.21	0.271
	H. cyst	1.44	0.486	0	-	1.58	0.208

23.05%) and 2013 (24.75%, 19.33%; Table 7.1). Fasiola and cirrhosis was the common causes of condemnations of livers at Abergelle (16.10%, 9.07%), Bishoftu (23.12%, 7.34%) and Kombolcha (25.55%, 15.99%) abattoirs. Hydatid cyst and Hepatitis were the two important causes of condemnations of livers at Abergelle (14.30%, 12.52%) and Bishoftu (36.76, 14.70%) abattoirs. Calcification of cyst, contamination, poor bleeding and C. *bovis* were prevalent at Abergell compared to the other abattoirs studied. Calcified cyst, heptitis and poor bleeding were more prevalent (P<0.0001) in the dry than the wet season while the prevalence of H. cyst and cirrhosis were more prevalent (P<0.0001) in the wet than the dry season (Table 7.3).

7.2.4 Causes of condemnations of lungs

Main causes of condemnations of lungs were H. *cyst* (23.01%), pneumonia (20.40), emphysema (18.93%), poor bleeding (17.89%), contamination (4.81%), Calcified cyst (3.11%) and pleurisis (2.28%; Table 7.1). The prevalence of H. *cyst* was significantly different (P<0.0001) between abattoirs (Table 7.2). H. *cyst* was relatively higher (P<0.0001) in Bishoftu (44.30%) compared to Abergelle (22.83%) and Kombolcha (10.01%) abattoirs (Table 7.3). Pneumonia, emphysema, poor bleeding, contamination, Calcified cyst and pleurisis were significantly different (P<0.0001) between years and abattoirs (Table 7.2). The prevalence of pneumonia, emphysema and poor bleeding were higher (P<0.0001) in 2011 (Table 7.1). These problems were higher (P<0.0001) at Abergelle abattoir compared to the other abattoirs studied. Poor bleeding was higher (P<0.0001) in the dry season compared to the wet season (Table 7.3).

Table 7.3 Condemnations of whole, partial carcasses and organs at abattoirs studied in the dry and the wet seasons

Condemnations	Conditions	Number (%) of carcasses condemned				
		Abergelle (n=39098)	Bishoftu (n=9227)	Kombolcha (n=14592)	Dry (n=26977)	Wet (n=35940)
Whole carcasses	Poor bleeding	69 (0.18)	0 (0.00)	0 (0.00)	69 (0.26)	0 (0.00)
	Abscess	33 (0.08)	0 (0.00)	7 (0.05)	21 (0.08)	19 (0.05)
	Adhesion	28 (0.07)	0 (0.00)	0 (0.00)	28 (0.1)	0 (0.00)
	Pleumonia	5 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.01)
	C. bovis	0 (0.00)	1 (0.01)	3 (0.02)	1 (0.00)	3 (0.01)
	TB	0 (0.00)	5 (0.05)	12 (0.08)	6 (0.02)	11 (0.03)
	Bruising	0 (0.00)	2 (0.02)	2 (0.01)	2 (0.01)	2 (0.01)
	Hydatid cyst	1 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.00)
Partial carcasses	Bruising	21456 (54.88)	2 (0.02)	0 (0.00)	10773 (39.93)	10685 (29.73)
	Poor bleeding	16103 (41.19)	0 (0.00)	0 (0.00)	7270 (26.95)	8833 (24.58)
	Contamination	7918 (20.25)	0 (0.00)	0 (0.00)	3595 (13.33)	4323 (12.03)
	Adhesion	5897 (15.08)	0 (0.00)	0 (0.00)	2256 (8.36)	3641 (10.13)
	Abscess	974 (2.49)	2 (0.02)	0 (0.00)	385 (1.43)	591 (1.64)
	Calcified cyst	72 (0.18)	0 (0.00)	0 (0.00)	0 (0.00)	72 (0.2)
	C. bovis	6 (0.02)	2 (0.02)	0 (0.00)	1 (0.00)	7 (0.02)
	Hydatid cyst	3 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.01)
	oedema	2 (0.01)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.01)
Liver	Faciola	6294 (16.10)	2133 (23.12)	3728 (25.55)	4356 (16.15)	7799 (21.70)
	Hydatid cyst	5592 (14.30)	3392 (36.76)	729 (5.00)	4094 (15.18)	5619 (15.63)
	Cirrhosis	3548 (9.07)	677 (7.34)	2333 (15.99)	2460 (9.12)	4098 (11.40)
	Calcified cyst	6550 (16.75)	91 (0.99)	3 (0.02)	3437 (12.74)	3207 (8.92)
	Hepaitis	4894 (12.52)	1356 (14.70)	0 (0.00)	3397 (12.59)	2853 (7.94)
	Contamination	4149 (10.61)	0 (0.00)	480 (3.29)	2206 (8.18)	2423 (6.74)
	C. bovis	3008 (7.69)	5 (0.05)	412 (2.82)	1589 (5.89)	1836 (5.11)
	Poor bleeding	3150 (8.06)	0 (0.00)	0 (0.00)	1374 (5.09)	1776 (4.94)
	Abscess	513 (1.31)	0 (0.00)	431 (2.95)	361 (1.34)	583 (1.62)
	Other*	184 (0.47)	34 (0.37)	1839 (12.60)	666 (2.47)	1391 (3.87)
Lung	Hydatid cyst	8928 (22.83)	4088 (44.30)	1461 (10.01)	6433 (23.85)	8044 (22.38)
	Pleumonia	9968 (25.49)	1673 (18.13)	1193 (8.18)	5200 (19.28)	7634 (21.24)
	Emphysema	10075 (25.77)	327 (3.54)	1508 (10.33)	5204 (19.29)	6706 (18.66)
	Calcified cyst	1927 (4.93)	28 (0.30)	0 (0.00)	941 (3.49)	1014 (2.82)
	Abscess	464 (1.19)	3 (0.03)	79 (0.54)	276 (1.02)	270 (0.75)
	Contamination	2518 (6.44)	0 (0.00)	509 (3.49)	1547 (5.73)	1480 (4.12)
	Poor bleeding	11258 (28.79)	0 (0.00)	0 (0.00)	5867 (21.75)	5391 (15.00)
	Pleurisis	283 (0.72)	0 (0.00)	1152 (7.89)	519 (1.92)	916 (2.55)
	other*	31 (0.08)	8 (0.09)	8 (0.05)	26 (0.10)	21 (0.06)
Kediney	Nephritis	1451 (3.71)	4060 (44.00)	1352 (9.27)	2626 (9.73)	4237 (11.79)
	Hydronephrosi	0 (0.00)	772 (8.37)	348 (2.38)	447 (1.66)	673 (1.87)

	Hydatid cyst	0 (0.00)	140 (1.52)	107 (0.73)	73 (0.27)	174 (0.48)
	Calcified cyst	16 (0.04)	51(0.55)	286 (1.96)	109 (0.40)	244 (0.68)
	Contamination	763 (1.95)	0 (0.00)	61 (0.42)	402 (1.49)	422 (1.17)
	oedema	6 (0.02)	0 (0.00)	1162 (7.96)	233 (0.86)	935 (2.60)
	Poor bleeding	297 (0.76)	0 (0.00)	0 (0.00)	245 (0.91)	52 (0.14)
	Hemorrage	0 (0.00)	0 (0.00)	1103 (7.56)	271 (1.00)	832 (2.31)
	Co. Cyst	0 (0.00)	0 (0.00)	802 (5.50)	249 (0.92)	553 (1.54)
	Infracts	0 (0.00)	0 (0.00)	400 (2.74)	127 (0.47)	273 (0.76)
	other*	87 (0.22)	12 (0.13)	39 (0.27)	100 (0.37)	38 (0.11)
Heart	Poor bleeding	13105 (33.52)	0 (0.00)	0 (0.00)	7048 (26.13)	6057 (16.85)
	Pericarditis	1530 (3.91)	559 (6.06)	799 (5.48)	1207 (4.47)	1681 (4.68)
	C. bovis	385 (0.98)	486 (5.27)	103 (0.71)	330 (1.22)	644 (1.79)
	Contamination	520 (1.33)	0 (0.00)	446 (3.06)	403 (1.49)	563 (1.57)
	oedema	0 (0.00)	0 (0.00)	758 (5.19)	182 (0.67)	576 (1.60)
	other*	766 (1.96)	56 (0.61)	600 (4.11)	562 (2.08)	784 (2.18)
Tongue	Abscess	2583 (6.61)	51 (0.55)	244 (1.67)	1407 (5.22)	1471 (4.09)
	C. bovis	54 (0.14)	378 (4.10)	63 (0.43)	138 (0.51)	357 (0.99)
	Contamination	305 (0.78)	0 (0.00)	151 (1.03)	242 (0.90)	214 (0.60)
	oedema	0 (0.00)	0 (0.00)	165 (1.13)	28 (0.10)	137 (0.38)
	other*	0 (0.00)	0 (0.00)	162 (1.11)	21 (0.08)	141 (0.39)
spleen	Splinities	0 (0.00)	0 (0.00)	1726 (11.83)	561 (2.08)	1165 (3.24)
	Hematoma	0 (0.00)	0 (0.00)	1039 (7.12)	345 (1.28)	694 (1.93)
	Contamination	1 (0.00)	0 (0.00)	449 (3.08)	149 (0.55)	301 (0.84)
	Splinomegalia	0 (0.00)	0 (0.00)	344 (2.36)	99 (0.37)	245 (0.68)
	Hydatid cyst	0 (0.00)	13 (0.14)	262 (1.80)	92 (0.34)	183 (0.51)
	Abscess	71 (0.18)	0 (0.00)	28 (0.19)	79 (0.29)	20 (0.06)
	other*	0 (0.00)	1 (0.01)	29 (0.20)	12 (0.04)	18 (0.05)
Head	Poor bleeding	11812 (30.21)	0 (0.00)	0 (0.00)	5637 (20.90)	6175 (17.18)
	Bruising	10469 (26.78)	0 (0.00)	257 (1.76)	5139 (19.05)	5587 (15.55)
	Abscess	1835 (4.69)	33 (0.36)	312 (2.14)	1179 (4.37)	1001 (2.79)
	Contamination	1302 (3.33)	0 (0.00)	210 (1.44)	747 (2.77)	765 (2.13)
	C. bovis	29 (0.07)	24 (0.26)	10 (0.07)	21 (0.08)	42 (0.12)
	other*	65 (0.17)	0 (0.00)	38 (0.26)	68 (0.25)	35 (0.10)
Intestine	Abscess	0 (0.00)	52 (0.56)	0 (0.00)	8 (0.03)	44 (0.12)
	C. bovis	0 (0.00)	9 (0.10)	0 (0.00)	9 (0.03)	1 (0.00)
	Hydatid cyst	0 (0.00)	10 (0.11)	0 (0.00)	10 (0.04)	0 (0.00)

*Other on liver (oedema, adhession, pleurisis, hemorrage, hematoma, tumer, peritonities, TB, Bruice, Jaundice); On lung (hemorrage, tumer, adhesion, c.bovis, TB) ;On kidney (tumer, abscess, c.bovis, bruising,); On heart (hemmorhage, calcified cyst, abscess, Hydatid cyst, tumer,); On tongue (hemorrhage, tumer, ulcer); on spleen (oedema, calcified cyst, hemorrhage, c.bovise, tumer); on head (Hydatid cyst, edema, adhesion)

7.2.5 Causes of condemnations of kidneys

The main causes of condemnations of kidneys were nephritis (10.91%). However, the prevalence of H. *cyst*, poor bleeding, calcified cyst, infracts, congenital cyst, hemorrhage, hydronephrosis and edema were in the range between 0.39% and 1.86% (Table 7.1). The prevalence of these problems was significantly (P<0.0001) different between abattoirs (Table 7.2). Nephritis, hydronephrosis and H. *cyst* were the major problems of Bishoftu abattoir. Contamination and poor bleeding were prevalent at Abergelle while Calcified cyst, edema, hemorrhage, congenital cyst and infrcats were prevalent at Komblocha abattoir (Table 7.3). All causes of condemnations except edema, infract and Calcified cyst was significantly (P<0.0001) different between years of study. Prevalence of nephritis was higher in 2012 (24.25%) and 2013 (19.74%) compared to other years studied (Table 7.1). Moreover, prevalence of edema, hemorrhages, congenital cyst, poor bleeding and H. *cyst* were significantly (P<0.0001) different between seasons (Table 7.2). Except poor bleeding, all the problems were more prevalent in the wet season compared to the dry season (Table 7.3).

7.2.6 Causes of condemnations of hearts

The main causes of condemnations of hearts were poor bleeding (20.83%) and pericarditis (4.59%). The prevalence of C. *bovis*, contamination and edema were in the range between 1.20% and 1.55% (Table 7.1). Poor bleeding, pericarditis, C. *bovis*, contamination and edema were significantly (P<0.0001) different between years and abattoirs (Table 7.2). The prevalence of poor bleeding and contamination were higher in 2010 and 2011. Pericarditis, C. *bovis* and edema were more prevalent in 2010, 2012 and 2013, respectively (Table 7.1). Poor bleeding was the major causes of condemnations of hearts at Abergelle abattoir while pricarditis and C. *bovis* were more prevalent at Bishoftu abattoir. The prevalence of contamination and edema were higher (P<0.0001) at Kombolcha abattoir compared to other abattoirs studied. Poor bleeding was higher (P<0.0001) in the dry season compared to the wet season (Table 7.3).

7.2.7 Causes of condemnations of tongues

Main cause of condemnations of tongues was abscess (4.71%). Condemnations due to C. *bovis*, contamination and edema were in the range between 0.26% and 0.79% (Table 7.1). The causes of condemnations of tongues were significantly different (P<0.0001) between years and abattoirs (Table 7.2). Abscess was higher in 2010 and 2011 while C. *bovis* was higher in 2012 and 2013. Contaminations of tongues were higher in 2011 while edema was higher in 2013 (Table 7.1). Abscess and C. *bovis* were higher (P<0.0001) at Abergelle and Bishoftu abattoirs, respectively, while contamination and edema was higher (P<0.0001) at Kombolcha abattoir. C.*bovis* and edema were higher (P<0.0001) in the wet season compared to the dry season (Table 7.3).

7.2.8 Causes of condemnations of spleens

The main causes of condemnations of spleen were splenities (2.74%) and hematoma (1.65%). Condemnations due to contamination, splenomegaly, H. *cyst* and abscess were in the range between 0.16% and 0.72% (Table 7.1). These problems were significantly (P<0.0001) different between abattoirs. The prevalence of splenities and hematoma were significantly (P<0.0001) affected by season (Table 7.2). These problems were mainly problems of Kombolcha abattoir particularly in the wet season (Table 7.3).

7.2.9 Causes of condemnations of heads

The main causes of condemnations of the heads were poor bleeding (18.77%) and bruising (17.05%). The prevalence of abscess, contamination and C. *bovis* were in the range between 0.10% and 3.46% (Table 7.1). These problems were significantly (P<0.0001) different between years and abattoirs (Table 7.2). Poor bleeding, bruising and contamination were higher in 2011 while abscess and C. *bovis* were higher in 2010 and 2012, respectively. Poor bleeding, bruising, abscess and contamination were the main causes of condemnations of head at Abergelle abattoir while C. *bovis* was relatively higher Bishoftu abattoir. Poor bleeding was higher (p<0.0001) in the dry season compared to the wet season (Table 7.3).

7.2.10 Causes of condemnations of intestine

Intestine was condemned due to abscess (0.08%), C. *bovis* (0.01%) and H. *cyst* (0.02%); Table 7.1). These problems were exclusively observed at Bishoftu abattoir (Table 7.3). The prevalence of abscess was higher (P<0.0001) in 2012, particularly in the wet season (Table 7.1 and 7.3).

7.2.11 Economic analysis of condemned organs

Condemnations of carcass and organs of Elfora Kombolcha abattoir from July 2010 to June 2013 is presented in table 7.4. More numbers of carcasses, livers, lungs, hearts, kidneys, heads, spleens and tongues were condemned during this period. The condemnations of liver account for 63.50%

which were followed by lung (36.83%) and kidney (34.04%). Spleen, heart, head and tongue account for 23.46%, 16.14%, 4.51% and 4.08% of condemnations, respectively.

Table 7.4 Financial loss due to condemnations of carcass and organs at ElforaKombolcha abattoir

	July 2010-June 2011(4031)	July 2011-June 2012 (4525)	July 2012-June 2013 (3506)	Total (13030)	Price	
Organ	Number (%)	Number (%)	Number (%)	Total (%)	Unite (ETB)	Total (ETB)
WC	6 (0.15)	12 (0.27)	5 (0.14)	23 (0.18)	9731.07	223814.6
PC	0.27 (0.01)	2 (0.04)	0.25 (0.01)	2.52 (0.02)	9731.07	24522.3
Head	214 (5.31)	175 (3.87)	199 (5.68)	588 (4.51)	50	29400
Heart	836 (20.74)	813 (17.97)	454 (12.95)	2103 (16.14)	20	42060
Liver	3095 (76.78)	3020 (66.74)	2159 (61.58)	8274 (63.50)	40	330960
Kidney	1851 (45.92)	1624 (35.89)	961 (27.41)	4436 (34.04)	10	44360
Lung	1772 (43.96)	1920 (42.43)	1107 (31.57)	4799 (36.83)	10	47990
Spleen	952 (23.62)	1184 (26.17)	921 (26.27)	3057 (23.46)	5	15285
Tongue	308 (7.64)	133 (2.94)	90 (2.57)	531 (4.08)	25	13275
Total						771,666.9

Analysis of the trend in condemnations of organs across the years of the study (Fig. 7.1) indicate there was a reduction in the number of condemnations of livers, lungs, kidney, hearts and tongue between 2010 and 2013. However, the level of the condemnation of spleens had increased during this period. The level of condemnations of head remained almost similar over the three years of the study.

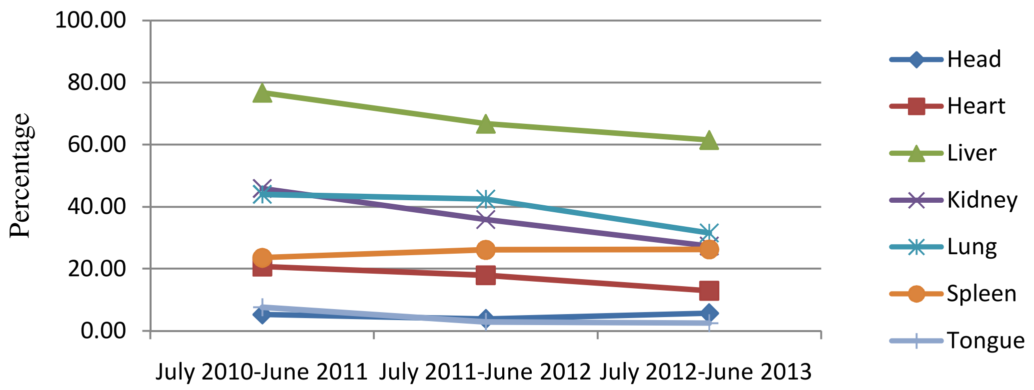


Figure 7.1 Trend in organs condemntion in Elfora Kombolcha abattoir from 2010-2013

The financial loss due to condemnation of carcasses and organs in the Elfora Kombolcha abattoir between July 2010 and June 2013 was about 771,666.9ETB (38,953.40 USD).

7.3 Discussion

7.3.1 Condemnations of whole carcasses

The results of the present study revealed that there were several disease conditions associated with the condemnations of carcasses and organs in local and export abattoirs in Ethiopia. The causes of condemnations of whole carcasses in the present study were similar to the report in Ontario, Zambiaand Tanzania (Phiri, 2006; Alton *et al.,* 2010; Mellau *et al.,* 2011).The prevalence of C. *bovis*, TB and H. *cyst* in present study were comparable to the report in Ethiopia, Cameron and Tanzania (Asseged *et al.,* 2004; Awah-Ndukum *et al.,* 2007; Mellau *et al.,* 2011). The lower prevalence of C.*bovis*, TB and H. *cyst* in the current study should not be underestimated as these diseases are zoonotic in their nature. Condemnations of whole carcasses due to bruising, contamination, pneumonia and poor bleeding were lower compared to the report in Ontario (Alton *et al.,* 2010).

7.3.2 Condemnations of partial carcasses

The partial condemnation due to bruising in the present study was less than the report in USA in 1998 and 2002 which was about 40% (Boleman *et al.,* 1998; McKenna *et al.,* 2002). However, it was comparable to the bruising reported in Canada and USA which was 34% and 33%, respectively in 2011 (NBQA, 2010/2011; Savell *et al.,* 2011). The high prevalence of bruising in the present study might be due to improper handling of cattle during transport, poor management in the Lairage and during slaughter. Cattle transportation occurs by trekking. Different stress condition faced during transportation and the excessive use of stick practiced during driving animal might expose the cattle for high level of bruising. The level of partial carcasses condemnations due to poor bleeding, contamination, adhesion and abscess in present study need considerable attention. Poor bleeding is one of the causes for dark cutting. Moreover, it will create a good opportunity for multiplication of bacteria on meat as blood is a good medium for growth of microorganisms. Poor bleeding and contamination might have contributed to the low quality of meat exported from Ethiopia. Anon (2006) has reported contamination, dark cutting and poor sanitation as the main drawback that affected export of meat from Ethiopia.

7.3.3 Condemnations of livers

The prevalence offaciolosis, H. *cyst*, calcified cyst and abscess in livers in the present study was relatively higher than the report in Northern Ethiopia and Northern Tanzania (Mellau *et al.,* 2011; Assefa and Tesfay, 2013). However, the prevalence of fasciolosis was comparable to the report in central Ethiopia and Zambia (Phiri, 2006; Aragaw *et al.,* 2012). In the present study there was a possibility of a liver being infected with more than one parasite at a time even though faciolosis was one of the main reasons of condemnations. Similar to the present study, faciolosis was reported as one of the main causes of condemnations of liver in some other studies (Andrews, 1999; Phiri, 2006; Tolosa and Tigre, 2007; Abunna *et al.,* 2009; Ibrahim *et al.,* 2010; Mellau *et al.,* 2011; Assefa and Tesfay, 2013; Mohamed, 2013). This indicates that faciola is one of the main economic important parasites in the Ethiopian cattle industry. Because of the dynamic epidemiology of fasciolosis (Mungube *et al.,* 2006), it is important to monitor its development within a year and develop strategy to reduce the incidence.

7.3.4 Condemnations of lungs

The causes of condemnations of lungs in present study were similarly reported in Northern Tanzania, Northern Ethiopia and Zambia (Phiri, 2006; Mellau *et al.,* 2011; Assefa and Tesfay, 2013). However, the prevalence of the causes of condemnations in the present study was relatively higher than those reports. The prevalence of hydatidosis in the present study was comparable to the report in eastern Ethiopia (Mulatu *et al.,* 2013). In the present study, hydatidosis was one of the important disease affecting all organs and carcasses. It affected carcass, liver, lungs, kidneys, spleen and intestine. This disease is zoonotic in its nature and important in developing countries (Eckert and Deplazes, 2004). The adult tapeworm is found in the small intestine of carnivores, particularly the dog. The metacestode (hydatid cyst) is found in a wide variety of ungulate animals and man (Soulsby, 1982; Urguhart *et al.,* 1988). Dogs are primary hosts for the parasite with livestock acting as intermediate host. The outcome of infection in livestock and humans is the development of hydatid cyst mainly in liver and lung. Hydatid cyst is a causes severe disease and sometimes death in humans. It is a cause of high treatment cost and poor animal production (Budke *et al.,* 2006). Because of the livestock and public health importance of hydatid cysts, this disease needs considerable attention. The prevalence rate of hydetidosis was higher in lung compared to other organs studied in the present study. Pneumonia was the other important problem of lungs. It is a complex problem developed from interaction between host, pathogens and environmental (Brodgen *et al.,* 1998). A number of factors can explain the high prevalence of pneumonia in the lungs in the present study.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Exhaustions and exposure of cattle for the dust during long distance trekking in search of feed and water, to markets and abattoirs, and parasites of lungs can be some of the causes of the problem. Animals have no proper housing with most farmers in Ethiopia. Poor housing condition might expose the cattle to various stresses like cold, wind, rain and dust. Consequently, opportunistic bacteria like Pasteurella spp. and Arcanobacterium pyogenes would get a chance to attack the lungs. Most cattle in Ethiopia experienced either of these stresses in one way or the other. Appropriate housing, transport and provision of feed and water at short distance can minimize this problem. Further more following appropriate procedure during slaughter can reduce the problem of emphysema as extensive gasping respiration during slaughter causes of this problem (FAO, 2000).

7.3.5 Condemnations of kidneys

The causes of condemnations of kidneys in the present study were similarly reported in some other studies (Mesele *et al.,* 2012; Mellau *et al.,* 2011; Phiri, 2006). However, the prevalence of nephritis in the present study was relatively higher than the report in these studies. The prevalence of hydropnephrosis in the present study was comparable to the report in Zambia and Tanzania (Phiri, 2006; Mellau *et al.,* 2011).

7.3.6 Condemnations of hearts

The causes of condemnations of hearts in the present study were similarly reported in some other studies (Phiri, 2006; Ashwani and Gebretsadik, 2008; Bekelle *et al.,* 2010; Mellau *et al.,* 2011; Amene *et al.,* 2012; Mesele *et al.,* 2012;Assefa and Tesfay, 2013). However, the prevalence of

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

cysticercus bovis in the present study was relatively higher than the prevalence of this problem in Adigrat and Jimma abattoirs in Ethiopia which were 0.27% and 0.8%, respectively (Bekelle *et al.,* 2010; Assefa and Tesfay, 2013). The prevalence of pericarditis in the present study was higher than the report in Zambia and Tanzania (Phiri, 2006; Mellau *et al.,* 2011).

7.3.7 Strategies to minimize commen causes of condemnations of carcasses and organs

Poor bleeding and contamination were the main causes of condemnations of carcasses, livers, lungs, kidneys, hearts and heads in the present study. Poor slaughtering procedure is the main reason for poor bleeding of carcasses. This problem can be minimized by having good management programs (GMP) at abattoirs. Stunning methods can affect the bleeding process (Gracey *et al.,* 1999). A suitable method of stunning should be applied so that efficient bleeding will occur during slaughter. The practice of good management program (GMP's) at abattoirs will help further in implementing efficient sanitary and hygienic practices during the processing of meat. Effective GMP's helps to reduce the level of spoilage of meat at abattoirs (Silliker, 1980).

The prevalence of abscess and C. *bovis* in the present study was relatively higher than the report in Zambia (Phiri, 2006). However, the prevalence of C. *bovis* in the present study was lower than 4.4% reported in south western Ethiopia (Megersa *et al.,* 2010). Abscess and C. *bovis* as contributed a lot for the condemnations of carcasses, livers, tongues, spleens, heads and intestines in the present study. Bovine cysticercosis has livestock and public health importance. Economic losses can occur due to the condemnation of heavily infected carcasses. Moreover, it will add further cost as infected carcasses need to remain freezing for some times and the need to boil infected meat. Bovine cysticercosis is caused by the larval stage (Cysticercus bovis) of the

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

human tapeworm Taenia saginata. The indirect life cycle of this parasite involves humans as the primary host and bovines as the intermediate host. Infection of humans with the adult tapeworm occurs by eating raw or insufficiently cooked or frozen beef (WHO/FAO/OIE, 2005; OIE, 2012). In Ethiopia, there is a practice of eating raw meat which is locally called; qurt.' In such circumstance it is important to eliminate the incidence of this parasite from the livestock sector to safe guard the health of the society. Changing the attitude of the society to abstain from eating raw meat will help to break the life cycle of the parasite. Taenia saginata is prevalent in sub-Saharan Africa, Latin America, Asia, and some Mediterranean countries. Tens of millions of people are likely infected with *T. saginata taenios* is worldwide (Craig, 2007). Even if the disease has a very low prevalence in the present study, its public health importance indicates the need to develop strategy to take strong preventive measures against the parasite.

The major causes of condemnations of carcasses and organs observed in the present study can be classified in to three categories. First category includes problems due to absence of good management program at abattoirs. The second category includes problems due to absence of good transport and handling of animals. The third category includes prevalent diseases in one or more of the region the abattoirs are located. Moreover, the third category can further be classified in to public and livestock health important diseases. Problems due to absence of good management program (GMP's) at abattoirs were poor bleeding and contaminations of carcasses and organs. These two problems contributed for significant numbers of condemnations of carcasses and organs. Condemnations of carcass and organs due to poor bleeding and contaminations were major problems of Abergelle abattoir. It is therefore important to establish GMP at this abattoir so that significant size of economic loss will be minimized. Problem due to absence of good transport and animal handling practice observed in the present study was condemnations of carcass and organs due to bruising. Bruising of animals during transport is the major source of economic loss in African and Asian countries. Moreover, it has also animal welfare implication as it shows excessive use of sticks during driving animals to the market and abattoirs (Cadmus and Adesokan, 2009). Grandin (1980) reported that about 50% of problem of bruising was caused by rough treatment of animals during transport. In Ethiopia, most cattle reach to abattoirs by trekking long distance and/or crossing a number of markets. This might contribute amount of bruising of carcasses and organs encountered in the present study. Training people involved in handling cattle and use of appropriate vehicle during transport can minimize this problem. Moreover, fighting between animals in the lairage was reported to be the causes of significant amount of bruising of carcasses (Warriss, 2003). Hence it is important to have well designed Lairage for cattle to minimize this problem.

In the present study, the problem of fasiola, cirrhosis, Hydatid cyst, pneumonia, emphysema, nephritis, pericarditis and abscess were common causes of condemnations of organs in the three abattoirs studied. More numbers of organs were condemned due to abscess in the present study. In liver abscess can be caused by Actinomyces (Corynebacterium) pyogenes, Streptococcus spp. and Staphylococcus spp. In the lungs, it can be caused by Pasteurella spp. and Actinomyces pyogenes (FAO, 2000). Strategy should be developed to minimize this problem in the country. Some disease problems were localized in a specific abattoir in the present study. Splinities, hematoma, splenomegaly, edema, hemorrhages and congenital cyst were the main causes of condemnations of organ in Kombolcha abattoir. These geographically limited problems need specific strategy to be minimized.

The more prevalence rate of poor bleeding and bruising in the dry season compared to the wet season indicate the need to develop season based strategy to reduce these incidences. The incidence of more numbers of bruising during dry season compared to the wet season can be explained by long trekking of cattle in the former season in search of feed and water as these resources are scarce in the dry season.

The condemnation of liver at Elfora Kombolcha abattoir in the present study was similar to the report at Kombolcha and Jimma municipality of Ethiopia which were 66.5% and 64.4% respectively (Nurit *et al.,* 2012; Amene *et al.,* 2012). However, it was less than the report in the Northern part of Ethiopia which were 17.58% and 31.1% (Assefa and Tesfay, 2013; Yifat *et al.,* 2011). The condemnation rate of lung in the present study was comparable to the report at Bahir Dar and Jimma municipal abattoirs in Ethiopia which were 25.8% and 46.2%, respectively (Amene *et al.,* 2012; Asmare *et al.,* 2012). However, it was less than the report in Gondar (Ethiopia), Adigrat (Ethiopia) and USA which were 8.19%, 19.68 % and 17.3%, respectively (Savell *et al.,* 2011; Mesele *et al.,* 2012; Assefa and Tesfay, 2013). The condemnations of kidney in the present study was higher than the report at Adigrat, Jimma and Mekelle municipality of Ethiopia which were1.21%, 18% and 5.77%, respectively (Shagaw *et al.,* 2009; Amene *et al.,* 2012; Assefa and Tesfay (2013). The condemnation of heart in the present study was comparable to the report at Mekelle municipality which was 3.71% (Shagaw *et al.,* 2009). However, it was higher than the report at Jimma local abattoir in Ethiopia (Amene *et al.,* 2012). The condemnations of tongue and head in the present study were relatively lower than the report in USA which were 10.0% and head 7.2%, respectively (Savell *et al.,* 2011).

The researchers didn't come across a report on total financial loss due to carcasses and organs condemned in Ethiopia. The direct financial loss due to liver condemnation in the present study was higher than the report at Elfora Kombolcha abattoir which was 12,810 ETB per annum (Nurit *et al.,* 2012). The annual economic loss in Bahr Dar local abattoir in Ethiopia from liver and lung condemnation was estimated to be about 170, 676 ETB (Asmare *et al.,* 2012).

7.4 Summary

About 27 causes of condemnations of carcasses and organs were identified in this study. The causes of condemnations of carcasses and organs were significantly (P<0.0001) different between abattoirs or years or season or all of the aforementioned in some cases. Condemnations due to the aforementioned causes caused big financial loss at Kombolcha abattoir. Bruising, contamination, poor bleeding were the most common causes of condemnations of carcasses and organs. These problems can be minimized by implementing good management program (GMP's) at the abattoirs, dehorning and appropriate handling of cattle during transport. Even though the prevalence of public and livestock health important diseases in the present study were lower, a strategy should be developed to reduces these problems in the future.

CHAPTER 8

8 CARCASS QUALITY AUDIT - A STRATEGY TO IMPROVE THE BEEF SECTOR IN ETHIOPIA

8.1 Introduction

Ethiopia has the largest population of cattle in Africa. However, the potential of the sector have not been fully utilized. Average carcass weight of cattle, per capita meat consumption and annual volume of meat produced was low between 1999 and 2009. Experience from developed countries indicate that implementing carcass quality audit aided to identify quality problems of carcasses, develop strategy and establish an educational plan to address the problems identified. The audit has helped in benchmarking carcass quality parameters to quantify the progress of the sector at intervals of time. The purpose of this paper is to share experienced from developed countries on carcass quality audit. Moreover, the possibilities of implementing export beef carcass quality audit (EBCQA) in Ethiopia will be discussed to improve the sector, sustain the quality, consistency and competitiveness of the country in beef industry.

8.2 Establishing beef carcass quality audit in Ethiopia

A carcass quality audit is one way of identifying and measuring quality problems of carcasses. It is a base to establish an educational plan to address the problems identified. Quality defects which can be managed primarily through the efforts of cattle producers will be identified. Bench mark quality parameters will be set to quantify the progress of the sector at specified intervals or years. A strategy to reduce the incidence of defects will be developed (NBQA, 2010/11). A National Beef Quality Audit (NBQA) was created in different countries to identify and measure quality problems and to establish an educational plan to address the problems identified. In USA audits were conducted in 1991, 1995, 1999, 2000, 2005 and 2010/11 (BQA, 2003; Savell *et al.,* 2011). In Canada audits were conducted in 1995, 1998/99 and 2010/11 (NBQA, 2010/11). In Romania national grading of quality of beef carcass and veal was conducted in 2008 (Petroman *et al.,* 2009). In Italy, effectiveness of carcass data collection in cattle slaughter house was evaluated in 2007 (Lazzaroni and Biagini, 2009). The EU has introduced in all member countries a system of carcass classification which gives some indication of the parameters to be used for the classification of animal carcasses aiming to facilitate intra-community exchange, to introduce criteria for determining the price in terms of quality and provide guidance to farmers to improve the quality characteristics of the product (Lazzaroni and Biagini, 2009).The aim of the NBQA was to measure quality defects which could be managed primarily through the efforts of cattle producers. It developed benchmarking quality parameters to measure the progress of the sector at different interval of time. Furthermore, the NBQA supports the development of strategies to reduce the incidence of defects. The ultimate objective of the NBQA is to enhance the quality and safety of beef while increasing the profitability of a country beef and cattle industry (NBQA, 2010/11).

The carcass classification system already developed by Ethiopian standard agency in 2012 is a good opportunity to implement export beef carcass quality audit (EBCQA) in the export abattoirs in Ethiopia. The reason for the implementation of the program on export abattoirs is due to the better facilities and the good practice of recording information in these abattoirs compared to the local abattoirs   Moreover, recently MOA has developed a sector solely focusing on the export of livestock and livestock products. This sector will play a coordinating role in the execution of

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

EBCQA. The audit will be conducted at two years intervals as the number of export abattoirs and the numbers of animals slaughtered per day are small compared to developed countries. Experience from the countries conducted the audit shows that collection of data can be accomplished by universities. In the case of USA, Colorado State University, Oklahoma State University and Texas A & M University were participated in collecting data for the auditing. The data was collected in the spring/summer and in the fall/winter from 50% of each lot on the slaughter floor and 10% in the cooler during a single day's production (one or two shifts, as appropriate). Based on the collected data carcasses were evaluated for coat color, breed/origin of cattle, brands, mud/manure, means of identification of cattle, sex, bruises, dentition, offal and carcass condemnation, carcass quality and yield information (Boleman *et al.,* 1995; McKenna *et al.,* 2002). In Romania and Italy, data was collected on categories of cattle slaughtered, degree of conformation, degree of fatness, traceability of slaughter animals (breed, sex, live weight and carcass weight), carcass defects and condemnations (Lazzaroni and Biagini, 2009; Petroman*et al,.* 2009). Based on the evaluation, carcasses quality problems were ranked and educational programs were developed to address these challenges (NBQA, 2010/11).

In Ethiopian context, data that will be collected for 5-10 days per year is sufficient to accomplish the audit. The universities should publish reports on the status of the carcass production and quality every other year. The aim of the report will be to identify major problems associated with carcass yield and quality. The concerned body (beef export sector of MOA) should prioritize these problems and seek solutions through the extension service program. A strategy will be developed to reduce the proportion of quality problems, defects, causes of condemnation of carcasses and organs in short and long term program. For institutes involved in the auditing activity, it is one way of serving the industry beyond their academic exercise. For these institutes, it will be an excellent opportunity to get retro-prospective and prospective data for research purposes. Most of the data required for the audit is information already recorded by abattoirs. Abattoir personnel usually record information on traceability of slaughtered animals such as breed (source of purchase), sex, live weight and carcass weight. Federal veterinary inspectors are well established in recording carcass defects and condemnations. Additional tasks expected from institutes involved in the auditing activity will be collecting information on classification of the carcasses (category, conformations and fat grade). This work will be done parallel to collecting recorded information at the abattoirs. Based on these assumptions, the humane, material and financial cost will be reasonable. One week training for personnel involved in the data collection on classification system will be sufficient to avoid subjective difference between technicians. Involving universities in different regional states will further minimize the cost of transport of researchers and materials. Gijiga Universiy, Haramaya Univesity, Hawassa Univesity, Bahrdar University and Mekelle University can conduct audits at export abattoirs in Solmali, Oromiya, SPNN, Amhara and Tigray regional states, respectively. However, institute like Haramaya University will take the responsibility of managing data, analyzing and writing the report because of the long experience in research and teaching activities. Data base management should be established at this center. Those data collected at interval of a year and used for reporting at specific years need be stored in this center. After long period of time, say ten years, these data at the management center will be used to develop long term strategy to solve quality problems. The out put of the activity should be publishable rather than a mere report to the concerned body and academic exercise. This will be an opportunity to announce the status of beef production and constraints so that every concerned body will aware of the situation. By developing export beef carcasses audit, the major yield and quality problems will be identified and profound solution will be found. The solution of these problems will be feed back to producers so that better quality beef will be produced for export market. This will sustain the quality, consistency and competitiveness of the country in beef industry.

8.3 Summary

The large livestock resources available in Ethiopia are not fully utilized. One of the major problems was inability to produce quality product for export purpose. Experience from developed countries show that establishing carcass quality audit will assist to identify problem and develop strategy to improve the sector. It is therefore suggested that establishing export beef carcass quality audit (EBCQA) in Ethiopia will be good opportunity to improve the sector, sustain the quality, consistency and competitiveness of the country in beef industry.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

CHAPTER 9

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

There are many oppertunities to improve the carcass quality and yield of cattle in Ethiopia. To exploit these opertunites, a number of problems should get solutions. These problems include improving weights, conformation, fat grade, meat yield, dark firm dry meat, bruisining, contamination, poor bleeding and disease conditions of cattle. These constraints can be solved by taking a holistic approach at producer level, during transport of cattle and good abattoir management.

The management practice at public and private abattoirs partly contribute to the poor quality carcasses. Lairage was not divided into compartments to accommodate different classes and types of cattle, stunning boxes were not used, enervation method of stunning was practiced, there were no means of sterilizing cutting equipment and bleeding was conducted on the floor at horizontal position at public abattoirs.

The present study revealed that more than 2/3 of cattle slaughtered at local abattoirs were inferior in their quality (fat grade 1). The proportion of inferior quality carcass was higher with cows and castrated bulls. Feeding cull cows is a viable option to improve yield and quality grade of carcasses. The relatively lower proportion of superior conformation (grade 1) and absence of superior fat (grade 3) for cows in the present study indicate the need to proper feeding of culled cows before slaughter. Some studies reported that cull cows can gain tremendous amounts of weight in relatively short times on high-grain diets. However, it should be noted that cull cows are not efficient in a feedlot and need to have every possible management strategy to maximize feed conversion efficiency such as using melengestrol acetate (MGA), ionophores and implants. The differences in carcass quality across abattoirs suggest the need to develop different strategy to increase the quality of carcass produced across region.

Most of cattle slaughtered at the abattoirs were indigenous local cattle. Only 1.44% Holstein Friesian and their crosses were used for beef purposes. Dairy is a rapidly developing industry in Ethiopia. In dairy industry, bull calves have little value as they compute for milk. Most dairy farmers prefer to get rid of bull calves as early as possible. This indicates the possibility of exploiting dairy beef in Ethiopia.

The present study revealed that there were no heifers/bulls less than 2 years of age slaughtered at studied abattoirs. Farmers should be advised to sell excess cattle at young stage. Creating paying market for young cattle encourage farmers to sell excess young animals. In addition to production of quality carcass from young cattle, selling excess young animals will reduce stocking density on the farms. By reducing stocking density on the farm, the body condition of available herd will be maintained in good condition.

The present study revealed the better performance of Boran cattle in terms of live weight, carcass weight and dressing percentage over Arado, Barka and Raya breeds. This is due to the long term improvement program implemented for the Boran cattle since 1960. The improvement of Boran cattle coupled with fattening experience created good opertunity to expoit carcass traits of the breed.

Poor bleeding and contamination of carcasses were some of the main causes of condemnations of carcasses and organs in the present study. These problems can be minimized by having good management programs at abattoirs. Mud from the skin and gastrointestinal contaminations are the main causes of contaminations of carcasses and organs.The primary goal of effective slaughter is to protect the sterile muscles of the carcass from being contaminated by the content of gastrointestinal tract and hide. In general it is important to establish regulatory systems ("directives") by the government of Ethiopia and design to implement and strictly enforce the laws.

The average length of horns of cattle in the abattoirs studied was >1/4 meter. Horns were implicated as one causes of bruising. The present study revealed bruising as one of the main causes of condemnations of carcasses and organs. Improper handlings during transport coupled with horn condition of cattle might be the causes of high prevalence of this problem. This problem dominated in area where cattle have longer horn lenths (Mekelle). Most cattle supplied for slaughter were indescrit breeds. These breeds were purchased from local big markets. To reach to these markets cattle should travel through differetn small markets. This might contribute for large size of bruising of carcasses and organs encountered in the present study. Creating awareness on handling of cattle and use of appropriate vehicle during transport might minimize this problem. Fighting between animals in the lairage was reported as one of major cause of bruising. Appropriate Lairage constraction and good managemt during cattle holding might minimize this problem. Dehorning cattle in feedlot prior to transporting/driving to abattoir can also contribute to minimize this problem.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

The present study revealed that more than 2/3 livers and 1/3 of lungs were condemned at abattoirs in Ethiopia. The main causes for condemnations of liver were Fasciola and H. *cyst* while the main causes of condemnations for lungs were H. *cyst*, pneumonia and emphysema. A strategy should be developed to reduce the incidence of Fasciola, H. *cyst*, pneumonia and emphysema. Even though the prevalence of diseases such as TB, cysticercosis and hydatidosis were low in the present study, its public health importance urges development of strategy to eliminate these problems.

To produce consistent and sustainable quality of beef, continous evaluation and monitorying program of carcass quality should be established. That is why National beef quality audit was created in developed countries and continous evaluation has been taking places at interval of years. In this program, problems are identified at interval of years and strategy will be developed to minimize these problems further. Furthermore, wether the strategy developed contributed in minimizing the problems will be evaluated. By this quality evaluation and monitoring program, it will be possible to maximize quality of beef from year to year. The carcass classification system already developed in Ethiopia is a good opportunity to implement export beef carcass quality audit (EBCQA) in the country. It is important to conduct the audit at interval of two years. By this audit, quality problems, defects, causes of condemnation of carcasses and organs will be identified at interval of two years. This information will support the development of strategies to reduce the incidence of defects in the future.

9.2 Recommendations

Based on the present finding, it was recommended that the country should develop law governing abattoirs operations. Moreover, hazard analysis at critical control point (HACCP) should be established in all abattoirs to ensure the welfare of animals, maximize efficiency and quality of cattle carcasses. Cattle should be fed properly to increase the proportion of superior conformations and fat of carcases. The proportion of heifer and bull less than 2 years slaughtered at abattoirs need to be increased by utilizing dairy beef and creating good market opportunity for farmers to sell excess cattle at younger age. To increase the quality of carcasses from culled cows, proper feeding of culled cows before slaughtering is suggested. Implementing long term breeding program to improve carcass and meat yield of Arado, Barka and Raya breeds is suggested. Implementing good abattoir management program and appropriate transporting facility for cattle are recommended. Dehorning cattle befor transporting to abattoirs are recommended to reduce the incidence of bruising. Training people involed on cattle transport and slaughter on proper handling of animals is required. These practices will minimize the level of stress of cattle which intern affects the quality of carcasses. Developing strategies to minimize the incidence of major disease problems such as Fasciola, H. *cyst* and pneumonia at producer level will reduce the degree of condemnation and financial losses from the sector. Establishing beef carcass quality audit in the country will help in identifying major quality problems and defects, minimize the degree of these problems and maintaining the quality of the carcass consistently.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Areas that are suggested for further research are:

- Evaluating beef quality (marbling, juiceness, palatability and flavor) of carcasses from different conformation, fat grade and categories of cattle
- Determine the perception of consumers on meat from different grades of conformation, fat and categories of cattle
- Look for options to maximize feed conversion efficiency of cull cows and draft bulls using every possible management strategy such as using MGA, ionophores, and implants.
- Conducting research on efficient dairy beef production and perception of the consumers toward dairy beef.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

LIST OF REFERENCES

Aalhus, J.L., Gariepy C., Murray A.C., Jones S.D.M. and Tong, A.K.W., 1991.Stunning and shackling influences on quality of porcine *longissimus dorsi* and *semimembranosus* muscles. *Meat Sci.,* 29,323-334.

Abdelhadi, O.A., Babiker, S.A. and Kijora, C., 2011. Estimation of Zebu cattle carcass weight using body measurements. Livestock Research for Rural Development.Volume 23, Article #12. Retrieved May 18, 2014, from http://www.lrrd.org/lrrd23/1/abde23012.htm

Abunna, F., Asfaw L., Megersa, B. and Regassa, A., 2010. Bovine Fasciolosis: Coprological, Abattoir Survey and its Economic Impact due to Liver Condemnation at Soddo Municipal Abattoir, Southern Ethiopia. Tropical Animal Health and Production, 42: 289-292.

Abunna, F., Fentaye S., Megersa, B., Regassa, A., 2012. Prevalence of bovine hydatidosis in Kombolcha ELFORA abattoir, North Eastern Ethiopia. Open Journal of Animal Sciences 2: 281-286

Abunna, F., Tilahun, G., Bersissa, K., Megersa, B., and Regassa, A., 2008. Bovine Cysticercosis in Awassa, Southern Ethiopia: Prevalence, risk factors and cyst viability, Zoonoses and Public Health, 55: 82-8.

Adzitey, F., 2011. Mini Review: Effect of pre-slaughter animal handling on carcass and meat quality. International Food Research Journal 18: 485-491

Adzitey, F and Huda, N., 2012. Effects of post-slaughter carcass handling on meat quality. Pak Vet J, 32(2): 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. and Dinko, M.M., 2011. Pre and post-slaughter animal handling by butchers in the Bawku Municipality of the Upper East Region of Ghana. Livestock Research for Rural Development. Volume 23, Article #39. Retrieved October 6, 2014, from http://www.lrrd.org/lrrd23/2/adzi23039.htm

Alton1, 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 http://www.biomedcentral.com/1746-6148/6/42

Amene, F., Eskindir, L. and Dawit, T., 2012. Cause, rate and economic implication of organ condemnation of cattle slaughtered at Jimma municipal abattoir, Southwestern Ethiopia. Global Veterinaria, 9 (4): 396-400.

Anderson, B. and Horder, J.C. (1979). Qld Agric. J. 105:281.

Andrews, S.J., 1999. The life cycle of fasciola hepatica. In Fasciolosis, Ed. Dalton, J.P. CABI Publishing, pp: 1-29.

Anon, 2002. The effect of the Gene STAR Marbling test under typical U.S. lot-fed finishing systems. http://www.frontierbeefsystems.com/GeneNOTE3026-26-02.pdf

Anon, 2004. Expenditure review of beef carcase classification scheme.The Department of Agriculture and Food, Dublin, Ireland.

Anon, 2006. Report of trade mission to Saudi Arabia, August 26-September 1, 2006. Ethiopia Sanitary and Phytosanitary Standard and Livestock and Meat Marketing Program (SPS-

LMM), Texas Agricultural Experiment Station (TAES)/Texas A&M University System. 4 pp.

Aragaw, K., Negus, Y., Denbarga, Y. and Sheferaw D. 2012. Fasciolosis in slaughtered cattle in Addis Ababa abattoir, Ethiopia. Global Veterinaria 8 (2): 115-118, 2012. ISSN 1992-6197. © IDOSI Publications.

Ashwani, K. and Gebretsadik, B., 2008. Occurrence of cysticercosis in cattle of parts of Tigray region of Ethiopia. J. Haryana Veterinarian, 47: 88-90.

Asmare, A., Biniyam, A. and Mersha, C., 2012. Major causes of lung and liver condemnation and financial impact in cattle slaughter at Bahir Dar municpial abattior. African J. Basic & Appl. Sci., 4 (5):165-171.

Asrat, G., 1996. Prevalence and economic significance of hydatidosis/Echinococcosis in slaughtered cattle, sheep and got in South Wollo. DVM thesis, Addis Ababa University, Debre *Zeit, Ethiopia.*

Assefa, A. and Tesfay H., 2013. Major causes of organ condemnation and economic loss in cattle slaughtered at Adigrat municipal abattoir, northern Ethiopia. Veterinary World, EISSN: 2231-0916. www.veterinaryworld.org/Vol.6/Oct-2013/8.pdf

Asseged, B., Woldesenbet, Z., Yimer, E. and Lemma, E., 2004. Evaluation of abattoir inspection for diagnosis of mycobacterium bovis infection in cattle at Addis Ababa abattoir. Tropical animal Health and Production, 36(6), 537-546.

Avery, A., 2004. Red meat and poultry production and consumption in Ethiopia and distribution in Addis Ababa. Borlaug-Ruan World Food Prize Intern, International Livestock Research Institute. Addis Ababa, Ethiopia

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

http://www.worldfoodprize.org/assets/YouthInstitute/BRinternship/2004/papers/AveryAbbey

Awah-Ndukum, J., Tchoumboue, J., and Niba, A.T., 2007. Current status of bovine tuberculosis and other pathological conditions at the SODEPA Douala abattoir, Dschang, Cameroon (1995–2003). Tropical Veterinarian, 25, 58–64.

Ayalew, W., Getahun E., Tibbo, M., Mamo, Y. and Rege J., 2003. Current state of knowledge on characterization of farm animal genetic resources in Ethiopia. In: Proceedings of the 11th Annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 28-30, 2003. ESAP, Addis Ababa. 441pp.

Aynalem H., Workneh A., Noah K., Tadelle D. and Azage T., 2011. Breeding strategy to improve Ethiopian Boran cattle for meat and milk production. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 26.Nairobi, Kenya, ILRI.

Alvarado, C.Z., Richards, M.P., O'Keefe, S.F. and Wang, H., 2007. The Effect of blood removal on oxidation and shelf life of broiler breast meat. Poultry Science, Vol. 86, No. 1, pp. 156-161.

Baker, F.H., Beck, A.M., Binkerd, E.F., Blosser, T.H., Brown, K.I., Corah, L.R., Curtis, S.E., Fox, M.W., Hahn, G.L., Johnson, D.E., Kearl, W.G., Kinsman, D.M., Lechtenberg, V.L., Marten, G.C., Montgomery, M.J., Ohlendorf, G.W., Preston, R.L., Rice, R.W., Ringer, R.K., Robinson, F.R., Schneider, N.R., Ullrey, D.E., Willham, R.L., Young, J.,1981. Scientific aspects of the welfare of food animals. Council for Agricultural Science and Technology (CAST), Report 91. Ames, IA, USA, 54

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Basarab, J.A., Aalhus, J.L. Shah, M.A. Mir, P.S. Baron, V.S., Dugan M., 2007. Effect of feeding sunflower seeds on the performance, carcass characteristics, meat quality, retail stability and sensory characteristics of pasture-fed and feedlot finished beef. Canadian Journal of Animal Science 87:15-27.

Basarab, J.A., Graham, B., Brethour, J.R. and Milligan, D., 1997. Sorting feeder cattle with a system that integrates ultra-sound back fat and marbling estimates with a model that maximizes future carcass value. http://www.agric.gov.ab.ca/research/researchupdate/97beef06.html

Berhe, G., Berhane, K. and Tadesse, G., 2009. Prevalence and economic significance of fasciolosis in cattle in Mekelle area of Ethiopia. Tropical Animal Health and Production, 41: 1503-1504.

Betru S. and Kawashima H., 2009. Pattern and determinants of meat consumption in urban and rural Ethiopia. Livestock Research for Rural Development.Volume 21, Article #143. Retrieved March 11, 2014, from http://www.lrrd.org/lrrd21/9/betr21143.htm

Biagini, D. and Lazzaroni, C., 2005. Carcass dissection and commercial meat yield in Piemontese and Belgian Blue double-muscled young bulls. Livestock Production Science 98:199–204

Bogh-Sorensen, L., 1980. Product temperatures in chilled cabinet. Paper no. 26. Paper presented at the preoceedings of the 26th European meeting of meat research, Colorado, Springs.

Boleman, S.L., Boleman, S.J., Morgan ,W.W., Hale, D.S., Griffin, D.B., Savell, J.W., Ames, R.P., Smith, M.T., Tatum, J.D., Field, T.G., Smith, G.C., Gardner, B.A., Morgan, J.B., Northcutt, S.L., Dolezal, H.G., Gill, D.R. and Ray, F.K., 1998. National Beef Quality

Audit-1995: Survey of producer-related defects and carcass quality and quantity attributes. J. Anim. Sci. 76:96-103.

Breuer, K., Heemsworth, P.H., Barnett, J.L., Mathews, L.R. and Coleman G.J., 2000. Behavioral response to humans and productivity of commercial dairy cows. Appl. Anim. Behav. Sci. 66:273-288.

Brodgen, K.A., Lehmkuhl, H., Cutlip, D. and Randall, C., 1998. Pasteurella haemolytica complicated respiratory infections in sheep and goats. Veterinary Research, 29 (3–4), 233–254.

Budke, C.M., Deplaxes, P. and Torgerson, P.R., 2006. Global socio-economic impact of cystic echinococcosis. Emerging Infectious Diseases 12(2): 296–303. doi: 10.3201/eid1202.050499 PMCID: PMC3373106

Cadmus, S.I.B. and Adesokan, H.K., 2009. Causes and implications of bovine organs/offal condemnations in some abattoirs in Western Nigeria. Tropical Animal Health and Production, 4: 1455-1463.

Cancian P.H., Gomes R.C., Manicardi F.R., Ianni A.C., Bonin M.N., Leme P.R., Silva S., 2013. Correlations of visual scores, carcass traits, feed efficiency and retail product yield in Nellore cattle.*Sci. Agric*. 71: 17-22

CARE International Kenya, 2010. Expanding Investment Finance in Northern Kenya and Other Arid Lands: Market Assessment. Annex 3: Sector Profiles. CARE/Ministry of State for Development of Northern Kenya and Other Arid Lands.17 pp.

Cianzio, D.S., Topel, D.G., Whitehurst, G.B., Beitz, D.C., and Self, H.L., 1985. Adipose tissue growth and cellularity: Changes in bovine adipocyte size and number. J. Anim. Sci. 60:970.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Chebo, C., Ayalew W. and Wuletaw, Z., 2013. On-farm phenotypic characterization of indigenous cattle populations of Gamo Goffa zone, Southern Ethiopia. Animal Genetic Resources, 1-12. Food and Agriculture Organization of the United Nations. doi:10.1017/S2078633612000046

Cornell University 2014. The Cornell small farms program, Cornell cooperative extension and Cornell University in Ithaca, NY.

Cortesi, M.X., 1994. Slaughterhouses and humane treatment. Rev. sci. tech. Off. int. Epiz.,13 (1): 171-193

Council of Europe 1974. Council Directive of 18 November on Stunning of Animals before Slaughter (74/577/EEC). Official Journal of the European Communities, No. L 316,26 November, 10-11.

Council of Europe, 1991. Recommendation No. R (91) 7 of the Committee of Ministers to Member States on the slaughter of animals. Adopted by the Committee of Ministers on 17 June, at the 460th meeting of the Ministers' Deputies, 15 pp.

Craig, P, Ito, A., 2007. Intestinal cestodes. Current Opinion in Infectious Diseases 20:524-32.

CSA (Central Statistical Agency) 2008. Federal Democratic Republic of Ethiopia. Central Statistical Agency. Statistical abstract. CSA, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency) 2010/2011. Federal Democratic Republic of Ethiopia. Central Statistical Agency. Statistical abstract. CSA, Addis Ababa, Ethiopia.

DAGRIS 2006. Domestic Animal Genetic Resources Information System (DAGRIS). (eds. J.E.O. Rege, W. Ayalew, E. Getahun, O. Hanotte and T. Dessie). International Livestock Research Institute, Addis Ababa, Ethiopia. http://dagris.ilri.cgiar.org

DAGRIS (Domestic Animal Genetic Resources Information System) 2011.International Livestock Research Institute, Addis Ababa, Ethiopia. http://dagris.ilri.cgiar.org/

Dirbaba, D., and B. Hurrissa. 2009. Live Animal Transport Services in Ethiopia: Current practices and future options . Norman Borlaug Institute for International Agriculture Working Paper 17th-TP-027-2009.Texas, US: College of Agriculture and Life Sciences at Texas A&M University, Texas AgriLife Research, and the Texas AgriLife ExtensionService. http://borlaug.tamu.edu/files/2012/03/Live-animal-transport-services-in-Ethiopia-Current-practices-and-future-actions.pdf

Drake, D.J., 2004. Understanding and improving beef cattle carcass quality. University of California. Division of Agriculture and Natural Resources. http://anrcatalog.ucdavise.edu

Drake, D.J., and Forero, L.C., 2001. Meeting carcass quality specification and carcass characteristics of northern California Cattle in allaiance, futurity and youth program. Pro. West. Sec. Amer. Soc. Anim. Sci. 52:239

EC., 2005. Health and consumer protection directorate genetal. Guidance document: Implementation of procedures based on the HACCP principles, and facilitation of the implementation of the HACCP principles in certain food businesses Brussels, Belgium.

Eckert, J. and Deplazes, P., 2004. Biological, epidemiological and clinical aspects of echinococcosis, Zoonoses of increasing concern. Clin.Microbiol. Rev., 17: 107-197.

Edea, Z., Dadi, H., Kim, S.W., Dassie, T., Kim, K.S., 2012. Coparison of SNP variation and distribution in indigenous Ethiopian and Korean cattle (Hanwoo) population. Genomic and informatics 10 (3): 200-205.

Eldridge, G.A., Barnett, J.L., Warner, R.D., Vowles, W.J. and Winfield, C.G., 1986. The handling and transport of slaughter cattle in relation to improving efficiency, safety, meat quality and animal welfare.Department of Agriculture and Rural Affairs, Melbourne, Australia.

Eldridge, G.A., Winfield, C.G. and Cahill, D.J., 1988. Responses of cattle to different space allowances, pen sizes and road conditions during transport. Australian Journal of Experimental Agriculture, 28, 155–159.

Eldridge, G.A., Warner, R.D., Winfield, C.G. and Vowles, W.J., 1989. Pre-slaughter management and marketing systems for cattle in relation to improving meat yield, meat quality and animal welfare. Melbourne, Australia: Department of Agriculture and Rural Affairs.

ES 2012. Grading live animal and carcass. Published by Ethiopian standard agency. ES 2789:2012. ICS: 67.120.10

FAO 1991. Guidelines for slaughtering, meat cutting and further processing. FAO Animal production and health paper 91. ISBN 92-5-102921-0

FAO 2000. Manual on meat inspection for developing countries. FAO Animal Production and Health paper 119

FAO 2004. Good practice for meat industry. FAO Animal Production and health. Rome, 2004. ISBN 92-5-105146-12

FAO (Food and Agriculture Organization of the United Nations), 2005. Production yearbook. FAO, Rome, Italy.

FAO 2008. Abattoir development. For Hygienic basic and medium-sized abattoirs. Animal Production and Health Commission for Asia and the Pacific.Regional Office for Asia and the Pacific. Bangko

FAOSTAT, 2003. FAO statistic data base on the World Wide Web. http://apps.fao.org/

Farmer, E., 2010. End market analysis of Ethiopian livestock and meat miro Report #164 ACDI/VOCA Consultant, with support from the Accelerated Microenterprise Advancement Project (AMAP), funded by USAID.

Faulkner, D.B., McKeith, F.K., Berger, L.L., Kesler, D.J. and Parrett, D.F., 1989. Effect of trenbolone acetate on performance and carcass characteristics of heifers and cows. J. Anim. Sci. 67:1907-1915.

Federal Register 1996. Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP) Systems. Final Rule.Fed.Regist 61: 38806-38989.

Feiner, G., 2006. Meat products handbook, practical science and technology.Wood HeadPublishing Limited and CRC Press LLC, Cambridge, England

Fell, L. R., Colditz, I.G., Walker, K.H. and Watson, D.L., 1999. Associations between temperament, performance and immune function in cattle entering a commercial feedlot. Australian Journal of Experimental Agriculture, 39, 795–802.

Ferguson, D.M., Bruce, H.L., Thompson, J.M., Egan, A.F., Perry, D. and Shorthose, W.R., 2001. Factors affecting beef palatability – Farm gate to chilled carcass. Australian Journal of Experimental Agriculture, 41, 879–891.

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

Fisher, A., 2007. Beef carcass classification in the EU: an historical perspective. In: Evaluation of carcass and meat quality in cattle and sheep. No.123. ISBN 978-90-8686-022-7

Fletcher, D.L., 2002. Poultry meat quality. Worlds Poultry Science Journal 58: 131- 145

Forrest, J., 2010b. Meat quality and safety. Aging meat. http://ag.ansc.purdue.edu/meat_quality/aging_meat.html.

Fluharty, F.L., 2003. Interactions of management and diet on final meat characteristics of beef animals. http://beef.osu.edu/library/mgtdiet.html

Funston, R.N., Paterson, J.A., Williams K.E., and Roberts, A.J., 2003. Effects of body condition, initial weight, and implant on feedlot and carcass characteristics of cull cows. Prof. Anim. Sci. 19:233-238.

Geesink, G.H., Mareko, M.H.D., Morton, J.D. and Bickerstaffe, R., 2001. Effects of stress and high voltage electrical stimulation on tenderness of lamb m. Longissimus. Meat Science, 57, 265–271.

Getaw, A., Beyene, D., Ayana, D., Megersa B. and Abunna, F., 2010. Hydatidosis: prevalence and its economic importance in ruminants slaughtered at Adama municipal abattoir, central Oromia, Ethiopia. Acta Tropica, 113: 221-225.

Gill, C.O., 2004. Visible contamination on animals and carcasses and the microbiological condition of meat. J. Food Protect 67: 413-419.

Gracey, J.F., 1981. Humane slaughter. *In* Thornton's meat hygiene. Ballière Tindall, London, 103-119.

Gracey, J.F., Collins, D.S. and Huey, R.J., 1999. Meat hygiene, 10th ed. (W.B.Saunders Company Ltd., London)

Graham JF, Byron J, Clark AJ, Kearney G, Orchard B. 2009. Effect of post weaning growth and bulls selected for extremes in retail beef yield and intramuscular fat on progeny live weight and carcass traits. *Animal Production Science* 49 (6): 493–503 http://dx.doi.org/10.1071/EA08181

Grandin, T., 1980. Bruises and carcass damage. International Journal for the Study of Animal Problems, 1(2), 121-137.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Grandin, T., 1996. Factors that impede animal movement at slaughter plants. J. Am. Vet. Med. Assoc. 209:757-759.

Grandin, T., 1999. Behavioral principles of handling livestock – update. Professional Animal Scientist, Dec. 1989. pp. 1-11.

Grandin, T., 2003. Good management practices for animal handling and stunning. American Meat Institute Foundation.

Grandin, T., 2003. Solving livestock handling problems in slaughter plants.In Animal welfare and meat science (pp. 42–68). Oxon, UK: CABI Publishing.

Gregory, N.G., 2005. Recent concerns about stunning and slaughter. Meat Sci. 70, 481-491.

Hahn, G.L., Mader, T.L., 1997. Heat waves in relation to thermoregulation, feeding behavior and mortality of feedlot cattle. Am SocAgricEng 1, 563-571

Halderman, M., 2004. The political economy of poor pro livestock policy making n Ethiopia. PPLPI working paper number 19

Hanson J (2000). Can electrolytes or chromium decrease weight losses or improve meat quality. www.grandin.com/meat/hand.stun.relate.quality

Harris, C., 2006. Dressing percengate of slaugher cattle. Govt of Alberta, 5 M Enterprises Inc. Suite, 4120, C Bot 141 West Jackson Boulevard Chicago IL 60604-2900, USA. http://www.the beef site.com/articles/759/dressing-percentage of slaughter cattle

Hassen, F., Bekele, E., Ayalew, W. and Dessie T., 2007. Genetic variability of five indigenous Ethiopian cattle breeds using RAPD markers. African Journal of Biotechnology Vol. 6 (19), pp. 2274-2279. ISSN 1684–5315. http://www.academicjournals.org/AJB

Hemsworth, P.H. 2003. Human-animal interactions in livestock production. Appl. Anim. Behav. Sci. 81:185-198.

Hemsworth, P.H. and Barnett, J.L., 2001. Human–animal interactions and animal stress. In G. P. Moberg & J. A. Mench (Eds.), The biology of animal stress – Basic principles and implications for animal welfare (pp. 309–336). Oxon, UK: CABI Publishing.

Holscher T., Herthum, S. and Kalm E., 1989. Einfluß von C02-Betäubung und Entblutung im Liegen auf die Fleischbeschaffenheit beim Schwein. Fleischwirtsch., 69 (5), 904-908.

Hurrissa, B., 2009. Community driven livestock marketing models: the case of Boran livestock trade share company of Ethiopia. Paper presented at the Regional Symposium on Livestock Marketing in the Horn of Africa: Working Towards 'Best Practices', 21-23 October 2009. TAES/SPS-LMM.10 pp.

Hutcheson, D., 2006. Feeding to produce export quality. Ethiopian Beef requirements and recommendations. Ethiopian Sanitary and Phytosanitary Standards and Livestock and Meat Marketing Program (SPS-LMM) Texas Agricultural Experiment Station (TAES)/Texas A&M University System

Ibrahim, N., Wasihun P. and Tolosa, T., 2010. Prevalence of bovines fasciolosis and economic importance due to liver condemnation at Kombolcah industrial abattoir, Ethioipia.The Internet J. Veterinary Medicine, 8(2).

ILRI (international Livestock Research Institute) 1995. Livestock Policy Analysis. ILRI Training Manual2.ILRI, Nairobi, Kenya, pp.264.

Jan Nell, A., 2006. Quick scan of the livestock and meat sector in Ethiopia: Issues and opportunities. Wageningen International, Wageningen, the Netherlands. E-mail: arendjan.nell@wur.nl, Website: www.wi.wur.nl

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Jay, J.M., 1992. Modern Food Microbiology. Microbiological Indicators of food safety and quality, Principles and Quality control, and microbiological criteria. New York: Van Nostrand Reinhold.

Jeremiah, L.E., Newman, J.A., Tong, A.K.W., & Gibson, L.L., 1988. The effects of castration preslaughter stress and zeranol implants on beef: Part 1 – The texture of loin steaks from bovine males. Meat Science, 22, 83–101.

Jobre, Y., Lobago, F., Tiruneh, R., Abebe, G. and Dorchie, P., 1996. Hydatidosis in three selected region in Ethiopia: An assessment trial on its prevalence, economic and public health importance. Revue de Medicine Veterinaire 147: 797-804.

Kebede, N., 2010. A retrospective survey of bovine Hydatidosis in three abattoirs of Amhara National Regional State, northwestern Ethiopia. Tropical Animal Health and Production, 42: 323-325.

Kebede, N., Abuhay, A., Tilahun, G. and Wossene, A., 2009a. Financial loss estimation, prevalence and characterization of hydatidosis of cattle slaughtered at DebreMarkos Municipality abattoir, Ethiopia. Tropical Animal Health and Production, 41: 1787-1789.

Kenny, F.J. & Tarrant, P.V., 1982. Behaviour of cattle during transport and penning before slaughter. *In* Transport of animals intended for breeding, production and slaughter (R. Moss, ed.). Martinus Nijhoff Publishers, The Hague, Boston and London, 87-102.

King, D.A., Pfeiffer, C.E., Randel, R.D., Welsh, T.H., Oliphint, R.A., Baird, B.E., 2006. Influence of animal temperament and stress responsiveness on the carcass quality and beef tenderness of feedlot cattle. Journal of Animal Science, 74, 546–556.

Kithuka, J.M., Maingi, N., and Njeruh, F.M., 2002. The prevalence and economic importance of bovine Fascioliasis in Kenya: an analysis of abattoir data, Ondestepoort, Journal of Veterinary Research, 69: 255-62.

Klopfenstein, T., Cooper, R., Jordon, D.J., Shain, D., Milton, T., Calkins, C. and Rossi, C., 2000. Effects of backgrounding and growing programs on beef carcass quality and yield. Proc. Amer. Soc. Anim. Sci. pp. 1–11. http://www.asas.org/jas/symposia/proceedings/0942.pdf

Knowles, T.G., Warriss, P.D., Brown, S.N. and Edwards, J.E., 1999. Effects on cattle of transportation by road for up to 31 hours. Veterinary Record, 145, 575–582.

Kumar, A., Kebede E. and Kassaye, E., 2010. Evaluation of quality of beef produced and sold in parts of Tigray Region of Ethiopia. Trop. Anim. Health Prod. 42:445–449 DOI 10.1007/s11250-009-9441-5

Lacourt, A., Tarrant, P.V., 1985. Glycogen depletion patterns in myofibres of cattle during stress. Meat Sci 15, 85-100

Lambooy E.,1990. The use of CO_2 for the stunning of slaughter pigs. Report of a meeting of experts held in Heeze, 26-27 January. Fleischwirtsch., 70 (10), 1173-1177.

Lawrie, R.A., 1979. Meat Science. Pergamon Press, New York.

Lazzaroni, C., 2007. Evaluation of carcass and meat quality in the EAAP. In: Evaluation of carcass and meat quality in cattle and sheep. Ed. Lazzaroni, C., Gigli, S. and Gabina, D. EAAP publication No.123, 2007. ISBN 978-90-8686-022-7

Lazzaroni C. and Biagini, D., 2009. Effectiveness of carcass data collection in a cattle slaughterhouse. Italian Journal of Animal Science 8 (2): 501-503.

Leach, T.M., 1978. Pre-slaughter stunning in the E.C. In: Hearing on pre-slaughter stunning (S. Fabiansson& A. Rutegârd, eds). The National Food Administration, Uppsala, 11-20.

Ledger, H.P. and Payne, W.J.A .,1990. Meat and carcass by-products. In: Introduction to Animal Husbandry in the Tropics. 4th Ed. Pub. Longman, Gp. Ltd. UK, pp 790-827.

Legese, G., Teklewold, H., Alemu, D. and Negassa, A., 2008. Live animal and meat export value chains in selected areas of Ethiopia: Constraints and opportunities for enhancing meat exports. Discussion Paper No. 12, People Livestock and the Environment.ILRI.47 pp.

Lemma, T., Geleta T., Sisay, A., and Abebe, T., 2007. Effects of four different basal diets on the carcass composition of finishing Borana bulls. Journal of Cell and Animal Biology Vol. 1 (2): 015-018.

Lengyel, Z., Husveth, F., Polgar, P. Szabo, F. and Magyar.L., 2003. Fatty acid composition of intramuscular lipids in various muscles of Holstein-Friesian bulls slaughtered at different ages. Meat Science 65:593-598.

Li, H., Bi, X., Lin, J., 2009. Different feeding patterns on the production performance of Ninghai chicken. Anim Husband Feed Sci. 30(5):82.

Little, P., John M., Roy B. and Getachew G., 2010. Pastoral economic growth and development in Ethiopia. Economic Development Research Institute (EDRI) Ethiopia and Department for International Development (DFID).Powerpoint presentation.

Livestock Marketing Authority (LMA) 2001.Assessment of Causes of Livestock Informal Trade in South, South eastern and Eastern Parts (unpublished) Addis Ababa, Ethiopia.

Lorenzen, C.L., Hale, D.S., Grimn, D,B., Savell, J.W., Miller, M.F.,Smith, G.C., 1992. National Beef Quality Audit: Carcassgrade traits of U.S. fed cattle. Journal of Animal Science 70 (Suppl. 1):227 (Abstr.)

Marenčić, D., Ivanković, A., Pintić, V., Kelava, N., Jakopović, T., 2012. Effect of the transport duration time and season on some physicochemical properties of beef meat.ArchivTierzucht 55 (2):123-131, ISSN 0003-9438

May, S.G., Savell, J.W., Lunt, D.K., Wilson, J.J., Laurenz, J.C. and Smith, S.B., 1994. Evidence for preadipocyte proliferation during culture of subcutaneous and intramuscular adipose tissues from Angus and Wagyu cross bred steers. J. Anim. Sci. 72: 3110.

McBeth,L.J., Gill, D.R., Krehbiel, C.R., Ball, R.L., Swanek, S.S., Choat, W.T. and Markham, C.E., 2001. Effect of health status during the receiving period on subsequent feedlot performance and carcass characteristics. Animal Science Research Report, Oklahoma State University. http://ansi.okstate.edu/research/2001rr/30/30.htm

McCance IP and Widdowson, E.M., 1997. The Composition of Food, 5th Ed. The Royal Society of Chemistry and the Ministry of Agriculture, Fisheries and Food, Cambridge.

McEvoy, J.M., Doherty, A.M., Finnerty, M., Sheridan, J.J., McGuire, L., Blair, I.S., McDowell, D.A., Harrington, D., 2000. The relationship between hide cleanliness and bacterial numbers on beef carcasses at a commercial abattoir. Lett. Appl. Microbiol 30: 390-395.

McFarlane, B.J. and Unruh, J.A., 1996. Effects of blast chilling and postmortem calcium chloride injection on meat tenderness of pork longissimus muscle. J Anim Sci, 74: 1842-1845.

McKenna, D.R., Roebert, D.L., Bates, P.K., Schmidt, T.B., Hale, D.S., Griffin, D.B., Savell, J.W., Brooks, J.C., Morgan, J.B., Montgomery, T.H., Belk, K.E. and Smith, G.C., 2002. National Beef Quality Audit-2000: survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. Journal of Animal Science, 80:1212-1222

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

McNally PW, Warris PD. 1996. Recent bruising in cattle at abattoirs. Vet. Record 138:126-128,

McNeill, J., McCollum, T. and Paschal, J., 2000. Summary report. College Station, Texas A & M University, Department of Animal Science, Ranch to Rail Publications. http://animalscience.tamu.edu/ansc/

Megersa, B., Tesfaye, E., Regassa, A., Abebe, R., Abunna, F., 2010. Bovine cysticercosis in cattle slaughtered at Jimma municipal abattoir, south western Ethiopia: Prevalence, Cyst viability and its socio-economic importance. Veterinary World Vol. 3(6): 257-262

Mekasha, Y., Urge, M., Kurtu, M.Y., Bayissa, M., 2011. Effect of strategic supplementation with different proportion of agro-industrial by-products and grass hay on body weight change and carcass characteristics of tropical Ogaden bull (Bosindicus) grazing native pasture. African Journal of Agricultural Research 6(4): 825-833

Mellau, B. L., Nonga, H. E. and Karimuribo, E. D., 2011. Slaughter stock abattoir survey of carcasses and organ/offal condemnations in Arusha region, northern Tanzania. Trop Anim Health Prod 43:857–864 DOI 10.1007/s11250-010-9773-1

Méndez, R. D., Meza, C. O., Berruecos, J. M., Garcés, P., Delgado, E. J. and Rubio M. S., 2009. A survey of beef carcass quality and quantity attributes in Mexico. Journal of Animal Science 87:3782-3790.

Mendizábal, J.A., Sagarzazu, M. and Purroy, A., 2006. Relation between conformation grade and different measurements of IGP Ternera de Navarra beef carcasses using computer image analysis. Options Méditerranéennes, 78: 293-296

Mersie, A., 1993. Survey of echinococcosis in eastern Ethiopia. Veterinary Parasitology, 47, 161-163. doi:10.1016/0304-4017(93)90187-R

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Mesele, G., Guadu, T., Bogale, B. and Chanie, M., 2012. Pathological conditions causing organ and carcass condemnation and their financial losses in cattle slaughtered in Gondar, northwest Ethiopia. African Journal of Basic & Applied Sciences 4 (6): 200-208, ISSN 2079-2034. © IDOSI Publications

Miller M., 2007. Dark, Firm and Dry Beef. National cattlemen's Beef Association. Texas Tech University. www.beefresearch.org

MLA (Meat and Livestock Australia) 2011. Effect of slaughter method on animal welfare and meat quality. Meat technology update 1/11 – January 2011, www.meatupdate.csiro.au

Moberg, G. P., 2001. Biological response to stress implications to animal welfare. In G. P. Moberg & J. A. Mench (Eds.), The biology of animal stress – Basic principles and implications for animal welfare (pp. 1–22). Oxon, UK: CABI Publishing.

Mohamed, S.S., 2013. Prevalence, health and economical impacts of liver diseases in slaughtered cattle and sheep during at Alkadroo abattoir, Sudan. Journal of Applied and Industrial Sciences 1(3): 6-11, ISSN: 2328-4595

Monin, G., 1988. Stress d'abattage et qualités de la viande. *Rec. Méd. vét,* 164 (10), 835-842.

Morales, M., Folch, C. Iraira, S. Teuber, N. and Realini.C.E., 2012. Nutritional quality of beef produced in Chile from different production systems. Chilean Journal of Agricultural Research 72:80-86.

Mulatu, M., Mekonnen, B., Tassew H. and Kumar, A., 2013. Bovine hydatidosis in eastern part of Ethiopia. Momona Ethiopian Journal of Science (MEJS), V5(1)107-114,2013, ©CNCS, Mekelle University, ISSN:2220-184X

Mungube, E.O., Bauni, S.M., Tenhagen, B.A., Wamae, L.W., Nginyi, J.M. and Mugambi, J.M., 2006. The prevalence and economic significance of fasciola gigantic and stilesia hepatica

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

in slaughtered animals in the semi-arid coastal Kenya. Tropical Animal Health and Production, 38: 475-483.

NABC (Netherland African Business Council) 2010. Fact Sheet: Livestock in Ethiopia and opportunity analyses for Dutch investment, September 2010

NBQA (National Beef Quality Audit) 2010/11. Plant Carcass Audit. The Canadian Cattlemen's Association. Canada

Ndou, S.P., Muchenje, V. and Chimonyo, M., 2011. Assessment and implications of animal welfare in beef production systems in developing countries. Afr. J. Biotechnol. 10, 1049-1064.

Negash, M., Lemma, T., Feyera, T., Dadi, H., Woldu, T., Alemu, T. and Shilima, B., 2008. Comparison of body weight gain performance and carcass characteristics of the two Ethiopian cattle breeds under natural pasture grazing management. Volume *20,* Article #117. http://www.lrrd.org/lrrd20/8/nega20117.htm

Negassa, A. and Jabbar, M. 2008. Livestock ownership, commercial off-take rates and their determinants in Ethiopia. ILRI and Texas A&M University System.40 pp.

Negassa A., Rashid S. and Gebremedhin B., 2011. Livestock production and marketing. Ethiopia Strategy Support Program II (ESSP II). ESSP II Working Paper 26

Negassa, M., Lemma, T., Feyera, T., Dadi, H., Woldu, T., Alemu, T. and Shilima, B., 2008. Comparison of body weight gain performance and carcass characteristics of the two Ethiopian cattle breeds under natural pasture grazing management. *Volume 20* ,Article *# 117.* http://www.lrrd.org/lrrd20/8/nega20117.htm

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

NEPAD–CAADP (New Partnership for Africa's Development–Comprehensive Africa Agriculture Development Programme), 2005. Ethiopia: Investment project profile 'Live Animal and Meat Export'—Preliminary options outline. 3 pp.

Nogalski, Z., Wielgosz-Groth, Z., Purwin, C., Sobczuk-Szul, M., Mochol, M., Pogorzelska-Przybyłek, P., and Winarski, R., 2014. Effect of slaughter weight on the carcass value of young crossbred ('Polish Holstein Friesian' × 'Limousin') steers and bulls. Chilean Journal of Agricultural Research 74(1): 59-66

NRC (NationalResearchCouncil) 1996. Nutrient requirements of beef cattle, 7th ed. Washington, DC. National Academy Press.

Nurit, M., Zerihun, H. and Serkalem, M., 2012. Major cause of liver condemnation and associated financial loss at Kombolcha Elfora abattoir, South Wollo, Ethiopia. Europ. J. Appl. Sci.,4 (4): 140-145.

OIE 2012. Terrestrial manual of diagnostic tests and vaccines. Chapter 2.9.5.Cysticercosis

Okoli, I.C., Agoh, E.C., Okoli, G.C., Idemi G.C. and Umesiobi, D.O., 2000. Bovine and Caprine Fasciolosis in Enugu State of Nigeria: Retrospective analysis of abattoir records (1983-1997) and six-month prevalence study, Bulletin of Animal Health and Production for Africa, 48: 7-11.

Park, G.B., Moon, S.S., Ko, Y.D., Ha, J.K., Lee, J.G., Chang, H.H. and Joo, S.T., 2002. Influence of slaughter weight and sex on yield and quality grades of Hanwoo (Korean native cattle) carcasses. Journal of Animal Science 80, 129-136.

Petroman, C., Balan, I., Petroman, I., Orboi, M., Banes, A., Trifu, C. and Marin, D., 2009. National grading of quality of beef and veal carcasses in Romania according to 'EUROP' system. Journal of Food, Agriculture and Environment 7, 173-174

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Pettiford, S.G., Ferguson, D.M., Lea, J.M., Lee, C., Paull, D.R., Reed, M.T., 2008. The effect of loading practices and 6 hour road transport on the physiological responses of yearling cattle. Australian Journal of Experimental Agriculture, 48, 1–6.

Phillips, C.J.C., 1993. Cattle behavior. Farming Press Books, Wharfdale Rd, Ipswich, U.K.

Phiria, A.M., 2006. Common conditions leading to cattle carcass and offal condemnations at 3 abattoirs in the western province of Zambia and their zoonotic implications to consumers. Tydskr.S.Afr.vet.Ver. 77(1): 28–32

Pritchard, R. H., and Berg, P. T., 1993. Feedlot performance and carcass traits of culled cows fed for slaughter. South Dakota Beef Report CATTLE 93-20:101-107.

Rahman, A., Islam M., Khan S., Ahmad S., Khattak T.A., Rahman, A., Uddin, S. and Zeb K., 2012. Dressing percentage and offal production of various breeds of Zebu cattle slaughtered at the Peshwar abattoir. Sarhad J. Agric. Vol.28, No.4: 655-659.

Raji, M.A., Salami, S.O. and Ameh, J.A., 2010. Pathological condition and lesions observed in slaughtered cattle at Zaria abattoir. Journal of Clinical Pathology and Forensic Medicine, 1: 9-12.

Reagan, J. O., Carpenter, Z. L. and Smith, G. C., 1976. Age-related traits affecting the tenderness of the bovine *longissimus* muscle. J. Anim. Sci. 43:1198.

Red Meat Abattoir Association (RMAA), 2011. Animal handling practical guidelines for abattoirs.

Regassa, A., Abunna, F., Mulugeta A. and Megersa, B., 2009. Major metacestodes in cattle slaughtered at Wolaita Soddo municipal abattoir, Southern Ethiopia: Prevalence, cyst viability, organ distribution and socio-economic implications. Tropical Animal Health and Production, 41: 1495-1502.

Regassa, F., Molla A. and Bekele, J., 2010. Study on the prevalence of cystic Hydatidosis and its economic significance in cattle slaughtered at Hawassa Municipal abattoir, Ethiopia. Tropical Animal Health and Production, 42: 977-984.

Reid, C.A., Small, A., Avery, S.M., Buncic, S., 2002. Presence of food borne pathogens on cattle hides. Food Control, 13: 411- 415.

Reverter, A. Johnston1,, D.J., Grase,r H.U. and Perry D., 2001. Prediction of retail beef yield percentage from a number of wholesale primal cuts for use in genetic evaluation. Proc. Assoc. Advmt. Anim. Breed. Genet. Vol 14. http://www.aaabg.org/livestocklibrary/2001/ab01112.pdf

Ring, C. and Kortmann R., 1988. Auswirkungen der elektrischen Betäubung von Schlachtschweinen auf die Fleischqualität. Fleischwirtsch 68 (3), 259-264.

Saperstein, A. and Farmer, E., 2006. Livestock value chain analysis report for Afar and northern Somali Regions of Ethiopia. ACDI/VOCA Pastoralist Livelihoods Initiative April 2006. 44 pp.

Sapp,R.L., Bertr, J.K. and, Pringle, T.D. and Wilson D.E., 2002. Effects of selection for ultrasound in tramuscular fat percentage in Angus bulls on carcass traits of progeny. J. Anim. Sci. 80: 2017.

SAS 2011. Statistical Analysis System user's guide: Statistics.SAS Inst. Inc., Cary .NC.

Savell, J.W., Branson, R.E., Cross, H.R., Stiffler, D.M., Wise, J. W., Griffin, D.B. and Smith, G.C., 1987. National consumer retail beef study: Palatability evaluation of beef loin steaks that differed in marbling, Journal of Food Science, 30,365

Savell, J.W., Hale, D.S., Griffin, D.B., Kerth, C.R., Belk K.E., Woerner D.R., Tatum, J.D., Lawrence, T.L., VanOverbeke D.L., Mafi, G.G., Raines, C.R., Jr. Robert J.D.,

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

O'Connor, M., Meadows, L., Shackelford, S.D., King, D.A., Wheeler, T.., 2011. National Beef Quality Audit – 2011: In-plant survey phase. Funded in part by The Beef Checkoff. USA.

Sebsibe, A., 2008. Sheep and Goat meat characteristics and quality (Chapter 12 of Sheep and Goat Production Handbook for Ethiopia). Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP). 16 pp.

Shegaw, S., Ashwani, K. and Kassaw, A., 2009. Organs condemnation and economic loss at Mekelle municipal abattoir, Ethiopia. J. Haryana Veterinarian, 48:17-22.

Sherikar, A.T., Bachhil, V.N., Thapliyal, D.C., 2004. Elements of Veterinary Public Health, (Indian Council ofAgricultural Research, New Delhi, India)

Short, R.E., Grings, E.E., MacNeil, M.D., Heitschmidt, R.K., Williams,C.B. and Bennett, G.L., 1999. Effects of sire growth potential, growing-finishingstrategy, and time on feed on performance, composition and efficiency of steers. J. Anim. Sci.77:2406.

Shorthose, W.R., 1988. Dark cutting meat in beef and sheep carcasses under the different environments of Australia. In: S. U. Fabiansson, W. R. Shorthose, and R. D. Warner (Ed.) Dark Cutting in Cattle and Sheep. Proceedings of an Australian Workshop.pp 68-74. Organized by Aust. Meat Livestock R and D Corp., Anim. Res. Inst. Victorian Dept. Agric. and Rural Affairs and CSIRO. Div. of Food Proc. Meat Res. Lab.

Silliker, J.H., 1980. Microbial Ecology of Foods, Vol. 2, New York: Academic Press.

Small, A., Wells-Burr, B., Buncic, S., 2005. An evaluation of selected methods for the decontamination of cattle hides prior to skinning. Meat Science 69: 263-268.

Smith, G.R., Bellinger, R.E., and Congdon, J.D., 1993.Thermal ecology of the high-altitude bunch grass lizard, Sceloporus jarrovi. Can. J. Zool., 71(11): 2152-2155.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Smith, S.B. and Crouse.J.D., 1984. Relative contributions of acetate, lactate and glucose to lipogenesis in bovine intramuscular and subcutaneous adipose tissue. J. Nutr. 114: 792.

Smith, S.B., Prior, R.L., Ferrell, C.L. and Mersmann, H.J., 1984. Interrelationships among diet, age, fat deposition and lipid metabolism in growing steers. J. Nutr. 114:153.

Soulsby, E.J.L., 1982. Helminthes, arthropods and protozoa of domesticated animals, 7th ed., pp: 119-127.

Spears, J.W.and Kegley, E.B., 2002. Effect of zinc source (zinc oxide vs. zinc proteinate) and level on performance, carcass characteristics, and immune response of growing and finishing steers. J. Anim. Sci. 80:2747.

SPS and LMMP, 2010. Focus on Ethiopia's meat and live animal export. Sanitary & Phytosanitary Standards and Livestock & Meat Marketing Program.Trade Bulletin 2, September 2010

SPS-LMM 2011. Ethiopia Sanitary &Phytosanitary Standards and Livestock & Meat Marketing Program. Final report 2005-2011. USAID

Stovall, T.C., Gill, D.R., Smith, R.A. and Ball, R.L., 2000. Impact of bovin erespiratory disease during the receiving period on feedlot performance and carcass traits. Animal Science Research Report, Oklahoma State University. http://www.ansi.okstate.edu/research/2000rr/16.htm

Strydom P.E., 2009. Do indigenous Southern African cattle breeds have the right genetics for commercial production of quality meat? Meat Science 80 (2008) 86–93

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Strydom, P.E. 2011. Quality related principles of the South African beef classification system in relation to grading and classification systems of the world. South African Journal of Animal Science, 41 (3)

Sullivan, G.M., 2007. Market opportunities for Ethiopian meat export. SPS-LMM

Swai, E.S. and E. Ulicky, 2009. An evaluation of the economic losses resulting from condemnation of cattle livers and loss of carcass weight due to fasciolosis: A case study from Hai town abattoir, Kilimanjaro region, Tanzania. Tanzania. Livestock Research for Rural Development, Volume 21, Article #186.Retrieved October 12, 2012, from http://www.lrrd.org/lrrd21/11/swai21186.htm.

Swatland, H.J., 2000. Slaughtering. Internet: http://bert.aps. uoguelph.ca/swatland/ch1.9.htm. p 10.

Tadelle, T. and Worku, T., 2007. The prevalence and economic significance of bovine fasciolosis at Jimma, abattoir, Ethiopia, The Internet Journal of Veterinary Medicine, 3: 15-16.

Tadesse, D. Ayalew, W. and Hegde, B.P., 2008. On-farm phenotypic characterization of cattle genetic resources in South and North Wollo Zones of Amhara Region, North Eastern Ethiopia. Ehiopian Journal of Animal Production 8:1 ISSN: 1607–3835

Tarrant, P.V., 1989. Animal behaviour and environment in the dark-cutting condition. In S. U. Fabiansson, W. R. Shorthose, & R. D. Warner (Eds.), Dark cutting in cattle and sheep (pp. 8–18). Sydney, Australia: Australian Meat and Livestock Research and Development Corporation.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Tarrant, P.V., 1990. Transportation of cattle by road. Applied Animal Behaviour Science, 28, 153–170.Warner (Eds.), Dark-cutting in Cattle and Sheep (pp. 68–73). Sydney, Australia: Australian Meat and Livestock Research and Development Corporation.

Tawah, C.L. and Rege, J.E.O., 1996. White Fulani cattle of west and central Africa. Animal Genetic Resources Information Bulletin 17:137–158.

Tegegne, A., 2004. Lessons learned from the borana cattle improvement programme at Adami Tulu and Abernossa cattle multiplication and improvement centre in Ethiopia. In the Proceeding of Farm Animal Biodiversity in Ethiopia: Status and Prospects. Processing of ESAP Proceedings of the 11th Annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 28-30, 2003. ESAP, Addis Ababa. 441pp.

Tefera, M., 2011. Oxenization versus tractorization: Options and constraints for Ethiopian framing system. International Journal of Sustainable Agriculture 3 (1): 11-20. ISSN 2079-2107. © IDOSI Publications, 2011

Terefe, D., Kebede, K. Beyene, D. and Wondimu, A., 2012. Prevalence and financial loss estimation of hydatidosis of cattle slaughtered at Addis Ababa abattoirs enterprise. Journal of Veterinary Medicine and Animal Health Vol. 4(3), pp. 42-47

Teye, G.A .and Sunkwa, W.K., 2010. Carcass characteristics of tropical beef cattle breeds (West African Shorthorn, Sanga and Zebu) in Ghana. African Journal of Food and Agriculture Nutrition and Development 10(7): 2866-2883

Thai Agricultural Standard 2005 Good manufacturing practice for abattoir. Published in the Royal Gazette Vol.122 Special Section 64D, dated 11 August B.E.2548. ICS 67.120 ISBN 974-403-253-7

Tolera, A. and Abebe, A., 2007. Livestock production in pastoral and agro-pastoral production system of Southern Ethiopia. Livestock Research for Rural Development 19:12

Tolosa, T. and Tigre, W., 2007. The prevalence and economic significance of bovine fasciolosis at Jimma abattoir, Ethiopia. The Internet J. Veterinary Medicine, 3(2).

Toro, P., Catrileo A., Aguilar C., and Vera R., 2009. Modeling supplementation strategies for beef steer rearing and fattening system in Southern Chile. Chilean Journal of Agricultural Research 69:207-213.

Troeger K., 1991. Slaughtering: animal protection and meat quality. Current practice. What needs to be done? Fleischwirtsch 71 (3), 298-302.

Urguhart, G.M., Armour, J.,Duncan, J.L., DunnA.M. and Jennings, F.W., 1988. Veterinary parasitology, Longman, UK, pp: 228.

Vieselmeyer, B.A., Rasby, R.J., Gwartney, B.L., Calkins, C.R., Stock, R.A. and Gosey, J.A., 1996. Use of expected progeny differences for marbling in beef: I. Production traits. J. Anim. Sci. 74: 1009.

Viljoena, H. F., de Kocka, H.L. and Webb, E.C., 2002. Consumer acceptability of dark, firm and dry (DFD) and normal pH beef steaks. Meat Science 61: 181–185.

Voisinet, B.D., Grandin, T., O'Connor, S.F., Tatum, J.D., & Deesing, M.J., 1997. Bos indicus cross feedlot cattle with excitable temperaments have tougher meat and a higher incidence of borderline dark cutters. Meat Science, 46, 367–377.

Waiblinger, S., Boivin, X., Pedersen, V., Tosi, M.V., Janczak, A.M., Visser, E. K. and Jones R. B., 2006. Assessing the human-animal relationship in farmed species: A critical review. Appl. Anim. Behav. Sci. 101: 185-242.

Warner, R.D., Ferguson, D.M., Cottrell, J.J. and Knee, B., 2007. Acute stress induced by the use of electric prodders pre-slaughter causes tougher beef meat. Australian Journal of Experimental Agriculture 47: 782–788.

Warner, R.D., Truscot, T.G., Eldridge, G.A., & Franz, P.R., 1998. A survey of the incidence of high pH beef meat in Victorian abattoirs. In 34th International Congress of Meat Science and Technology (pp. 150–151). Brisbane, Australia.

Warris, P.D., 1984. Exsanguination of animals at slaughter and the residual blood content of meat. *Vet. Rec.,* 115,292-295.

Warriss, P.D., 2000. Meat science: An introductory text. CAB-International: England: Wallingford.

Warriss, P.D., 2003. Optimal lairage times and conditions for slaughter pigs: a review. Veterinary Record 153: 170-176.

Warriss, P.D., Brown, S.N., Nute, G.R., Knowles, T.G., Edwards, J.E., Perry, A.M., 1995. Potential interactions between the effects of pre-slaughter stress and postmortem electrical-stimulation of the carcasses on meat quality in pigs. Meat Science, 41, 55–68.

Weglarz, A., 2010. Quality of beef from semi-intensively fattened heifers and bulls. Animal Science Papers and Reports 28 (3), 207-218

Wheeler, T.L., Koohmaraie, M. and Crouse. J.D., 1991. Effects of calcium chloride injection and hot boning on the tenderness of round muscles. J. Anim. Sci. 69:4871.

WHO/FAO/OIE 2005. Guidelines for the surveillance, prevention and control of taeniosis/cysticercosis.

Whipple, G. and Koohmaraie, M., 1993. Calcium chloride effects on beef steak tenderness and calpain proteolytic activity. Meat Sci. 33:265.

Wilkens, L.J., Gregory, N.G. and Wotton, S.B., 1999. Effectiveness of different electrical stunning regimes for turkeys and consequences for carcass quality. Brit Poult Sci, 40: 478-484.

Wythes, J.R., Arthur, R.J., Thompson, P.J.M., Williams, G.E. and Bond, J.H., 1981. Effects of transporting cows various distances on liveweight, carcase traits and muscle pH. Australian Journal of Experimental Agriculture and Animal Husbandry, 21, 557–561.

Yifat, D., Gedefaw, D. and Desie, S., 2011. Major causes of organ condemnation and financial significance of cattle slaughtered at Gondar Elfora Abattoir, Northern Ethiopia. Global Veterinaria, 7 (5): 487-490.

Yorks, T.P., Ward, G.M. and Cramer, D.A., 1980. Energy Considerations in Translating Cattle in into Edible Beef. Food Technology, Vol. 34, No. 5, p. 54.

Zaujec, K., Mojto, J., Gondeková, M., 2012. Comparison of meat quality in bulls and cows. Journal of Microbiology, Biotechnology and Food sciences 1, 1098-1108

Zerabruk, M., Vangen M. and Haile M., 2007. The status of cattle genetic resources in North Ethiopia: on farm characterization of six major cattle breeds. Anim. Genet. Resour. Info. Bull., 40: 15-32.

Zocchi, C. and Sams, A.R., 1999. Tenderness of broiler breast fillets from carcasses treated with electrical stimulation and extended chilling times. Poult Sci, 78: 495-498.

ZoBell, D.R., Whittier, D. and Holmgren, L., 2005. Beef quality and yield grading. Utah State University. AG/Beef/2005-03