

**The classification of beef, pork and mutton carcasses in a selected high
throughput abattoir in the Eastern Cape Province, South Africa**

By

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Declaration

I, Soji Zimkhitha, vow that this research is an outcome of my original work conducted under the supervision of Professor Voster Muchenje. This dissertation has not been submitted for previous application of a Masters’ degree to any other University. All citations and sources of information used have been duly acknowledged.

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By

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Abstract

The carcass classification system was implemented in South Africa as a quality assurance scheme to address consumer uncertainties on the quality of meat they purchase. Although carcass classification is presumed to provide information that can be useful to the meat industry from primary producers to customers, it is argued that the standards used in the system provide inadequate description of the carcass quality related characteristics as it only describes scores and measurements but does not rank for meat quality. Nonetheless, attributes used to evaluate meat quality include eating quality, appearance, freshness, and nutritional value. However, these attributes are neglected in the South African classification system. Two trials were, therefore, conducted to evaluate the classification of red meat and characterise the quality of beef carcasses subjected to the SA classification system at a high throughput abattoir, where five different classification characteristics (age, sex, conformation, bruising and fatness) were used for sheep and cattle carcasses, while the PORCUS classification system was used for pigs. On the first trial a total of 300 animals comprising of 100 cattle, 100 sheep and 100 pigs were used to evaluate the associations between animal traits, carcass traits and carcass classification, while on the second trial beef samples from the *Muscularis longissimus thoracis et lumborum* of Angus, Bonsmara, Fleckvieh, Non-descript and Simmental genotypes (n=175) were harvested to characterise the quality of beef carcass classes. Significant associations ($P<0.05$) were found between carcass classes and genotypes of cattle, sheep and pigs. Almost 70% of cattle carcasses were in the C classes mainly in the

C2 carcass class, while 77% of sheep carcasses were of A2 class and 50% of pig carcasses were of P class. Significant differences ($P<0.05$) were observed across genotypes on some meat characteristics (a^* , H_{ab} , pH_{24} , TL%, CL% and WBSF) of beef carcass classes. The C2 carcass class of Angus genotype had a darker colour (L^*) than the Non-descript and Bonsmara genotypes. Redness (a^*) of the Bonsmara C2 carcass class differed ($P<0.05$) from that of Angus, Fleckvieh and Non-descript genotypes. The Non-descript genotype had more yellow subcutaneous fat than all other genotypes. Angus and Simmental genotypes had the toughest meat (40.29 ± 11.62 and 38.71 ± 9.33 , respectively), while Non-descript and Fleckvieh genotypes had tender meat (31.53 ± 12.62 and 32.00 ± 7.92 , respectively). It was concluded that meat quality characteristics varied within carcasses of the same class across genotypes. Thus consumers might pick differences on the quality of carcasses falling within the same class due to the breed effect which, however, does not form part of the SA classification system.

Keywords: Beef, breed, C2 class, carcass classification, carcass quality, consumers, fat colour, genotype, meat colour, meat tenderness.

List of abbreviations

| | |
|------------------|--------------------------------|
| a* | Redness of meat |
| b* | Yellowness of meat |
| CL% | Cooking loss percentage |
| H _{ab} | Hue angle |
| L* | Lightness of meat |
| pH ₂₄ | Meat pH |
| PROC CORR | Correlation procedure |
| PROC FREQ | Frequency procedure |
| PROC GLM | General Linear Model procedure |
| SI | Saturation index |
| SF | Subcutaneous fat |
| TL% | Thawing loss percentage |
| WBSF | Warner Bratzler Shear Force |
| WCM | Warm carcass mass |

Dedication

This dissertation is dedicated to my late grandmother **Nela Nolifini Noficwa** who always encouraged me to reach for the stars.

Acknowledgments

Firstly I would like to give praise and honour to the highest God, my redeemer, it is said that

“He who kneels before God can stand before anyone” and so I called “the Lord” and I was saved from all who hate me, Psalm 18:3.

For the Lord said in his word:

“For I know the plans I have for you, plans to prosper you and not to harm you, plans to give you hope and future” - Jeremiah 29:11.

So with all my heart I praise the Lord I will never forget how kind he has been.

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Table of Contents

| | |
|---|----------|
| Declaration..... | i |
| List of abbreviations | iv |
| Dedication..... | v |
| Acknowledgments..... | vi |
| List of Tables | xii |
| List of Figures | xiii |
| Chapter 1: Introduction | 1 |
| 1.1. Background..... | 1 |
| 1.2. Problem statement..... | 3 |
| 1.3. Justification..... | 4 |
| 1.4. Objective..... | 4 |
| 1.4.1. Specific objectives..... | 4 |
| 1.5. Hypothesis..... | 5 |
| 1.6. References..... | 6 |
| Chapter 2: Literature Review | 8 |
| 2.1. Introduction..... | 8 |
| 2.2. Meat production chain in South Africa..... | 11 |
| 2.3. Livestock production in South Africa..... | 12 |
| 2.3.1. Pork production..... | 12 |
| 2.3.2. Beef production..... | 13 |

| | |
|--|----|
| 2.3.3. Mutton production..... | 13 |
| 2.3.4. Goat production..... | 14 |
| 2.4. Livestock production in the informal sector | 14 |
| 2.4.1. Reasons for keeping livestock in the informal sector | 15 |
| 2.5. Livestock marketing..... | 15 |
| 2.5.1. Informal livestock marketing channels | 18 |
| 2.6. Incentives to formal classification system | 19 |
| 2.6.1. Classification at abattoir level | 19 |
| 2.6.2. Techniques of carcass classification | 20 |
| 2.6.3. Pork carcass classification..... | 21 |
| 2.6.4. Beef, mutton and chevon classification..... | 23 |
| 2.6.4.1. Age, conformation, damage and sex classification | 23 |
| 2.6.4.2. Fat classification | 25 |
| 2.7. Significance of a formal classification system..... | 27 |
| 2.7.1. Benefits of the classification system | 28 |
| 2.8. Applicability of the formal classification system to the informal livestock sector..... | 29 |
| 2.9. Challenges that may impede implementation of the formal carcass classification in the informal sector | 30 |
| 2.9.1. Effect of low level of management on carcass classification parameters | 31 |
| 2.9.2. Price determination | 33 |
| 2.9.3. Multi-purpose nature and traditional use of livestock..... | 33 |
| 2.9.4. Availability of marketing channels | 34 |

| | |
|---|-----------|
| 2.10. Summary | 36 |
| 2.11. References..... | 37 |
| Chapter 3: Associations between animal traits, carcass traits and carcass classification in a selected abattoir in the Eastern Cape Province, South Africa | 47 |
| 3.1. Introduction..... | 48 |
| 3.2. Materials and Methods..... | 50 |
| 3.2.1. Ethical clearance | 50 |
| 3.2.2. Experimental site description | 51 |
| 3.2.3. Animal description | 51 |
| 3.2.4. Data collection..... | 51 |
| 3.3. Statistical analysis..... | 52 |
| 3.4. Results and Discussion | 52 |
| 3.5. Conclusions..... | 72 |
| 3.6. References..... | 73 |
| Chapter 4: Effect of genotype and age on some quality characteristics of beef carcasses subjected to the South African classification system | 76 |
| 4.1. Introduction..... | 77 |
| 4.2. Materials and Methods..... | 80 |
| 4.2.1. Experimental site description | 80 |
| 4.2.2. Animal description | 80 |
| 4.2.3. Data collection..... | 81 |
| 4.2.4 Carcass classification..... | 81 |

| | |
|---|------------|
| 4.2.5 Meat sample harvesting and measurements | 82 |
| 4.6. Statistical analysis | 84 |
| 4.4. Results and Discussion | 85 |
| 4.5. Conclusions..... | 100 |
| 4.6. References..... | 101 |
| Chapter 5 General discussion, conclusions and recommendations..... | 105 |
| 5.1. General discussion..... | 105 |
| 5.2. Conclusions | 108 |
| 5.3. Recommendations | 108 |
| 5.4. References | 109 |

List of Tables

| | |
|---|----|
| Table 2. 1: Pork classification system..... | 22 |
| Table 2. 2: Carcass classification of beef, mutton and chevon based on age, conformation, damage and sex | 24 |
| Table 2. 3: Beef and mutton carcass classification on fatness | 26 |
| Table 3. 1: Associations between sex and the A-, AB-, B- and C-carcass classes in cattle and sheep, and P-, O-, and R-carcass classes in pigs..... | 68 |
| Table 3. 2: Associations between breed and the A-, AB-, B-, and C-carcass classes in cattle and sheep, and P-, O-, and R-carcass classes in pigs | 70 |
| Table 3. 3: Associations between warm carcass mass (WCM) and the A-, AB-, B-, and C-carcass classes in cattle and sheep, and P-, O-, and R-carcass classes in pigs..... | 71 |
| Table 4. 1: Interactions between age measured as number of erupted incisors present at slaughter, and genotype on meat quality attributes of B2 and C2 carcass classes..... | 93 |
| Table 4. 2: Least square means (\pm SE) of meat quality attributes for C2 carcass classes of different beef genotypes reared under different feedlot systems. | 96 |
| Table 4. 3: Pearson's correlation coefficients among the meat quality attributes within the C2 carcass classes from different beef genotypes reared under different feedlot systems..... | 99 |

List of Figures

| | |
|---|----|
| Figure 2. 1: Formal marketing channels of livestock in South Africa..... | 16 |
| Figure 2. 2: Informal marketing channels of livestock in South Africa | 17 |
| Figure 3. 1: Warm carcass mass of cattle slaughtered at the abattoir..... | 53 |
| Figure 3. 2: Warm carcass mass of sheep slaughtered at the abattoir..... | 54 |
| Figure 3. 3: Warm carcass mass of pigs slaughtered at the abattoir | 55 |
| Figure 3. 4: Cattle breeds slaughtered at the abattoir | 57 |
| Figure 3. 5: Carcass classes produced per cattle breed..... | 58 |
| Figure 3. 6: Sheep breeds slaughtered at the abattoir | 60 |
| Figure 3. 7: Carcass classes produced per sheep breed | 61 |
| Figure 3. 8: Pig breeds slaughtered at the abattoir..... | 62 |
| Figure 3. 9: Carcass classes produced per pig breed | 63 |
| Figure 3. 10: Class of cattle slaughtered at the abattoir..... | 65 |
| Figure 3. 11: Sex of sheep slaughtered at the abattoir | 66 |
| Figure 3. 12: Sex of pigs slaughtered at the abattoir | 67 |
| Figure 4. 1: Carcass classes produced from different beef genotypes slaughtered in a high throughput abattoir..... | 86 |
| Figure 4. 2: Number of incisors present at slaughter on C2-class steers of different genotypes | 90 |

Chapter 1: Introduction

1.1. Background

There is an increase in the demand for meat and meat products in South Africa (Taljaard *et al.*, 2006; Spies, 2011). This increase in demand exerts pressure on the agricultural sector to look for ways of meeting consumer demands for meat and meat products in a sustainable way. On the other hand, consumer awareness on the relationship between diet and their health is also increasing, leading to high demand for fresh, high quality and health promoting foods (Taljaard *et al.*, 2006; Scollan *et al.*, 2010). This has an impact on the way food is produced, harvested, processed, packaged, transported and displayed in retail outlets. Furthermore, the increase in the distribution chain of the South African meat industry demonstrates a significant need for carcass description as a quality assurance scheme. This is mainly because customers are unable to see the carcass before purchasing, thus they require a system that will guarantee good quality for the meat they purchase (Mitchell, 2014).

Quality assurance schemes are, therefore, intended to provide assurance by outlining the aspects of quality which are essential to the consumer. South Africa has legislative measures aimed at ensuring that the food being produced is generally of good quality and safe for human consumption (PARSAC, 2012). These legislative measures include the Meat Safety Act (Act No.40 of 2000) and the Agricultural product standards act (Act No.119 of 1990), which are commonly used as quality assurance schemes in the country.

The Meat Safety Act makes provisions for measures to ensure meat safety and the safety of animal products through meat inspection. Meat inspection is the process that involves the screening of all animals and meat to ensure safety for human consumption (Ababa, 2010;

RMIF, 2013). The Act clearly states that each animal entering the abattoir must be inspected prior to slaughter, during slaughter and after slaughter (Tomis, 2011).

The Agricultural Product Standards Act, on the other hand, makes provisions for measures to ensure carcass description through carcass classification and marking of meat intended for sale. According to Strydom (2011) carcass classification system describes the quality and meat yield that benefits traders and consumers. It is used to predict the saleable amount of meat from the carcass. Carcass classification is a process that involves the allocation of class codes to carcasses, allowing consumers to select a carcass according to their own preferences (KZN DAEA, 2005). The classification system for red meat (beef, mutton and chevon) and Pork in South Africa is based on physical characteristics comprising of conformation, fatness, age, sex and bruising (RMIF, 2013). Age is, however not considered in pork classification (SAMIC, 2006).

Standard scores are allocated on each carcass depending on the degree of each characteristic with the following classes for beef, mutton and chevon. Conformation (1-very flat, 2-flat, 3-medium, 4-round and 5-very round), fatness (0- no fat, 1- very lean, 2- lean, 3-medium, 4-fat, 5-slightly overfat, 6-extremely overfat), age (0 teeth-A, 1-2teeth-AB, 3-6teeth-B, more than 6 teeth- C), sex (the carcass of a ram or a bull as well as of hamel, a kapater or an ox showing signs of late castration of the AB,B or C age classes are identified) and bruising (1-slight, 2-moderate, 3-severe). In pork classification a PORCUS classification system is used where scores are allocated depending on meat percentage and amount of subcutaneous fat measured using a hennessy grading apparatus: The South African classification system describes the scores for each class very well, however, the system is not used to characterise carcass quality. This is mainly because the system does not rank for the quality of meat from each

carcass class. Thus, the scores alone might not provide adequate information useful to the consumers and primary producers in terms of quality.

1.2. Problem statement

Although carcass classification is presumed to provide a wide range of information that can be useful to the meat industry from primary producers to customers, the system appears not being able to provide information in terms of carcass quality. As a result, consistency in meat quality is compromised to consumers in South Africa. Strydom (2011) argued that the standards used in the SA classification system provide inadequate description of the carcass quality related characteristics as it only describes scores and measurements but does not rank for quality. Nonetheless, attributes used to evaluate meat quality include eating quality, appearance, freshness, and nutritional value (Cho *et al.*, 2010). However, these characteristics tend to be neglected in the classification system.

Animal characteristics such as the breed do not form part of the SA classification system. Nonetheless, breed has significant effects on carcass traits (lean-fat ratio, conformation and dressing %), meat quality traits (meat colour and cooking loss) and sensory traits (tenderness and juiciness) (Chambaz *et al.*, 2003). These traits are useful to the consumers as they prefer meat that is tender, juicy, of good flavour, colour and aroma (Curtis *et al.*, 2006). Therefore there is evidence that the SA classification system does not fully satisfy the quality requirements of consumers.

1.3. Justification

The carcass classification system is used as one of the quality assurance schemes in South Africa. However there is some evidence that the current classification system does not adequately satisfy consumer preferences in terms of quality. A review by Srydom (2011) concurs, further highlighting that the SA classification system does not rank for quality. Since quality assurance schemes are intended at providing quality assurance by describing the quality related characteristics, there is a need for the South African classification system to rank for the quality of carcass classes across different breeds for the benefit of all players in the meat industry. By so doing, an accurate and ameliorated classification system can therefore be developed where a precise quality for each carcass class will be provided.

This study will therefore help in providing quality products to the consumers, at the same time it will ensure that the farmers are not short-changed by charging of flat prices per carcass slaughtered at the abattoir. A quality product will ensure profitability to the farmers as they will get value for the produce brought to the market. It might also indirectly influence farmers to produce carcasses which meet certain standards which will translate into a carcass class that fetches the most amount of money on the market.

1.4. Objective

The broad objective of the study was to determine the classification of beef, pork and mutton carcasses in a selected high throughput abattoir in the Eastern Cape Province, South Africa.

1.4.1. Specific objectives

- To determine the associations between animal traits, carcass traits and carcass classification in a selected abattoir in the Eastern Cape Province, South Africa.

- To determine the effect of genotype and age on some quality characteristics (pH, colour, tenderness, cooking and thawing loss) of beef carcasses subjected to the South African classification system.

1.5. Hypothesis

The null hypotheses tested were:

- There are no associations between animal traits, carcass traits and carcass classification in a selected abattoir in the Eastern Cape Province, South Africa.
- Genotype and age have no effect on some quality characteristics (pH, meat colour, meat tenderness, cooking and thawing loss) of beef carcasses subjected to the South African classification system.

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Chapter 2: Literature Review

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(See appendix 2)

2.1. Introduction

There is an increasing demand for food of animal origin in developing countries of sub-Saharan Africa and this trend is projected to continue for a long time. Consumption of meat has increased worldwide (Thornton, 2010), with highest increases being observed in the developing countries for all meat types (Thornton *et al.*, 2009). Similar trends are being observed in South Africa (Taljaard *et al.*, 2006; Spies, 2011). The population increase, urbanisation, changing lifestyles and consumer preferences associated with increasing disposable incomes as the middle income class increases in South Africa are expected to create market opportunities for small-scale livestock farmers (Scholtz *et al.*, 2008; Thornton, 2010; Webb and Casey, 2010).

South Africa is a net importer of mutton, lamb meat and beef as the consumption of these red meat types exceeds supply on the domestic market (DAFF, 2011; DAFF, 2012b). However, it is a net exporter of pork (DAFF, 2011). Coetzee (1998) reported that approximately 1% of the total uptake of goats is slaughtered at commercial abattoirs for distribution to urban retail outlets. This is mainly because most urbanised consumers prefer beef and mutton, while goat meat is mostly consumed during cultural ceremonies. A huge potential, therefore, exists for the small-scale sector to play a significant role in the red meat supply chain. However, for the small-scale farmers to enter the formal market which is characterised by meat inspection and carcass classification they must comply with food safety and quality standards (Mokoena,

2007). This is mainly because the efficacy of formal marketing requires that products must conform to pre-established standards. With increased risks of food-borne diseases, changing consumer tastes and market requirements, strict quality control mechanisms are being put in place along the value chain from the “farm to the fork” to aid in animal traceability and to ensure that high quality meat with a long shelf life reaches the consumer (Grunert, 2006; PARSAC, 2012; Govender *et al.*, 2013). Consumers nowadays demand good quality meat which is safe and possesses health promoting attributes (Taljaard *et al.*, 2006; Scollan *et al.*, 2010) due to an increasing awareness of the relationship between their health and diet (Scollan *et al.*, 2010). Attributes used to evaluate meat quality include eating quality, appearance, freshness and nutritional value (Cho *et al.*, 2010). Eating quality is most commonly used when forming an expectation of quality before purchase and for judging quality. It is a combination of tenderness, flavour and juiciness (Cho *et al.*, 2010). However, these characteristics are not visible to the consumer at point of purchase and are highly variable and subjective.

Variation in eating quality, particularly tenderness, is the main concern of consumers with perceived toughness resulting in unacceptable eating quality. Carcass grading schemes estimate saleable meat yield and determine the palatability or eating quality of meat by including parameters such as marbling or intra-muscular fat content (Indurain *et al.*, 2009). Marbling which is associated with juiciness, tenderness and palatability, is given high economic value and substantial premiums in beef (Indurain *et al.*, 2009; Burrow and Prayaga, 2004), and is often reflected in carcass grading schemes (Cho *et al.*, 2010). Although the primary function of a carcass quality grading scheme is to segment carcasses into groups with similar palatability attributes, it does not account for differences in eating quality at the consumer level, which are related to cut type and cooking effects (Cho *et al.*, 2010). The

South African carcass classification system does not include any measure of meat quality. It has a measure of subcutaneous fat but not intramuscular fat (marbling). This shows that the South African carcass classification system is strongly inclined towards meat sellers and does not attempt to indicate the expected eating quality of the meat of the classified carcasses.

The South African classification system involves the allocation of class codes to carcasses based on the sex (signs of late castration are determined), age (0 teeth = A – very young animal; 1 - 2 teeth = AB – young animal, 3 - 6 teeth = B – old animal and more than 6 teeth = C – very old animal), conformation (1 – very flat, 2 – flat, 3 – medium, 4 – round and 5 – very round), bruising (1 – slight, 2 – moderate, 3 – severe) and fat (0 – no fat, 1 – very lean, 2 – lean, 3 – medium, 4 – fat, 5 – slightly overfat, 6 – extremely overfat) characteristics (Agricultural Products Standard Act, 1990; SAMIC, 2006; Strydom, 2011). The classification system used in the formal sector is not viewed as favourable by communal farmers who shun the formal market as they do not appreciate the benefits of the system. Due to various challenges, communal farmers are less likely to get premium bonuses from these characteristics in the classification.

Challenges besetting communal farmers such as poor nutrition, poor management practices, inadequate knowledge, multiple roles of livestock and not keeping abreast with current technology affect emerging livestock farmers who are unable to obtain and understand formal market information (Coetzee *et al.*, 2005; Baloyi, 2010). As a result the system is not totally friendly to them as they are less likely to benefit from it. Consequently, they market their livestock through informal channels. In addition, the standards in the formal marketing system have been reported to be perceived negatively by the informal sector (Van de Moosdijk and Schieferli, 2002). Despite the low levels of literacy, limitations to improved

technology and communication systems which burden the informal sector, it constitutes a significant component of the agricultural economy and barriers to using the classification system should be identified and removed. This review seeks to assess the relevance of formal classification of red meat carcasses to the informal sector in relation to the level of confidence that small-scale subsistence farmers and emerging farmers have in the current formal classification system. The review also seeks to make recommendations to relevant stakeholders, on ways to ameliorate the undesirable effect of the classification system on the informal sector. Possible areas which need further research to develop the classification system in South Africa are also identified in the review.

2.2. Meat production chain in South Africa

The meat production chain in South Africa can be divided into the formal and informal sector. The formal sector comprises of commercial farmers while the informal sector is composed of small-scale subsistence farmers and emerging farmers (Scholtz *et al.*, 2008; Spies and Cloete, 2013). Livestock in the formal sector mainly comes from intensive farming systems for beef, mutton, swine and poultry (Oliver, 2004). The formal market involves farmers, feedlots/ auctions, abattoirs, wholesalers, retailers and consumers (DAFF, 2013a). At the processing level in the formal sector the quality control of livestock production is the responsibility of the Department of Health (Van Zyl *et al.*, 2006). Contrary to the formal sector, livestock in the informal sector is supplied by communal farmers who are located far from the formal market. The informal market includes farmer-to-farmer or farmer-to-consumer and/or farmer-to-unregistered buyer sales. The key players in the informal food chain are communal area farmers, auctioneers, speculators and local traders, and the quality control in the informal sector is directly dependent on the livestock owner (Van Zyl *et al.*, 2006).

2.3. Livestock production in South Africa

In South Africa, there are about 38 500 commercial farms and intensive units and an estimated two million communal and emerging farmers involved in livestock production (RMRD SA, 2012; Meissner *et al.*, 2013; AgriEco, 2013). The country has about 13.6 million beef cattle, 24.2 million sheep, 1.13 million pigs and 6.7 million goats, with emerging and communal farmers owning 12% of sheep (2.95 million), 63% of goats (4.221 million), 28% of pigs (316 400), 41% of cattle (5.58 million) (RMRD SA, 2012; AgriEco 2013; DAFF, 2013a). For the 2009/10 period, nearly 14.8% of the total gross value of the agricultural sector was contributed by the red meat sector. In the 2012/13 period 10.1% of the total gross value (14.8 %) was from cattle, 2.5% from sheep (DAFF, 2010; DAFF, 2011) and 2.15% from pigs (DAFF, 2012a; DAFF, 2013a).

2.3.1. Pork production

The South African pork industry is small compared to the beef and chicken industries (Davids *et al.*, 2014). However, it is fairly large in terms of the overall South African agricultural sector as it contributes 2.15% to the primary agricultural sector (DAFF, 2013a). Pigs are owned by 4000 commercial farmers, 19 stud breeders and about 100 smallholder farmers in South Africa (DAFF, 2011; 2012a; 2013a). The total number of sows is 125 000, of which 100 000 sows belong to the commercial and 25 000 to smallholder farmers (DAFF, 2011; 2012a; 2013a). The average gross value of pigs slaughtered over the past 10 years amounts to R 2.5 billion per annum. It has been further indicated that there was a steady increase in contribution of pork from 2002/3 to 2005/06 and a significant increase from 2006/7 to 2011/2012 to the gross value of agricultural production. This is mainly owing to increases in prices (DAFF, 2013a). Prices received by farmers have positively influenced the quantity of pork produced. Consequently, in the 2011/2012 season South Africa produced

2.08 million tonnes of pork while the local consumption was only 239 000 tonnes in the same year, making South Africa self-sufficient in pork production (DAFF, 2012a; DAFF 2013a). Pork production, therefore, outstrips local consumption, so that South Africa is a net pork exporter (DAFF, 2011; DAFF, 2012a; DAFF, 2013a).

2.3.2. Beef production

The long-term contribution of the red meat sector and beef to the total gross value of agricultural production in South Africa from 1996/97 to 2008/2009 stood at 13.2% and 9.4%, respectively (Spies, 2011). Local demand for beef still outstrips local supply. The beef supplied by the two farming sectors meets only 85% of the beef requirements in South Africa leaving a deficit of about 15% which is catered for through imports, making South Africa a net importer of beef (DAFF, 2011). More than 70% of all beef slaughtered in the formal sector in South Africa originates from commercial feedlots, where 67% of the feedlot animals are either crossbreeds or British and European imported breeds (53%) (Scholtz *et al.*, 2008). The trends of beef production have been reported to be similar to those of mutton and lamb.

2.3.3. Mutton production

There are about 24.2 million sheep in South Africa, which are raised by approximately 8 000 commercial and 5 800 communal farmers, with mutton having an average gross production value of R 3.9 billion per annum (DAFF, 2013b). The sheep breeds that are normally raised are the Dorper, which is commonly produced in arid areas and bred for mutton due to its good carcass conformation and fat, and the dual purpose breeds (mutton and wool), Damara, Meatmaster, Suffolk and Dormer (DAFF, 2012b). The industry experiences a growing demand for mutton which cannot be matched by local production (RPO, 2014). This has resulted in the country importing mutton to meet domestic demand and consequently being a

net importer of mutton (Burger *et al.*, 2013). Apart from not being able to meet domestic demand, the mutton industry faces other challenges such as veterinary and traceability issues, noncompliance by some abattoirs to Health and Safety Acts, predation and theft (DAFF, 2013b).

2.3.4. Goat production

There are about 6.6 million goats in South Africa (De Villiers *et al.*, 2009). Sixty three percent of these animals are indigenous goats that are owned by communal area farmers and the remaining 27% percent are mainly Boer and Angora breeds that are reared by commercial farmers (DAFF, 2013d). Only 5.5% of the goats are sold and slaughtered in the formal sector, while the majority of the sales are conducted on an informal basis in the communal areas, often leading to traditional slaughter for religious ceremonies (DAFF, 2012c). Traders and speculators are the major drivers of transactions involving indigenous goats that occur in the informal sector (DAFF, 2013d).

2.4. Livestock production in the informal sector

In 1992, the South Africa meat industry was deregulated. After deregulation, new legislation including the Marketing of Agricultural Products Act, Act No.47 of 1996 was formed. The Marketing of Agricultural Products Act No.47 of 1996 makes provisions that allow meat producers to sell their products to customers of their choice at mutually agreed prices. The legislation resulted in a surge in the informal sector leading to the sale of livestock through informal channels in South Africa. The emerging livestock farmers subsequently took advantage of the free marketing system. Van de Moosdijk and Schieferli (2002) advocated that all livestock should conform to the regulations on animal identification for traceability

purposes. Unfortunately, the informal sector has not taken heed of this recommendation due to various reasons for keeping livestock and the free marketing system which enables them to ignore the regulations.

2.4.1. Reasons for keeping livestock in the informal sector

Several studies have reported that income generation is the main reason for livestock keeping in the smallholder farming sector in South Africa (Musemwa *et al.*, 2007; Mapiye *et al.*, 2009b; Tada *et al.*, 2012). Other reasons for livestock keeping include household animal protein supply (consumption), “live banks” for immediate cash needs, draught power provision, milk, manure and use of livestock in traditional ceremonies such as weddings, funerals, appeasement of ancestral spirits and as bride price (lobola) (Mngomezulu, 2010). Fifty-nine percent of farmers reported income generation as the main reason for keeping cattle while 26% of farmers reported that they keep cattle mainly for family consumption (meat and milk) (Musemwa *et al.*, 2008). These are the reasons most communal farmers are less inclined to sell their livestock by means of formal marketing.

2.5. Livestock marketing

Various marketing channels are used to market livestock in South Africa, although they can be broadly categorised into informal and formal channels (Musemwa *et al.*, 2007) as illustrated in Figures 2.1 and 2.2. Meat in the formal livestock sector is supplied mainly by commercial farmers. When animals reach the desired market weight, they are taken to abattoirs where quality assurance schemes comprising of carcass classification and meat inspection take place. From the abattoirs the meat is then marketed to wholesalers, retailers, processors or butcheries. The consumers can then buy from all these marketing channels.

Formal livestock marketing channels

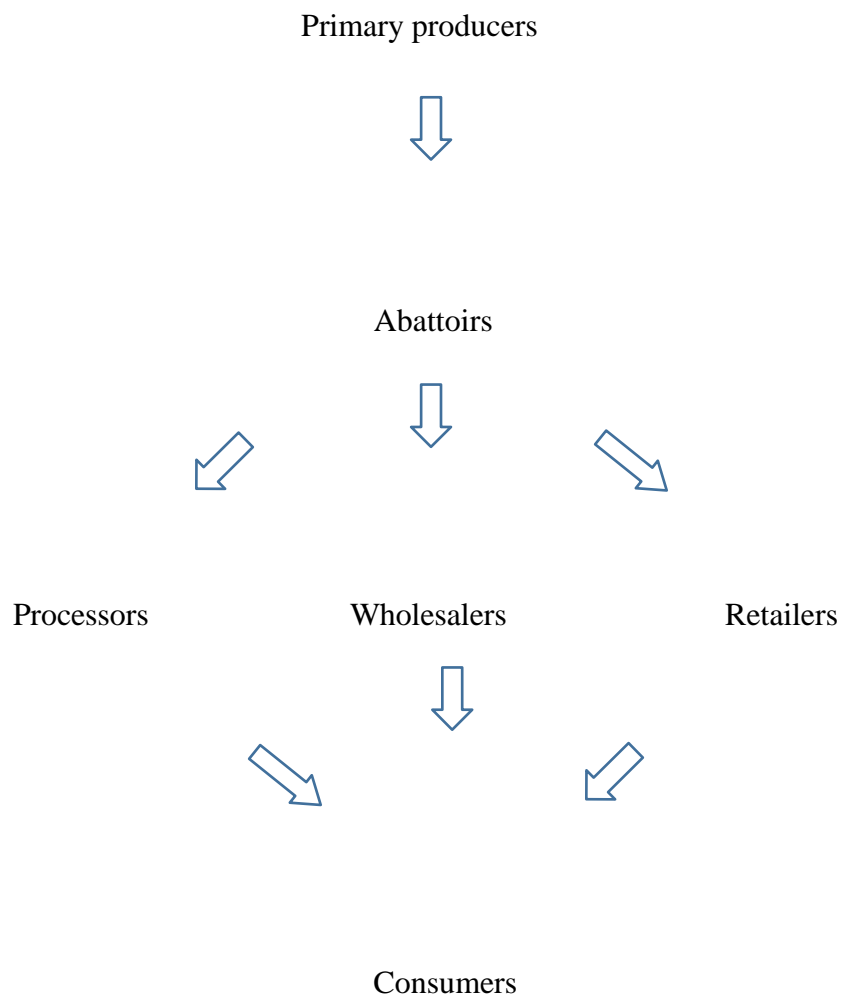


Figure 2. 1: Formal marketing channels of livestock in South Africa.

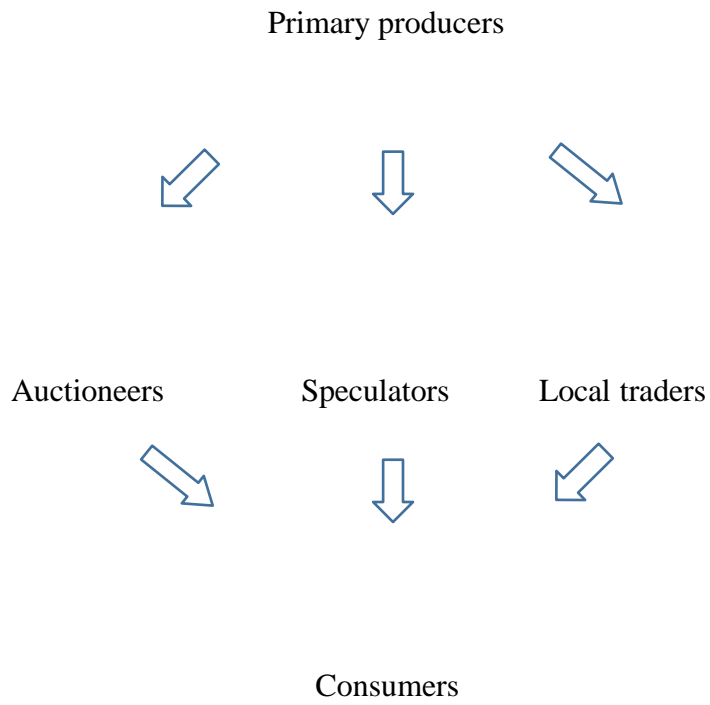


Figure 2. 2: Informal marketing channels of livestock in South Africa.

2.5.1. Informal livestock marketing channels

According to Musemwa *et al.* (2008) and Groenewald and Jooste (2012), smallholder farmers sell their livestock through informal markets to speculators and at auctions. The elderly and uneducated farmers prefer to sell their livestock through private sales to neighbours and relatives, while the younger farmers with at least secondary level education use private sales, auctions, abattoirs and speculators (Musemwa *et al.*, 2008). The prices are determined on mutually based visual appraisal or live weight. The major shortcomings of the informal markets are seasonality of the markets, poor market information on both prices and the quality required (Groenewald and Jooste, 2012). As a result, farmers often sell their livestock below market value, especially, to speculators, due to bad timing and a weak bargaining position (Groenewald and Jooste, 2012).

Furthermore, the multiple roles of livestock have both positive and negative effects on the off-take rate in smallholder farming communities. On one hand, they provide an easy route with low transaction costs to the livestock producers as they do not need to transport the livestock to distant markets (Musemwa *et al.*, 2008). On the other hand, the local buyers in the form of neighbours and relatives have low purchasing power (Mngomezulu, 2010) and, therefore, offer prices below the actual value of the animals being sold, while speculators take advantage of the lack of market information to short change the farmers (Musemwa *et al.*, 2007; Murphy, 2012). When farmers are in a precarious position due to pressing cash needs, they end up being price takers and hence sell off their animals from a position of low bargaining power.

2.6. Incentives to formal classification system

Historically, consumers have not been allowed to purchase meat directly from abattoirs and this resulted in an unwarranted increase in number of players in the meat distribution chain (FAO, 2000; Mitchell, 2014). The increase in the size of the distribution chain and the decline of face-to-face purchasing in the meat industry resulted in the need for carcass description (DOA, 2006; Mitchell, 2014). This was mainly because customers were unable to see the carcass before purchasing, thus they required a system that would describe the origin of the meat cuts in terms of carcass descriptions (SAMIC, 2006). The carcass description that is used in the formal meat value chain in South Africa is the carcass classification system. Strydom (2011) stated that the carcass classification system describes the quality and meat yield that benefit traders and consumers. Carcass classification is used to predict the amount of saleable meat from the carcass. As a classification system, it needs to be accurate, simple to apply, cheap and should be verifiable (Strydom, 2011).

2.6.1. Classification at abattoir level

The Meat Safety Act, 2000 (Act No of 40 of 2000) prohibits the slaughter of animals at any other place than approved abattoirs for the purpose of obtaining meat that is suitable for human and animal consumption. The only exception is for meat that is intended for own consumption. Approved abattoirs operate on the basis of valid registration certificates as proof that they meet certain requirements relating to structure and layout. Such abattoirs are required to have qualified meat inspectors and classifiers and are also regularly inspected to ensure that they meet hygiene requirements by removal of sick, infected and contaminated meat and animal products from the food chain. There are approximately 495 abattoirs in South Africa, grouped into five classes (A, B, C, D and E), depending on the number of animals they slaughter (DAFF, 2013b).

Abattoirs in classes A and B are highly regulated and slaughter close to 60% of the cattle. Class A-abattoirs have no limit on the number of animals, thus they can slaughter 100 slaughter units and more per day and are responsible for up to 40% of all slaughters. Class B-abattoirs slaughter up to 100 slaughter units/day, class C-abattoirs can slaughter up to 50 slaughter units/day, class D-abattoirs up to 15 slaughter units per day and class E-abattoirs up to 8 slaughter units per day (Agricultural Product standards Act, No.119 of 1990) or (classification and marking of meat). Class A- and B-abattoirs are highly controlled (regulated) and are linked to feedlots (DAFF, 2012a). The primary processing work is done at abattoirs and includes removal of the hides and quartering of the whole carcass. It is in these abattoirs that classification of carcasses should start. Butchers, hotels and supermarket then process the meat into different retail food commodities.

2.6.2. Techniques of carcass classification

Meat 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 (AHDB, 2008). It is a process which begins with meat inspection (MI) and covers a wider action involving carcass classification which is the allocation of a class code to carcasses, allowing a consumer to select a carcass according to his/her own preferences (KZN DAEA, 2005). Unlike carcass grading systems, carcass class codes do not imply that a carcass in one class is more or less desirable than a carcass in any other class (KZN DAEA, 2005).

The classification system for red meat from cattle, sheep and goats in South Africa is based on five physical characteristics comprising of age, fatness, conformation, damage and sex (RMIF, 2013). The assessment is based on visual appraisal by trained meat classifiers who are audited on a regular basis (Strydom *et al.*, 2005; South African Meat Industry Company,

2006). As indicated by Strydom (2008), the uptake of the broad and well-intended objectives of the classification systems will depend on factors such as:

- Accuracy – where applied science will enable consistency in grouping of beef carcasses;
- Simplicity – where all segments of the industry understand how the system works;
- Ease of application – quick and easily implemented online or before the carcass is sold;
- Cost – use of simple inexpensive equipment;
- Measures against tampering – ability to verify correctness of class awarded and that the class should not be subject to change once awarded.

The following sections describe the carcass classification systems that are used in the pork, mutton, goat and beef formal sectors:

2.6.3. Pork carcass classification

Pig carcasses are assessed using the PORCUS classification system, as shown in Table 2.1, where fatness, conformation, damage and sex are the main characteristics (DOA, 2006). Fat content assessment is carried out using the Hennessey classification apparatus (Hugo and Roodt, 2015), while the percentage of meat is measured between the second and third rib, 45 mm from the carcass midline (SAMIC, 2006). Age is not considered in pork classification (DOA, 2006).

Table 2. 1: Pork classification system.

| Class | Calculated % meat of carcass | Fat thickness measured by means of an intrascope (mm) |
|--------------|-------------------------------------|--|
| Suckling pig | * | ** |
| P | ≥ 70 | ≤ 12 |
| O | 68 - 69 | 13 - 17 |
| R | 66 - 67 | 18 - 22 |
| C | 64 - 65 | 23 - 27 |
| U | 62 - 63 | 28 - 32 |
| S | ≤ 61 | > 32 |
| Sausage pig | * | ** |
| Rough pig | * | ** |

Source: Department of Agriculture, 2006.

* Specifications neither meat percentage (%) nor fat thickness apply for the three classes; suckling, sausage and rough pig. Pigs that fall within the PORCUS-classes are the ones that are classified.

2.6.4. Beef, mutton and chevon classification

Beef, mutton and chevon (goat slaughtered shortly after weaning) carcasses that are sold through the formal marketing system undergo a similar carcass classification that is based on age of the animal, fat content, conformation, bruises or damage to the carcass and sex of the animal (Agricultural Product Standards Act, No 119 of 1990). However, the Red Meat Industry Forum in South Africa has indicated that amongst these five physical characteristics the most significant characteristics during meat purchasing are age and fatness. With regard to animal sex, the major concern is the better taste of castrated male animals and most farmers castrate their animals due to higher prices they get from castrated animals (RMIF, 2013).

2.6.4.1. Age, conformation, damage and sex classification

The South African classification system classifies beef, mutton and chevon carcass maturity based on dentition alone and excludes ossification. According to Lawrence *et al.* (2001), dentition better describes the age of the animals across breeds and the level of nutrition compared to bone ossification. Strydom (2011) highlighted that age measured by dentition is the only component in the South African classification system that has a bearing on quality attributes of a carcass, for example tenderness. The United States Department of Agriculture (1992) has a different classification system for age that is based on muscular and skeletal development. Under the USDA (1992) system, the age of sheep is determined by assessing the joint structure on one or two front cannon bone. Furthermore, classification simply groups carcasses into consumer preference categories which do not necessarily imply that the one is better than the other. Table 2.2 shows specific age, sex, damage and conformation classification for beef, mutton and chevon.

Table 2. 2: Carcass classification of beef, mutton and chevon based on age, conformation, damage and sex.

| Characteristic | Class | Class description | Comment |
|----------------|-------|---|---|
| Age | A | No permanent incisors | Carcass whose head is not available for determination of age is deemed to be in class C |
| | AB | At least one but not more than two permanent incisor teeth | |
| | B | Has at least three but not more than six permanent incisors | |
| | C | Has more than six permanent incisors | |
| Conformation | 1 | Very flat | |
| | 2 | Flat | |
| | 3 | Medium | |
| | 4 | Round | |
| | 5 | Very round | |
| Damage | 0 | Undamaged | Classification considers damage in relation to locality, extent and depth of damage plus fat to meat to bone ratio |
| | 1 | Disturbed to a slight extent | |
| | 2 | Moderately disturbed | |
| | 3 | Is severely disturbed | |
| Sex | | | The carcass of a ram or a bull as well as of a *hamel, a *kapater or an ox showing signs of late castration of the A-, AB-, B- or C-age classes, are identified |

* “hamel” and “kapater” refer to castrated male sheep and goats, respectively.

2.6.4.2. Fat classification

Fat is said to be an unpopular component of meat for consumers in many countries as it is considered unhealthy (Wood *et al.*, 2008). Despite this, fat and fatty acids whether in muscle or adipose tissue, make a significant contribution to various aspects of meat quality such as juiciness, and are fundamental to the nutritional value of meat (Wood *et al.*, 2008). Intramuscular fat content (marbling) is considered a better parameter with regards to juiciness, tenderness and flavour and is often included in carcass grading systems. Marbling has been shown to influence consumer purchasing behaviour at the retail level, with consumers preferring lean to medium marbling rather than marbled cuts.

In the case of the South African classification system, only the subcutaneous fat classification is used. As shown in Table 2.3 the scoring of the fat class differs slightly across the two types of meat, but no scores are given for chevon in the SA classification system (SAMIC, 2006). Regarding the health-related aspects of fat, meat quality evaluations have been taken further to determine the proportions of n-3: n-6 in the fat depot (Wood *et al.*, 2003). n-3 fatty acids are considered healthier than n-6 fatty acids (Wood *et al.*, 2008). Feedlot finished animals tend to contain more n-6 than n-3, while veld finished animals are found to have more n-3 than n-6 fatty acids (Wood *et al.*, 2003) This evaluation of type of fatty acids in the fat depot does not form part of the South African classification system (Schönfeldt *et al.*, 2011), so that animals both from feedlots and veld finished systems are marketed in the formal channel. Most smallholder farmers finish their animals off veld and stand to benefit from a carcass classification system that recognises the importance of the ratio of n-3 and n-6 in the meat.

Table 2. 3: Beef and mutton carcass classification on fatness.

| Characteristic | Fatness class | Beef | | Mutton | |
|---------------------|---------------|---------------------|----------------------|---------------------|------------------------|
| | | Carcass description | Comment | Carcass description | Comment |
| No fat | 0 | Nil | $SF < 1$ | Nil | $SF < 1$ |
| Very lean | 1 | $SF < 1$ | $1 \leq SF \leq 3.6$ | $SF < 1$ | $1 \leq SF < 5.6$ |
| Lean | 2 | $1 < SF \leq 3$ | $3.6 < SF \leq 5.6$ | $1 \leq SF < 4$ | $5.6 \leq SF \leq 8.6$ |
| Medium | 3 | $3 < SF \leq 5$ | $5.6 < SF \leq 7.6$ | $4 < SF \leq 7$ | $8.6 < SF \leq 11.6$ |
| Fat | 4 | $5 < SF \leq 7$ | $7.6 < SF \leq 9.6$ | $7 < SF \leq 9$ | $11.6 < SF \leq 14.6$ |
| Slightly over fat | 5 | $7 < SF \leq 10$ | $9.6 < SF < 11.7$ | $9 < SF \leq 11$ | $14.6 < SF \leq 17.6$ |
| Excessively overfat | 6 | $10 < SF$ | $11.7 < SF$ | $11 < SF$ | $17.6 < SF$ |

SF: subcutaneous fat thickness (mm).

2.7. Significance of a formal classification system

Consumer perception of meat quality is changing due to improved education and awareness of the relationship between health and nutrition. Consumer demands are changing as the public now find it more beneficial to improve health-related aspects through diet. Nowadays, consumers demand more information about product quality (Grunert, 2006). Credence quality is also important to consumers regarding rising concern about safety, health, convenience, locality and ethical factors (Warriss, 2000). According to Bernués *et al.* (2003), providing consumers with information on quality characteristics of the product enables them to evaluate quality during the process of making purchasing decisions.

A meat supplier must understand consumer demands, tangible and intangible relating to meat quality and incorporate them into the product and process characteristics in order to satisfy these demands (Bernués *et al.*, 2003). For instance, the red meat sector, especially the beef sector, faces challenges relating to meat safety due to disease outbreaks (FAO, 2000). Meat quality due to variability in attributes such as tenderness and meat colour as various breeds are used in a wide range of production systems from veld finished to feedlot grain finished animals is also a challenge (Muchenje *et al.*, 2008b). Lack of consumer-oriented communication from the industry has been cited as one of the main problems of the meat sector (Murphy, 2012). Meeting consumer expectations of quality and supplying them with reliable, impartial information will enable the meat industry to stay in business or to expand (Bernués *et al.*, 2003). The consumer decision process is affected by properties of the food supplied by the industry, factors related to the consumer and the environment.

The red meat classification system in South Africa and in most countries with recognised classification systems is applied on a voluntary basis in licensed registered slaughter facilities

due to deregulation of the meat industry (NDA, 2010). Although carcass classification is being applied on a voluntary basis, most retailers and wholesalers prefer classified meat as a guarantee of product safety and quality in line with consumer demands (AHDB, 2008).

In South Africa, animal carcasses are only subjected to classification on the slaughter floor with no quality indication or value attached to the classification (Strydom, 2011). This is similar to the European Grid System (Strydom, 2011). However, in the Canadian, Japanese, South Korean, USA and Australian systems there is a further assessment at the chiller stage of meat quality attributes such as marbling score, meat colour, meat texture, fat colour, fat thickness and skeletal development (Polkighorne *et al.*, 2008;). These give an indication of the meat quality and expected eating quality to both the retailer and the consumers.

2.7.1. Benefits of the classification system

According to SAMIC, a classification system for red meat serves four roles, namely:

- It provides a platform for meat traders to describe their requirements when purchasing carcasses;
- It creates variety in the market with the intention of optimising consumer satisfaction;
- It enables use of price differentials;
- It is used in determining selling prices for carcasses and cuts.

A well-designed classification system is very informative and very useful to all stakeholders in the meat value chain. A classification system is designed to provide a trading platform for stakeholders in the meat value chain where they communicate using the same language (Strydom, 2011). It gives vital information through a feedback system to farmers about the

type of animals they should rear to meet the requirements of consumers. It encourages producers to improve livestock performance through use of premiums for carcasses that meets the requirements of consumers and discourages supply of livestock that has a low demand or is of poor standard (SAMIC, 2006; Strydom, 2011). As such, it also creates a platform for consumers to make known their demands and preferences (Mitchell, 2014).

Classification systems are tied to pricing systems for carcasses and meat and, therefore, assist producers and statutory bodies to trade efficiently and more transparently (Strydom, 2011). Carcass classification has a direct relationship to saleable meat yield (AHDB, 2008). Therefore, it can promote labelling or marking of classification information to the point of sale for branding purposes, or as quality assurance (Strydom, 2011). Hence, carcass classification systems are being developed continually to serve the purpose of facilitating trading of a very heterogeneous meat product by means of simple and universally understood language to describe the quality and yield of a carcass (Hall *et al.*, 2015). This results in economic benefits for all role players in the production chain, from producer to meat trader ultimately meeting consumer expectations and providing satisfaction.

2.8. Applicability of the formal classification system to the informal livestock sector

The quality and value of animals to be marketed are determined by physical characteristics in the classification system. However, basic procedures such as carcass classification are not practiced by the informal sector yet they are supposed to act as feedback mechanisms to the traders and farmers as well as guarantee quality to the consumers. The FAO (2000) indicated that in the informal food chain, meat is mostly supplied by communal farmers. The quality and value of carcasses depend on the physical characteristics of the animals, though it is commonly known that animals from communal farmers might not possess the desired

characteristics. This is mainly owing to some challenges that impede the implementation of the formal carcass classification in the informal sector. As a result farmers would rather opt for the informal market where considerations such as selling of animals which provide carcasses of good conformation, less bruising, lean meat, no signs of late castration and selling of young animals do not apply.

Abattoirs are, therefore, not popular marketing channels in the informal sector. Young, educated small-scale farmers were, however, found to prefer selling their livestock through abattoirs and auctions rather than through private sales and speculators (Musemwa *et al.*, 2008), although the proportion of such farmers is low (6%). On the other hand, most of the older small-scale or communal farmers, who are the majority of small-scale and communal farmers, have a low level of education and tend to mistrust the classification system and shun abattoirs as a result (Musemwa *et al.*, 2008; Tada *et al.*, 2012). It would, therefore, be difficult for them to adopt the red meat classification system if most or all of the above concerns are not addressed.

2.9. Challenges that may impede implementation of the formal carcass classification in the informal sector

The informal sector has unique attributes that might hamper the participants from appreciating the importance of formal carcass classification. In the communal setting, livestock perform multiple roles such as provision of draught power, milk, manure, use at traditional ceremonies, payment of dowry and are a form of “live bank” (Musemwa *et al.*, 2007). The animals normally realise a terminal value for meat or are sold at mature age. Off-take is thus usually low, ranging from between 5% to 10% (Nkhori, 2004). Sales are not planned and livestock are either sold at an old age or when the need for cash arises

(Mngomezulu, 2010). Unfortunately, the formal sector classifies carcasses of livestock that are sold at an old age as class C, their conformation tends to be flat and they attract discounted prices. Musemwa *et al.* (2010) reported that communal farmers shunned formal markets for fear of having their cattle condemned.

Apart from age at time of sale, the pricing system in the formal market is not favourable for indigenous animals, the majority of which have a compact body (Musemwa *et al.*, 2010) and would not compete well on body conformation which is one of the formal classification criteria. Other constraints that limit the informal livestock producers' market include the slow maturing rate of indigenous breeds, poor nutrition, poor health management, marketing challenges, low levels of management (Spies, 2011; Spies and Cloete, 2013), poor quality of animals produced, poor performance of herds, inconsistency production, poor pasture management, elevated feed prices and production costs (Spies and Cloete, 2013). Coetzee *et al.* (2005) indicated five main marketing limitations faced by small-scale farmers in South Africa which were confirmed by Spies (2011) in the Free State Province. The limitations include poor condition of livestock, lack of marketing information, the unwillingness and inability to adopt livestock identification practices, lack of infrastructure and poor production and marketing management (Spies and Cloete, 2013). These limitations drive informal livestock producers away from the formal market which is inclusive of the classification system. Some of the challenges impeding the implementation of the formal classification system are further discussed below.

2.9.1. Effect of low level of management on carcass classification parameters

The majority of communal farmers keep indigenous rather than exotic breeds (Musemwa *et al.*, 2010). The indigenous breeds of livestock have low growth rates and are slow maturing.

Popular beef breeds mostly found in cattle ranches of South Africa include the indigenous Nguni and Afrikaner and locally developed Bonsmara (Muchenje, 2007). Animals such as the Nguni do not have excellent carcass conformation and thus communal farmers are not likely to get a bonus for carcass conformation (Muchenje *et al.*, 2008a; b). As a result farmers would rather opt for the informal sector where such a consideration is not so important. Polkinghorne *et al.* (2008) reported a decrease in palatability scores with increase in the level of the slow maturing *B. indicus* genes in cattle.

Combined effects of slow maturing breeds and poor nutrition on small-scale subsistence and emerging farmers result in animals being marketed or slaughtered at a mature age, which are normally classified as C-class. Age plays an important role in determining meat tenderness and farmers get premium bonuses for meat from young animals (DAFF, 2011). The C-class carcasses have been reported to fetch lower prices per kilogram sold (Polkinghorne *et al.*, 2008). Fishell *et al.* (1987) reported that meat from fast growing livestock was more tender compared to meat from slow maturing ones.

Cattle in the small-scale sector are sometimes used for draught purposes and are given less time during the day to forage and recover from work and thus become lean. In the case of fatness, farmers get premium bonuses for carcasses that are not too lean or not too fat. The FAO (2000) indicated that animals that are very lean or excessively fat fetch lower prices per kilogram in the formal classification system. In addition, poor management practices by communal farmers often result in the sale of animals that are poorly castrated or are castrated late, and are consequently classified as bull carcasses that are in low demand, and are poorly priced (DAFF, 2013c). Some of these animals are in poor health and at risk of being condemned at abattoirs (Stärk *et al.*, 2014; Dupuy *et al.*, 2014). Despite this, castrated male

animals are sold for higher prices than non-castrated animals that are bruised during handling and transport which consequently results in financial losses to farmers (RMIF, 2013). These limitations, therefore, further drive communal farmers away from formal marketing to informal marketing channels.

2.9.2. Price determination

The informal market appears attractive to most communal and emerging farmers because animals are sold at prices which are negotiated and mutually agreed upon by both buyer and seller. In addition, the sale of the product is convenient with no added costs such as transportation or commissions (Musemwa *et al.*, 2010). On the other hand, getting animals ready for the market in the formal sector involves preparations, which range from additional feeding or fattening and restraining of animals (Smith *et al.*, 2004). It also encompasses transportation costs, handling of animals when loading and off-loading from vehicles (Tarrant and Grandin, 2000), which reduce the margins realised per animal sold (Musemwa *et al.*, 2008). These additional requirements discourage the communal or emerging farmer from participating in the formal market. Injuries of animals that may occur during transportation from the farm to the slaughter facility lead to downgrading or condemnation of carcasses (Grandin, 2000) and in worse cases the dead on arrival (DOAs) carcasses cause heavy financial loss to farmers.

2.9.3. Multi-purpose nature and traditional use of livestock

Contrary to the formal sector, livestock in the informal sector are usually kept for their multi-purpose roles. They are the main suppliers for milk, meat, hides, horns, are used during religious or traditional ceremonies, to pay dowries or are kept as a form of savings (Dovie *et al.*, 2006; Simela *et al.*, 2006; Van Zyl *et al.*, 2006; Musemwa *et al.*, 2010). Animals such as

cattle also provide dung which is used as manure for soil fertilisation and provide draught power for crop cultivation and transportation of goods in communal areas (Shackleton *et al.*, 1999; Bayer *et al.*, 2004).

The multipurpose contribution of livestock to rural livelihoods makes producers reluctant to market their animals through abattoirs (Musemwa *et al.*, 2010). Animals intended for traditional ritual are not inspected nor slaughtered at an abattoir for purposes of classification but are rather killed in a ritual that follows the intended purpose of the ceremony. This further encourages the communal and emerging farmers to sell animals through the informal sector as livestock that are sold for traditional or religious ceremony usually attract a premium price in this sector. There is usually a high demand for animals for traditional slaughter and farmers make significant profit through this marketing channel and thus shun the formal marketing channel (Mngomezulu, 2010).

2.9.4. Availability of marketing channels

In terms of cattle ownership, individual households own small herds. The herd size ranges from as low as seven animals per household in the communal sector to 24 head of cattle per household in the small-scale commercial sector (Musemwa *et al.*, 2007; Mapiye *et al.*, 2009a), limiting their ability to sell animals for a regular income. Jooste (2001) found small-scale farmers to be in a precarious market position, which, because of their small number of livestock, cannot attract buyers to their farms. The small-scale farmers end up selling their animals through local informal marketing channels that sometimes have low purchasing power that do not recoup the appropriate value for their livestock (Musemwa *et al.*, 2010; Nkosi & Kirsten, 1993). Transport costs when selling few animals to abattoirs would be too

high to justify their return. Therefore, farmers resort to selling to local buyers in the informal market (Mapiye *et al.*, 2009a; Musemwa *et al.*, 2010).

Communal farmers are further challenged by the absence of infrastructures (livestock auction sale pens, loading and offloading ramps and road networks) and lack of institutional marketing arrangements (lack of marketing agents/organisers, lack of marketing information) when they want to market their animals (Musemwa *et al.*, 2007; Murphy, 2012). These challenges result in small-scale producers selling livestock through the informal channel at prices which are mutually agreed upon by the buyer and the seller, where key players are local traders (Van Zyl *et al.*, 2006), and the marketing is convenient with no added transportation or commission costs.

The communal farmers might, therefore, need plenty of incentive and encouragement to pursue formal markets that have a lot of challenges and classification systems that are not aligned to the multi-objective nature of their production systems. Musemwa *et al.* (2008) laments the lack of research and paucity of development strategies that are aimed at identifying and addressing marketing problems faced by communal farmers, and the need to find niche markets for them. Making use of marketing channels that provide best cattle prices which provide high returns remains a challenge in communal farming (Mngomezulu, 2010). There is scope, however, for small-scale farmers to use formal markets. For example Vimiso and Muchenje (2013) observed that the majority of slaughters that were performed at a small abattoir were of cattle brought on the hoof from communal farmers within its vicinity.

2.10. Summary

The livestock sector is a very important component of the economy in South Africa as over 65% of the country is suitable for extensive farming. A significant proportion of the livestock (cattle, sheep, goats and pigs) are owned by communal and small-scale emerging farmers who play a very insignificant role in the informal sector. The off-take rate from the informal sector is very low but it has a huge potential to participate in the formal meat supply chain. However, members of the informal livestock sector perceive their profitability being adversely affected by the standard abattoir meat classification system.

Challenges relating to absence of infrastructure and slaughter facilities in their vicinity, problems of shortage of feed, lack of access to veterinary health care support all affect the condition of the livestock from this sector resulting in their livestock being downgraded and consequently not fetching premium prices. As an alternative, farmers resort to selling their livestock through informal markets and risk introducing contaminated or sick animals not fit for human consumption into the food chain. Consequently, consumers may buy meat which is either unsafe to their health or of poor quality from such market channels. It was, therefore, concluded that the informal sector has characteristics that hamper appreciation of the importance of formal carcass classification. Research and development efforts must address marketing constraints faced by communal farmers as well as promoting formal marketing of livestock in this sector to ensure supply of safe meat and profitability to communal livestock farmers. It is also recommended that the classification system takes into consideration the ranking of carcasses according to meat quality attributes for quality assurance both to farmers for the carcasses they produce and to consumers for the meat they purchase.

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**Chapter 3: Associations between animal traits, carcass traits and carcass classification
in a selected abattoir in the Eastern Cape Province, South Africa**

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(See appendix 3)

Abstract

In this study the associations between animal traits, carcass traits and carcass classification within cattle, sheep and pigs slaughtered in a high throughput abattoir were determined. Classes of carcasses from cattle, sheep and pigs delivered for slaughter at this abattoir were recorded and analysed. Significant associations were found between carcass classes and breeds of all livestock species. Of all the cattle delivered to the abattoir, the non-descript ones dominated the AB2 category while the Bonsmara and Brahman dominated the C categories. Almost 70% of carcasses of the cattle delivered to the abattoir were in the C classes. In sheep, the dominant category was A2 with a percentage of 77%, and the Dorper was the most dominant in this category. In pigs, the P class was the most dominant with about 50%, and the Duroc X Landrace cross dominated this category. However, significant associations between sex and carcass classes were only found in cattle. Warm carcass mass (WCM) had significant associations with carcass classes of cattle and sheep only. It can be concluded that while associations between carcass classes and breeds were found in all species, associations between sex and carcasses were dependent on species.

Keywords: Livestock breeds, sex, warm carcass mass

3.1. Introduction

The carcass classification system was established in most meat producing countries in the early to middle 1900s (Strydom, 2011). It involves the allocation of a class code to carcasses, allowing consumers to select a carcass according to their own preferences (KZN DAEA, 2005). Fisher (2007) indicated that the classification system provides the advantage of having a common language to describe carcasses within a country thus improving marketing efficiency and transparency. Strydom (2011) reported that carcass classification systems are intended to describe the quality and meat yield of carcasses to the benefit of traders and consumers. However, it was further concluded that the criteria used in the classification systems gave limited to descriptions of the quality related characteristics of the carcasses. This is mainly because the system only describes scores and measurements but does not allocate rank according to carcass quality (Strydom, 2011).

In South Africa for instance, data recorded for beef, mutton and pork classification includes scores for conformation with classes (1 – very flat, 2 – flat, 3 – medium, 4 – round and 5 – very round), fatness (0 – no fat, 1 – very lean, 2 – lean, 3 – medium, 4 – fat, 5 – slightly overfat and 6 – extremely overfat), sex (the carcass of a ram or a bull as well as of hamel, a kapater or an ox showing signs of late castration of the AB-, B- or C-age classes are identified), bruising (1 – slight, 2 – moderate and 3 – severe) and age (0 teeth – A, 1–2 teeth – AB, 3–6 teeth – B, more than 6 teeth – C). Age is, however not considered in pork classification (SAMIC, 2006). These traits are based on visual examination of carcasses, with the only exception being the measurement of the subcutaneous fat on pig carcasses where a Hennessy grading apparatus is used (SAMIC, 2006).

Consumers on the other hand have strong preferences in relation to meat quality. They prefer meat they consume to be tender, juicy, of good flavour, colour, aroma and to be safe and of good quality (Curtis *et al.*, 2006). These characteristics are not visible to the consumer at the point of purchase and yet they tend to be neglected in the classification system. At present the point of contention in relation to the classification system is that quality is not ranked and consumers are not able to do this for themselves in retail outlets. If possible it would also provide quality assurance for different carcass classes.

According to a report by Red Meat Industry Forum (RMIF) (2013), age and fatness are the most significant characteristics used in the classification system. The Food and Agriculture Organization (FAO) also indicated that body conformation might not have a direct impact on meat quality as it is only important when consumers want to select cuts based on preferences linked to the meat-to-bone ratio. Moreover, the main concerns associated with the sex characteristic are the higher prices that castrated male animals fetch, the better taste of their meat and the high fat content (FAO, 2000). Furthermore a study by Destefanis *et al.* (2003) also proved that castration induces higher fat deposition and lower water content in muscle. Litwinczuk *et al.* (2006) and Zhang *et al.* (2006) reported that meat from heifers has significantly higher fat content than meat from bulls.

Intact males and castrated males have also been reported to have higher protein and ash contents than females, with intact males also having higher muscle development than castrated males, nonetheless they have lower fat deposition than castrated males. It has also been indicated that the damage characteristic in the classification system is only used when part of the carcass contains bruises after slaughtering and the specific part is usually trimmed off (RMIF, 2013). However, the appearance of the untrimmed parts of a damaged carcass can

deteriorate and serve as a growth medium for microorganisms causing the meat to spoil more rapidly than normal (Adziety, 2011). According to the FAO (2001), spoiled meat develops colour change, off-smells, rancidity and slime which can make consumers ill.

Although the classification system allocates scores on the extremes of these characteristics (age, sex, bruising, fat and conformation) it does not rank for the quality to be expected from each of the carcass classes exhibiting such extremes. This can prove problematic for consumers because they do not know what type of quality they are paying for in a specific class. Moreover animal traits such as breed are not included in the classification system. Breed has been proven to affect carcass and meat quality (Juárez *et al.*, 2009).

In addition, carcass traits such as warm carcass mass (WCM) are significant for the determination of lean and fat carcasses through dressing percentage (Knight, 2013). This therefore suggests that associations should be tested between animal traits such as breed, carcass traits such as warm carcass mass (WCM) and carcass classes in the classification system. The objective of this study was, therefore, to determine the associations between animal traits, carcass traits and carcass classes within cattle, sheep and pigs that were slaughtered in a high throughput abattoir.

3.2. Materials and Methods

3.2.1. Ethical Clearance

Consent to carry out the study was approved and issued by the University of Fort Hare Ethical Clearance committee (Reference Number: MUC151SSOJ01) (Appendix 1).

3.2.2. Experimental site description

The study was conducted at East London Abattoir in the Eastern Cape Province of South Africa. East London is located at 32.9° S and 27.87° E with a total area of 168, 86 km². The abattoir is a high throughput commercial abattoir which can slaughter up to 1000 livestock units per day and is furnished with modern technology to improve production. It operates under the laws and regulations of the Meat Safety Act (Act No. 40 of 2000) (SAMIC, 2006) governing the abattoirs in the Republic of South Africa.

3.2.3. Animal description

Data was collected from 100 cattle, 100 sheep and 100 pigs that were slaughtered within a week, but on different days at this abattoir. Six different cattle breeds (Bonsmara (n=16), Brahman (n=16), Simmental (n=16), Friesland (n=16), Jersey (n=16) and Non-descript (n=17), 3 different sheep breeds (Dorper (n=33), Black head-Persian (n=33) and Merino (n=34)) and 2 pig breeds (Duroc X Large White (DuroLarge) (n=50) crosses and Duroc X Landrace (DuroLand) (n=50) crosses were studied. All the animals used in the study were delivered from different farms.

3.2.4. Data collection

The animals were observed during offloading at the abattoir and the farm identity numbers were recorded. Animals were then followed through the slaughter floor where initially breed and sex were recorded before slaughter and thereafter age was recorded using the dentition method. Carcasses were further followed up to the point where they were classified and warm carcass mass and carcass classes were recorded.

3.3. Statistical analysis

Data was analysed using the Statistical Analysis Systems (SAS) package of 2009. Frequency procedure (PROC FREQ) and Chi-square tests were used to examine the relationships between the animal traits, carcass traits and carcass classes. Statistical significance was tested at the 95% level with all findings with *P*-value (< 0.05) considered to be statistically significant.

3.4. Results and discussion

A similar trend was observed in WCM of all three livestock species tested. There were fewer animals of high WCM than of low WCM in all the livestock species tested, with ranges (1–4%; 1–5% and 24%) for cattle, sheep and pigs, respectively (Figures 3.1; 3.2 and 3.3). Warm carcass mass can be used to determine the dressing percentage of animals and it has been reported that heavier carcasses result in higher returns which may be attributed to the fact that they have more muscles than fat and are thus leaner (Knight, 2013). Lean meat is said to be generally preferred in the market and therefore fetches higher premiums.

Since WCM has also been proven to have an influence on carcass quality traits such as lean-fat ratio, this therefore suggests that if WCM was included in the South African classification system, most farmers slaughtering their animals in this abattoir would be receiving low premiums as they are producing animals of low WCM with less lean meat. Therefore, WCM could motivate farmers to produce animals of high weights thus improving carcass quality traits such as the lean-to fat ratio. In addition dressing percentage with heavier breeds would produce more muscle and more lean meat per carcass (Knight, 2013).

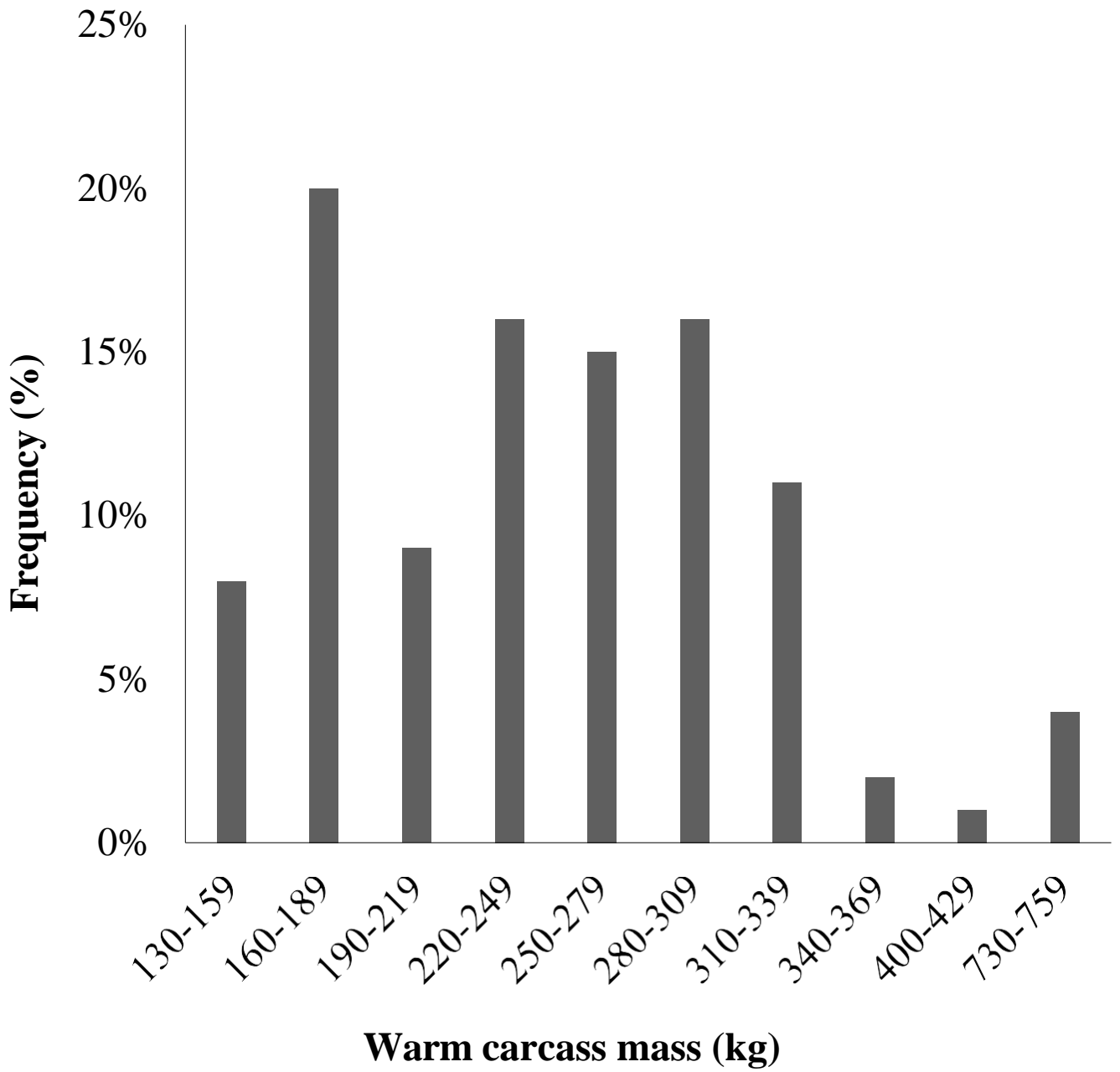


Figure 3. 1: Warm carcass mass of cattle slaughtered at the abattoir.

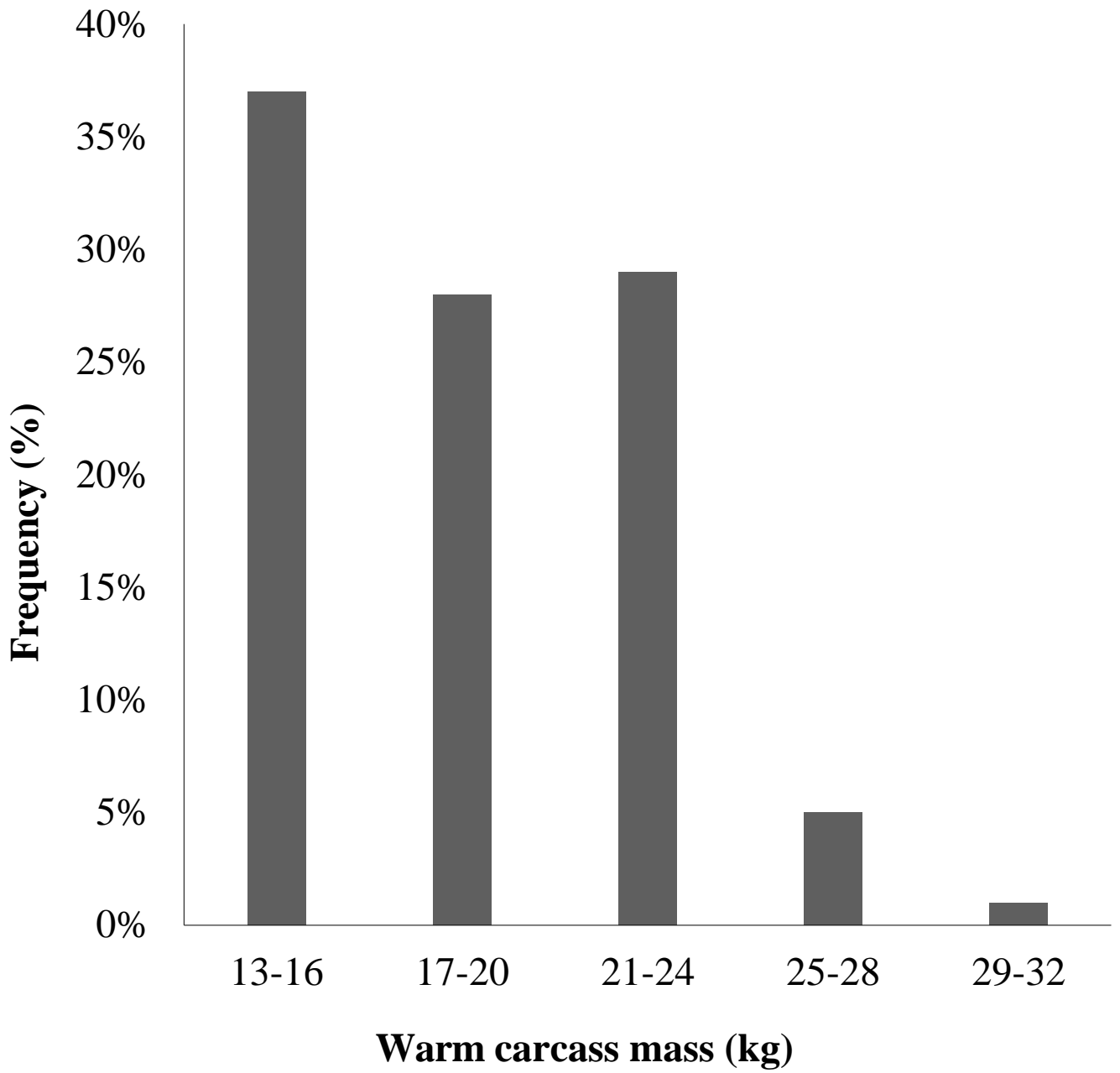


Figure 3. 2: Warm carcass mass of sheep slaughtered at the abattoir.

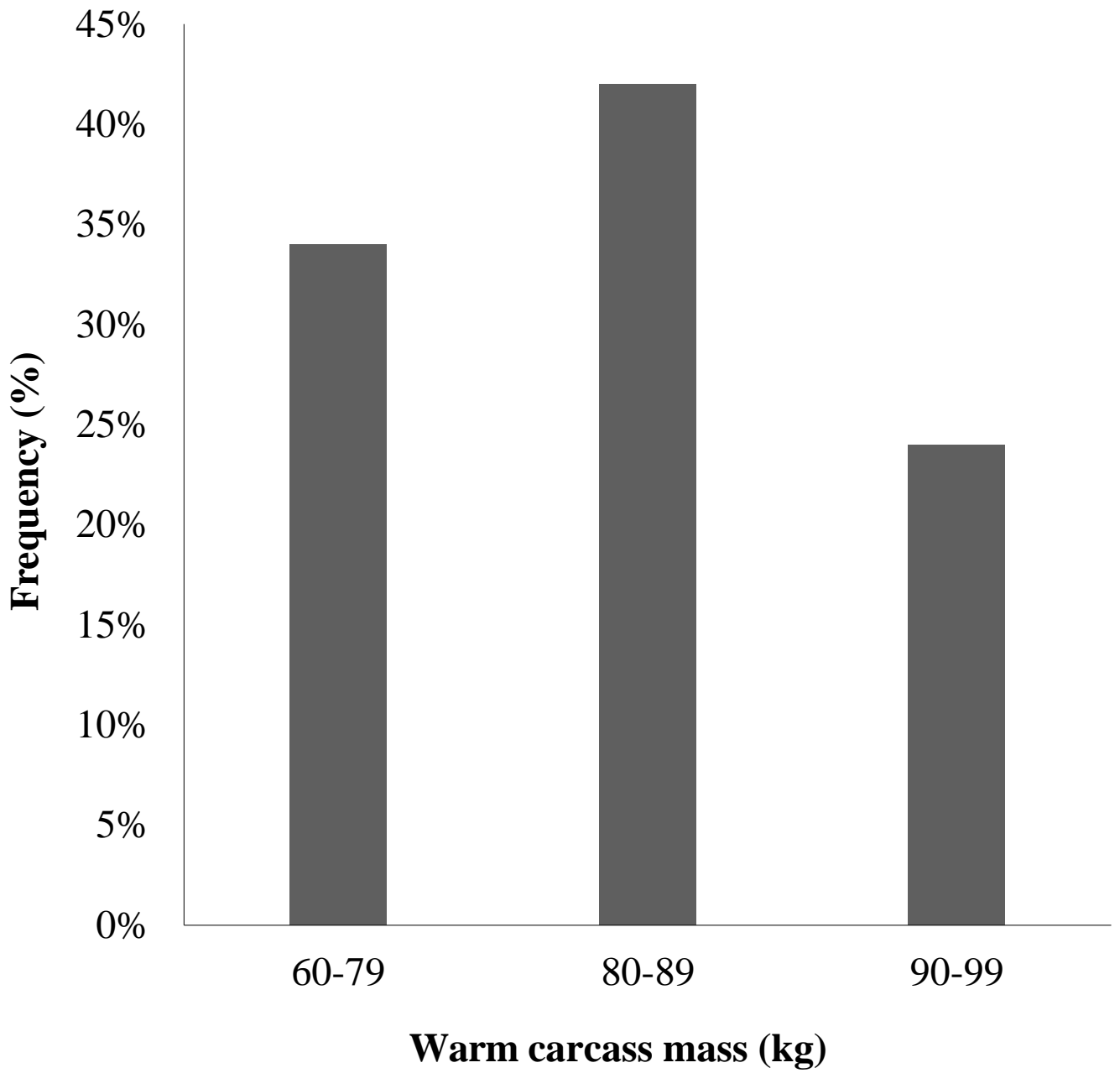


Figure 3. 3: Warm carcass mass of pigs slaughtered at the abattoir.

Figure 3.4 shows that most of the farmers predominantly produce the Bonsmara breed followed by Non-descript breeds with the least common breed being the Simmental. The Bonsmara breed dominates the feedlot industry and the Simmental breed also plays a major role in the industry. In contrast, the Non-descript breeds dominate the emerging sector in South Africa (Scholtz *et al.*, 2008). The Bonsmara breed is well recognised for being well muscled with high meat yield and quality (Muchenje *et al.*, 2008).

Dairy cattle on the other hand are intended for milk production which can influence their carcass quality traits (lean-to-fat ratio, dressing percentage and conformation) and consequently their meat quality traits (taste, colour and texture). However, at this abattoir it was mentioned that farmers raise dairy cattle specifically for beef production. There is a need to investigate the reasons for such a practice and to also determine the quality of meat from these dairy breeds that are reared to only produce meat. Moreover, research also needs to be done on meat quality of non-descript breeds which are common in the emerging livestock sector.

Figure 3.5 shows that most of the farmers produce cattle of the C-age class (69%). Meat from the C-class animals is classified as meat from very old animals with low tenderness (SAMIC, 2006). Consequently these cattle fetch lower premium bonuses because of their age classification. The C-class was mostly dominated by the Bonsmara breed, particularly the C2-class. According to SAMIC (2006) a score of 2 in the fat class is classified as lean meat, thus the fat content in the C2-class is low giving an advantage of high premium bonuses to these farmers because consumers prefer lean meat.

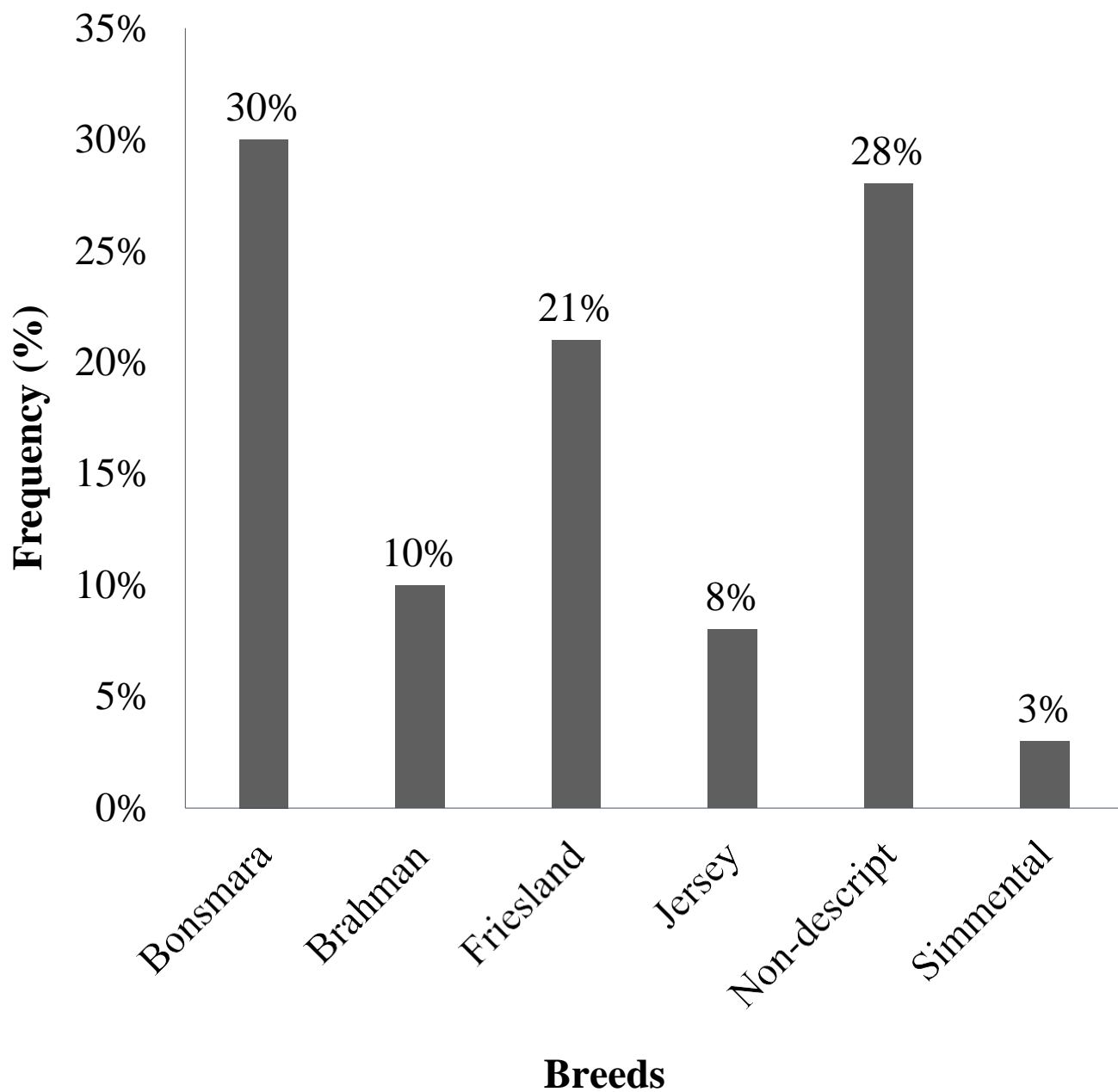


Figure 3. 4: Cattle breeds slaughtered at the abattoir.

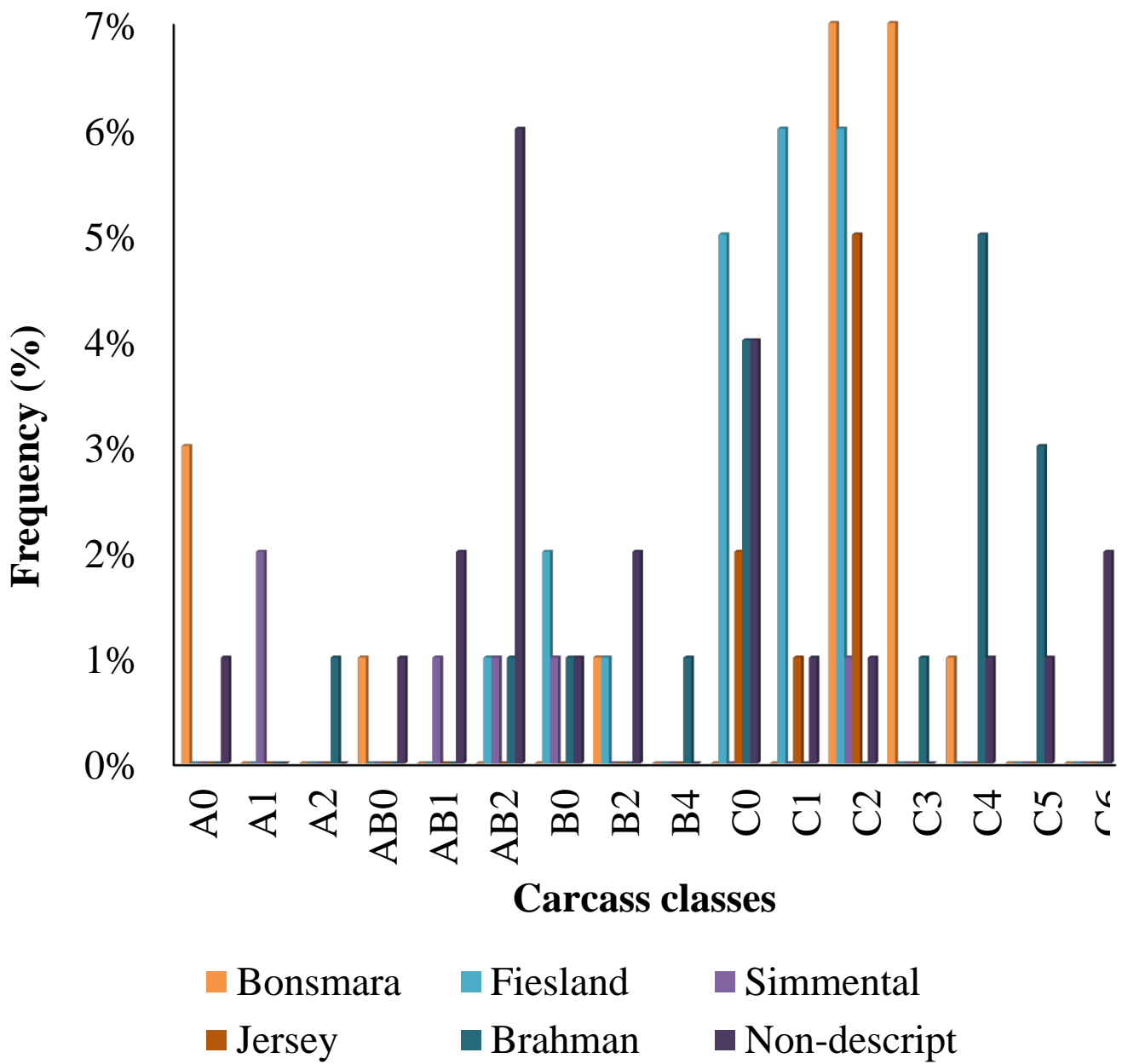


Figure 3. 5: Carcass classes produced per cattle breed.

A- Carcass with 0 incisors present at slaughter

AB- carcass with 1-2 incisors present at slaughter

B- Carcass with 6 incisors present at slaughter

C- Carcass with >6 incisors present at slaughter

Figure 3.6 shows that most farmers produce the Dorper sheep breed with Blackhead Persian being the least preferred. Different sheep breeds have been reported to have different carcass quality traits (Hanrahan, 1999) and thus also different meat quality traits (Tshabalala *et al.*, 2003). Figure 3.7 further shows that most sheep farmers produce mutton carcasses of the A-age class (91%) particularly the A2-class (77%). The A2-class is the most desirable class in South Africa as it is classified as meat from a very young animal which is most tender and lean. The Dorper breed dominated the A2-class (38%). Nonetheless, the Merino and Blackhead Persian were also dominant in the A2-class compared to other classes.

Figure 3.8 shows that in pigs most farmers produced Duroc x Large White crosses (54%). Ryu *et al.* (2008) indicated that different pig breeds have different carcass and meat quality traits. Figure 3.9 further shows that the pig farmers mostly produced the P-class with a percentage of 49%. However, a large percentage (44%) falls in the O-class and the R-class is the least produced. This may be attributed to the fact that these classes are preferred in the order of P, O, R, C, U, S; thus producers produce pork classes with the highest preference ratings as to be expected.

As reported (Strydom, 2011), age and fat are the most important characteristics used in the SA classification system. However, no rankings are made in terms of age in pork classification. The P-class which is classified as a carcass with 70% and more meat and ($1 \text{ mm} \geq \text{subcutaneous fat thickness} \leq 12 \text{ mm}$), was mostly dominated by the Duroc X Landrace crosses. The Duroc X Large White crosses dominated the O-class which is classified as a carcass with ($68 \leq \text{Meat\%} \leq 69$) and ($12 \text{ mm} \leq \text{subcutaneous fat thickness} \leq 17 \text{ mm}$). Few (7%) Duroc X Large White crosses dominated the R-class which is classified as ($66 \leq \text{Meat\%} \leq 67$) and ($17 \leq \text{Subcutaneous fat thickness} \leq 22 \text{ mm}$).

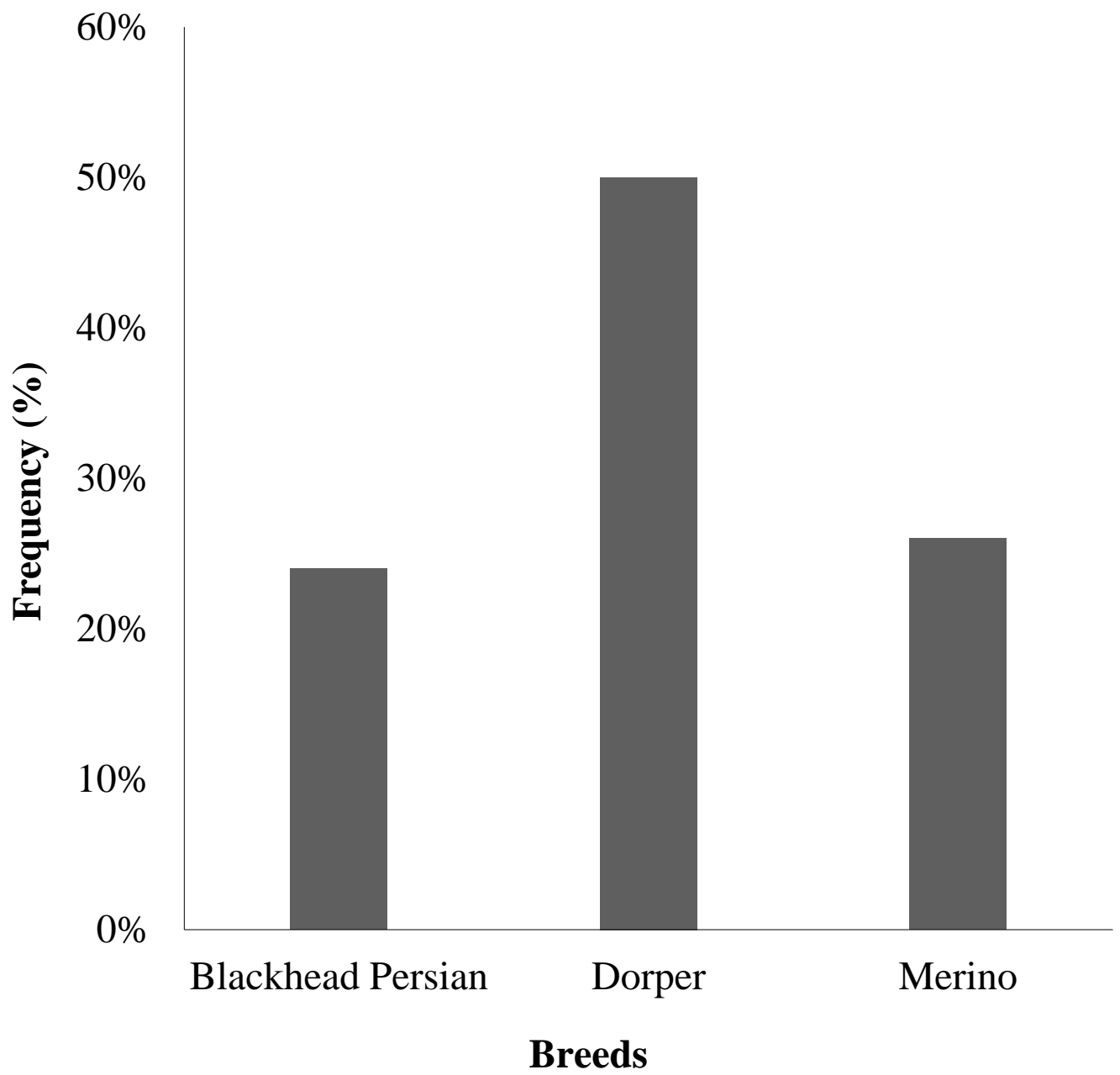


Figure 3. 6: Sheep breeds slaughtered at the abattoir.

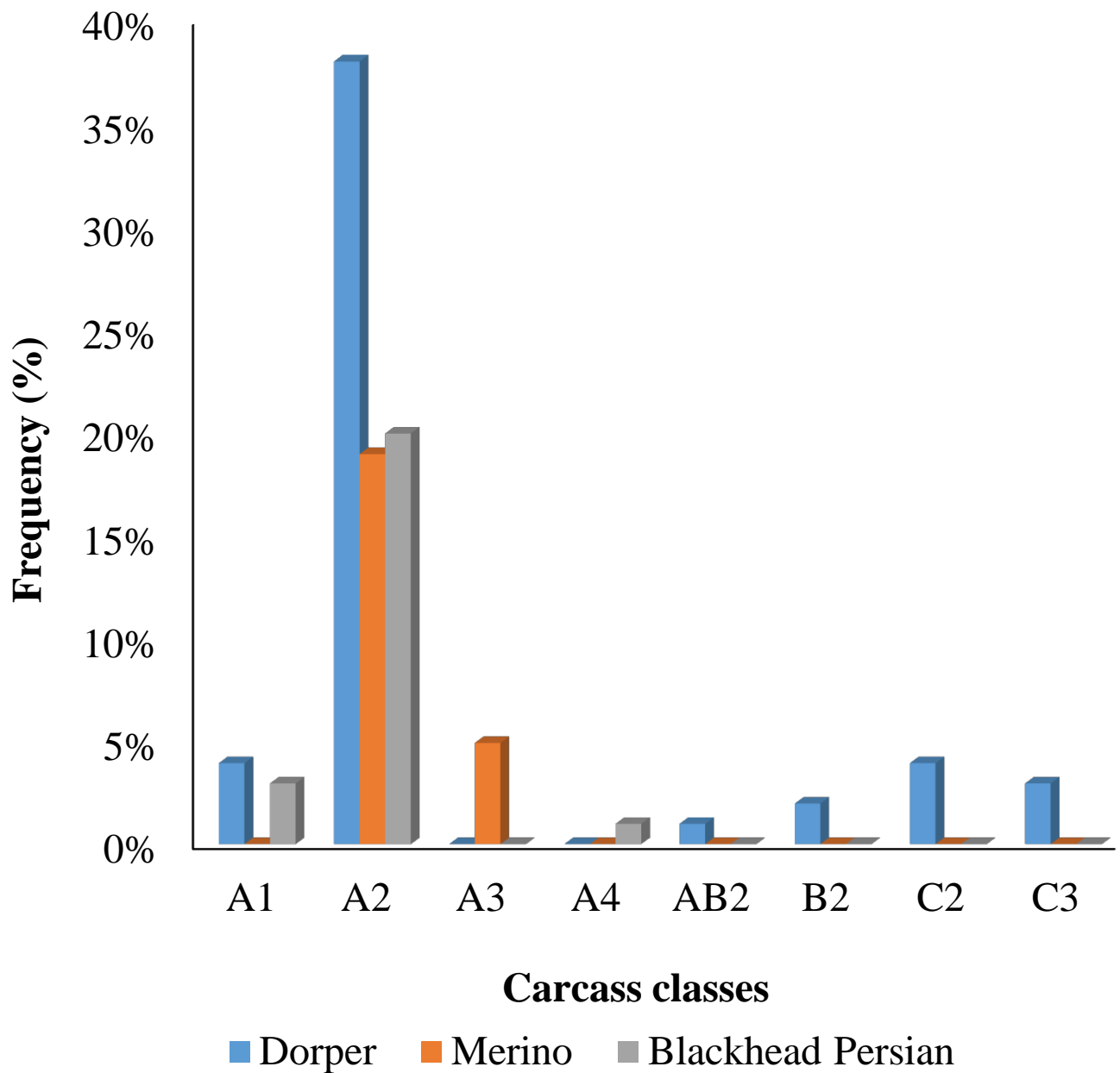


Figure 3. 7: Carcass classes produced per sheep breed.

A-Carcass with 0 incisors present at slaughter

AB- carcass with 1-2 incisors present at slaughter

B- Carcass with 6 incisors present at slaughter

C- Carcass with >6 incisors present at slaughter

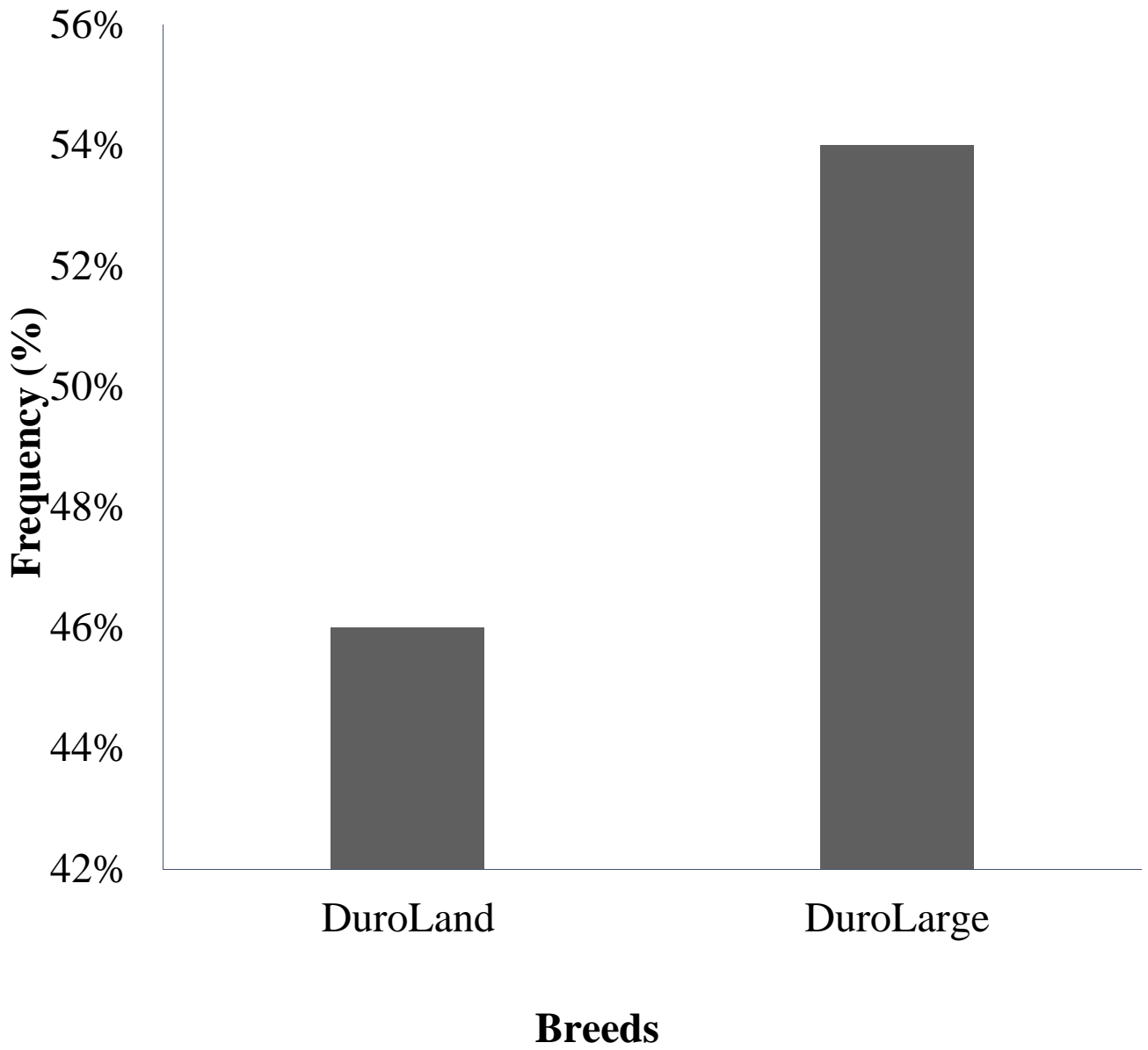


Figure 3. 8: Pig breeds slaughtered at the abattoir.

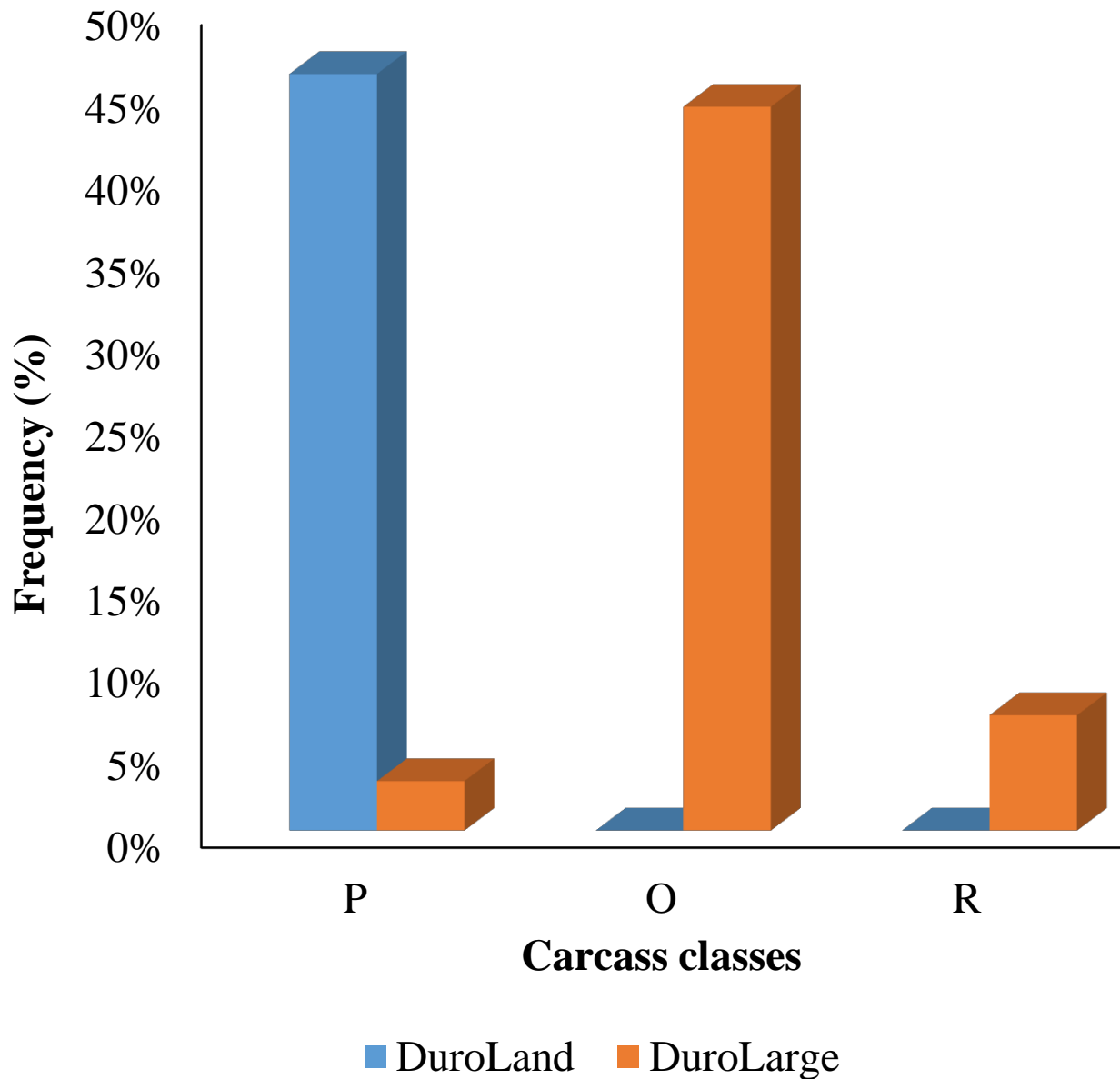


Figure 3. 9: Carcass classes produced per pig breed.

P - Carcass with meat percentage of $\geq 70\%$ and fat thickness $< 12\text{mm}$

O - Carcass with meat percentage of 68-69 % and fat thickness 13-17mm

R - Carcass with meat percentage 66-67% and fat thickness 18-22mm

Figure 3.10 shows that most of the cattle that were delivered to this abattoir were cows (56%) while 26% were castrated cattle. The least delivered were heifers (9%) and bulls (9%). However, castrated animals have been reported to have good carcass and meat quality traits (Destefanis *et al.*, 2003; Litwinczuk *et al.*, 2006; Zhang, *et al.*, 2010). Figure 3.11 shows that more rams/male castrates than ewes were slaughtered at this abattoir. However, more sows than boars were slaughtered (Figure 3.12). This could be due to the fact that the farmers try to avoid boar taint which has a negative effect on pork quality or due to the fact that there is a very low number of boars kept at farms compared to sows, the farmers may only need one boar per 30 sows.

The results in Table 3.1 show that there was an association ($P < 0.001$) between class and sex of cattle, but in sheep and pigs there was no association between the two variables ($P > 0.05$). According to Destefanis *et al.* (2003), Litwinczki *et al.* (2006) and Zhang *et al.* (2010), sex has an effect on various meat quality attributes such as muscle chemical composition, fat deposition, protein and ash content. Therefore, research needs to be conducted on the interactions between sex and carcass classes of all red meat producing livestock species to provide the carcass quality exhibited by the sex characteristic in each class.

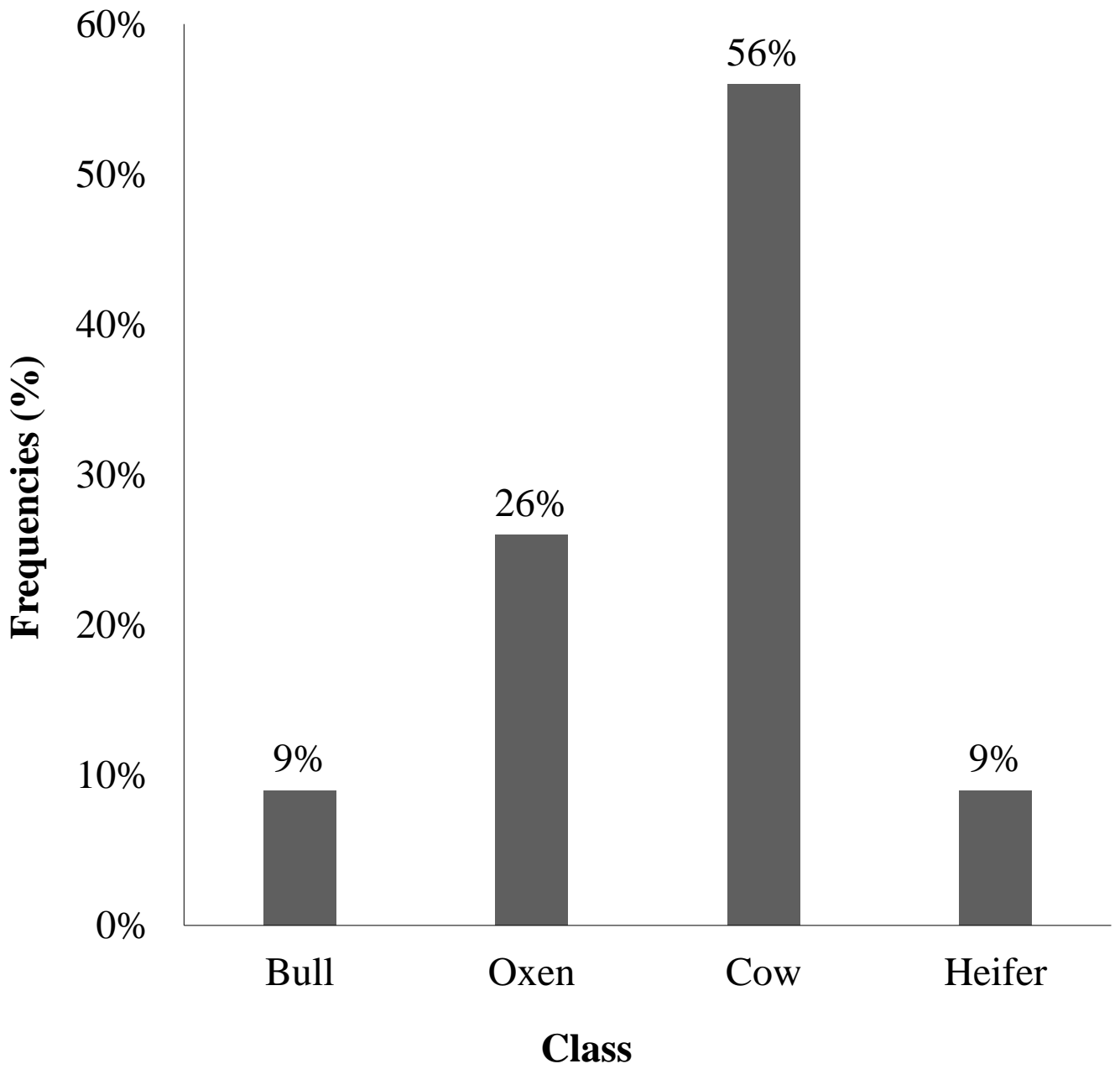


Figure 3. 10: Class of cattle slaughtered at the abattoir.

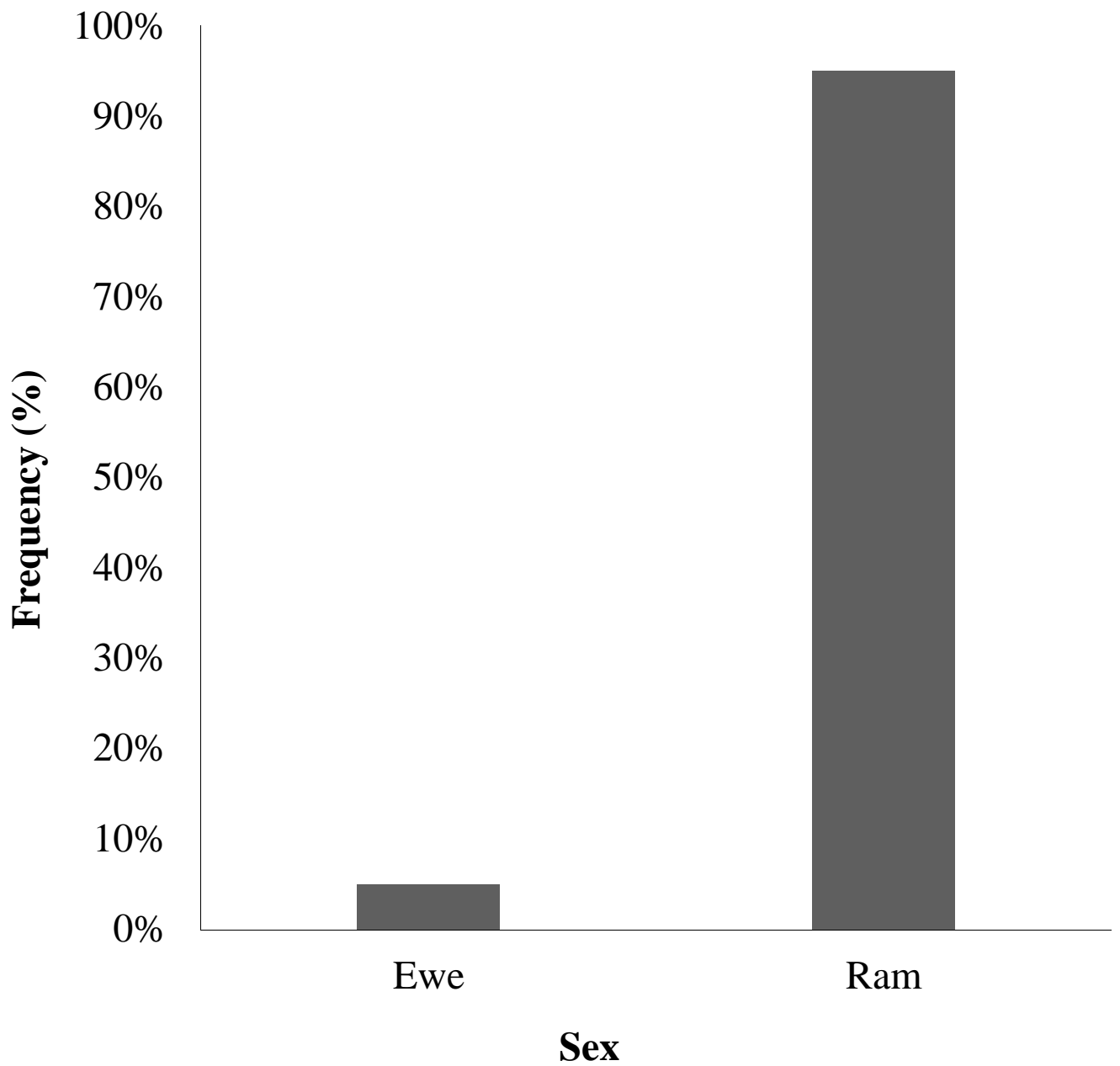


Figure 3. 11: Sex of sheep slaughtered at the abattoir.

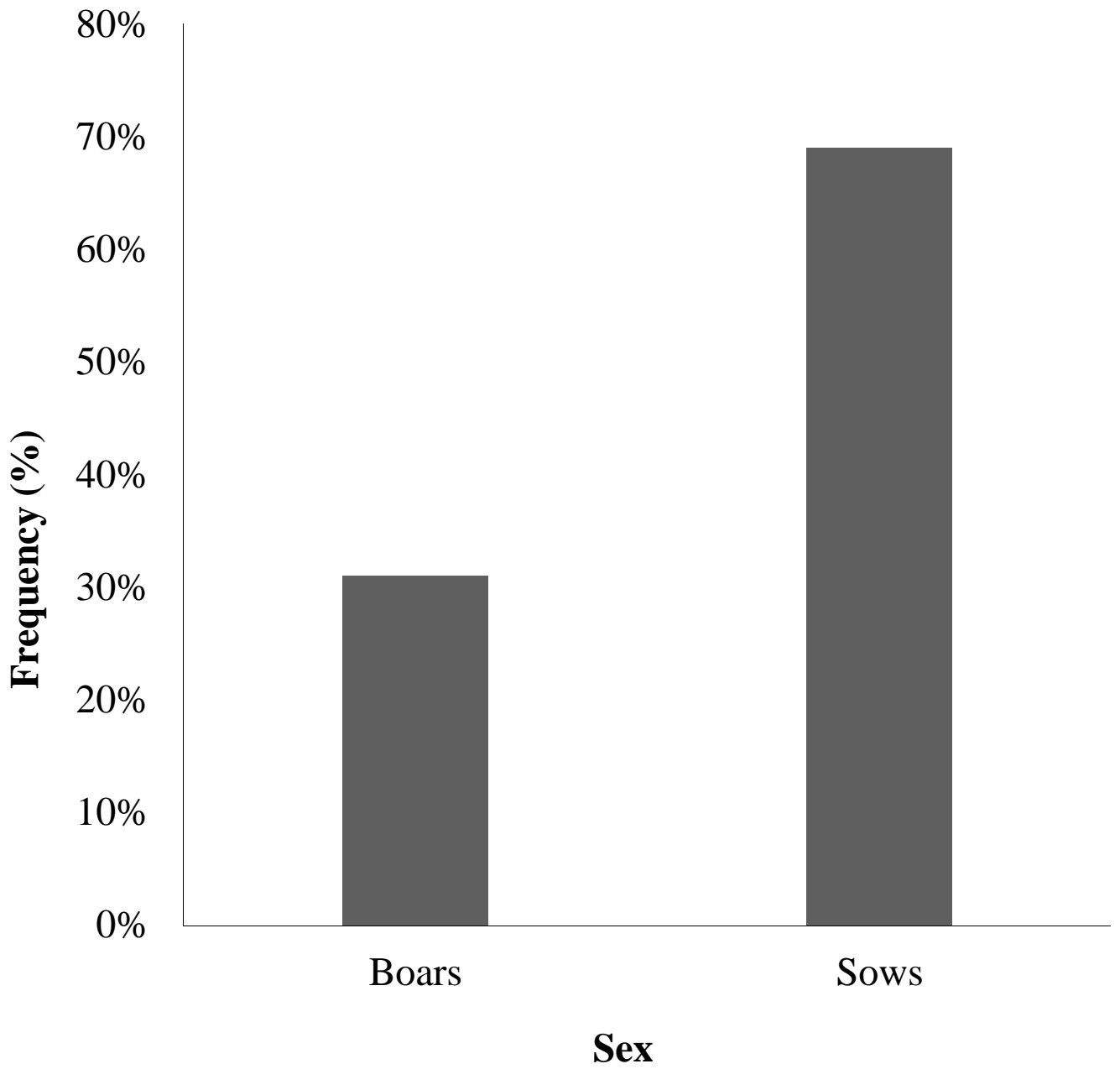


Figure 3. 12: Sex of pigs slaughtered at the abattoir.

Table 3. 1: Associations between sex and the A-, AB-, B- and C-carcass classes in cattle and sheep, and P-, O-, and R-carcass classes in pigs.

| Species | Chi value | P value | Association |
|---------|-----------|---------|-------------|
| Cattle | 193.192 | <.001 | * |
| Sheep | 4.201 | 0.756 | NS |
| Pig | 3.942 | 0.139 | NS |

*Significant association ($P < 0.001$); NS = No significant association ($P > 0.05$)

A-Carcass with 0 incisors present at slaughter

AB- carcass with 1-2 incisors present at slaughter

B-Carcass with 6 incisors present at slaughter

C-Carcass with >6 incisors present at slaughter

P - Carcass with meat percentage of $\geq 70\%$ and fat thickness <12mm

O - Carcass with meat percentage of 68-69 % and fat thickness 13-17mm

R - Carcass with meat percentage 66-67% and fat thickness 18-22mm

Table 3.2 shows that there were significant breed by class associations in carcasses from cattle, sheep and pigs. Associations between sheep breeds and carcass quality have been reported in the study by Shackelford *et al.* (2012) which showed that progeny of Suffolk sires were heavier than progeny of other breeds. This was also evident from the carcass weights and the 12th rib fat percentage which was greater for Dorper progeny than those of other breeds, except White Dorper and Katahdin. The study further indicated that Finnsheep and Romanov sires had a greater percentage of intramuscular fat and also achieved greater marbling scores than the other breeds. Such results comprehensively show that breed diversity has an effect on some carcass characteristics and consequently also on sheep carcass classes. Sheep with better marbling or intra-muscular fat should thus have better carcass classes since marbling improves meat tenderness, juiciness and aroma (Curtis *et al.*, 2006). The marbling factor is, however, not considered in the SA classification system.

Therefore more research still needs to be done on the relationships between breed and carcass classes across all red meat producing species. Rankings should be made based on the carcass quality attributes of each class in a specific breed and marbling scores and the relationship between these two variables should perhaps be considered. Table 3.3 on the other hand further shows that there were associations between WCM and carcass class ($P > 0.05$) in sheep and cattle while there was no association between the two variables in pig carcasses. This variation calls for more research on the possible relationships between carcass weights and classes within livestock species from different production systems. Since Knight (2013) found that heavier animals result in higher returns because they have more muscle/flesh than fat and are therefore leaner, studies integrating carcass classification with different species weights should be carried out.

Table 3. 2: Associations between breed and the A-, AB-, B-, and C-carcass classes in cattle and sheep and P-, O-, and R-carcass classes in pigs.

| Species | Chi value | P value | Association |
|----------------|------------------|----------------|--------------------|
| Cattle | 131.142 | <.0001 | *** |
| Sheep | 118.641 | <.0001 | *** |
| Pig | 88.993 | <.0001 | *** |

* Significant association ($P < 0.001$)

A-Carcass with 0 incisors present at slaughter

AB- carcass with 1-2 incisors present at slaughter

B-Carcass with 6 incisors present at slaughter

C-Carcass with >6 incisors present at slaughter

P - Carcass with meat percentage of $\geq 70\%$ and fat thickness <12mm

O - Carcass with meat percentage of 68-69 % and fat thickness 13-17mm

R - Carcass with meat percentage 66-67% and fat thickness 18-22mm

Table 3. 3: Associations between warm carcass mass (WCM) and the A-, AB-, B-, and C-carcass classes in cattle and sheep and P-, O-, and R-carcass classes in pigs.

| Species | Chi value | P value | Association |
|----------------|------------------|----------------|--------------------|
| Cattle | 1330.413 | 0.0458 | * |
| Sheep | 627.529 | <.0001 | *** |
| Pig | 141.272 | 0.3609 | NS |

**Significant association ($P < 0.001$) ;*($P < 0.05$); NS = No significant associations

A-Carcass with 0 incisors present at slaughter

AB- carcass with 1-2 incisors present at slaughter

B-Carcass with 6 incisors present at slaughter

C-Carcass with >6 incisors present at slaughter

P - Carcass with meat percentage of $\geq 70\%$ and fat thickness <12mm

O - Carcass with meat percentage of 68-69 % and fat thickness 13-17mm

R - Carcass with meat percentage 66-67% and fat thickness 18-22mm

3.5. Conclusions

Associations were found between breed and carcass classes of cattle, sheep and pigs. Sex was only found to be associated with all carcass classes in cattle. Significant associations were also found between WCM and carcass classes of cattle and sheep. No associations were found between carcass classes and WCM of pigs. The results from this study suggest that animal traits such as breed and carcass traits such as WCM affect carcass classes. More research should therefore be done on the relationship between the breed, WCM and the A-, AB-, B- and C-classes in sheep and cattle and P-, O- and R-classes in pigs.

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**Chapter 4: Effect of genotype and age on some quality characteristics of beef carcasses
subjected to the South African classification system**

Published in *Meat Science* (117:205-211)

(See appendix 4)

Abstract

The quality of beef from steers (n=175) classified using the South African Beef Carcass Classification system was evaluated. The *Muscularis longissimus thoracis et lumborum* of steers with six, seven and eight incisors present at slaughter from Angus, Bonsmara, Fleckvieh, Non-descript and Simmental genotypes were used for meat quality measurements. Significant differences ($P < 0.05$) were observed across genotypes on a^* , H_{ab} , pH_{24} , TL%, CL% and WBSF of steers with six, seven and eight erupted incisors. Angus C2 carcass classes had a darker colour (L^*) than the Non-descript and Bonsmara genotypes. Redness of the Bonsmara C2 carcass class differed ($P < 0.05$) from that of Angus, Fleckvieh and Non-descript genotypes. The Non-descript genotype had more yellow subcutaneous fat than all other genotypes. Angus and Simmental genotypes had the toughest meat (WBSF) (40.29 ± 11.62 and 38.71 ± 9.33 , respectively), while Non-descript and Fleckvieh genotypes had tender meat (31.53 ± 12.62 and 32.00 ± 7.92 , respectively). Meat quality characteristics varied within animals of the same age and consequently of the same class across genotypes.

Keywords: Breed, carcass classification, dentition, fat colour, meat colour, meat pH, meat tenderness

4.1. Introduction

Carcass classification and grading systems are developed with an attempt to describe the yield and quality of carcasses (Strydom, 2011). These systems are established for necessary information to all stakeholders in the meat production chain, as well as to provide a satisfying eating experience to consumers. According to Fisher (2007), a beef classification system increases price precision. Conroy (2010) further highlighted the significant role of beef carcass classification as a marketing tool among the European countries. Polinghorne and Thompson (2010) evaluated the classification and grading systems for beef carcasses in seven countries around the world. These countries included the Republic of South Africa, South Korea, United States of America Japan, Europe, Canada and Australia. Among these countries, only the Australian (AUS-MEAT), European (EUROP) and South African (SA) systems are considered as classification systems. The Meat Standards Australia (MSA) and other four countries (Canada, Japan, South Korea and USA) use the grading system.

In carcass grading systems, carcasses are graded in order of merit from the most preferred to the least preferred grades, while in the classification systems codes are allocated to each carcass in a manner that does not imply that one carcass class is better than the other (Strydom, 2011). Among the criteria used in the grading and classification systems, only the AUS-MEAT and MSA use pre-slaughter criteria in addition to slaughter floor measurements. All other classification and grading systems rely on slaughter floor measurements. Although the slaughter floor measurements vary among these systems, measurements such as; carcass weight, sex and age are common in all systems but with different methodologies. The EUROP, SA and AUS-MEAT classification systems only perform slaughter floor measurements. However, grading schemes go beyond the slaughter floor to perform chiller

measurements. The chiller processes measure meat quality attributes which include marbling score, meat and fat colour, pH, firmness and texture among others. The MSA also performs post chiller measurements which include ageing time and cooking method. Meat quality attributes are, however, not included in the EUROP and SA classification systems. Nonetheless, consumers are increasingly demanding meat that is of good colour, aroma, flavour and tenderness among other attributes and they cannot rank these for themselves in the retail outlets. In addition, South Africa exports beef to Europe (DAFF, 2012), and the beef carcasses are subjected to the EUROP classification system for the European consumer market and payment to the South African suppliers. There is, therefore, a need for the EUROP and SA classification systems to rank these quality attributes for a satisfying eating experience of consumers and fair returns to beef producers and meat traders.

There are different beef production systems in South Africa which are distinguished by the availability and type of natural resources, commercial availability and local consumer demands (Frylinck *et al.*, 2013). The Eastern Cape Province of South Africa in particular has approximately 3.1 million beef cattle which comprise nearly a quarter of the total population in South Africa (NDA, 2008). Sixty five percent of these cattle come from communal farmers (ECDC, 2003). However, communal farmers have little access to formal markets which include the “carcass classification system” at abattoirs. These farmers would rather opt to sell their animals through informal markets which include farmer-to-farmers sales or through auctions to feedlot producers. In addition, Musemwa *et al.* (2008) Groenewald and Jooste (2012) reported that most animals that find their way to formal markets from communal farmers are sold through auctions.

Although this is the case, the South African classification system was developed and implemented in 1992 as a necessary tool for the marketing and trading of SA red meat carcasses (Hall *et al.*, 2015). This was in response to findings which confirmed changes in the quality attributes as well as physical and nutrient composition of SA beef carcasses due to age and degree of fatness. The SA classification system classifies beef carcasses into four age groups which are determined based on the number of erupted incisors present at slaughter using a dentition method with classes A (0 incisors), AB (1-2 incisors), B (3-6 incisors) and C (>6 incisors). Nonetheless, the system has not been evaluated to assess meat quality from animals with different number of incisors present at slaughter. However, animals falling within AB, B and C classes have different number of incisors present at slaughter, which indicate differences on age due to different stages at which the incisors develop. Thus, differences might be picked within animals of the same class due to differences on the number of incisors present at slaughter.

The system also classifies carcasses based on the amount of subcutaneous fat with classes ranging from 0 (no fat) to 6 (extremely over fat). Age and fat codes have been reported as key determinants of market price, with young animals and fat code 2 fetching high premiums (Hall *et al.*, 2015). These factors, therefore, increase economic incentives among beef production systems to produce A2 class animals. However, it has been argued that although A-age animals are sold for high prices since they are considered to be most tender and consequently of better quality, this is not always the case as many other factors besides age can affect tenderness (Strydom *et al.*, 2011), and one such factor can be the breed. Nonetheless, Strydom (2011) argued that the current classification system gives limited description of the quality-related characteristics as it only describes scores and measurements without ranking for meat quality attributes. Since the implementation of the current

classification system, it has not been evaluated to assess cogency with regards to the quality of beef carcass classes from different breeds. However, Muchenje *et al.* (2008) reported that associations among meat quality attributes may vary depending on breed, which is, however, not evaluated in the SA classification system. In addition, it has also been reported that breed has significant effects on carcass traits (lean-fat ratio, conformation and dressing %), meat quality traits (meat colour and cooking loss), and sensory traits (tenderness and juiciness) (Chambaz *et al.*, 2003; Muchenje *et al.*, 2008). These traits are significant for a satisfying eating experience to consumers and future purchasing decisions. Therefore, there is a need for information on the quality of South African beef carcass classes across different breeds with different number of erupted incisors present at slaughter to address consumer uncertainties. This study sought to investigate the quality of meat from SA carcass classes across different beef breeds with different number of erupted incisors present at slaughter

4.2. Materials and Methods

4.2.1. Experimental site description

The study site is the same as used in Chapter 3, Section 3.2.2.

4.2.2. Animal description

Five different beef genotypes (Angus, Bonsmara, Fleckvieh, Non-descript and Simmental) from different feedlot systems were selected at abattoir lairages. Thirty five steers of different age categories were selected from each genotype after slaughter during dentition making a total of 175 steers.

4.2.3. Data collection

Animals were slaughtered humanely at the abattoir according to the rules and regulations stipulated on the Meat Safety Act (Act no. 40 of 2000). Before slaughter, the animals were stunned using a captive bolt gun with a steel bolt that was powered by a cartridge. The velocity of the bolt used was 55 m/s. The animals were driven through stunning boxes with non-slippery floor to prevent them from falling. Solid panels around the stunning boxes were used to block the vision of approaching animals to prevent them from looking out onto the slaughter floor.

After the animal settled in the stunning box, the bolt was driven into the animal's brain. After each animal was shot the bolt retracted, and was reset for the next animal. The stunner was used to terminate the cattle's consciousness before exsanguination was initiated. Exsanguination was done using a sharp knife to cut the jugular vein across the animals' neck on a line slaughter system. Following the humane slaughter, the carcasses were subjected to the SA classification system under the regulations set for the classification and marking of meat anticipated for sale in the Republic of South Africa (Act No.119 of 1990) (Agricultural Product Standard Act, 1990).

4.2.4 Carcass classification

Five classification categories (age, sex, conformation, bruising and fatness) were used. The age of the steers was determined using a dentition method described by the South African Meat Industry Company (SAMIC, 2006) depending on the number of erupted incisors present at slaughter with classes A (0 incisors), AB (1-2 incisors), B (3-6 incisors) and C (>6 incisors). Visual appraisal was used to determine the degree of subcutaneous fat (SF) in

millimetres (mm) with scores ranging from 0 (No Fat), 1 ($SF < 1\text{mm}$), 2 ($1 \leq SF \leq 3$), 3 ($3 \leq SF \leq 5$), 4 ($5 \leq SF \leq 7$), 5 ($7 \leq SF \leq 10$), 6 ($10 \leq SF$). Bruising (1 slightly damaged - 3 excessively damaged) and conformation (1 very flat - 5 very round) were also determined and assigned scores by visual appraisal.

4.2.5 Meat sample harvesting and measurements

Meat samples were harvested from the *Longissimus thoracis et. lumborum* (LTL) muscle. The muscles were cut from the carcasses before chilling at the abattoir. Vacuum packaging was done on the samples before they were stored in a cooler box half filled with ice cubes. The samples were stored in a cooler box for approximately 180 minutes during transportation. After transportation they were stored at -20°C refrigerator temperature. The samples were then analysed for meat and subcutaneous fat colour (lightness; L^* , redness; a^* and yellowness; b^*), pH, thawing loss (TL %), cooking loss (CL %) and Warner Bratzler Shear Force (WBSF).

4.2.5.1 Meat pH

After 24 hours of slaughter meat pH was measured at the University of Fort Hare Meat Science laboratory. A portable digital pH meter (Crison pH 25) with a piercing electrode was used to measure pH on the samples. The pH meter was fitted with a sharp metal to prevent breakage of the probe by the raw meat. The pH meter was first calibrated with standard solutions of pH 4, 7 and 9. Measurements were then taken after calibration.

4.2.5.2. Meat colour

Meat colour was also measured 24 hours after slaughter. The colour was measured based on the standards from the Commission International De I Eclairage, (1976) which are lightness (L*), redness (a*) and yellowness (b*). A Minolta colour guide machine (model 45/0 BYK-Gardner GmbH) with a 20 mm diameter, illuminant D65-day light and 10° standard was used to measure the meat colour. The results were taken after 3 readings achieved by rotating the device by 90° on the sample surfaces 3 times. Saturation index was then calculated as $(a^*^2 + b^*^2)^{0.5}$ and the hue angle was also calculated as $[\tan^{-1}((b^*/ a^*))]$ using a method by Setser (1984).

4.2.5.3. Thawing and cooking loss measurement

The samples were weighed before freezing using a portable weighing scale and subsequently frozen at -20°C for 7 days. After 7 days, the frozen samples were reweighed and thawed at room temperature for 24 hours. After thawing the samples were re-weighed, placed in a water tight PVC-plastic bag and then boiled at 72°C for 45 minutes in a water bath (Model TRH). After cooking, meat samples were cooled down to room temperature. The samples were then re-weighed. Calculations for thawing and cooking loss were done using the following formulae;

$$\text{Cooking loss (CL) \%} = \frac{\text{Weight before cooking} - \text{Weight after cooking}}{\text{Weight before cooking}} \times 100\%$$

$$\text{Thawing loss (TL) \%} = \frac{\text{Weight before freezing} - \text{Weight after thawing}}{\text{Weight before freezing}} \times 100\%$$

4.2.5.4. Meat tenderness

Following the thawing and cooking loss measurements, the samples were analysed for tenderness using the Warner-Bratzler Shear Force (WBSF). From each sample, three subsamples of approximately 12, 5 mm core diameter were extracted from the samples parallel to the long axis of the muscle fibres (AMSA, 1995). Each core was sheared once through the centre at an angle perpendicular to the direction of the fibre using the Warner Bratzler shear device attached to the Universal Instron apparatus (model 3344, crosshead speed=400mm/min). WBSF was measured as the peak force (kg) average for three cores per sample.

4.6. Statistical analysis

The data was analysed using the Statistical Analysis System (2009). Frequency procedure (PROC FREQ) was used to describe carcass classes produced per genotype and the number of incisors present at slaughter on each genotype. Interactions between genotype and dentition were computed using PROC GLM within the C2 carcass class. The General linear model procedure (PROC GLM) was also used to test the effect of genotype on meat quality attributes within the C2 carcass class across genotypes. The significant difference between least square means was compared using fishers' least significant difference (LSD). Correlations among the meat quality attributes within the C2 carcass classes across genotypes were also computed using the correlation procedure (PROC CORR). The following model was used:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk}$$

μ = Overall mean

α_i = i^{th} effect of genotype (Angus, Bonsmara, Fleckvieh, Non-descript and Simmental)

$\beta_j = j^{\text{th}}$ effect of age (6, 7 and 8 erupted incisors)

$(\alpha\beta)_{ij}$ = Interaction between genotype and age

ϵ_{ijk} = Random error

4.4. Results and Discussion

A uniform conformation score (Class 3) was found in all carcasses in the current study. According to the South African Meat Industry Company (SAMIC, 2006), conformation is significant when consumers want to select cuts of preference in the market and carcasses falling within class code 3 are classified as “medium”. Most consumers prefer to buy cuts of class 3 to 5 in the markets. The results from the current study, therefore, suggest that all genotypes compared favourably with each other in terms of conformation; as a result, all carcasses provided the most preferred size of cuts.

The carcasses also had no traces of bruises; hence no damage scores were allocated. SAMIC (2006) states that if a carcass is bruised, the extent of damage will consequently have an effect on the price when being sold with severely damaged carcasses (bruise score 3) fetching low prices. It appears that all farmers were adhering to expected pre-slaughter handling procedures for reduced incidences of bruising. The results from the current study, therefore, suggest that all carcasses would fetch high premiums for conformation and damage classification in the market. Variations were, however, observed on age and fat code scores. As illustrated in Figure 4.1, the C-class had the highest total frequency (78.9%) compared to other age categories. The C-class is associated with animals slaughtered at an older age with more than 6 erupted incisors.

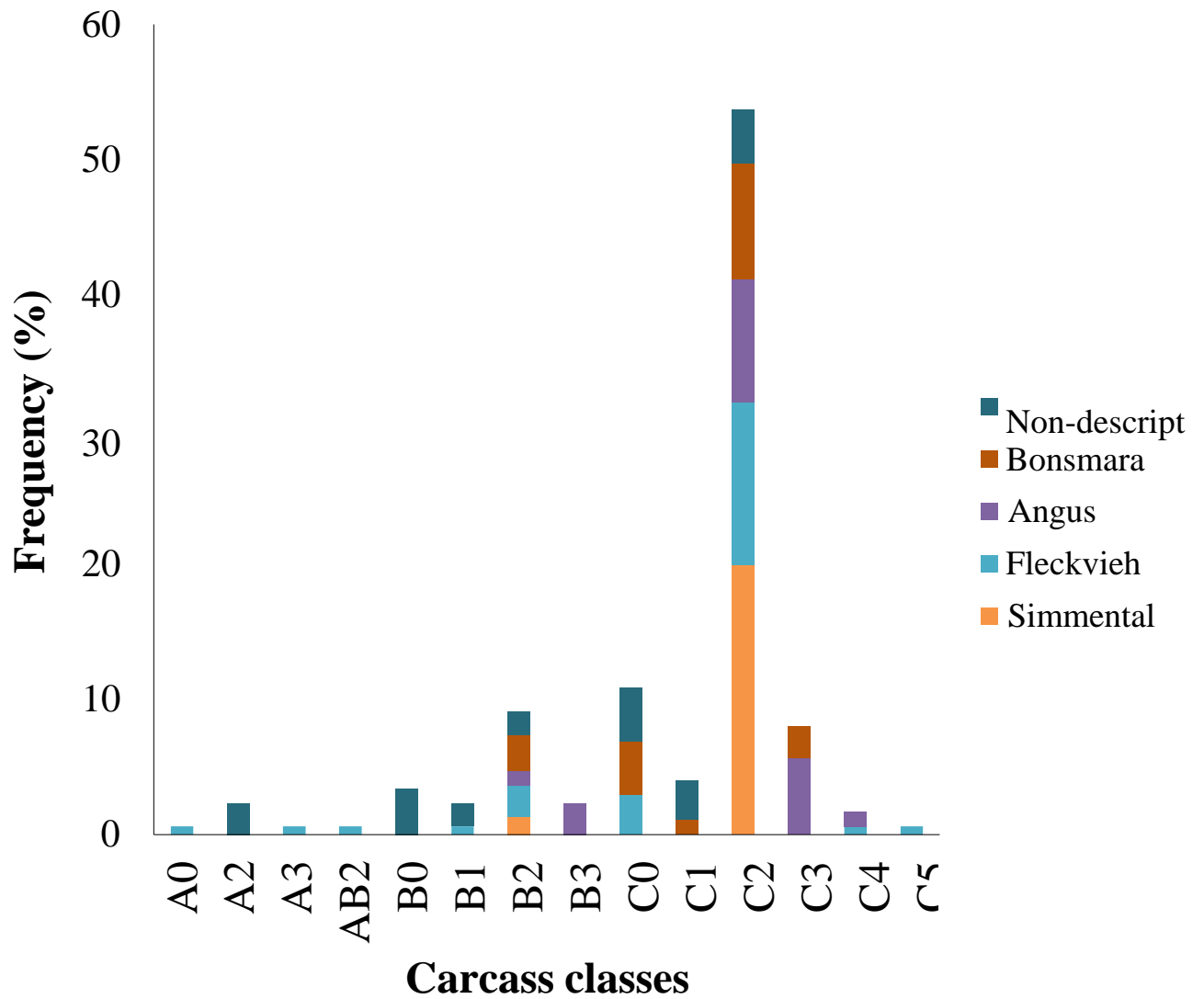


Figure 4. 1: Carcass classes produced from different beef genotypes slaughtered in a high throughput abattoir.

1 Carcasses within the C-class are considered undesirable for the market as they are presumed
2 to be less tender (SAMIC, 2006). Consequently, farmers often get low premiums for C-class
3 carcasses. Based on the level of fatness, fat code “2” was the most dominant across all age
4 categories (A, AB, B and C). Carcasses of fat code 2 are regarded as lean meat with
5 subcutaneous fat ranging from 2 to 3 millimeters and are mostly preferable in the market,
6 thus, fetching high premiums. The C2 class was, therefore, the most prevalent class (53.7%)
7 and was dominated by the Simmental genotype (37, 2%). These results are similar to those
8 reported by Soji *et al.* (2015a) that the C2 class is likely to be more dominant on animals
9 subjected to slaughter at selected abattoirs in the Eastern Cape Province, South Africa. It is
10 therefore, clear from the results that some feedlot systems in some areas of the Eastern Cape
11 Province mostly send cattle of C-age category for slaughter.

12

13 The C-age cattle ultimately produce carcass classes with least preference in the market.
14 According to the South African Beef Carcass Classification System (SABCCS), animals are
15 usually slaughtered at an early A-age class of 12-16 months before the eruption of permanent
16 incisors or after the eruption of up to two permanent incisors (AB- age class) (Government
17 Notice No. R. 342. 1999) and this is usually expected in the feedlot systems. Frylinck *et al.*
18 (2013) further reported that pasture reared animals are sometimes slaughtered after the
19 eruption of 3-6 permanent incisors (B-age class) which is rarely produced in the feedlot
20 systems. Although the feedlot system is presumed to be a system that mostly sends animals of
21 the A and AB age categories, contradictory findings were observed in the current study.
22 Some of the “C”-age animals in these feedlot systems might be old culled animals from the
23 communal pasture based systems which are fattened for marketing. These results are similar
24 to those reported by Hall *et al.* (2015). Therefore, feedlots purchase such old animals from
25 communal farmers for onward supply to formal abattoirs. These old animals may be below

26 the target market weight due to production challenges besetting communal farmers at the
27 time of purchase in auctions, making fattening in feedlots a necessity. Mapiye *et al.* (2009)
28 reported that inadequate protein supplementation is one of the main constraints faced by
29 communal farmers, which consequently results in slow growth rates. Hence, when pasture-
30 reared animals are in feedlot systems they require extra time to be finished to the desirable
31 target market weights. This consequently results in the delayed attainment of the required
32 slaughter weight leading to animals being slaughtered at a mature age and, thus, fetching low
33 C-class premiums. This was confirmed on the Non-descript genotypes in the current study.
34 The Non-descript is a crossed genotype with unknown parental genotypes and is mostly
35 found in communal areas (Scholtz *et al.*, 2008).

36

37 It is often difficult to relate the Non-descript genotype with specific growth rates and overall
38 performance since the genotype varies from one animal to another. However, the prevalence
39 of C2 carcass class from the Non-descript genotype can also be attributed to longer subjection
40 of these animals to inadequate protein and carbohydrate supplementation on communal
41 pasture-based system before being auctioned to the feedlots which consequently resulted in
42 slow growth rates. Moreover, although genotypes such as Fleckvieh, Angus and Simmental
43 are known for their fast maturing rates (Muchenje *et al.*, 2008), thus, are expected to produce
44 A and AB carcasses, most of them were also unexpectedly slaughtered at C-age in the current
45 study. Furthermore, the Bonsmara which is a locally developed composite genotype also
46 dominated the C-age category and consequently resulted in low C-premium carcasses. The
47 Bonsmara is a medium maturing *Bos taurus africanus* genotype (Strydom, 2002). Thus, it can
48 be at least expected to reach slaughter weight at B-age category.

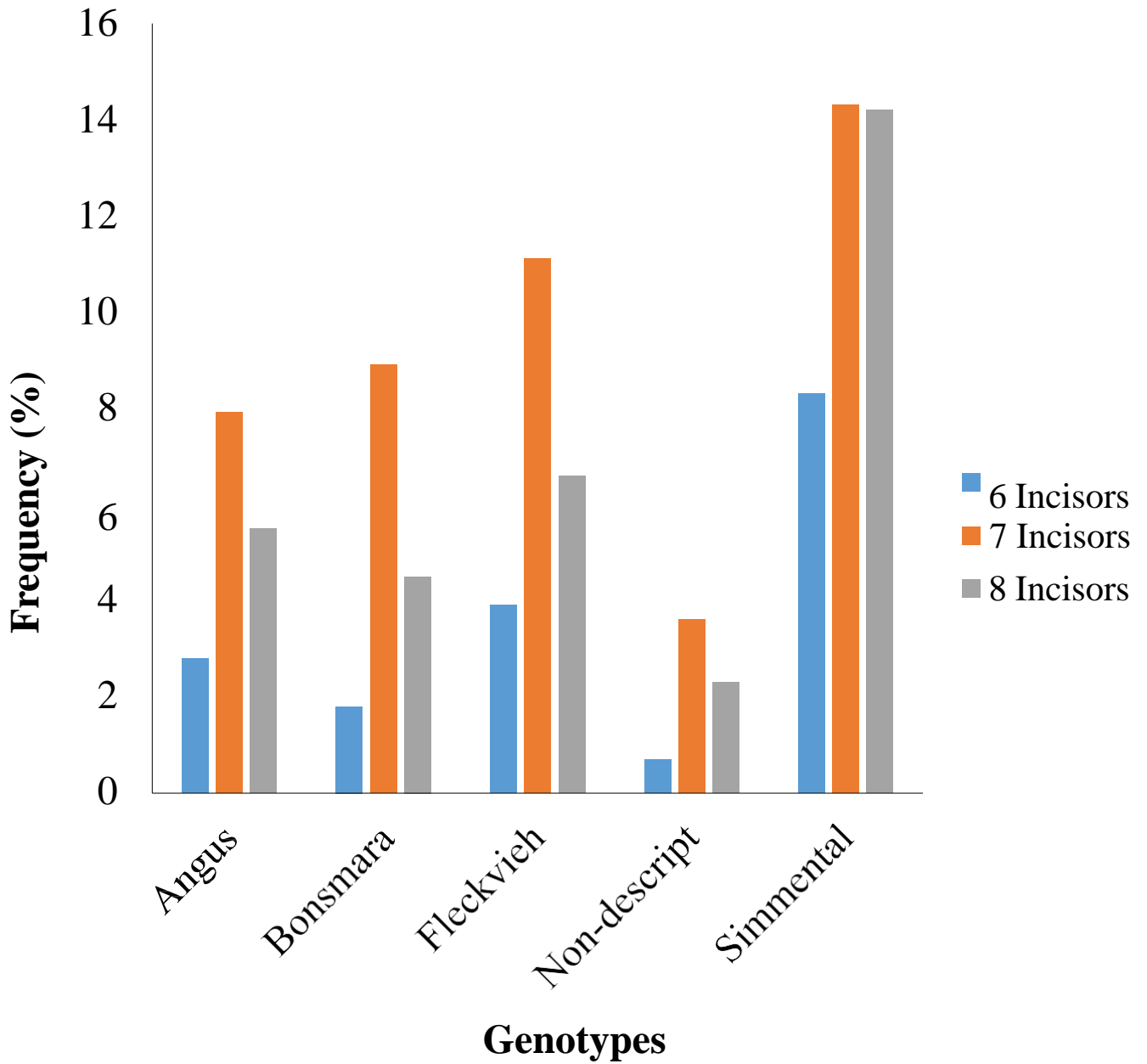
49 These results, therefore, suggest that there are also significant differences among genotypes
50 in terms of growth rates, and consequently the attainment of desired slaughter weight on
51 animals subjected to feedlot systems (Hall *et al.*, 2015). Thus, under these circumstances
52 different meat quality attributes might be expected from animals of the same age but different
53 genotypes.

54

55 Among the steers that were evaluated, it was noted that the most dominant were of B and C
56 age categories. The B-age steers all had six erupted incisors (17.5%) and C-age steers had
57 seven and eight erupted incisors present at slaughter with percentages (45.9 and 33.1,
58 respectively) distributed across all genotypes (Figure 4.2). There were very few A (0 erupted
59 incisors) and AB (2 erupted incisors) steers distributed between the Fleckvieh and Non-
60 descript genotypes. Dentition has long been used to classify carcasses in the SA
61 classification system. Strydom (2011) indicated that 0, 1-2, 3-6 and >6 number of permanent
62 incisors present at slaughter distinguish the A, AB, B and C classes respectively in the SA
63 classification system. Moreover, Lawrence *et al.* (2001) regarded a dentition based system
64 more accurate than the USDA maturity-based system to classify carcasses.

65

66 However, the system does not evaluate for differences within the same class animals with
67 different number of incisors present at slaughter. Strydom (2011) reported that significant
68 shear force values occurred within age groups than among age groups. Thus consumers might
69 pick differences on meat quality attributes of animals falling within the same class due to
70 differences on the number of incisors present at slaughter. Further classification of carcasses
71 within the same class could therefore provide more accurate technique of classifying beef
72 carcasses into less variable classes.



74

75 **Figure 4. 2:** Number of incisors present at slaughter on C2-class steers of different
76 genotypes.

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80

81 Table 4.1 shows the interactions between age measured as the number of erupted incisors
82 present at slaughter, and genotype on meat quality attributes of B2 and C2 carcass. There
83 were no interactions found between age and genotype on L*, a*, b*, H_{ab}, SI, pH₂₄, TL%, and
84 WBSF, however, interactions ($P < 0.0001$) of age and genotype were found on CL%. Meat
85 quality attributes as affected by age and genotype among steers with 6 (B2), 7 and 8 (C2)
86 erupted incisors present at slaughter were therefore evaluated separately. There were no
87 significant differences found ($P > 0.05$) in all meat quality attributes (L*, a*, b*, H_{ab}, SI, pH₂₄,
88 TL%, CL% and WBSF) among steers with six, seven and eight erupted incisors within the
89 same genotype. Thus, within the same genotype steers with six erupted incisors present at
90 slaughter had the same meat quality attributes as those with seven and eight erupted incisors.
91 According to SAMIC (2006) animals with six incisors at slaughter are classified as B-class
92 animals while those with seven and eight incisors are classified as C-class animals.

93

94 The current results show that some B-class animals might have the same meat quality
95 attributes as C-class animals if they are of the same genotype irrespective of the age
96 difference. Significant differences ($P < 0.05$) were, however, observed across genotypes in
97 some meat quality attributes (a*, H_{ab}, pH₂₄, TL%, CL% and WBSF). The results concur with
98 the findings by Chambaz *et al.* (2003) that meat quality attributes vary between breeds.
99 Significant differences ($P < 0.05$) were observed on redness (a*) of steers with seven and eight
100 erupted incisors across genotypes. Redness of Bonsmara steers with both seven and eight
101 erupted incisors was different from that of Fleckvieh but was similar to all other genotypes.
102 Significant differences ($P < 0.05$) in hue angle (H_{ab}) were observed across genotypes with
103 eight erupted incisors. The H_{ab} of Fleckvieh steers with eight erupted incisors was different

104 from those of Bonsmara, Non-descript and Simmental genotypes. Modika *et al.* (2015) also
105 observed differences on H_{ab} values between breeds of the same age.

106 **Table 4. 1:** Interactions between age measured as number of erupted incisors present at slaughter, and genotype on meat quality attributes of B2
 107 and C2 carcass classes.

| Meat quality attributes | Genotype | Age | | |
|-------------------------|--------------|----------------------------|----------------------------|----------------------------|
| | | 6 erupted incisors (B2) | 7 erupted incisors (C2) | 8 erupted incisors (C2) |
| L* | Angus | 30.4 ^a ± 1.33 | 30 ^a ± 1.21 | 28.7 ^a ± 1.33 |
| | Bonsmara | 33.8 ^a ± 1.49 | 32.7 ^a ± 1.12 | 31.9 ^a ± 1.49 |
| | Fleckvieh | 33 ^a ± 1.21 | 30.8 ^a ± 0.99 | 31.2 ^a ± 1.21 |
| | Non-descript | 32 ^a ± 1.71 | 34 ^a ± 2.10 | 32.5 ^a ± 2.10 |
| | Simmental | 31 ^a ± 0.94 | 30.7 ^a ± 0.86 | 31.7 ^a ± 0.82 |
| a* | Angus | 15.4 ^a ± 0.93 | 16.1 ^{ab} ± 0.85 | 15.1 ^{ab} ± 0.93 |
| | Bonsmara | 13.2 ^a ± 1.04 | 13.9 ^b ± 2.11 | 13.3 ^b ± 1.04 |
| | Fleckvieh | 14 ^a ± 0.85 | 16.6 ^a ± 2.48 | 16.5 ^a ± 0.85 |
| | Non-descript | 15.4 ^a ± 1.21 | 15.6 ^{ab} ± 1.48 | 14.9 ^{ab} ± 1.47 |
| | Simmental | 14.1 ^a ± 0.66 | 14.8 ^b ± 0.60 | 14.4 ^b ± 0.58 |
| b* | Angus | 10.7 ^a ± 0.99 | 11.2 ^a ± 0.90 | 10.1 ^a ± 0.99 |
| | Bonsmara | 10.5 ^a ± 1.11 | 11 ^a ± 0.84 | 10.2 ^a ± 1.11 |
| | Fleckvieh | 9.7 ^a ± 0.90 | 11.8 ^a ± 0.74 | 10 ^a ± 0.96 |
| | Non-descript | 11.7 ^a ± 0.42 | 13.9 ^a ± 1.28 | 12.8 ^a ± 1.57 |
| | Simmental | 10.9 ^a ± 1.74 | 11.3 ^a ± 0.64 | 10.4 ^a ± 0.61 |
| H_{ab} | Angus | 33.9 ^a ± 2.16 | 35 ^a ± 4.19 | 33.3 ^{ab} ± 2.16 |
| | Bonsmara | 38.3 ^a ± 2.41 | 38.2 ^a ± 1.82 | 37.5 ^a ± 2.41 |
| | Fleckvieh | 34.3 ^a ± 1.97 | 35.3 ^a ± 4.71 | 30.7 ^b ± 1.97 |
| | Non-descript | 37.5 ^a ± 2.78 | 41.6 ^a ± 3.41 | 40.8 ^a ± 3.41 |
| | Simmental | 37.5 ^a ± 1.52 | 37.4 ^a ± 1.39 | 35.6 ^a ± 1.34 |

| | | | | |
|-------------|--------------|---------------------------|---------------------------|---------------------------|
| SI | Angus | 18.9 ^a ± 1.18 | 19.6 ^a ± 1.08 | 18.2 ^a ± 1.18 |
| | Bonsmara | 16.9 ^a ± 1.32 | 17.8 ^a ± 1.00 | 16.7 ^a ± 1.32 |
| | Fleckvieh | 17.1 ^a ± 1.08 | 20.4 ^a ± 0.89 | 19.3 ^a ± 1.08 |
| | Non-descript | 19.3 ^a ± 1.52 | 20.9 ^a ± 1.86 | 19.6 ^a ± 1.86 |
| | Simmental | 17.8 ^a ± 0.83 | 18.7 ^a ± 0.76 | 17.8 ^a ± 0.76 |
| pH | Angus | 6.1 ^a ± 0.08 | 6.2 ^a ± 0.08 | 7.2 ^{abc} ± 1.06 |
| | Bonsmara | 6 ^a ± 0.09 | 6.1 ^a ± 0.07 | 6.3 ^b ± 1.18 |
| | Fleckvieh | 6 ^a ± 0.07 | 6.1 ^a ± 0.06 | 5.4 ^b ± 0.96 |
| | Non-descript | 6.2 ^a ± 0.11 | 6 ^a ± 0.13 | 5.6 ^c ± 1.67 |
| | Simmental | 6.1 ^a ± 0.06 | 6 ^a ± 0.14 | 4.6 ^b ± 0.65 |
| TL% | Angus | 4.2 ^a ± 1.06 | 5.7 ^{ab} ± 0.96 | 7.2 ^a ± 1.06 |
| | Bonsmara | 4.6 ^a ± 1.18 | 7.7 ^a ± 0.89 | 6.3 ^{ab} ± 1.18 |
| | Fleckvieh | 5.2 ^a ± 0.96 | 5 ^b ± 0.79 | 5.4 ^{ab} ± 0.96 |
| | Non-descript | 6 ^a ± 1.36 | 6.4 ^{ab} ± 1.67 | 5.6 ^{ab} ± 1.67 |
| | Simmental | 4.8 ^a ± 0.75 | 5.3 ^b ± 0.68 | 4.6 ^b ± 0.65 |
| CL% | Angus | 23.1 ^{ac} ± 2.25 | 21 ^a ± 2.05 | 23.1 ^{ab} ± 2.25 |
| | Bonsmara | 29.1 ^a ± 2.52 | 14 ^b ± 1.90 | 23.2 ^{ab} ± 2.52 |
| | Fleckvieh | 24.8 ^{ac} ± 2.05 | 24.9 ^a ± 1.68 | 18.2 ^b ± 2.05 |
| | Non-descript | 8 ^b ± 2.91 | 11.7 ^b ± 3.56 | 16.2 ^b ± 3.56 |
| | Simmental | 23 ^c ± 1.59 | 25.2 ^a ± 1.45 | 26.2 ^a ± 3.60 |
| WBSF | Angus | 42 ^a ± 4.35 | 39.3 ^a ± 3.97 | 41.8 ^a ± 4.35 |
| | Bonsmara | 41.9 ^a ± 4.86 | 29.9 ^{ab} ± 3.68 | 43.4 ^a ± 4.86 |
| | Fleckvieh | 21 ^b ± 3.97 | 32.3 ^{ab} ± 3.24 | 33.3 ^a ± 3.97 |
| | Non-descript | 35.2 ^{ab} ± 5.62 | 24.3 ^b ± 6.88 | 33.3 ^a ± 6.88 |
| | Simmental | 37.8 ^{ab} ± 3.08 | 38.2 ^{ab} ± 2.81 | 39.8 ^a ± 2.70 |

a, b, c Means within a column bearing different superscripts per trait differ at $P < 0.05$; $P < 0.01$; $P < 0.001$; L* - lightness; a* - redness; b* - yellowness; Hab - Hue angle; SI - saturation index; pH - meat pH; TL% - Thawing loss percentage; CL% - cooking loss percentage; WBSF - Warner Bratzler Shear Force.

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Significant differences ($P < 0.05$) in pH_{24} were also observed only on steers with eight erupted incisors with pH_{24} of Non-descript genotypes being different from that of Bonsmara, Fleckvieh and Simmental. Significant differences ($P < 0.05$) in TL% were found across genotypes with seven and eight erupted incisors. In steers with seven erupted incisors, the TL% of Bonsmara was different from that of Fleckvieh and Simmental, while in steers with eight erupted incisors the TL% of the Simmental genotype was different from that of Angus. Most significant differences were found in CL% across all genotypes with six, seven and eight erupted incisors. The CL% of the Non-descript steers with six erupted incisors was different from that of all other genotypes, while in steers with seven erupted incisors the Non-descript was only similar to Bonsmara and in steers with eight erupted incisors the Non-descript was different from Simmental.

In tenderness (WBSF), steers of Fleckvieh with six erupted incisors were different from those of Angus and Bonsmara, while in steers with seven erupted incisors tenderness of the Non-descript genotype was different from that of Angus. These results are similar to those reported by Modika *et al.* (2015) where significant differences on WBSF were observed between breeds than within the same breeds. These results comprehensively show that there are genotype effects on meat quality attributes of carcasses falling within the same class. Thus, the following section further evaluates meat quality attributes across genotypes of the same class. Meat quality characteristics of the C2 carcass class across different genotypes were evaluated and are shown on Table 4.2.

Table 4. 2: Least square means (\pm SE) of meat quality attributes for C2 carcass classes of different beef genotypes reared under different feedlot systems.

| Meat quality attributes | Breeds | | | | |
|-------------------------------|---------------------------------|----------------------------------|---------------------------------|-------------------------------|---------------------------------|
| | Angus (n=16) | Bonsmara (n=15) | Fleckvieh (n=21) | NonDescript (n=7) | Simmental (n=35) |
| L* (n=94) | 29.7 ^b \pm 3.5 | 32.8 ^a \pm 3.40 | 31.5 ^{a, b} \pm 2.79 | 32.7 ^a \pm 2.53 | 31.1 ^{a, b} \pm 2.53 |
| a* (n=94) | 15.6 ^a \pm 2.18 | 13.5 ^b \pm 1.66 | 15.9 ^a \pm 3.11 | 15.3 ^a \pm 1.10 | 14.5 ^{a, b} \pm 1.45 |
| b* (n=94) | 10.7 ^b \pm 2.57 | 10.6 ^b \pm 1.85 | 10.7 ^b \pm 2.66 | 12.7 ^a \pm 1.13 | 10.8 ^b \pm 1.93 |
| H_{ab} (n=94) | 34.2 ^b \pm 5.35 | 38 ^a \pm 4.67 | 33.7 ^b \pm 5.30 | 39.6 ^a \pm 2.80 | 36.8 ^{a, b} \pm 4.31 |
| SI (n=94) | 18.9 ^{a, b} \pm 2.87 | 17.3 ^b \pm 2.08 | 19.2 ^{a, b} \pm 3.73 | 19.9 ^a \pm 1.23 | 18.1 ^{a, b} \pm 2.00 |
| pH₂₄ (n=94) | 6.2 ^{a, b} \pm 0.15 | 6.1 ^{a, b} \pm 0.12 | 6 ^b \pm 0.24 | 6.2 ^a \pm 0.39 | 6 ^b \pm 0.12 |
| TL% (n=94) | 5.7 ^a \pm 2.80 | 6.5 ^a \pm 2.64 | 5.2 ^a \pm 2.20 | 6 ^a \pm 2.70 | 4.9 ^a \pm 2.00 |
| CL% (n=94) | 22.3 ^a \pm 5.35 | 20.5 ^a \pm 8.91 | 22.9 ^a \pm 5.87 | 11.4 ^b \pm 5.43 | 25 ^a \pm 4.05 |
| WBSF (n=94) | 40.3 ^a \pm 11.62 | 36.7 ^{a, b} \pm 10.37 | 32 ^b \pm 7.92 | 31.5 ^b \pm 12.62 | 38.7 ^{a, b} \pm 9.33 |

^{a, b} Means within a row bearing different superscripts differ at $P < 0.05$; $P < 0.01$; $P < 0.001$.

L-lightness; a*- redness- b*-yellowness; H_{ab} - Hue angle; SI -saturation index; pH- meat pH
SI -saturation index; TL%- Thawing loss percentage; CL% -cooking loss percentage; WBSF-
Warner Bratzler Shear Force.

Meat colour measured as lightness (L^*) for C2 carcass classes of Bonsmara, Fleckvieh, Non-Descript and Simmental did not differ significantly ($P>0.05$). However, the Angus genotype differed significantly ($P<0.05$) from Non-descript and Bonsmara. The C2 carcass classes of Angus, Fleckvieh and Simmental genotypes appeared to be darker than those of Bonsmara and Non-descript. Moreover, redness (a^*) of Bonsmara differed from that of Angus, Fleckvieh and Non-descript. The Bonsmara cuts were light red while cuts from other genotypes had a darker colour than the Bonsmara.

Hence, the Hue angle (H_{ab}) for the Bonsmara genotype differed significantly ($P<0.05$) from that of Fleckvieh and Angus. Significant Chroma (SI) differences ($P<0.05$) were found between Bonsmara and Non-descript genotypes. The subcutaneous fat colour measured as yellowness (b^*) for C2 carcass classes of the Non-descript genotype differed significantly ($P<0.05$) from C2 carcass classes of all other genotypes. This can be associated with high carotenoid levels in grasses consumed by these animals before being finished in feedlots. Muchenje *et al.* (2008) reported that consumers often perceive meat with yellow fat colour as being from old diseased animals. Although yellow carcass fat is negatively correlated with old diseased cows, Daley *et al.* (2010) reported that yellow fat in carcasses is often associated with healthy fatty acids.

However, the evaluation of fatty acid composition does not form part of the South African classification system. This implies that the consumers still have an incorrect impression on the subcutaneous yellow fat colour and this might lead to incorrect downgrading of meat from animals producing yellow fat carcasses. The SA classification system therefore, needs to recognise the significance of n- 3: n-6 fatty acid ratios. In addition, the pH_{24} of the Non-

descript genotype differed significantly ($P<0.05$) from that of Fleckvieh and Simmental. However, after 24 hours of slaughter all the pH values were >5.8 . High pH values ($\text{pH}>5.8$) 24 hours after slaughter are associated with dark firm and dry meat (DFD) thus the high pH values may have also contributed to the darker C2 carcass cuts across the genotypes.

Furthermore, no significant differences ($P>0.05$) were found in thawing loss (TL %) among all genotypes. The Non-Descript genotype had low CL % ($P<0.05$) compared to all other genotypes. In addition, tenderness (WBSF) of Angus differed significantly ($P<0.05$) from that of Fleckvieh and Non-Descript genotypes. Although according to SAMIC (2006) animals of the same age are presumed to have similar tenderness, the current results show that this is not always the case as many other factors besides age might affect tenderness and one such factor is the genotype. The current study discovered that meat tenderness from the same muscle differed amongst animals of the same age from different genotypes.

The Angus and Simmental genotypes had the toughest meat (40.29 ± 11.62 and 38.71 ± 9.33 , respectively), while the Non-descript and Fleckvieh had tender meat (31.53 ± 12.62 and 32.00 ± 7.92 , respectively) in the current study. These results are similar to those reported by Reuter *et al.* (2002) stating that tenderness varies among animals, genotypes, muscles and cuts. The South African carcass classification system, therefore, needs to adopt the classification system that will measure and rank the meat quality attributes across genotypes. Table 4.3 shows correlation among meat quality attributes of the C2 carcass class.

Table 4. 3: Pearson’s correlation coefficients among the meat quality attributes within the C2 carcass classes from different beef genotypes reared under different feedlot systems.

| | L* | a* | b* | Hue | Chroma | pH₂₄ | TL% | CL% | WBSF |
|------------------------|-----------|-----------|-----------|------------|---------------|------------------------|------------|------------|-------------|
| L* | - | -0.271** | 0.380*** | 0.631*** | -0.004 | -0.196 | 0.284** | -0.051 | -0.080 |
| a* | | - | 0.521*** | -0.205* | 0.917*** | -0.079 | 0.060 | -0.030 | -0.033 |
| b* | | | - | 0.719*** | 0.817*** | -0.206* | 0.298** | -0.089 | -0.059 |
| Hue | | | | - | 0.194 | -0.166 | 0.271** | -0.092 | -0.058 |
| Chroma | | | | | - | -0.151 | 0.184 | -0.068 | -0.058 |
| pH₂₄ | | | | | | - | -0.176 | -0.187 | 0.213* |
| TL% | | | | | | | - | -0.189 | -0.045 |
| CL% | | | | | | | | - | 0.420*** |
| WBSF | | | | | | | | | - |

Correlation significance; * $P < 0.05$, ** $P < 0.01$; *** $P < 0.001$; NS - not significant at $P > 0.05$.

L-lightness; a*- redness- b*-yellowness; H_{ab}- Hue angle; SI-saturation index; pH- meat pH; TL%- Thawing loss percentage; CL%-cooking loss percentage; WBSF- Warner bratzler shear force.

Some meat quality traits did not correlate ($P>0.05$) with CL%, pH and WBSF. However, significant positive correlations ($P<0.001$) were found between tenderness (WBSF) and CL%. Aaslyng *et al.* (2003) reported that changes in meat juiciness are closely associated with CL%, while juiciness is closely associated with tenderness. Thus, the Non-descript genotype which had the lowest CL% (11.41 ± 5.43) had tender meat than other genotypes in the current study. Most significant positive correlations ($P<0.001$) were, however, among the meat colour characteristics such as lightness (L^*), redness (a^*), yellowness (b^*), H_{ab} and SI. According to Webb and Erasmus (2013), “meat colour is not an important eating characteristic but is a major factor in the consumers’ choice”. Thus, the results in the current study show that each colorimetric parameter has an effect on how the other colorimetric parameter in a carcass class appears on the display outlets, and this consequently affects consumers’ purchasing decisions on preferred carcass classes.

4.5. Conclusions

The present study has shown significant differences on quality related characteristics of carcass classes among genotypes of the same age. Significant differences were also observed on age measured as the number of erupted incisors present at slaughter across genotypes. It can therefore, be concluded that, even though the SA classification system indicates that meat tenderness decreases with increasing slaughter age, the current study shows that animals of the same age differ in tenderness depending on genotype. Moreover, meat quality attributes of the C2 carcass class varied from genotype to genotype. Thus, there is a need to assess and rank meat quality attributes in the SA classification system for fair returns to producers and a satisfying eating experience to consumers.

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Chapter 5 General discussion, conclusions and recommendations

5.1. General discussion

The broad objective of the study was to evaluate the classification of beef, mutton and pork carcasses, and to characterise the quality of beef carcasses subjected to the South African classification system. In Chapter 2 the study reviewed the relevance of the formal classification system to the informal sector. Selling of meat through formal markets which include classification at abattoirs was found to be a major challenge in the informal sector which comprises of small-scale and emerging farmers (Musemwa *et al.* 2008; Groenewald and Jooste, 2012). Although marketing ought to play a vital role in the process of transforming small-scale and emerging farmers into commercial farmers, the informal livestock sector was found to face a number of challenges which are related to market access (Musemwa *et al.*, 2007; Murphy, 2012). As a result low market off-take rate was reported in the informal sector (DAFF, 2012).

The low off-take rate in the informal sector was also related to cultural values and poor production systems rather than marketing failures only (Mngomezulu, 2010). Communal farmers were found to produce indigenous breeds which are perceived as having low premium bonuses particularly on cattle (Musemwa *et al.*, 2010). However, indigenous breeds form a bulk of cattle owned by communal farmers. Factors such as selling of older animals, leanness of animals and poor conformation in the informal livestock sector were reported to result in low premium bonuses. Thus it was discovered that there is a major problem to link the informal livestock producers to formal markets, this is mainly because these producers fail to meet the certain standards required in the formal markets, thus the classification

system is not viewed favourable to informal livestock producers as they are less likely to benefit from it.

In Chapter 3 associations between animal traits, carcass traits and carcass classification within cattle, sheep and pigs slaughtered at a high throughput abattoir were determined. Significant associations were found between carcass classes and breeds of all livestock species. This was attributed to the significant breed effects on carcass traits (Chambaz *et al.*, 2003). Almost 70% of cattle carcasses were in the C classes, while in sheep 77% of carcasses were in A2 classes and in pigs, about 50% of carcasses dominated the P class. According to SAMIC (2006) C- class carcasses are the least preferred in the market as they are presumed to be from older animals and thus are less tender. Furthermore, in the PORCUS classification system P-class is mostly preferred in the market. Therefore, pig and sheep producers in the current study produced carcasses which are mostly preferred in the market. However, the prevalence of the C-class carcasses from cattle was attributed to the delayed attainment of the slaughter weight resulting from longer fattening periods in the feedlot systems (Hall *et al.*, 2015).

Moreover, significant associations between sex and carcass classes were only found in cattle. Warm carcass mass (WCM) had significant associations with carcass classes of cattle and sheep only. Knight (2013) reported that heavier animals fetch higher returns due to more muscle than fat resulting in leaner carcasses which are more preferred in the market. However, most farmers in the current study produced animals of low carcass weight. It was, therefore, noted in the study that while associations between carcass classes and breeds were found in all species, associations between sex and carcasses were dependent on species. Since

the dominant carcass classes in sheep and pigs (A2 and P, respectively) are presumed to be of better quality with high consumer preference and market prices in the South African meat industry, further research (Chapter 4) was done to characterise the quality of the dominant beef C2 classes which are often associated with low consumer preferences and market prices. Some quality characteristics (L^* , a^* , b^* , pH_{24} , thawing loss, cooking loss and WBSF) of beef C2 carcass classes from different genotypes with different number of incisors present at slaughter reared from different feedlot systems were therefore evaluated. It was found that although the feedlot system is presumed to be a system that mostly sends animals of the A and AB age categories (Frylinck *et al.*, 2013) contradictory findings were observed in the current study where feedlots were dominated by the C-class animals.

The results were associated with the tendency of feedlot producers to purchase old animals from communal farmers for onward supply to formal abattoirs. These old animals may be below the target market weight due to production challenges besetting communal farmers at the time of purchase in auctions (Musemwa *et al.*, 2008), making fattening in feedlots longer than expected. This consequently resulted in the delayed attainment of the required slaughter weight leading to animals being slaughtered at a mature age and, thus, fetching low C-class premiums. It was also found that there were no significant differences ($P>0.05$) in all meat quality attributes (L^* , a^* , b^* , H_{ab} , SI, pH_{24} , TL%, CL% and WBSF) within the same genotype irrespective of the different number of incisors present at slaughter.

However, significant differences ($P<0.05$) were observed across genotypes in some meat quality attributes (a^* , H_{ab} , pH_{24} , TL%, CL% and WBSF) of beef C2 carcasses. These results concur with the findings by Muchenje *et al.* (2008) that meat quality attributes may vary

depending on breed. Findings from this study provided evidence that there were positive associations between carcass classes and breeds of cattle, sheep and pigs. It was, therefore, concluded that although according to the South African classification system, tenderness decreases with increasing slaughter age, beef steers of the same age differed in tenderness due to the breed effect, thus meat quality attributes within carcasses of the same class also differed across breeds.

5.2. Conclusions

Results from this study showed some variations on meat quality attributes of carcasses falling within the same class due to breed effect. Although according to the SA classification system animals of the same class are presumed to be of the same quality, the current study discovered that meat quality attributes of beef steers falling within the same class and consequently of the same age varied from breed to breed. Hence positive associations were found between carcass classes and breeds of all livestock species.

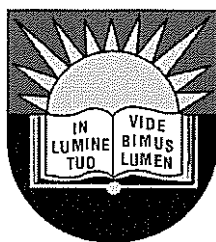
5.3. Recommendations

The current classification system should, therefore, consider ranking meat quality attributes across breeds within the same carcass class for a more accurate quality assurance system. This could provide quality assurance to consumers for the meat they purchase and will also ensure farmers that they are not short-changed by low premiums.

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University of Fort Hare
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ETHICAL CLEARANCE CERTIFICATE
REC-270710-028-RA Level 01

Certificate Reference Number: MUC151SSOJ01

Project title: **Beef, pork, mutton carass classification and meat inspection in the Eastern Cape Province, South Africa**

Nature of Project: Masters

Principal Researcher: Zimkhitha Soji

Supervisor: Prof V Muchenje

Co-supervisor:

On behalf of the University of Fort Hare's Research Ethics Committee (UREC) hereby give ethical approval in respect of the undertakings contained in the *above-mentioned* project and research instrument(s). Should any other instruments be used, these require separate authorization. The Researcher may therefore commence with the research as from the date of this certificate, using the reference number indicated *above*.

Please note that the UREC must be informed immediately of

- Any material change in the conditions or undertakings mentioned in the document
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research

The Principal Researcher must report to the UREC in the prescribed format, where applicable, annually, and at the end of the project, in respect of ethical compliance.

Special conditions: Research that includes children as per the official regulations of the act must take the following into account:

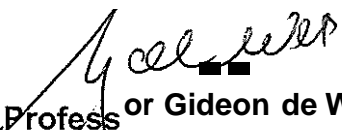
Note: The UREC is aware of the provisions of s71 of the National Health Act 61 of 2003 and that matters pertaining to obtaining the Minister's consent are under discussion and remain unresolved. Nonetheless, as was decided at a meeting between the National Health Research Ethics Committee and stakeholders on 6 June 2013, university ethics committees may continue to grant ethical clearance for research involving children without the Minister's consent, provided that the prescripts of the previous rules have been met. This certificate is granted in terms of this agreement.

The UREC retains the right to

- Withdraw or amend this Ethical Clearance Certificate if
 - o Any unethical principal or practices are revealed or suspected o
 - o Relevant information has been withheld or misrepresented
 - o Regulatory changes of whatsoever nature so require
 - o The conditions contained in the Certificate have not been adhered to
- Request access to any information or data at any time during the course or after completion of the project.
- In addition to the need to comply with the highest level of ethical conduct principle investigators must report back annually as an evaluation and monitoring mechanism on the progress being made by the research. Such a report must be sent to the Dean of Research's office

The Ethics Committee wished you well in your research.

Yours sincerely


Professor Gideon de Wet
Dean of Research

08 June 2015

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*Peer-reviewed Proceedings of the 12th Meat Symposium:
Relevance of the South African Carcass Classification system*

Relevance of the formal red meat classification system to the South African informal livestock sector

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Abstract

In 1992 the South African meat industry was deregulated and this led to the formation of the new Marketing of Agricultural Products Act, Act no. 47 of 1996. The Act made provisions for producers to sell animals to customers of their own choice at mutually agreed prices. Thus, producers in the informal sector took advantage of the free marketing system. The result was a substantial increase in the number of animals slaughtered in the informal sector. Unfortunately the requirements for animal identification are not always observed in this sector. Challenges faced by communal farmers which include the multipurpose roles of livestock, lack of slaughter facilities within reasonable distance and lack of access to market information make them less willing to sell their animals through the formal market. The formal market is characterised by meat inspection and carcass classification which scare away the communal farmers for fear of income loss through animal condemnation. The informal sector might not recognise the importance of formal carcass classification. There is need to direct research and development efforts to address marketing constraints faced by communal farmers, and to promote formal marketing of livestock for meat quality assurance and a fair return to the farmers. This review seeks to assess the relevance of formal classification of red meat carcasses to the informal sector, make recommendations on ways to ameliorate the undesirable effect of the classification system on the informal sector, and identify possible areas which need further research to develop the classification system in South Africa.

Keywords: Communal farmers, marketing system, meat industry

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Introduction

There is an increasing demand for food of animal origin in developing countries of sub-Saharan Africa and this trend is projected to continue for a long time. Consumption of meat has increased worldwide (Thornton, 2010), with highest increases being observed in the developing countries for all meat types (Thornton *et al.*, 2009). Similar trends are being observed in South Africa (Taljaard *et al.*, 2006; Spies, 2011). The population increase, urbanisation, changing lifestyles and consumer preferences associated with increasing disposable incomes as the middle income class increases in South Africa are expected to create market opportunities for small-scale livestock farmers (Scholtz *et al.*, 2008; Thornton *et al.*, 2010; Webb & Casey, 2010).

South Africa is a net importer of mutton, lamb meat and beef as the consumption of these red meat types exceeds supply on the domestic market (DAFF, 2011; DAFF, 2012b). However, it is a net exporter of pork (DAFF, 2011). Coetzee (1998) reported that approximately 1% of the total uptake of goats is slaughtered at commercial abattoirs for distribution to urban retail outlets. This is mainly because most urbanised consumers prefer beef and mutton, while goat meat is mostly consumed during cultural ceremonies. A huge potential, therefore, exists for the small-scale sector to play a significant role in the red meat supply chain. However, for the small-scale farmers to enter the formal market which is characterised by meat inspection and carcass classification they must comply with food safety and quality standards (Mokoena, 2007). This is mainly because the efficacy of formal marketing requires that products must conform to pre-established standards.

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With increased risks of food-borne diseases, changing consumers' tastes and market requirements, strict quality control mechanisms are being put in place along the value chain from "farm to the fork" to aid in animal traceability and to ensure that high quality meat with a long shelf life reaches the consumer (Grunert, 2006; PARSAC, 2012; Govender *et al.*, 2013). Consumers nowadays demand good quality meat which is safe and possesses health promoting attributes (Taljaard *et al.*, 2006; Schollan *et al.*, 2010) due to an increasing awareness of the relationship between their health and diet (Schollan *et al.*, 2010). Attributes used to evaluate meat quality include eating quality, appearance, freshness and nutritional value (Cho *et al.*, 2010). Eating quality is most commonly used when forming an expectation of quality before purchase and for judging quality. It is a combination of tenderness, flavour and juiciness (Cho *et al.*, 2010). However, these characteristics are not visible to the consumer at point of purchase and are highly variable and subjective.

Variation in eating quality, particularly tenderness, is the main concern of consumers with perceived toughness resulting in unacceptable eating quality. Carcass grading schemes estimate saleable meat yield and determine the palatability or eating quality of meat by including parameters such as marbling or intramuscular fat content (Indurain *et al.*, 2009). Marbling which is associated with juiciness, tenderness and palatability, is given high economic value and substantial premiums in beef (Indurain *et al.*, 2009; Burrow & Prayaga, 2004), and is often reflected in carcass grading schemes (Cho *et al.*, 2010). Although the primary function of a carcass quality grading scheme is to segment carcasses into groups with similar palatability attributes, it does not account for differences in eating quality at the consumer level, which are related to cut type and cooking effects (Cho *et al.*, 2010). The South African carcass classification system does not include any measure of meat quality. It has a measure of subcutaneous fat but not intramuscular fat (marbling). This shows that the South African carcass classification system is strongly inclined towards meat sellers and does not attempt to indicate the expected eating quality of the meat of the classified carcasses.

The South African classification system involves the allocation of class codes to carcasses based on the sex (signs of late castration are determined), age (0 teeth = A – very young animal, 1 - 2 teeth = AB – young animal, 3 - 6 teeth = B – old animal and more than 6 teeth = C – very old animal); conformation (1 – very flat, 2 – flat, 3 – medium, 4 – round and 5 – very round); bruising (1 – slight, 2 – moderate, 3 – severe) and fat (0 – no fat, 1 – very lean, 2 – lean, 3 – medium, 4 – fat, 5 – slightly overfat, 6 – extremely overfat) characteristics (Agricultural Products Standard Act, 1990; SAMIC, 2006; Strydom, 2011). The classification system used in the formal sector is not viewed as favourable by communal farmers who shun the formal market as they do not appreciate the benefits of the system. Due to various challenges, communal farmers are less likely to get premium bonuses from these characteristics in the classification.

Challenges besetting communal farmers such as poor nutrition, poor management practices, inadequate knowledge, multiple roles of livestock and not keeping abreast with current technology, affect emerging livestock farmers who are unable to obtain and understand formal market information (Coetzee *et al.*, 2005; Baloyi, 2010). As a result the system is not totally friendly to them as they are less likely to benefit from it. Consequently, they market their livestock through informal channels. In addition, the standards in the formal marketing system have been reported to be perceived negatively by the informal sector (Van de Moosdijk & Schiferli, 2002). Despite the low levels of literacy, limitations to improved technology and communication systems which burden the informal sector, it constitutes a significant component of the agricultural economy and barriers to using the classification system should be identified and removed.

This review seeks to assess the relevance of formal classification of red meat carcasses to the informal sector in relation to the level of confidence that small-scale subsistence farmers and emerging farmers have in the current formal classification system. The review also seeks to make recommendations to relevant stakeholders on ways to ameliorate the undesirable effect of the classification system on the informal sector. Possible areas which need further research to develop the classification system in South Africa are also identified in the review.

Meat production chain in South Africa

The meat production chain in South Africa can be divided into the formal and informal sector. The formal sector comprises of commercial farmers while the informal sector is composed of small-scale subsistence farmers and emerging farmers (Scholtz *et al.*, 2008; Spies & Cloete, 2013). Livestock in the formal sector mainly comes from intensive farming systems for beef, mutton, pigs and poultry (Oliver, 2004). The formal market involves farmers, feedlots/auctions, abattoirs, wholesalers, retailers and consumers (DAFF, 2013a). At the processing level in the formal sector the quality control of livestock production is the responsibility of the Department of Health (Van Zyl *et al.*, 2006). Contrary to the formal sector, livestock in the informal sector is supplied by communal farmers who are located far from the formal market. The informal market includes farmer-to-farmer or farmer-to-consumer and/or farmer-to-unregistered buyer sales. The key players in the informal food chain are communal area farmers, auctioneers, speculators and local

traders, and the quality control in the informal sector is directly dependent on the livestock owner (Van Zyl *et al.*, 2006).

Livestock production in South Africa

In South Africa there are about 38 500 commercial farms and intensive units and an estimated two million communal and emerging farmers involved in livestock production (RMRD SA, 2012; AgriEco, 2013; Meissner *et al.*, 2013). The country has about 13.6 million beef cattle, 24.2 million sheep, 1.13 million pigs and 6.7 million goats, with emerging and communal farmers owning 12% of the sheep (2.95 million), 63% of the goats (4.221 million), 28% of the pigs (316 400) and 41% of the cattle (5.58 million) (RMRD SA, 2012; AgriEco 2013; DAFF, 2013a). For the 2009/10 period, nearly 14.8% of the total gross value of the agricultural sector was contributed by the red meat sector. In the 2012/13 period 10.1% of the total gross value (14.8 %) was from cattle, 2.5% from sheep (DAFF, 2010; DAFF, 2011a) and 2.15% from pigs (DAFF, 2012a; DAFF, 2013a).

Pork production

The South African pork industry is small compared to the beef and chicken industries (Davids *et al.*, 2014). However, it is fairly large in terms of the overall South African agricultural sector as it contributes 2.15% to the primary agricultural sector (DAFF, 2013a). Pigs are owned by 4 000 commercial farmers, 19 stud breeders and about 100 smallholder farmers in South Africa (DAFF, 2011; 2012a; 2013a). The total number of sows is 125 000, of which 100 000 sows belong to the commercial and 25 000 to smallholder farmers (DAFF, 2011; 2012a; 2013a). The average gross value of pigs slaughtered over the past 10 years amounts to R 2.5 billion per annum. It has been further indicated that there was a steady increase in contribution of pork from 2002/3 to 2005/06 and a significant increase from 2006/7 to 2011/2012 to the gross value of agricultural production. This is mainly owing to increases in prices (DAFF, 2013a).

Prices received by farmers have positively influenced the quantity of pork produced. Consequently, in the 2011/2012 season South Africa produced 2.08 million tonnes of pork while the local consumption was only 239 000 tonnes in the same year, making South Africa self-sufficient in pork production (DAFF, 2012a; DAFF 2013a). Pork production, therefore, outstrips local consumption, so that South Africa is a net pork exporter (DAFF, 2011; DAFF, 2012a; DAFF, 2013a).

Beef production

The long-term contribution of the red meat sector and beef to the total gross value of agricultural production in South Africa from 1996/97 to 2008/2009 stood at 13.2% and 9.4%, respectively (Spies, 2011). Local demand for beef still outstrips local supply. The beef supplied by the two farming sectors meets only 85% of the beef requirements in South Africa, leaving a deficit of about 15% which is catered for through imports, making South Africa a net importer of beef (DAFF, 2011). More than 70% of all beef slaughtered in the formal sector in South Africa originates from commercial feedlots, where 67% of the feedlot animals are either crossbreeds or British and European imported breeds (53%) (Scholtz *et al.*, 2008). The trends of beef production have been reported to be similar to those of mutton and lamb.

Mutton production

There are about 24.2 million sheep in South Africa, which are raised by approximately 8 000 commercial and 5 800 communal farmers, with mutton having an average gross production value of R 3.9 billion per annum (DAFF, 2013b). The sheep breeds that are normally raised are the Dorper, which is commonly produced in arid areas and bred for mutton due to its good carcass conformation and fat, and the dual purpose breeds (mutton and wool), Damara, Meatmaster, Suffolk and Dormer (DAFF, 2012b). The industry experiences a growing demand for mutton which cannot be matched by local production. This has resulted in the country importing mutton to meet domestic demand and consequently being a net importer of mutton. Apart from not being able to meet domestic demand, the mutton industry faces other challenges such as veterinary and traceability issues, noncompliance by some abattoirs to Health and Safety Acts, predation and theft (DAFF, 2013b).

Goat production

There are about 6.6 million goats in South Africa (De Villiers *et al.*, 2009). Sixty-three percent of these animals are indigenous goats that are owned by communal area farmers and the remaining 27% percent are mainly Boer and Angora breeds that are reared by commercial farmers (DAFF, 2013d). Only 5.5% of the goats are sold and slaughtered in the formal sector, while the majority of the sales are conducted on an informal basis in the communal areas, often leading to traditional slaughter for religious ceremonies (DAFF,

2012c). Traders and speculators are the major drivers of transactions involving indigenous goats that occur in the informal sector (DAFF, 2013d).

Livestock production in the informal sector

In 1992, the South Africa meat industry was deregulated. After deregulation, new legislation including the Marketing of Agricultural Products Act (Act No. 47 of 1996) makes provisions that allow meat producers to sell their products to customers of their choice at mutually agreed prices. The legislation resulted in a surge in the informal sector leading to the sale of livestock through informal channels in South Africa. The emerging livestock farmers subsequently took advantage of the free marketing system. Van de Moosdijk & Schieferli (2002) advocated that all livestock should conform to the regulations on animal identification for traceability purposes. Unfortunately, the informal sector has not taken heed of this recommendation due to various reasons for keeping livestock and the free marketing system which enables them to ignore the regulations.

Reasons for keeping livestock in the informal sector

Several studies have reported that income generation is the main reason for livestock keeping in the smallholder farming sector in South Africa (Musemwa *et al.*, 2007; Mapiye *et al.*, 2009b; Tada *et al.*, 2012). Other reasons for livestock keeping include household animal protein supply (consumption), "live banks" for immediate cash needs, draught power provision, milk, manure and use of livestock in traditional ceremonies such as weddings, funerals, appeasement of ancestral spirits and as bride price (lobola) (Mngomezulu, 2010). Fifty-nine percent of farmers reported income generation as the main reason for keeping cattle while 26% of farmers reported that they keep cattle mainly for family consumption (meat and milk) (Musemwa *et al.*, 2008). These are the reasons most communal farmers are less inclined to sell their livestock by means of formal marketing.

Livestock marketing

Various marketing channels are used to market livestock in South Africa, although they can be broadly categorised into informal and formal channels (Musemwa *et al.*, 2007) as illustrated in Figures 1 and 2.

Formal livestock marketing channels

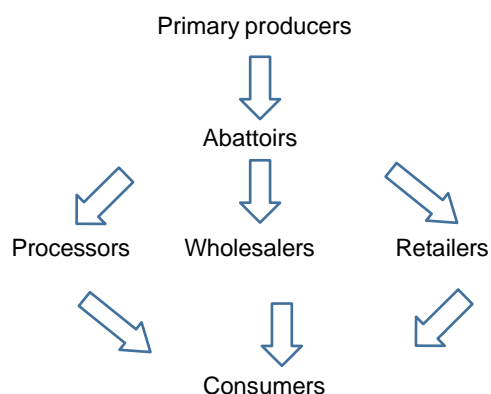


Figure 1 Formal marketing channels of livestock in South Africa.

Meat in the formal livestock sector is supplied mainly by commercial farmers. When animals reach the desired market weight, they are taken to abattoirs where quality assurance schemes comprising of carcass classification and meat inspection take place. From the abattoirs the meat is then marketed to wholesalers, retailers, processors or butcheries. The consumers can then buy from all these marketing channels.

Informal livestock marketing channels

According to Musemwa *et al.* (2008) and Groenewald & Jooste (2012), smallholder farmers sell their livestock through informal markets to speculators and at auctions. The elderly and uneducated farmers prefer to sell their livestock through private sales to neighbours and relatives, while the younger farmers with at least secondary level education use private sales, auctions, abattoirs and speculators (Musemwa *et al.*, 2008). The prices are determined on mutually based visual appraisal or live weight. The major shortcomings

of the informal markets are seasonality of the markets, poor market information on both prices and the quality required (Groenewald & Jooste, 2012). As a result, farmers often sell their livestock below market value, especially, to speculators, due to bad timing and a weak bargaining position (Groenewald & Jooste, 2012).

Furthermore, the multiple roles of livestock have both positive and negative effects on the off-take rate in smallholder farming communities. On one hand, they provide an easy route with low transaction costs to the livestock producers as they do not need to transport the livestock to distant markets (Musemwa *et al.*, 2008). On the other hand, the local buyers in the form of neighbours and relatives have low purchasing power and, therefore, offer prices below the actual value of the animals being sold, while speculators take advantage of the lack of market information to short change the farmers. When farmers are in a precarious position due to pressing cash needs, they end up being price takers and hence sell off their animals from a position of low bargaining power.

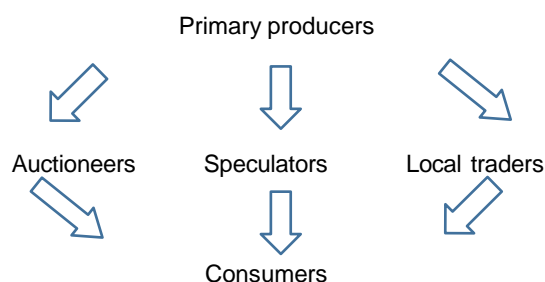


Figure 2 Informal marketing channels of livestock in South Africa.

Incentives to formal classification system

Historically, consumers have not been allowed to purchase meat directly from abattoirs and this resulted in an unwarranted increase in number of players in the meat distribution chain (Mitchell, 2014). The increase in the size of the distribution chain and the decline of face-to-face purchasing in the meat industry resulted in the need for carcass description (Mitchell, 2014). This was mainly because customers were unable to see the carcass before purchasing, thus they required a system that would describe the origin of the meat cuts in terms of carcass descriptions. The carcass description that is used in the formal meat value chain in South Africa is the carcass classification system. Strydom (2011) stated that the carcass classification system describes the quality and meat yield that benefit traders and consumers. Carcass classification is used to predict the amount of saleable meat from the carcass. As a classification system, it needs to be accurate, simple to apply, cheap and should be verifiable (Strydom, 2011).

Classification at abattoir level

The Meat Safety Act, 2000 (Act No of 40 of 2000) prohibits the slaughter of animals at any other place than approved abattoirs for the purpose of obtaining meat that is suitable for human and animal consumption. The only exception is for meat that is intended for own consumption. Approved abattoirs operate on the basis of valid registration certificates as proof that they meet certain requirements relating to structure and layout. Such abattoirs are required to have qualified meat inspectors and classifiers and are also regularly inspected to ensure that they meet hygiene requirements by removal of sick, infected and contaminated meat and animal products from the food chain. There are approximately 495 abattoirs in South Africa, grouped into five classes (A, B, C, D and E), depending on the number of animals they slaughter (DAFF, 2013b).

Abattoirs in classes A and B are highly regulated and slaughter close to 60% of the cattle. Class A-abattoirs have no limit on the number of animals, thus they can slaughter 100 slaughter units and more per day and are responsible for up to 40% of all slaughters. Class B-abattoirs slaughter up to 100 slaughter units/day, class C-abattoirs can slaughter up to 50 slaughter units/day, class D-abattoirs up to 15 slaughter units per day and class E-abattoirs up to 8 slaughter units per day (Agricultural Product standards Act, No.119 of 1990) or (classification and marking of meat). Class A- and B-abattoirs are highly controlled (regulated) and are linked to feedlots (DAFF, 2012a). The primary processing work is done at abattoirs and includes removal of the hides and quartering of the whole carcass. It is in these abattoirs that classification of carcasses should start. Butchers, hotels and supermarket then process the meat into different retail food commodities.

Techniques of carcass classification

Meat 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 (AHDB, 2008). It is a process which begins with meat inspection (MI) and covers a wider action involving carcass classification which is the allocation of a class code to carcasses, allowing a consumer to select a carcass according to his/her own preferences (KZN DAEA, 2005). Unlike carcass grading systems, carcass class codes do not imply that a carcass in one class is more or less desirable than a carcass in any other class (KZN DAEA, 2005).

The classification system for red meat from cattle, sheep and goats in South Africa is based on five physical characteristics comprising of age, fatness, conformation, damage and sex (RMIF, 2013). The assessment is based on visual appraisal by trained meat classifiers who are audited on a regular basis (Strydom *et al.*, 2005; South African Meat Industry Company, 2006). As indicated by Strydom (2008), the uptake of the broad and well-intended objectives of the classification systems will depend on factors such as:

- Accuracy – where applied science will enable consistency in grouping of beef carcasses;
- Simplicity – where all segments of the industry understand how the system works;
- Ease of application – quick and easy implemented online or before the carcass is sold;
- Cost – use of simple inexpensive equipment;
- Measures against tampering – ability to verify correctness of class awarded and that the class should not be subject to change once awarded.

The following sections describe the carcass classification systems that are used in the pork, mutton, goat and beef formal sectors:

Pork carcass classification

Pig carcasses are assessed using the PORCUS classification system, as shown in Table 1, where fatness, conformation, damage and sex are the main characteristics (DOA, 2006). Fat content assessment is carried out using the Hennessey classification apparatus. Age is, however, not considered in pork classification (DOA, 2006).

Table 1 Pork classification system

| Class | Calculated % meat of carcass | Fat thickness measured by means of an intrascope (mm) |
|--------------|------------------------------|---|
| Suckling pig | * | ** |
| P | ≥70 | ≤12 |
| O | 68 - 69 | 13 - 7 |
| R | 66 - 7 | 18 - 2 |
| C | 64 - 5 | 23 - 7 |
| U | 62 - 3 | 28 - 2 |
| S | ≤61 | >32 |
| Sausage pig | * | ** |
| Rough pig | * | ** |

Source: Department of Agriculture, 2006.

In the pork classification system specifications, neither meat percentage (%) nor fat thickness applies for the three classes: suckling, sausage and rough pig. Pigs that fall in the PORCUS-classes are the ones that are classified. The percentage of meat is measured between the second and third rib, 45 mm from the carcass midline (SAMIC, 2006).

Beef, mutton and chevon classification

Beef, mutton and chevon (goat slaughtered shortly after weaning) carcasses that are sold through the formal marketing system undergo a similar carcass classification that is based on age of the animal, fat content, conformation, bruises or damage to the carcass and sex of the animal (Agricultural Product Standards Act, No 119 of 1990). However, the Red Meat Industry Forum in South Africa has indicated that

among these five physical characteristics the most significant characteristics during meat purchasing are age and fatness. With regard to animal sex, the major concern is the better taste of castrated male animals and most farmers castrate their animals due to higher prices they get from castrated animals (RMIF, 2013).

Age, conformation, damage and sex classification

The South African classification system classifies beef, mutton and chevon carcass maturity based on dentition alone and excludes ossification. According to Lawrence *et al.* (2001), dentition better describes the age of the animals across breeds and the level of nutrition compared to bone ossification. Strydom (2011) highlighted that age measured by dentition is the only component in the South African classification system that has a bearing on quality attributes of a carcass, for example tenderness. The United States Department of Agriculture (1992) has a different classification system for age that is based on muscular and skeletal development. Under the USDA (1992) system, the age of sheep is determined by assessing the joint structure on one or two front cannon bone.

Furthermore, classification simply groups carcasses into consumer preference categories which do not necessarily imply that the one is better than the other. Table 2 shows specific age, sex, damage and conformation classification for beef, mutton and chevon.

Table 2 Carcass classification of beef, mutton and chevon based on age, conformation, damage and sex

| Characteristic | Class | Class description | Comment |
|----------------|-------|---|---|
| Age | A | No permanent incisors | Carcass whose head is not available for determination of age is deemed to be in class C |
| | AB | At least one but not more than two permanent incisor teeth | |
| | B | Has at least three but not more than six permanent incisors | |
| | C | Has more than six permanent incisors | |
| Conformation | 1 | Very flat | |
| | 2 | Flat | |
| | 3 | Medium | |
| | 4 | Round | |
| | 5 | Very round | |
| Damage | 0 | Undamaged | Classification considers damage in relation to locality, extent and depth of damage plus fat to meat to bone ratio |
| | 1 | Disturbed to a slight extent | |
| | 2 | Moderately disturbed | |
| | 3 | Is severely disturbed | |
| Sex | | | The carcass of a ram or a bull as well as of a *hamel, a *kapater or an ox showing signs of late castration of the A-, AB-, B- or C-age classes, are identified |

* "hamel" and "kapater" refer to castrated male sheep and goats, respectively.

Fat classification

Fat is said to be an unpopular component of meat for consumers in many countries as it is considered unhealthy (Wood *et al.*, 2008). Despite this, fat and fatty acids whether in muscle or adipose tissue, make a significant contribution to various aspects of meat quality such as juiciness, and are fundamental to the nutritional value of meat (Wood *et al.*, 2008). Intramuscular fat content (marbling) is considered a better parameter with regards to juiciness, tenderness and flavour and is often included in carcass grading systems. Marbling has been shown to influence consumer purchasing behaviour at the retail level, with consumers preferring lean to medium marbling rather than marbled cuts. In the case of the South African classification system, only the subcutaneous fat classification is used. As shown in Tables 3 the scoring of

the fat class differs slightly across the two types of meat, but no scores are given for chevon in the South African classification system.

Table 3 Beef and mutton carcass classification on fatness

| Characteristic Fat content | Fatness class | Beef | | Mutton | |
|-------------------------------|------------------|------------------------|-----------------|------------------------|------------------|
| | | Carcass description | Comment | Carcass description | Comment |
| No fat | 0 | Nil | SF < 1 | Nil | SF < 1 |
| Very lean | 1 | SF < 1 | 1 ≤ SF ≤ 3.6 | SF < 1 | 1 ≤ SF < 5.6 |
| Lean | 2 | 1 < SF ≤ 3 | 3.6 < SF ≤ 5.6 | 1 ≤ SF ≤ 4 | 5.6 ≤ SF ≤ 8.6 |
| Medium | 3 | 3 < SF ≤ 5 | 5.6 < SF ≤ 7.6 | 4 < SF ≤ 7 | 8.6 < SF ≤ 11.6 |
| Fat | 4 | 5 < SF ≤ 7 | 7.6 < SF ≤ 9.6 | 7 < SF ≤ 9 | 11.6 < SF ≤ 14.6 |
| Slightly over fat | 5 | 7 < SF ≤ 10 | 9.6 < SF ≤ 11.7 | 9 < SF ≤ 11 | 14.6 < SF ≤ 17.6 |
| Excessively overfat | 6 | 10 < SF | 11.7 < SF | 11 < SF | 17.6 < SF |

SF: subcutaneous fat thickness (mm).

Regarding the health-related aspects of fat, meat quality evaluations have been taken further to determine the proportions of n-3 : n-6 in the fat depot (Wood *et al.*, 2003). n-3 fatty acids are considered healthier than n-6 fatty acids (Wood *et al.*, 2008). Feedlot finished animals tend to contain more n-6 than n-3, while veld finished animals are found to have more n-3 than n-6 fatty acids (Wood *et al.*, 2003). This evaluation of type of fatty acids in the fat depot does not form part of the South African classification system, so that animals both from feedlots and veld finished systems are marketed in the formal channel. Most smallholder farmers finish their animals off veld and stand to benefit from a carcass classification system that recognises the importance of the ratio of n-3 and n-6 in the meat.

Significance of a formal classification system

Consumer perception of meat quality is changing due to improved education and awareness of the relationship between health and nutrition. Consumer demands are changing as the public now find it more beneficial to improve health-related aspects through diet. Nowadays, consumers demand more information about product quality (Grunert, 2006). Credence quality is also important to consumers regarding rising concern about safety, health, convenience, locality and ethical factors (Warriss, 2000). According to Bernués *et al.* (2003), providing consumers with information on quality characteristics of the product enables them to evaluate quality during the process of making purchasing decisions.

A meat supplier must understand consumer demands, tangible and intangible relating to meat quality and incorporate them into the product and process characteristics in order to satisfy these demands (Bernués *et al.*, 2003). For instance, the red meat sector, especially the beef sector, faces challenges relating to meat safety due to disease outbreaks. Meat quality is due to variability in attributes such as tenderness and meat colour as a range of different breeds are used in a wide range of production systems from veld finished to feedlot grain finished animals, which is also a challenge. Lack of consumer-oriented communication from the industry has been cited as one of the main problems of the meat sector. Meeting consumer expectations of quality and supplying them with reliable, impartial information will enable the meat industry to stay in business or to expand (Bernués *et al.*, 2003). The consumer decision process is affected by properties of the food supplied by the industry, factors related to the consumer and the environment.

The red meat classification system in South Africa and in most countries with recognised classification systems is applied on a voluntary basis in licensed registered slaughter facilities due to deregulation of the meat industry (NDA, 2010). Although carcass classification is being applied on a voluntary basis, most retailers and wholesalers prefer classified meat as a guarantee of product safety and quality in line with consumer demands (AHDB, 2008).

In South Africa, animal carcasses are only subjected to classification on the slaughter floor with no quality indication or value attached to the classification (Strydom, 2011). This is similar to the European Grid System (Strydom, 2011). However, in the Canadian, Japanese, South Korean, USA and Australian systems there are further assessments at the chiller stage of meat quality attributes such as marbling score, meat

colour, meat texture, fat colour, fat thickness and skeletal development (Strydom, 2011). These give an indication of the meat quality and expected eating quality to both the retailer and the consumers.

Benefits of the classification system

According to SAMIC, a classification system for red meat serves four roles, namely:

- It provides a platform for meat traders to describe their requirements when purchasing carcasses;
- It creates variety in the market with the intention of optimising consumer satisfaction;
- It enables use of price differentials;
- It is used in determining selling prices for carcasses and cuts.

A well-designed classification system is very informative and very useful to all stakeholders in the meat value chain. A classification system is designed to provide a trading platform for stakeholders in the meat value chain where they communicate using the same language (Strydom, 2011). It gives vital information through a feedback system to farmers about the type of animals they should rear to meet the requirements of consumers. It encourages producers to improve livestock performance through use of premiums for carcasses that meet the requirements of consumers and discourage supply of livestock that has a low demand or is of poor standard (Strydom, 2011). As such, it also creates a platform for consumers to make known their demands and preferences (Strydom, 2011; Mitchell, 2014).

Classification systems are tied to pricing systems for carcasses and meat and, therefore, assist producers and statutory bodies to trade efficiently and more transparently (Strydom, 2011). Carcass classification has a direct relationship to saleable meat yield (AHDB, 2008). Therefore, it can promote labelling or marking of classification information to the point of sale for branding purposes, or as quality assurance (Strydom, 2011). Hence, carcass classification systems are being developed continually to serve the purpose of facilitating trading of a very heterogeneous meat product by means of simple and universally understood language to describe the quality and yield of a carcass. This results in economic benefits for all role players in the production chain, from producer to meat trader, ultimately meeting consumer expectations and providing satisfaction.

Applicability of the formal classification system to the informal livestock sector

The quality and value of animals to be marketed are determined by physical characteristics in the classification system. However, basic procedures such as carcass classification are not practiced by the informal sector yet they are supposed to act as feedback mechanisms to the traders and farmers as well as guarantee quality to the consumers.

The FAO (2000) indicated that in the informal food chain, meat is mostly supplied by communal farmers. The quality and value of carcasses depend on the physical characteristics of the animals, though it is commonly known that animals from communal farmers might not possess the desired characteristics. This is mainly owing to some challenges that impede the implementation of the formal carcass classification in the informal sector. As a result farmers would rather opt for the informal market where considerations such as selling of animals which provide carcasses of good conformation, less bruising, lean meat, no signs of late castration and selling of young animals do not apply.

Abattoirs are, therefore, not popular marketing channels in the informal sector. Young, educated small-scale farmers were, however, found to prefer selling their livestock through abattoirs and auctions rather than through private sales and speculators (Musemwa *et al.*, 2008), although the proportion of such farmers is low (6%). On the other hand, most of the older small-scale or communal farmers, who are the majority of small-scale and communal farmers, have a low level of education and tend to mistrust the classification system and shun abattoirs as a result (Musemwa *et al.*, 2008; Tada *et al.*, 2012). It would, therefore, be difficult for them to adopt the red meat classification system if most or all of the above concerns are not addressed.

Challenges that may impede implementation of the formal carcass classification in the informal sector

The informal sector has unique attributes that might hamper the participants from appreciating the importance of formal carcass classification. In the communal setting, livestock perform multiple roles such as provision of draught power, milk, manure, use at traditional ceremonies, payment of dowry and are a form of "live bank" (Musemwa *et al.*, 2007). The animals normally realise a terminal value for meat or are sold at mature age. Off-take is thus usually low, ranging from between 5% to 10% (Nkhoru, 2004). Sales are not planned and livestock are either sold at an old age or when the need for cash arises (Mngomezulu, 2010). Unfortunately, the formal sector classifies carcasses of livestock that are sold at an old age as class C, their

conformation tends to be flat and they attract discounted prices. Musemwa *et al.* (2010) reported that communal farmers shunned formal markets for fear of having their cattle condemned.

Apart from age at time of sale, the pricing system in the formal market is not favourable for indigenous animals, the majority of which have a compact body (Musemwa *et al.*, 2010) and would not compete well on body conformation which is one of the formal classification criteria. Other constraints that limit the informal livestock producers' market include the slow maturing rate of indigenous breeds, poor nutrition, poor health management, marketing challenges, low levels of management (Spies, 2011; Spies & Cloete, 2013), poor quality of animals produced, poor performance of herds, inconsistency production, poor pasture management, elevated feed prices and production costs (Spies & Cloete, 2013). Coetzee *et al.* (2005) indicated five main marketing limitations faced by small-scale farmers in South Africa which were confirmed by Spies (2011) in the Free State Province. The limitations include poor condition of livestock, lack of marketing information, the unwillingness and inability to adopt livestock identification practices, lack of infrastructure and poor production and marketing management (Spies & Cloete, 2013). These limitations drive informal livestock producers away from the formal market which is inclusive of the classification system. Some of the challenges impeding the implementation of the formal classification system are further discussed below.

Effect of low level of management on carcass classification parameters

The majority of communal farmers keep indigenous rather than exotic breeds (Musemwa *et al.*, 2010). The indigenous breeds of livestock have low growth rates and are slow maturing. Popular beef breeds mostly found in cattle ranches of South Africa include the indigenous Nguni and Afrikaner and locally developed Bonsmara (Muchenje, 2007). Animals such as the Nguni do not have excellent carcass conformation and thus communal farmers are not likely to get a bonus for carcass conformation (Muchenje *et al.*, 2008a; b). As a result farmers would rather opt for the informal sector where such a consideration is not so important. Polkinghorne *et al.* (2008) reported a decrease in palatability scores with increase in the level of the slow maturing *B. indicus* genes in cattle. The combined effects of slow maturing breeds and poor nutrition on small-scale subsistence and emerging farmers result in animals being marketed or slaughtered at a mature age, which are normally classified as C-class. Age plays an important role in determining meat tenderness and farmers get premium bonuses for meat from young animals (DAFF, 2011). The C-class carcasses have been reported to fetch lower prices per kilogram sold (Polkinghorne *et al.*, 2008). Fishell *et al.* (1987) reported that meat from fast growing livestock was more tender compared to meat from slow maturing ones.

Cattle in the small-scale sector are sometimes used for draught purposes and are given less time during the day to forage and recover from work and thus become lean. In the case of fatness, farmers get premium bonuses for carcasses that are not too lean or not too fat. The FAO (2000) indicated that animals that are very lean or excessively fat fetch lower prices per kilogram in the formal classification system. In addition, poor management practices by communal farmers often result in the sale of animals that are poorly castrated or are castrated late, and are consequently classified as bull carcasses that are in low demand, and are poorly priced (DAFF, 2013c). Some of these animals are in poor health and at risk of being condemned at abattoirs (Dupuy *et al.*, 2014; Stärk *et al.*, 2014). Despite this, castrated male animals are sold for higher prices than non-castrated animals that are bruised during handling and transport which consequently results in financial losses to farmers (RMIF, 2013). These limitations, therefore, further drive communal farmers away from formal marketing to informal marketing channels.

Price determination

The informal market appears attractive to most communal and emerging farmers because animals are sold at prices which are negotiated and mutually agreed upon by both buyer and seller. In addition, the sale of the product is convenient with no added costs such as transportation or commissions (Musemwa *et al.*, 2010). On the other hand, getting animals ready for the market in the formal sector involves preparations, which range from additional feeding or fattening and restraining of animals (Smith *et al.*, 2004). It also encompasses transportation costs, handling of animals when loading and off-loading from vehicles (Tarrant & Grandin, 2000), which reduce the margins realised per animal sold (Musemwa *et al.*, 2008). These additional requirements discourage the communal or emerging farmer from participating in the formal market. Injuries of animals that may occur during transportation from the farm to the slaughter facility lead to downgrading or condemnation of carcasses (Grandin, 2000) and in worse cases the dead on arrival (DOAs) carcasses cause heavy financial loss to farmers.

Multi-purpose nature and traditional use of livestock

Contrary to the formal sector, livestock in the informal sector are usually kept for their multi-purpose roles. They are the main suppliers for milk, meat, hides, horns, are used during religious or traditional ceremonies, to pay dowries or are kept as a form of savings (Van Zyl *et al.*, 2006; Dovie *et al.*, 2006; Simela *et al.*, 2006; Musemwa *et al.*, 2010). Animals such as cattle also provide dung which is used as manure for soil fertilisation, and provide draught power for crop cultivation and transportation of goods in communal areas (Shackleton *et al.*, 1999; Bayer *et al.*, 2004). The multipurpose contribution of livestock to rural livelihoods makes producers reluctant to market their animals through abattoirs (Musemwa *et al.*, 2010). Animals intended for traditional ritual are not inspected nor slaughtered at an abattoir for purposes of classification but are rather killed in a ritual that follows the intended purpose of the ceremony. This further encourages the communal and emerging farmers to sell animals through the informal sector as livestock that are sold for traditional or religious ceremony usually attract a premium price in this sector. There is usually a high demand for animals for traditional slaughter and farmers make significant profit through this marketing channel and thus shun the formal marketing channel (Mngomezulu, 2010).

Availability of marketing channels

In terms of cattle ownership, individual households own small herds. The herd size ranges from as low as seven animals per household in the communal sector to 24 head of cattle per household in the small-scale commercial sector (Musemwa *et al.*, 2007; Mapiye *et al.*, 2009a), limiting their ability to sell animals for a regular income. Jooste (2001) found small-scale farmers to be in a precarious market position, which, because of their small number of livestock, cannot attract buyers to their farms. The small-scale farmers end up selling their animals through local informal marketing channels that sometimes have low purchasing power that do not recoup the appropriate value for their livestock (Nkosi & Kirsten, 1993; Musemwa *et al.*, 2010). Transport costs when selling few animals to abattoirs would be too high to justify their return. Therefore, farmers resort to selling to local buyers in the informal market (Mapiye *et al.*, 2009a; Musemwa *et al.*, 2010).

Communal farmers are further challenged by the absence of infrastructures (livestock auction sale pens, loading and offloading ramps and road networks) and lack of institutional marketing arrangements (lack of marketing agents/organisers, lack of marketing information) when they want to market their animals (Musemwa *et al.*, 2007; Murphy, 2012). These challenges result in small-scale producers selling livestock through the informal channel at prices which are mutually agreed upon by the buyer and the seller, where key players are local traders (Van Zyl *et al.*, 2006), and the marketing is convenient with no added transportation or commission costs. The communal farmers might, therefore, need plenty of incentive and encouragement to pursue formal markets that have a lot of challenges and classification systems that are not aligned to the multi-objective nature of their production systems. Musemwa *et al.* (2008) laments the lack of research and paucity of development strategies that are aimed at identifying and addressing marketing problems faced by communal farmers, and the need to find niche markets for them. Making use of marketing channels that provide best cattle prices which provide high returns remains a challenge in communal farming (Mngomezulu, 2010). There is scope, however, for small-scale farmers to use formal markets, for example Vimiso & Muchenje (2013) observed that the majority of slaughters that were performed at a small abattoir were of cattle brought on the hoof from communal farmers within its vicinity.

Conclusion and recommendations

The livestock sector is a very important component of the economy in South Africa as over 65% of the country is suitable for extensive farming. A significant proportion of the livestock (cattle, sheep, goats and pigs) are owned by communal and small-scale emerging farmers who play a very insignificant role in the informal sector. The off-take rate from the informal sector is very low but it has a huge potential to participate in the formal meat supply chain. However, members of the informal livestock sector perceive their profitability being adversely affected by the standard abattoir meat classification system. Challenges relating to absence of infrastructure and slaughter facilities in their vicinity, problems of shortage of feed, lack of access to veterinary health care support all affect the condition of the livestock from this sector resulting in their livestock being downgraded and consequently not fetching premium prices. As an alternative, farmers resort to selling their livestock through informal markets and risk introducing contaminated or sick animals not fit for human consumption into the food chain. Consequently, consumers may buy meat which is either unsafe to their health or of poor quality from such market channels. It was, therefore, concluded that the informal sector has characteristics that hamper appreciation of the importance of formal carcass classification. Research and development efforts must address marketing constraints faced by communal farmers as well as promoting formal marketing of livestock in this sector to ensure supply of safe meat and profitability to communal livestock farmers. It is also recommended that the classification system takes into consideration

the ranking of carcasses according to meat quality attributes for quality assurance both to farmers for the carcasses they produce and to consumers for the meat they purchase.

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Associations between animal traits, carcass traits and carcass classification in a selected abattoir in the Eastern Cape Province, South Africa

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Abstract

In this study the associations between animal traits, carcass traits and carcass classification within cattle, sheep and pigs slaughtered in a high throughput abattoir were determined. Classes of carcasses from cattle, sheep and pigs delivered for slaughter at this abattoir were recorded and analysed. Significant associations were found between carcass classes and breeds of all livestock species. Of all the cattle delivered to the abattoir, the non-descript ones dominated the AB2 category while the Bonsmara and Brahman dominated the C categories. Almost 70% of carcasses of the cattle delivered to the abattoir were in the C classes. In the sheep, the dominant category was A2 with a percentage of 77%, and the Dorper was the most dominant in this category. In pigs, the P class was the most dominant with about 50%, and the Duroc X Landrace cross dominated this category. However, significant associations between sex and carcass classes were only found in cattle. Warm carcass mass had significant associations with carcass classes of cattle and sheep only. It can be concluded that while associations between carcass classes and breeds were found in all species, associations between sex and carcasses were dependent on species.

Keywords: Livestock breeds, sex, warm carcass mass

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Introduction

The carcass classification system was established in most meat producing countries in the early to middle 1900s (Strydom, 2011). It involves the allocation of a class code to carcasses, allowing consumers to select a carcass according to their own preferences (KZN DAEA, 2005). Fisher (2007) indicated that the classification system provides the advantage of having a common language to describe carcasses within a country thus improving marketing efficiency and transparency. Strydom (2011) reported that carcass classification systems are intended to describe the quality and meat yield of carcasses to the benefit of traders and consumers. However, it was further concluded that the criteria used in the classification systems gave limited descriptions of the quality related characteristics of the carcasses. This is mainly because the system only describes scores and measurements but does not allocate rank according to carcass quality (Strydom, 2011).

In South Africa for instance, data recorded for beef, mutton and pork classification includes scores for conformation with classes (1 – very flat, 2 – flat, 3 – medium, 4 – round and 5 – very round), fatness (0 – no fat, 1 – very lean, 2 – lean, 3 – medium, 4 – fat, 5 – slightly overfat and 6 – extremely overfat), sex (the carcass of a ram or a bull as well as of a hamel, a kapater or an ox showing signs of late castration of the AB-, B- or C-age classes are identified), bruising (1 – slight, 2 – moderate and 3 – severe) and age (0 teeth – A, 1–2 teeth – AB, 3–6 teeth – B, more than 6 teeth – C). Age is, however, not considered in pork classification (SAMIC, 2006). These traits are based on visual examination of carcasses, with the only exception being the measurement of the subcutaneous fat on pig carcasses where a Hennessy grading apparatus is used (SAMIC, 2006).

Consumers on the other hand have strong preferences in relation to meat quality. They prefer the meat they consume to be tender, juicy, of good flavour, colour, aroma and to be safe and of good quality (Curtis *et al.*, 2006). These characteristics are not visible to the consumer at the point of purchase and yet they tend to be neglected in the classification system. At present the point of contention in relation to the

classification system is that quality is not ranked and consumers are not able to do this for themselves in retail outlets. If possible it would also provide quality assurance for different carcass classes.

According to a report by the Red Meat Industry Forum (RMIF) (2013), age and fatness are the most significant characteristics used in the classification system. The Food and Agriculture Organization (FAO, 2001) also indicated that body conformation might not have a direct impact on meat quality as it is only important when consumers want to select cuts based on preferences linked to the meat-to-bone ratio. Moreover, the main concerns associated with the sex characteristic are the higher prices that castrated male animals fetch, the better taste of their meat and the high fat content (FAO, 2000). Furthermore a study by Destefanis *et al.* (2003) proved that castration induces higher fat deposition and lower water content in muscle. Litwinczuk *et al.* (2006) and Zhang *et al.* (2006) reported that meat from heifers has significantly higher fat content than meat from bulls. It has also been reported that meat from intact males and castrated males have higher protein and ash contents than females, with intact males also having higher muscle development than castrated males. Nonetheless, they have lower fat deposition than castrated males. It has been indicated that the damage characteristic in the classification system is only used when part of the carcass contains bruises after slaughtering and the specific part is usually trimmed off (RMIF, 2013). However, the appearance of the untrimmed parts of a damaged carcass can deteriorate and serve as a growth medium for microorganisms causing the meat to spoil more rapidly than normal (Adziety, 2011). According to the FAO (2001), spoiled meat develops colour change, off-smells, rancidity and slime which can make consumers ill.

Although the classification system allocates scores on the extremes of these characteristics (age, sex, bruising, fat and conformation) it does not rank for the quality to be expected from each of the carcass classes exhibiting such extremes. This can prove problematic for consumers because they do not know what type of quality they are paying for in a specific class. Moreover animal traits such as breed are not included in the classification system. Breed has been proven to affect carcass and meat quality (Juárez *et al.*, 2009). In addition, carcass traits such as warm carcass mass (WCM) are significant for the determination of lean and fat carcasses through dressing percentage (Knight, 2013). This therefore suggests that associations should be tested between animal traits such as breed, carcass traits such as warm carcass mass (WCM) and carcass classes in the classification system. The objective of this study was, therefore, to determine the associations between animal traits, carcass traits and carcass classes within cattle, sheep and pigs that were slaughtered in a high throughput abattoir.

Materials and Methods

The study was conducted at a selected high throughput abattoir in the Eastern Cape Province of South Africa. The abattoir slaughters up to 1000 livestock units per day. Data was collected from 100 cattle, 100 sheep and 100 pigs that were slaughtered within a week, but on different days at this abattoir. Six cattle breeds (Bonsmara, Brahman, Simmental, Friesland, Jersey and non-descript), three different sheep breeds (Dorper, Blackhead Persian and Merino) and two pig breeds (Duroc X Large White (DuroLarge) crosses and Duroc X Landrace (DuroLand) crosses) were studied. All the animals used in the study were delivered from different farms. The animals were observed during offloading at the abattoir and farm identity numbers were recorded. Animals were then followed through the slaughter floor where initially breed and sex were recorded before slaughter and thereafter age was recorded using the dentition method. Carcasses were further followed up to the point where they were classified and warm carcass mass and carcass classes were recorded. Data were analysed using the Statistical Analysis Systems (SAS) package of 2009. Frequency procedure (PROC FREQ) and Chi-square tests were used to examine the relationships between the animal traits, carcass traits and carcass classes. Statistical significance was tested at the 95% level with all findings with P -value <0.05 considered to be statistically significant.

Results and Discussion

A similar trend was observed in WCM of all three livestock species tested. There were fewer animals of high WCM than of low WCM in all the livestock species tested, with ranges (1% - 4%; 1% - 5% and 24%) for cattle, sheep and pigs, respectively (Figures 1, 2 and 3). Warm carcass mass can be used to determine the dressing percentage of animals and it has been reported that heavier animals result in higher returns which may be attributed to the fact that they have more muscles than fat and are thus leaner (Knight, 2013). Lean meat is said to be generally preferred in the market and therefore fetches higher premiums. Since WCM has also been proven to have an influence on carcass quality traits such as lean-fat ratio, this therefore suggests that if WCM was included in the South African classification system, most farmers slaughtering their animals in this abattoir would be receiving low premiums as they are producing animals of low WCM with less lean meat. Therefore, WCM could motivate farmers to produce animals of high weights

thus improving carcass quality traits such as the lean-to fat ratio. In addition dressing percentage with heavier breeds would produce more muscle and more lean meat per carcass (Knight, 2013).

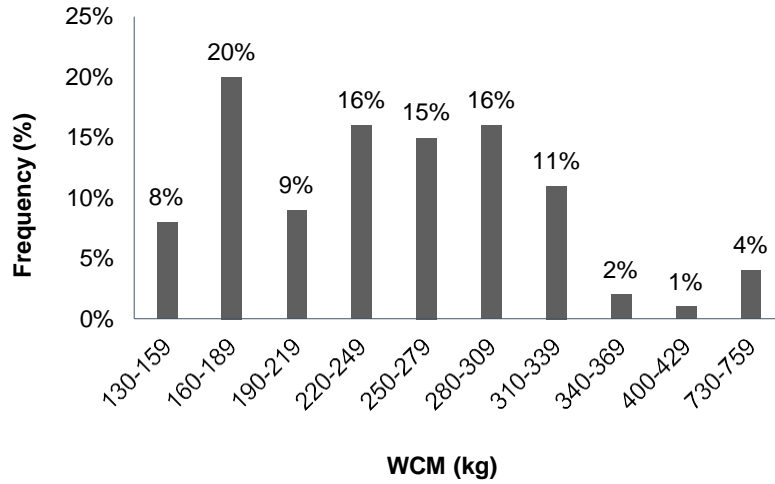


Figure 1 Warm carcass mass (WCM) of cattle slaughtered at the abattoir.

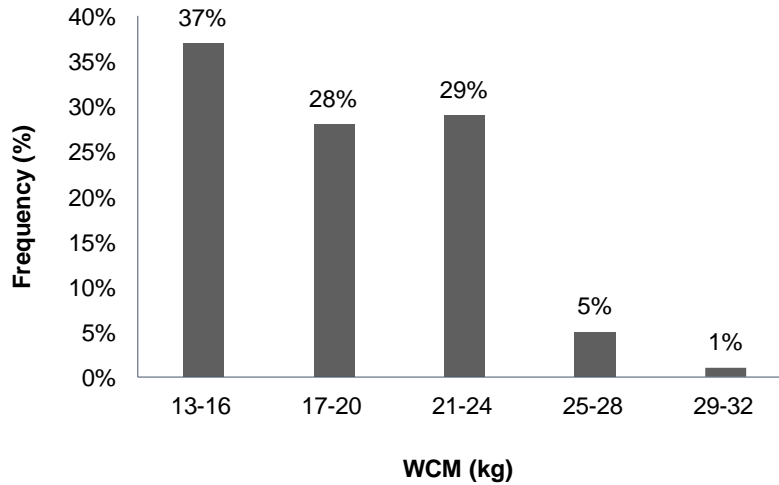


Figure 2 Warm carcass mass (WCM) of sheep slaughtered at the abattoir.

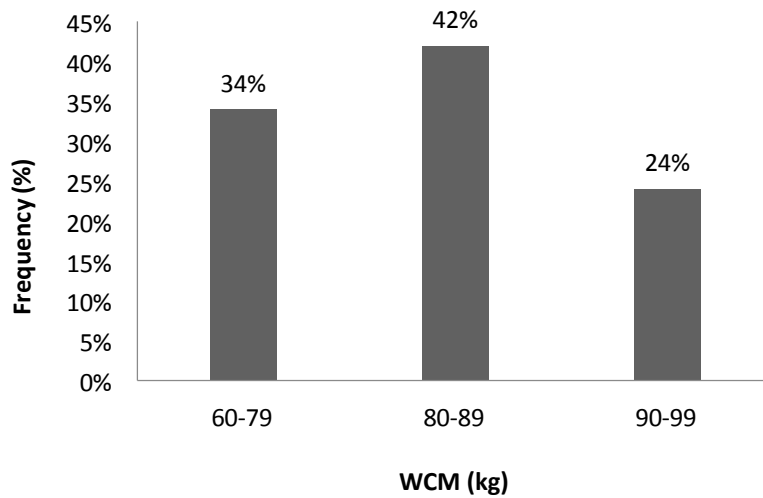


Figure 3 Warm carcass mass (WCM) of pigs slaughtered at the abattoir.

Figure 4 shows that most of the farmers predominantly produce the Bonsmara breed followed by non-descript breeds with the least common breed being the Simmental. The Bonsmara breed dominates the feedlot industry and the Simmental breed also plays a major role in the industry. In contrast, the non-descript breeds dominate the emerging sector in South Africa (Scholtz *et al.*, 2008). The Bonsmara breed is well recognised for being well muscled with high meat yield and quality (Muchenje *et al.*, 2008). Dairy cattle on the other hand are intended for milk production which can influence their carcass quality traits (lean-to-fat ratio, dressing percentage and conformation) and consequently their meat quality traits (taste, colour and texture). However, at this abattoir it was mentioned that farmers raise dairy cattle specifically for beef production. There is a need to investigate the reasons for such a practice and to also determine the quality of meat from these dairy breeds that are reared to only produce meat. Moreover, research also needs to be done on meat quality of non-descript breeds which are common in the emerging livestock sector.

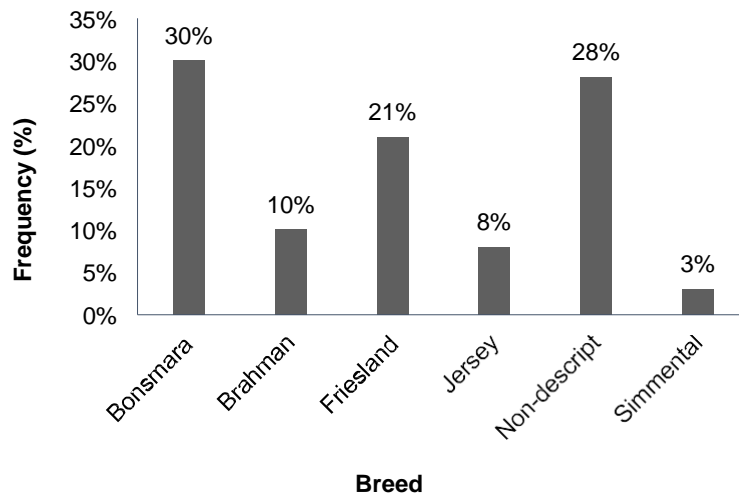


Figure 4 Cattle breeds slaughtered at the abattoir.

Figure 5 shows that most of the farmers produce cattle of the C-age class. Meat from the C-class animals is classified as meat from very old animals with low tenderness (SAMIC, 2006). Consequently these cattle fetch lower premium bonuses because of their age classification. The C-class was mostly dominated by the Bonsmara breed and particularly the C2-class. According to SAMIC (2006) a score of 2 in the fat class is classified as lean meat, thus the fat content in the C2-class is low, giving an advantage of high premium bonuses to these farmers because consumers prefer lean meat.

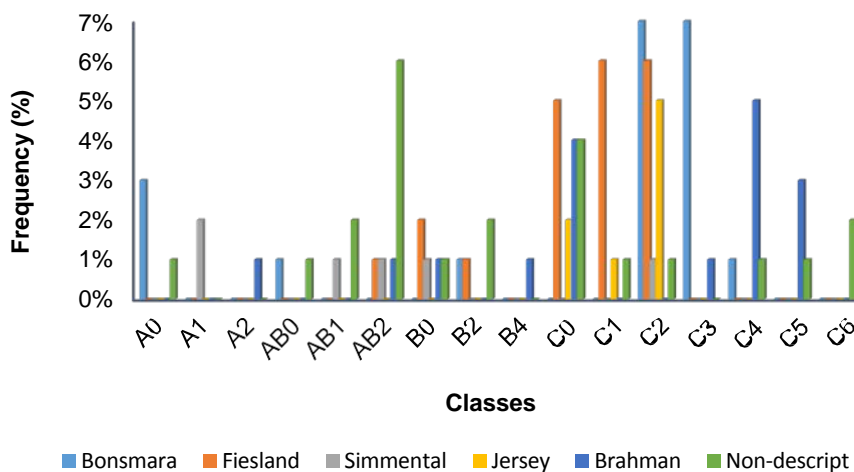


Figure 5 Carcass classes produced per cattle breed.

Figure 6 shows that a very low percentage (7%) of farmers produces beef carcasses of the A-class while a large percentage (69%) produces cattle of the C-class. The percentages of AB- and B-classes on the other hand are in between the A- and C-classes with percentages of 14% and 10%, respectively. The dominant fat score was 2 (39%) which is classified as lean meat which is generally preferred in the market.

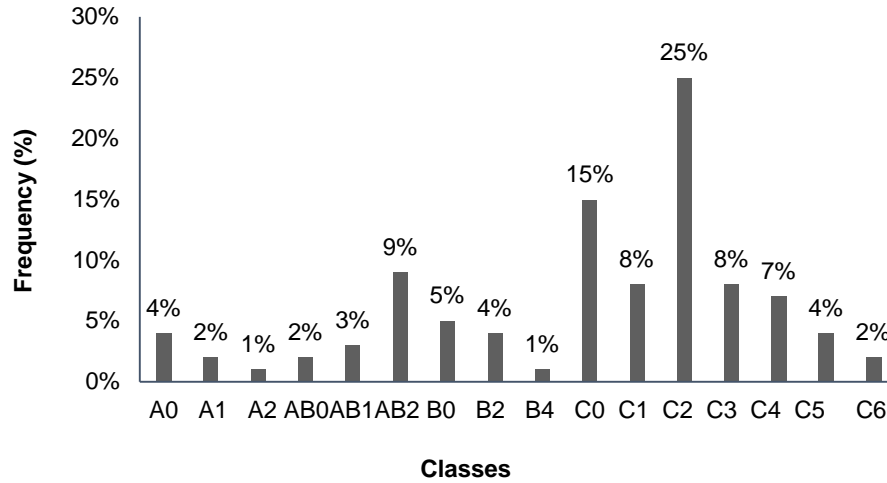


Figure 6 Carcass classes of cattle slaughtered at the abattoir.

Figure 7 shows that most farmers produce the Dorper sheep breed with Blackhead Persian being the least preferred. Different sheep breeds have been reported to have different carcass quality traits (Hanrahan, 1999) and thus also different meat quality traits (Tshabalala *et al.*, 2003).

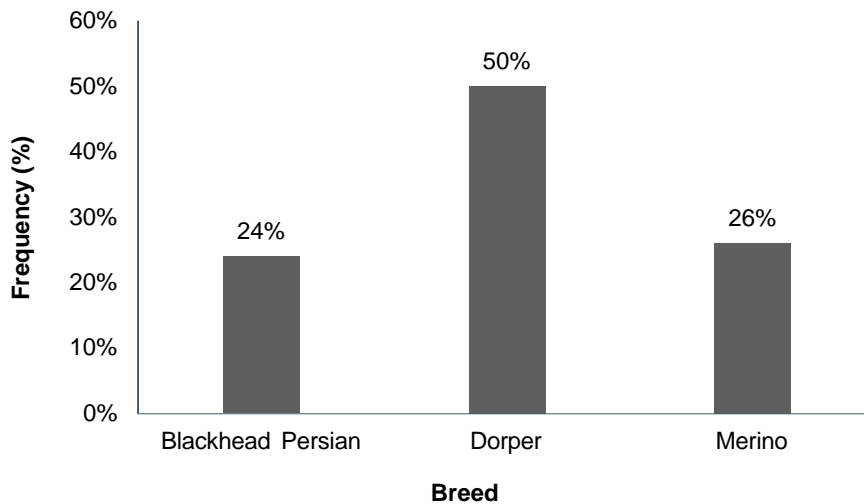


Figure 7 Sheep breeds slaughtered at the abattoir.

Figure 8 shows that most sheep farmers produce mutton carcasses of the A-age class particularly the A2-class (77%). The A2-class is the most desirable class in South Africa as it is classified as meat from a very young animal which is most tender and lean. The Dorper breed dominated the A2-class (38%). Nonetheless, the Merino and Blackhead Persian were also dominant in the A2-class compared to other classes.

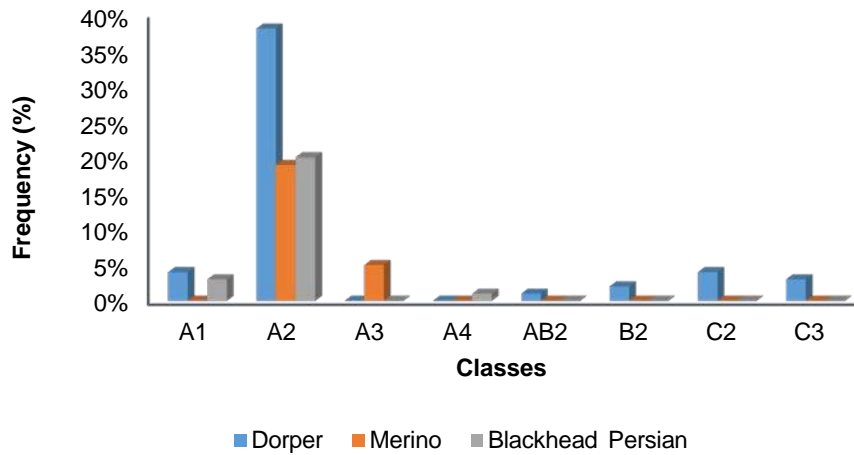


Figure 8 Carcass classes produced per sheep breed.

Figure 9 shows that a very low percentage (1%) of farmers produces mutton carcasses of the AB-class while a large percentage (91%) produces carcasses of the A-class. The B- and C-classes are in between the A- and the AB-classes with percentages of 2% and 8%, respectively. The dominant fat score was 2 (80%) which is classified as lean meat which is generally preferred in the market. Thus most farmers are producing lean mutton.

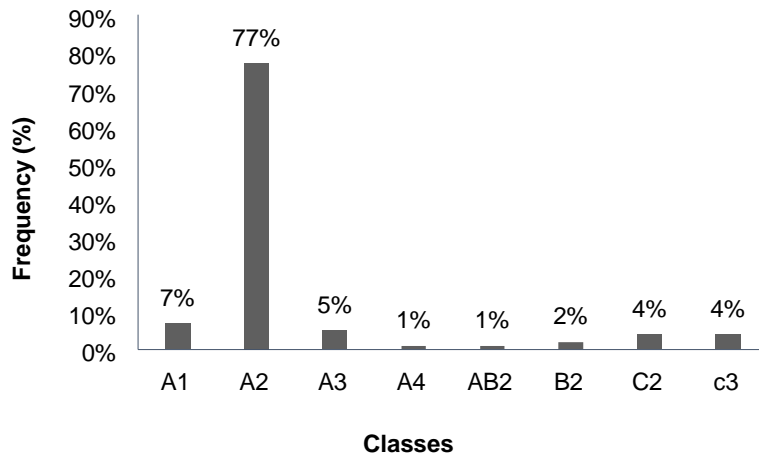


Figure 9 Carcass classes of sheep slaughtered at the abattoir.

Figure 10 shows that most pig farmers produced Duroc X Large White crosses (54%). Ryu *et al.* (2008) indicated that different pig breeds have different carcass and meat quality traits.

Figure 11 shows that the pig farmers mostly produced the P-class with a percentage of 49%. As reported (Strydom, 2011), age and fat are the most important characteristics used in the SA classification system. No rankings are made in terms of age in pork classification. The P-class which is classified as a carcass with 70% and more meat and (1 mm \geq subcutaneous fat thickness \leq 12 mm), was mostly dominated by the Duroc X Landrace crosses. The Duroc X Large White crosses dominated the O-class which is classified as a carcass with (68 \leq Meat% \leq 69) and (12 mm \leq subcutaneous fat thickness \leq 17 mm). Few (7%) Duroc X Large White crosses dominated the R-class which is classified as (66 \leq Meat% \leq 67) and (17 \leq subcutaneous fat thickness \leq 22 mm).

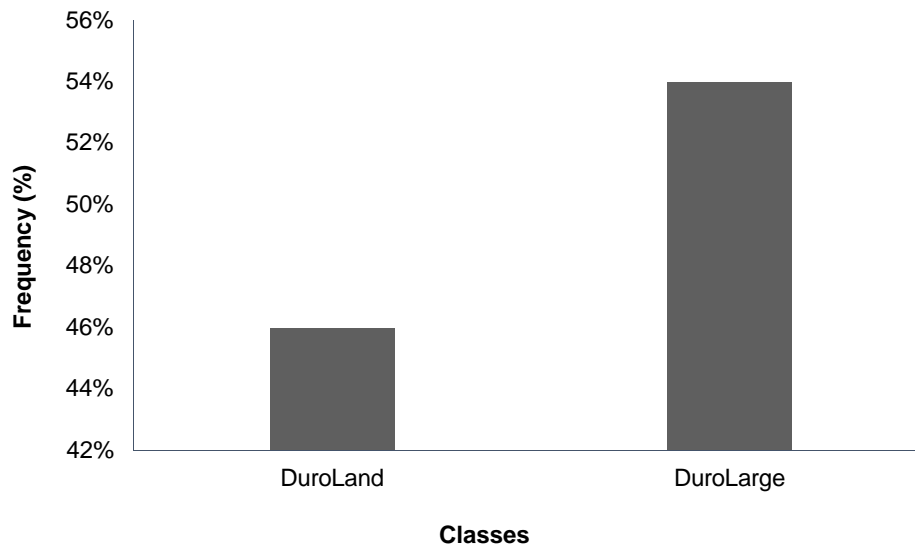


Figure 10 Pig breeds slaughtered at the abattoir.

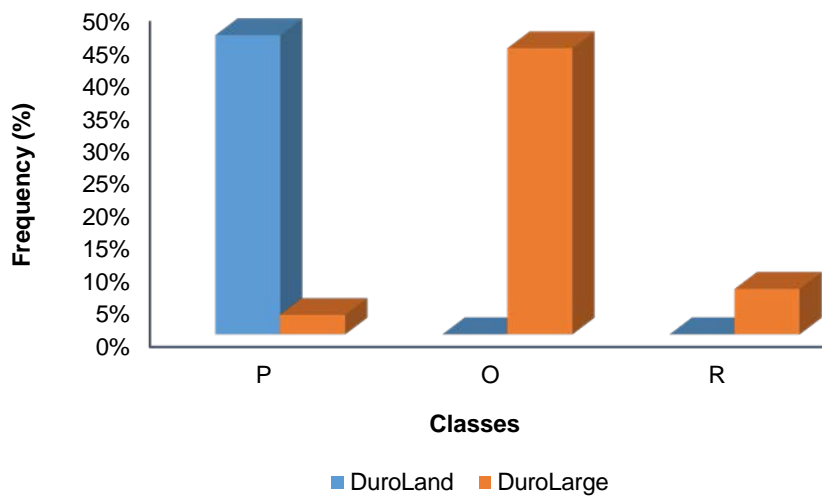


Figure 11 Carcass classes produced per pig breed.

Figure 12 shows that the most produced pork class is the P-class (49%). However, a large percentage (44%) also falls in the O-class and the R-class is the least produced. This may be attributed to the fact that these classes are preferred in the order of P, O, R, C, U, S; thus producers produce pork classes with the highest preference ratings, as to be expected.

Figure 13 shows that most of the cattle that were delivered to this abattoir were cows (56%) while 26% were castrated cattle. The least delivered were heifers (9%) and bulls (9%). However, castrated animals have been reported to have good carcass and meat quality traits (Destefanis *et al.*, 2003; Litwinczuk *et al.*, 2006; Zhang *et al.*, 2010). Figure 14 shows that more rams/male castrates than ewes were slaughtered at this abattoir. However, more sows than boars were slaughtered (Figure 15). This could be due to the fact that the farmers try to avoid boar taint which has a negative effect on pork quality.

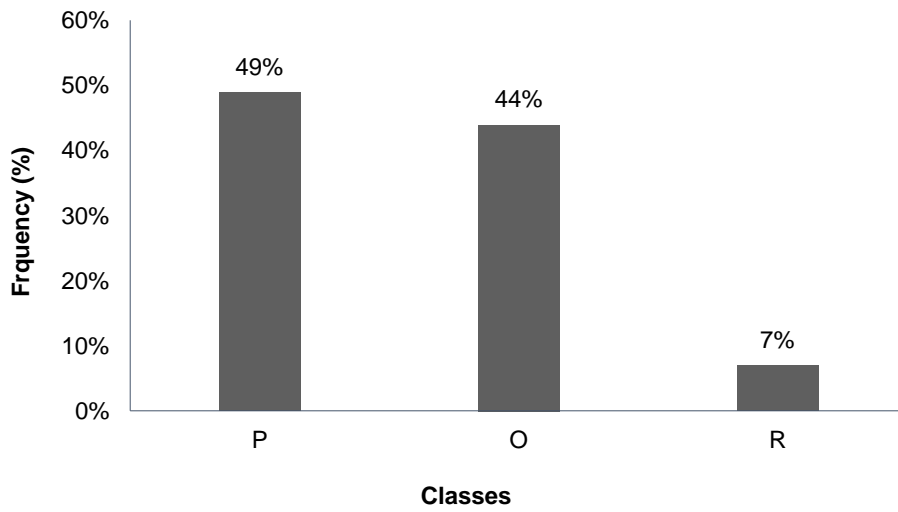


Figure 12 Pork carcass classes produced at the abattoir.

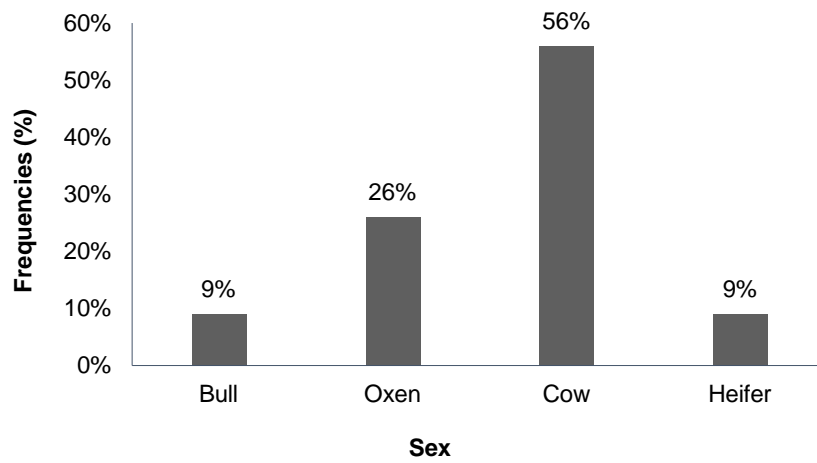


Figure 13 Sex of cattle slaughtered at the abattoir.

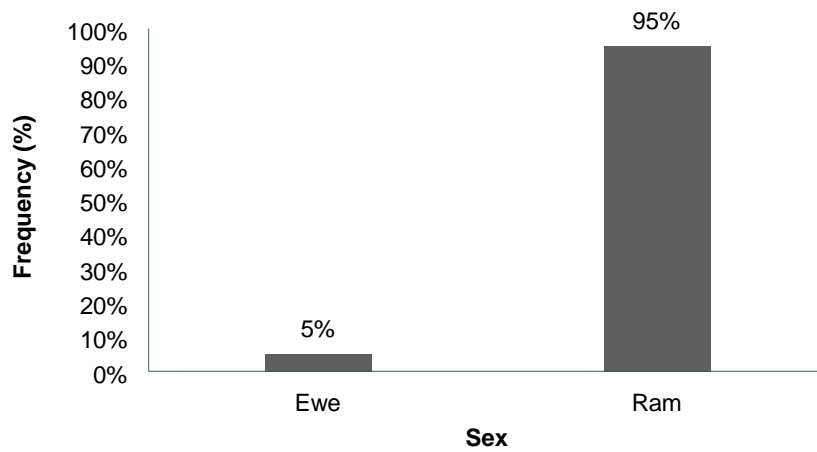


Figure 14 Sex of sheep slaughtered at the abattoir.

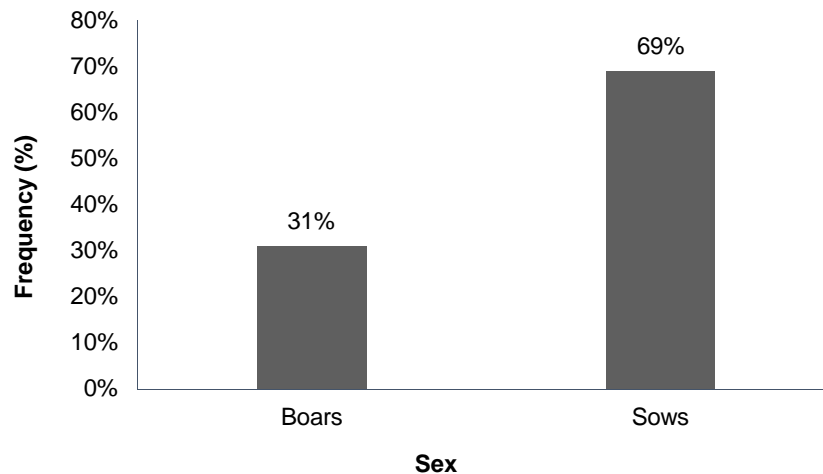


Figure 15 Sex of pigs slaughtered at the abattoir.

The results in Table 1 show that there was an association ($P < 0.001$) between class and sex of cattle, but in sheep and pigs there was no association between the two variables ($P > 0.05$). According to Destefanis *et al.* (2003), Litwinczki *et al.* (2006) and Zhang *et al.* (2010), sex has an effect on various meat quality attributes such as muscle chemical composition, fat deposition, protein and ash content. Therefore, research needs to be conducted on the interactions between sex and carcass classes of all red meat producing livestock species to provide the carcass quality exhibited by the sex characteristic in each class.

Table 2 shows that there were significant breed by class associations in carcasses from cattle, sheep and pigs. Associations between sheep breeds and carcass quality have been reported in the study by Shackelford *et al.* (2012) which showed that progeny of Suffolk sires were heavier than progeny of other breeds. This was also evident from the carcass weights and the 12th rib fat percentage which was greater for Dorper progeny than those of other breeds, except White Dorper and Katahdin. The study further indicated that Finnsheep and Romanov sires had a greater percentage of intramuscular fat and also achieved greater marbling scores than the other breeds. Such results comprehensively show that breed diversity has an effect on some carcass characteristics and consequently also on sheep carcass classes. Sheep with better marbling or intra-muscular fat should thus have better carcass classes since marbling improves meat tenderness, juiciness and aroma (Curtis *et al.*, 2006). The marbling factor is, however, not considered in the SA classification system. Therefore, more research still needs to be done on the relationships between breed and carcass classes across all red meat producing species. Rankings should be made based on the carcass quality attributes of each class in a specific breed and marbling scores and the relationship between these two variables should perhaps be considered.

Table 1 Associations between sex and the A-, AB-, B- and C-carcass classes in cattle and sheep, and P-, O-, and R-carcass classes in pigs

| Species | Chi value | P-value | Association |
|---------|-----------|---------|-------------|
| Cattle | 193.192 | <0.001 | * |
| Sheep | 4.201 | 0.756 | NS |
| Pig | 3.942 | 0.139 | NS |

* Significant association ($P < 0.001$); NS: No significant association ($P > 0.05$).

Table 3 shows that there were associations between WCM and carcass class ($P > 0.05$) in sheep and cattle while there was no association between the two variables in pig carcasses. This variation calls for more research on the possible relationships between carcass weights and classes within livestock species from different production systems. Since Knight (2013) found that heavier animals result in higher returns

because they have more muscle/flesh than fat and are therefore leaner, studies integrating carcass classification with different species weights should be carried out.

Table 2 Associations between breed and the A-, AB-, B-, and C-carcass classes in cattle and sheep and P-, O-, and R-carcass classes in pigs

| Species | Chi value | P-value | Association |
|---------|-----------|---------|-------------|
| Cattle | 131.142 | <0.0001 | * |
| Sheep | 118.641 | <0.0001 | * |
| Pig | 88.993 | <0.0001 | * |

* Significant association ($P < 0.001$).

Table 3 Associations between warm carcass mass (WCM) and the A-, AB-, B-, and C-carcass classes in cattle and sheep and P-, O-, and R-carcass classes in pigs

| Species | Chi value | P-value | Association |
|---------|-----------|---------|-------------|
| Cattle | 1330.413 | 0.0458 | * |
| Sheep | 627.529 | <.0001 | ** |
| Pig | 141.272 | 0.3609 | NS |

**Significant association ($P < 0.001$); *($P < 0.05$); NS: No significant associations.

Conclusion

Associations were found between breed and carcass classes of cattle, sheep and pigs. Sex was only found to be associated with all carcass classes in cattle. Significant associations were also found between WCM and carcass classes of cattle and sheep. No associations were found between carcass classes and WCM of pigs. The results from this study suggest that animal traits such as breed and carcass traits such as WCM affect carcass classes. More research should therefore be done on the relationship between the breed, WCM and the A-, AB-, B- and C-classes in sheep and cattle and P-, O- and R-classes in pigs.

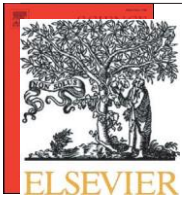
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Effect of genotype and age on some carcass and meat quality traits of beef carcasses subjected to the South African classification system

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Genotype and age effects on pH₂₄, L*, a*, b*, tenderness (WBSF), cooking (CL %), and thawing loss (TL %) of beef carcasses subjected to the South African classification system were determined. Carcass traits (bruising, subcutaneous fat (SF), and conformation) were also measured. Meat quality measurements were taken on the *longissimus thoracis et lumborum* (n = 175) of A, AB, B, and C carcasses from Angus, Bonsmara, Fleckvieh, Non-descript, and Simmental genotypes. No bruises were evident in all carcasses. All carcasses scored medium conformation (class 3) while in SF classification, class 2 had the greatest frequency (66.3%). Genotypic effects (P < 0.05) were observed for a*, hue angle (HA), pH₂₄, TL%, CL%, and WBSF between steers with six, seven, and eight incisors. Notable differences (P < 0.05) were observed for tenderness where Angus and Simmental had least tender meat while Non-descript and Fleckvieh had the tenderest meat within the C-age class. Meat quality varied within animals of the same age-class across genotypes.

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1. Introduction

Carcass classification and grading systems are developed with an attempt to describe the yield and features of carcasses which are useful for trading and pricing purposes (Polkinghorne & Thompson, 2010; Strydom, 2011). In Europe, the carcass classification system has been highlighted as a significant tool for market transparency and regulations (Font-i-Furnols et al., 2016). These systems are established to convey information to all stakeholders in the meat production chain, as well as, to provide a satisfying eating experience to consumers. However, the current South African (SA) classification system segregates carcasses into classes that provide information based on the expected eating quality and yield, but it disregards the quality related characteristics of carcasses. Strydom et al. (2015) further highlighted that the current SA classification system only describes carcasses according to certain measurements or scores and does not rank carcasses according to quality and price. They further stated that the carcass is presented to the wholesaler or retailer listing all the attributes that have been evaluated. Nonetheless, these scores alone do not provide any information on the quality of meat.

Polkinghorne and Thompson (2010) evaluated the classification and grading systems for beef carcasses in seven countries around the world. These countries included the Republic of South Africa, South Korea, United States of America (USA), Japan, Europe, Canada, and Australia; with Australia having two different governing systems which include the Australian meat classification (AUS-MEAT) and Meat Standards

Australia (MSA). Among these countries only the Australian (AUS-MEAT), European (EUROP), and SA systems are considered as classification systems. The Meat Standards Australia (MSA) and other four countries (Canada, Japan, South Korea, and USA) use the grading system. According to AHDB Industry consulting (2008) carcass classification is a system that only describes features of a carcass which are useful in the trading industry, while the grading system involves ranking carcasses based on quality in order of merit from the most preferred to the least preferred grades. Generally, the main difference between grading and classification systems is that the classification system does not measure quality attributes. Among the criteria used in the grading and classification systems, only the AUS-MEAT and MSA use pre-slaughter criteria in addition to slaughter floor measurements. All other classification and grading systems rely solely on slaughter floor measurements. Although the slaughter floor measurements vary among these systems, measurements such as: carcass weight, sex, and age are common in all systems but using different methodologies. The EUROP, SA, and AUS-MEAT classification systems only consider slaughter floor measurements, while the grading schemes also use chiller measurements such as marbling score, lean and fat colour, pH, firmness, and texture among others (Polkinghorne & Thompson, 2010).

These meat quality attributes are, however, not included in the EUROP and SA classification systems. Nonetheless, consumers are increasingly demanding meat that is of acceptable colour, aroma, flavour, and tenderness among other attributes and they cannot rank these meat quality attributes for themselves in the retail outlets. Furthermore, previous research confirmed changes in the quality attributes, physical and nutrient composition of SA beef carcasses due to age and degree of fatness (Hall, Schönfeldt, & Pretorius, 2015). The SA classification

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system classifies beef carcasses into four age groups which are determined based on the number of incisors present at slaughter using a dentition method with classes A (0 incisors), AB (1–2 incisors), B (3–6 incisors), and C (N 6 incisors). However, the system does not clearly differentiate meat quality from animals within the same class but with different number of incisors, for an example in the AB (1–2 incisors), B (3–6 incisors) and C (N 6 incisors) classes. Although differences might be detected within animals of the same class due to differences on the number of incisors present at slaughter.

The system also classifies carcasses based on the amount of subcutaneous fat with classes ranging from 0 (no fat) to 6 (extremely over fat). Age and fat codes have been reported as key determinants of market price, with young animals (A-class) and fat code 2 fetching high prices (Hall et al., 2015). However, it has been argued that although A-class animals are sold for high prices since they are presumed to be most tender and consequently of better quality, this is not always the case as many other factors besides age can affect tenderness (Strydom, 2011), such as breed. Since the implementation of the current classification system, it has not been evaluated to assess cogency with regards to the quality of beef carcass classes from different breeds.

Breed can have significant effects on carcass traits (lean-fat ratio, conformation, and dressing %), meat quality traits (meat colour and cooking loss), and sensory traits (tenderness and juiciness) (Chambaz, Scheeder, Kreuzer, & Dufey, 2003; Muchenje, Dzama, Chimonyo, Raats, & Strydom, 2008). These traits are significant for a satisfying eating experience to consumers and future purchasing decisions. Therefore, there is a need for information on the quality of South African beef carcass classes across different breeds with different number of erupted incisors present at slaughter to address consumer uncertainties. This study sought to investigate carcass and meat quality from SA carcass classes across different beef breeds with different number of erupted incisors present at slaughter.

2. Materials and methods

2.1. Ethical clearance

Consent to carry out the study was approved and issued by the University of Fort Hare Ethical Clearance committee (Reference Number: MUC151SSOJ01).

2.2. Experimental site description

The study was conducted at East London Abattoir in the Eastern Cape Province of South Africa. East London is located at 32.9° S and 27.87° E with a total area of 168, 86 km². The abattoir is a high throughput commercial abattoir which slaughters up to 1000 livestock units per day and is furnished with modern technology to improve production. It operates under the laws and regulations of the Meat Safety Act (Act No. 40 of 2000) (SAMIC, 2006) governing the abattoirs in the Republic of South Africa.

2.3. Animal description

Five different beef genotypes (Angus, Bonsmara, Fleckvieh, Non-descript, and Simmental) from different feedlot systems were used in the study. The origin of the studied animals was traced from the cattle identification, registration and movement documents issued by the truck drivers on arrival. Four feedlots were traced as pure breed producing feedlots (Angus, Bonsmara, Fleckvieh and Simmental) with each feedlot producing cattle of the same genotypes; and one feedlot produced crossbreeds (Non-descript) with various genotypes. From each feedlot system thirty five steers of different age categories were selected making a total of 175 steers (35 × 5).

2.4. Data collection

Animals from the same feedlots were selected across multiple visits. The animals were humanely slaughtered at the abattoir. Following the humane slaughter, the carcasses were subjected to the SA classification system under the regulations set for the classification and marking of meat anticipated for sale in the Republic of South Africa (Act No.119 of 1990) (Agricultural Products Standards Act, 1990).

2.4.1. Carcass classification

Five classification categories (age, sex, conformation, bruising, and fatness) were used. The age of the steers was determined using a dentition method described by the South African Meat Industry Company (SAMIC, 2006) depending on the number of erupted incisors present at slaughter with classes A (0 incisors), AB (1–2 incisors), B (3–6 incisors), and C (N6 incisors). Visual appraisal was used to determine the degree of subcutaneous fat (SF) in millimetres (mm) with scores ranging from 0 (No Fat), 1 (SF b 1), 2(1 ≤ SF ≤ 3), 3(3 ≤ SF ≤ 5), 4(5 ≤ SF ≤ 7) 5(7 ≤ SF ≤ 10), and 6(10 ≤ SF). Bruising (1 slightly damaged–3 excessively damaged) and conformation (1 very flat–5 very round) were also determined and assigned scores by visual appraisal.

2.4.2. Meat sample harvesting and measurements

Meat samples (approximately 2.5 kg) were harvested from the *longissimus thoracis et lumborum* (LTL) after dressing the carcasses. Smaller sub-sections of the LTL muscle (100 mm thick) from the left side of each carcass were sampled from the 10th rib in the direction of the rump for meat quality measurements. Samples were vacuum packaged before they were stored in a cooler box half filled with ice cubes. The samples were stored in a cooler box for approximately 180 min during transportation. After transportation, they were frozen at –20 °C refrigerator temperature until meat colour (lightness; L*, redness; a*, and yellowness; b*), pH, and thawing loss (TL %) analyses were performed 24 h after slaughter. Cooking loss (CL %), and Warner Bratzler Shear Force (WBSF) measurements were done after 7 days of refrigeration. Before meat quality analyses were done, the samples were thawed at 4 °C for 24 h. The 100 mm thick subsections were processed into 30 mm steaks for WBSF measurements and 20 mm steaks for CIE Lab colour measurements by means of a bandsaw.

2.4.2.1. Meat pH. A portable digital pH metre (Crison pH 25) with a piercing electrode was used to measure pH of the LTL muscle 24 h after slaughter.

2.4.2.2. Meat colour. The Commission International De L'Éclairage (CIE) L*, a*, and, b* values (Commission International De L'Éclairage, 1976) were determined on the LTL muscle. A Minolta colour guide machine (model 45/0 BYK- Gardner GmbH) with a 20 mm diameter, illuminant D65-day light and 10° standard was used to measure the meat colour. The results were taken after 3 readings achieved by rotating the device by 90° on the sample surfaces 3 times. Saturation index (SI) was then calculated as $(a^2 + b^2)^{0.5}$ and the hue angle (HA) was also calculated as $[\tan^{-1}((b^*/a^*))]$ using a method by Setser (1984).

2.4.2.3. Thawing and cooking loss measurement. The samples were weighed before freezing using a portable weighing scale (LBK 12) and subsequently frozen at –20 °C for 7 days. After 7 days, the frozen samples were reweighed and thawed at 4 °C for 24 h. After thawing the samples were re-weighed and placed in water tight PVC-plastic bags before they were boiled. The samples were boiled using a water bath (Model TRH) which was pre-heated to 72 °C for 45 min to boil water. It was then pre-set to 71 °C before the samples were cooked and the samples were cooked to a final internal temperature of 71 °C (AMSA, 1995). After cooking, meat samples were cooled to room temperature (±20 °C) measured using an analogue thermometer for 5 h. The

samples were then re-weighed. Calculations for thawing and cooking loss were done using the following formulae:

$$\text{Thawing loss } \delta_{TL} \% = \frac{\text{weight from freezer} - \text{weight after melting}}{\text{weight from freezer}} \times 100\%$$

$$\text{Cooking loss } \delta_{CL} \% = \frac{\text{weight before cooking} - \text{weight after cooking}}{\text{weight before cooking}} \times 100\%$$

2.4.2.4. Meat tenderness. Following the thawing and cooking loss measurements, Warner-Bratzler Shear Force (WBSF) test (WBSF) was done on the processed 30 mm steaks. From each sample, three sub samples of approximately 12.7 mm core diameter were extracted parallel to the long axis of the muscle fibres (AMSA, 1995). Each core was sheared once through the centre at an angle perpendicular to the direction of the fibre using the Warner Bratzler shear device attached to the Universal Instron apparatus (model 3344, crosshead speed = 400 mm/min). WBSF was measured as the peak force (Newtons) average for three cores per sample.

2.5. Statistical analysis

The data obtained from the study was analysed using the Statistical Analysis System version 9.1 of 2003. Frequencies for the carcass classes produced and the number of incisors present at slaughter per each genotype was determined using the PROC FREQ of SAS (2003). The effect of age category (B2 and C2) and genotype on meat quality across genotypes were computed using the General linear model procedure (PROC GLM) of SAS (2003). Another separate analysis was run using the PROC GLM of SAS (2003) to test the effect of genotype on carcass and meat quality attributes within the C2 carcass class. Comparison between means for the meat quality attributes were computed using the Fishers' least significant difference (LSD) method and the means were considered to be statistically different at $P < 0.05$. Correlations among the carcass and meat quality attributes within the C2 carcass classes across genotypes were also computed using the correlation procedure (PROC CORR).

3. Results and discussion

A uniform conformation score (class 3) was found in all carcasses in the current study. According to the South African Meat Industry Company (SAMIC, 2006), conformation is significant when consumers want to select cuts of preference in the market and carcasses falling within class code 3 are classified as "medium". Most consumers prefer to buy cuts of class 3 to 5 in the markets (SAMIC, 2006). The results from the current study, therefore, suggest that all genotypes compared favourably with each other in terms of conformation; as a result, all carcasses provided the most preferred size of cuts.

In addition the carcasses had no traces of bruises; hence no damage scores were allocated. SAMIC (2006) states that if a carcass is bruised, the extent of damage will consequently have an effect on the price when being sold with severely damaged carcasses (bruise score 3) fetching low prices. The results from the current study, therefore, suggest that all carcasses would not be downgraded for conformation and damage classification in the market. Variations were, however, observed on age and fat classification. As illustrated in Fig. 1, the C-classification had the greatest frequency (78.9%) compared to other age classifications.

Carcasses within the C-class are considered undesirable for the market as they are presumed to be old and less tender (SAMIC, 2006). Consequently, farmers often get low prices for C-class carcasses. In fat classification, class 2 had the greatest frequency (66.3%) throughout

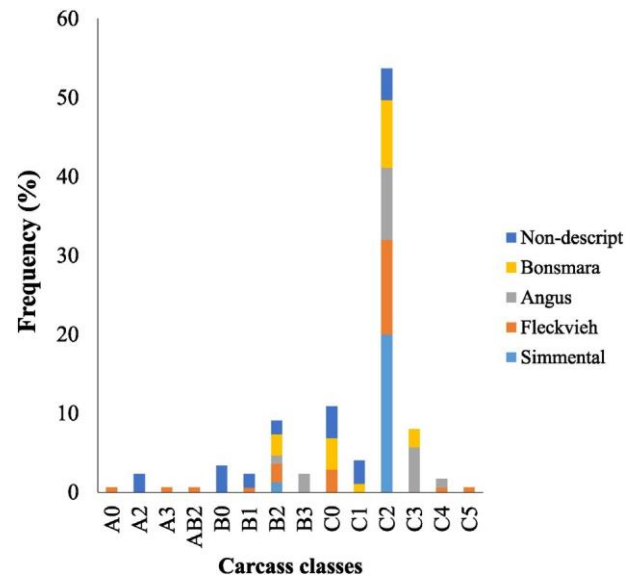


Fig. 1. Age categories and fat classes produced from different beef genotypes slaughtered in a high throughput abattoir, with common medium conformation (class 3) and no bruise scores.

(A, AB, B, and C) carcasses. Carcasses of fat code 2 are regarded as lean meat with subcutaneous fat ranging from 2 to 3 mm. In South Africa consumers prefer lean meat with little visible fat, thus carcasses are produced to suit consumer preferences and are seldom trimmed of excess fat (du Plessis & Hoffman, 2007). The class 2 fat classification is, therefore, mostly preferable in the market, thus, fetching high prices and this explains why most of the carcasses in the current study were of C2 class (53.7%). The C2 class was dominated by the Simmental genotype (37.2%). These results are similar to those reported by Soji, Mabusela and Muchenje (2015) that the C2 class is likely to be more dominant on animals subjected to slaughter at selected abattoirs in the Eastern Cape Province, South Africa.

It is therefore, clear from the results that certain feedlot systems in some areas of the Eastern Cape Province mostly send cattle of C-age category for slaughter. These cattle ultimately produce carcass classes with the lowest preference in the market. According to the South African Beef Carcass Classification System (SABCCS), it is usually expected that animals are slaughtered at an early A-age class of 12–16 months before the eruption of permanent incisors or after the eruption of up to two permanent incisors (AB-age class) (Government Notice No. R. 342, 1999), and this is mostly expected from feedlot animals. Nonetheless, although the feedlot system is presumed to be a system that mostly sends animals of A and AB age categories, contradictory findings were observed in the current study where the feedlot animals mostly fell within the C-age classification.

The C-age classification is, however, usually expected from pasture-reared animals where animals are sometimes slaughtered after the eruption of 3–6 (class B) (Frylinck, Strydom, Webb, & du Toit, 2013) or N6 (class C) permanent incisors. Thus, some of the "C"-age animals that were found to dominate the feedlot systems in the current study are old culled animals (Hall et al., 2015), while others might have been purchased by feedlot farmers from the pasture based systems at auctions for onward supply to formal abattoirs. This is mainly because communal farmers have little or no access to formal markets such as abattoirs. These farmers would rather opt to sell their animals through informal markets which include farmer-to-farmer sales or through auctions to feedlot producers. Thus some of the animals that find their way to formal markets were originally from communal farmers.

These old animals may be below the target market weight due to production challenges besetting communal farmers at the time of purchase in auctions. Mapiye, Chimonyo, Dzama, Raats, and Mapekula

(2009) reported that inadequate protein supplementation is one of the main constraints faced by communal farmers, which consequently results in slow growth rates of pasture reared animals. Purchas, Burnham, and Morris (2002) also stated that slow growers resulted in older animals and poorer carcass condition. This consequently results in the delayed attainment of the required slaughter weight leading to animals being sold and slaughtered at a mature age and, thus, fetching low C-class prices. This was confirmed on the Non-descript genotype in the current study. The Non-descript is a crossed genotype with unknown parental genotypes and is mostly found in communal areas (Scholtz, Bester, Mamabolo, & Ramsay, 2008). These animals are often sold to feedlots by communal farmers for quick cash. Thus the prevalence of C-age class from the Non-descript genotype can also be attributed to longer subjection of these animals to inadequate protein and carbohydrate supplementation on communal pasture-based system before being auctioned to the feedlots. This consequently resulted in delayed attainment of the required slaughter weight.

Genotypes such as Fleckvieh, Angus, and Simmental are known for their fast maturing rates (Muchenje et al., 2008) and thus are expected to produce A and AB carcasses. Most of them were also unexpectedly slaughtered at C-age in the current study. Moreover, the Bonsmara which is a locally developed composite genotype also dominated the C-age classification and consequently resulted in low C-prices carcasses. Nonetheless, the Bonsmara is a medium maturing *Bos taurus africanus* genotype (Strydom, 2002). Thus, it can be at least expected to reach slaughter weight at B-age category. These results, therefore, suggest that there are significant differences among genotypes in terms of growth rates, and consequently the attainment of desired slaughter weight. The different growth rates between genotypes may affect the age at which the animals are slaughtered and the class of carcasses they fall into.

Strydom et al. (2015) indicated that animal age provides a fairly accurate description of expected eating quality. Ageing bovine by dentition has been used since 1936 as a characteristic to grade carcasses, presumably because carcasses of younger cattle were considered to be of higher quality than those of older cattle (Government Notice No. 1548 of 1936). This is also the case in the current SA classification system. The number of permanent incisors at slaughter has been used since 1949 to distinguish the age classification (Government Notice No. 992 of 1949; Strydom, 2011). Lawrence, Whatley, Montgomery, and Perino (2001) also regarded a dentition-based system more accurate than the USDA maturity-based system to classify carcasses. Among the animals that were evaluated in the current study, steers with six, seven, and eight incisors had the greatest frequencies (17.5, 45.9, and 33.1%) distributed across genotypes (Fig. 2).

In the current classification system animals with N 6 incisors at slaughter are all classified as C-class animals, the system does not evaluate for differences within the same class animals with different number of incisors present at slaughter. However, Strydom (2011) reported significantly different shear force values within age groups than among age groups. Thus consumers might detect differences in meat quality attributes of animals falling within the same age-class due to different number of incisors present at slaughter. Further classification of carcasses within the same class therefore provides a more accurate technique of classifying beef carcasses into less variable classes. However, it must also be noted that age alone might not be the only source of variation in tenderness or other meat quality attributes. Other factors such as breed could significantly influence the meat quality of beef animals. The following section (Table 1), therefore, discusses meat quality attributes that can be expected from different genotypes with different number of incisors present at slaughter.

Meat quality attributes as affected by age and genotype among steers with 6 (B2), 7 (C2), and 8 (C2) erupted incisors present at slaughter were evaluated. There were no differences found ($P > 0.05$) in all meat quality attributes (L^* , a^* , b^* , hue angle (HA), saturation index (SI), pH_{24} , TL%, CL%, and WBSF) among steers with six, seven and eight

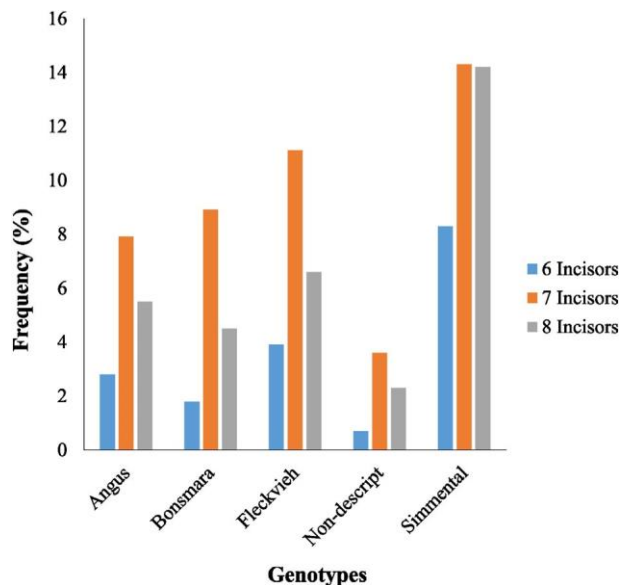


Fig. 2. Age (by dentition) of different B2 and C2-class genotypes slaughtered in a high throughput abattoir.

erupted incisors within the same genotype across all age categories. According to SAMIC (2006), animals with six incisors at slaughter are classified as B-class animals while those with seven and eight incisors are classified as C-class animals. The current results showed that in the same genotype, the B-class animals had the same meat quality attributes as C-class animals. This might be due to similar animal characteristics among these animals such as carcass morphology related to fat quality or meat quality (Guerrero, Valero, Campo, & Sañudo, 2013). The current classification system, therefore, might sometimes disadvantage farmers who produce C-class animals with meat that may be similar or equal to that of B-class animals in terms of quality.

Differences ($P < 0.05$) were, however, observed across genotypes in some meat quality attributes (a^* , HA, pH_{24} , TL%, CL%, and WBSF). The results concur with the findings by Chambaz et al. (2003) that meat quality attributes vary between breeds. Differences ($P < 0.05$) were found for LTL redness (a^*) between steers with seven and eight erupted incisors across genotypes. Redness of LTL from Bonsmara steers with both seven and eight erupted incisors was different from that of Fleckvieh but similar to all other genotypes. Differences ($P < 0.05$) in the LTL HA were found between genotypes with eight erupted incisors. The LTL HA of Fleckvieh steers with eight erupted incisors was different from those of Bonsmara, Non-descript, and Simmental genotypes. Modika et al. (2015) also found differences in HA values of LTL between breeds of the same age. Differences ($P < 0.05$) in LTL pH_{24} were also found between steers with eight erupted incisors where LTL pH_{24} of Non-descript genotype was different from those of Bonsmara, Fleckvieh, and Simmental.

Differences ($P < 0.05$) in TL% of LTL were found between genotypes with seven incisors as well as between those with eight erupted incisors. In LTL of steers with seven erupted incisors, the TL% of Bonsmara was different from those of Fleckvieh and Simmental, while in steers with eight erupted incisors the TL% from Simmental genotypes was different from that of Angus. Most significant differences were found in CL% across all genotypes with six, seven and eight erupted incisors. The CL% of LTL from the Non-descript steers with six erupted incisors was different from those of all other genotypes, while in steers with seven erupted incisors the CL% of the Non-descript cattle was only similar to Bonsmara and in steers with eight erupted incisors the CL% from Non-descript steers was different from the Simmental steers. Fleckvieh steers with six erupted incisors had different WBSF of LTL than Angus and Bonsmara, while Non-descript steers with seven

Table 1
Effect of age category within B2 and C2 genotypes on meat quality.

| Genotype | Number of incisors | Meat quality variables | | | | | | | | | |
|--------------|--------------------|--------------------------|---------------------------|--------------------------|---------------------------|--------------------------|---------------------------|--------------------------|---------------------------|---------------------------|--|
| | | L* | a* | b* | HA | SI | pH ₂₄ | TL% | CL% | WBSF | |
| Angus | 6 | 30.4 ^a ± 1.33 | 15.4 ^a ± 0.93 | 10.7 ^a ± 0.99 | 33.9 ^a ± 2.16 | 18.9 ^a ± 1.18 | 6.1 ^a ± 0.08 | 4.2 ^a ± 1.06 | 23.1 ^{ac} ± 2.25 | 42.3 ^a ± 4.35 | |
| Bonsmara | | 33.8 ^a ± 1.49 | 13.2 ^a ± 1.04 | 10.5 ^a ± 1.11 | 38.3 ^a ± 2.41 | 16.9 ^a ± 1.32 | 6.1 ^a ± 0.09 | 4.6 ^a ± 1.18 | 29.1 ^a ± 2.52 | 41.9 ^a ± 4.86 | |
| Fleckvieh | | 32.9 ^a ± 1.21 | 14.1 ^a ± 0.85 | 9.7 ^a ± 0.90 | 34.3 ^a ± 1.97 | 17.1 ^a ± 1.08 | 6.1 ^a ± 0.07 | 5.2 ^a ± 0.96 | 24.8 ^{ac} ± 2.05 | 21.2 ^b ± 3.97 | |
| Non-Descript | | 32.2 ^a ± 1.71 | 15.4 ^a ± 1.21 | 11.7 ^a ± 0.42 | 37.5 ^a ± 2.78 | 19.3 ^a ± 1.52 | 6.2 ^a ± 0.11 | 6.1 ^a ± 1.36 | 8.2 ^b ± 2.91 | 35.2 ^{ab} ± 5.62 | |
| Simmental | | 31.1 ^a ± 0.94 | 14.1 ^a ± 0.66 | 10.9 ^a ± 1.74 | 37.5 ^a ± 1.52 | 17.8 ^a ± 0.83 | 6.1 ^a ± 0.06 | 4.8 ^a ± 0.75 | 23.1 ^c ± 1.59 | 37.8 ^{ab} ± 3.08 | |
| Angus | 7 | 29.9 ^a ± 1.21 | 16.1 ^{ab} ± 0.85 | 11.2 ^a ± 0.90 | 35.1 ^a ± 4.19 | 19.6 ^a ± 1.08 | 6.2 ^a ± 0.08 | 5.7 ^{ab} ± 0.96 | 21.2 ^a ± 2.05 | 39.3 ^a ± 3.97 | |
| Bonsmara | | 32.7 ^a ± 1.12 | 13.9 ^b ± 2.11 | 11.1 ^a ± 0.84 | 38.2 ^a ± 1.82 | 17.8 ^a ± 1.00 | 6.1 ^a ± 0.07 | 7.7 ^a ± 0.89 | 14.1 ^b ± 1.90 | 29.9 ^{ab} ± 3.68 | |
| Fleckvieh | | 30.8 ^a ± 0.99 | 16.6 ^a ± 2.48 | 11.8 ^a ± 0.74 | 35.3 ^a ± 4.71 | 20.4 ^a ± 0.89 | 6.1 ^a ± 0.06 | 5.1 ^b ± 0.79 | 24.9 ^a ± 1.68 | 32.3 ^{ab} ± 3.24 | |
| Non-Descript | | 34.1 ^a ± 2.10 | 15.6 ^{ab} ± 1.48 | 13.9 ^a ± 1.28 | 41.6 ^a ± 3.41 | 20.9 ^a ± 1.86 | 6.1 ^a ± 0.13 | 6.4 ^{ab} ± 1.67 | 11.7 ^b ± 3.56 | 24.3 ^b ± 6.88 | |
| Simmental | | 30.7 ^a ± 0.86 | 14.8 ^b ± 0.60 | 11.3 ^a ± 0.64 | 37.4 ^a ± 1.39 | 18.7 ^a ± 0.76 | 6.1 ^a ± 0.14 | 5.3 ^b ± 0.68 | 25.2 ^a ± 1.45 | 38.2 ^{ab} ± 2.81 | |
| Angus | 8 | 28.7 ^a ± 1.33 | 15.1 ^{ab} ± 0.93 | 10.1 ^a ± 0.99 | 33.3 ^{ab} ± 2.16 | 18.2 ^a ± 1.18 | 7.2 ^{abc} ± 1.06 | 7.2 ^a ± 1.06 | 23.1 ^{ab} ± 2.25 | 41.8 ^a ± 4.35 | |
| Bonsmara | | 31.9 ^a ± 1.49 | 13.3 ^b ± 1.04 | 10.2 ^a ± 1.11 | 37.5 ^a ± 2.41 | 16.7 ^a ± 1.32 | 6.3 ^b ± 1.18 | 6.3 ^{ab} ± 1.18 | 23.2 ^{ab} ± 2.52 | 43.4 ^a ± 4.86 | |
| Fleckvieh | | 31.2 ^a ± 1.21 | 16.5 ^a ± 0.85 | 10.1 ^a ± 0.96 | 30.7 ^b ± 1.97 | 19.3 ^a ± 1.08 | 5.4 ^b ± 0.96 | 5.4 ^b ± 0.96 | 18.2 ^b ± 2.05 | 33.3 ^a ± 3.97 | |
| Non-Descript | | 32.5 ^a ± 2.10 | 14.9 ^{ab} ± 1.47 | 12.8 ^a ± 1.57 | 40.8 ^a ± 3.41 | 19.6 ^a ± 1.86 | 5.6 ^c ± 1.67 | 5.6 ^{ab} ± 1.67 | 16.2 ^b ± 3.56 | 33.3 ^a ± 6.88 | |
| Simmental | | 31.7 ^a ± 0.82 | 14.4 ^b ± 0.58 | 10.4 ^a ± 0.61 | 35.6 ^a ± 1.34 | 17.8 ^a ± 0.76 | 4.6 ^b ± 0.65 | 4.6 ^b ± 0.65 | 26.2 ^a ± 3.60 | 39.8 ^a ± 2.70 | |

^{a, b, c} Means within a column bearing different superscripts per trait differ at $P < 0.05$; L* – lightness; a* – redness; b* – yellowness; HA – Hue angle; SI – saturation index; pH₂₄ – meat pH; TL% – Thawing loss percentage; CL% – cooking loss percentage; WBSF – Warner Bratzler Shear Force (Newtons).

erupted incisors had WBSF values different from that of Angus. These results are similar to those reported by Modika et al. (2015) where there were greater WBSF differences within than between breed types. Strydom et al. (2015) also reported that variations in tenderness are much broader than can be described by age alone. Sañudo et al. (2004) and Waritthitham, Lambert, Langholz, Wicke, and Gauly (2010) also reported that breed is an important factor that can influence meat quality including muscle structure and meat physiology. These results comprehensively show that there are breed effects on tenderness of carcasses falling within the same age-class (B2) or (C2). Further evaluation of the breed effect on meat quality was, therefore, done on C2 class animals which were mostly dominant in the current study with all genotypes represented in the class (Table 2).

The muscle colour (L*) for C2 carcass classes of Bonsmara, Fleckvieh, Non-Descript, and Simmental did not differ significantly ($P > 0.05$). These results are similar to those reported by Chambaz et al. (2003), Vieira, Cerdeño, Serrano, Lavín, and Mantecó (2007) and Muchenje et al. (2008) who also found no differences in L* among different breeds. However, the Angus genotype differed significantly ($P < 0.05$) from Non-descript and Bonsmara. The muscle colour of the C2 carcass classes of Angus, Fleckvieh, and Simmental genotypes appeared to be darker than those of Bonsmara and Non-descript. Moreover, redness (a*) of muscles from Bonsmara differed from those of Angus, Fleckvieh and Non-descript. The Bonsmara cuts were less red while cuts from other genotypes were more red. Hence, the LTL HA of Bonsmara genotype differed ($P < 0.05$) from those of Fleckvieh and Angus.

Muscle colour SI differences ($P < 0.05$) were found between Bonsmara and Non-descript genotype. The muscle b* for C2 carcass class of the Non-descript genotype differed ($P < 0.05$) from C2 carcass

classes of all other genotypes. The Non-descript genotype had higher b*-values compared to other genotypes. The higher LTL b* values in the muscle of Non-descript genotype can be associated with high intramuscular fat content (Bispo, Monserrat, González, Franco, & Moreno, 2010; Mancini & Hunt, 2005; Waritthitham et al., 2010) with yellow colour. The yellow intramuscular fat colour may be associated with high carotenoid levels in grasses consumed by these animals in pasture based system before being finished in feedlots. However, other factors including age and/or different fatty acid content may also be associated with yellow fat carcasses. Soji, Chikwanda, et al. (2015) reported that the evaluation of fatty acid composition does not form part of the South African classification system. Likewise, muscle colour is not evaluated in the current SA classification.

In addition, the muscle pH₂₄ of the Non-descript genotype differed ($P < 0.05$) from those of Fleckvieh and Simmental. However, all the pH values were > 5.8 at 24 h after slaughter. High pH values (pH > 5.8) 24 h after slaughter are associated with dark firm and dry meat (DFD) thus the high pH values may have also contributed to the darker C2 carcass cuts across the genotypes. Furthermore, no differences ($P > 0.05$) were found in thawing loss (TL%) in LTL among all genotypes. The LTL of Non-descript genotype steers had low CL% ($P < 0.05$) compared to all other genotypes. In addition, the WBSF values of Angus LTL differed ($P < 0.05$) from those of Fleckvieh and Non-descript genotypes.

Although according to SAMIC (2006), animals of the same age are presumed to have similar tenderness, the current results show that this is not always the case as many other factors such as breed might also affect tenderness. The current classification system uses age as the only indicator of tenderness implying that optimal tender meat is obtained from carcasses of animals with no permanent teeth (class

Table 2
Least square means (±SE) of meat quality attributes for C2 carcass classes of different beef genotypes reared from different feedlot based systems.

| Meat quality attributes | Breeds | | | | | P-value |
|---------------------------|---------------------------|----------------------------|---------------------------|---------------------------|---------------------------|---------|
| | Angus (n = 16) | Bonsmara (n = 15) | Fleckvieh (n = 21) | Non-descript (n = 7) | Simmental (n = 35) | |
| L* (n = 94) | 29.7 ^b ± 3.5 | 32.8 ^a ± 3.40 | 31.5 ^{ab} ± 2.79 | 32.7 ^a ± 2.53 | 31.1 ^{ab} ± 2.53 | 0.0798 |
| a* (n = 94) | 15.6 ^a ± 2.18 | 13.5 ^b ± 1.66 | 15.9 ^a ± 3.11 | 15.3 ^a ± 1.10 | 14.5 ^{ab} ± 1.45 | 0.0045 |
| b* (n = 94) | 10.7 ^b ± 2.57 | 10.6 ^b ± 1.85 | 10.7 ^b ± 2.66 | 12.7 ^a ± 1.13 | 10.8 ^b ± 1.93 | 0.0877 |
| HA (n = 94) | 34.2 ^b ± 5.35 | 38.1 ^a ± 4.67 | 33.7 ^b ± 5.30 | 39.6 ^a ± 2.80 | 36.8 ^{ab} ± 4.31 | 0.0060 |
| SI (n = 94) | 18.9 ^{ab} ± 2.87 | 17.3 ^b ± 2.08 | 19.2 ^{ab} ± 3.73 | 19.9 ^a ± 1.23 | 18.1 ^{ab} ± 2.00 | 0.0304 |
| pH ₂₄ (n = 94) | 6.2 ^{ab} ± 0.15 | 6.1 ^{ab} ± 0.12 | 6.1 ^b ± 0.24 | 6.2 ^a ± 0.39 | 6.1 ^b ± 0.12 | 0.0497 |
| TL% (n = 94) | 5.7 ^a ± 2.80 | 6.5 ^a ± 2.64 | 5.2 ^a ± 2.20 | 6.1 ^a ± 2.70 | 4.9 ^a ± 2.00 | 0.1311 |
| CL% (n = 94) | 22.3 ^a ± 5.35 | 20.5 ^a ± 8.91 | 22.9 ^a ± 5.87 | 11.4 ^b ± 5.43 | 25.2 ^a ± 4.05 | 0.0001 |
| WBSF (n = 94) | 40.3 ^a ± 11.62 | 36.7 ^{ab} ± 10.37 | 32.2 ^b ± 7.92 | 31.5 ^b ± 12.62 | 38.7 ^{ab} ± 9.33 | 0.0540 |

^{a, b} Means within a row bearing different superscripts differ at $P < 0.001$. L* – lightness; a* – redness; b* – yellowness; HA – Hue angle; SI – saturation index; pH₂₄ – meat pH; SI – saturation index; TL% – Thawing loss percentage; CL% – cooking loss percentage; WBSF – Warner Bratzler Shear Force (Newtons).

Table 3

Pearson's correlation coefficients among the meat quality attributes within the C2 carcass classes of genotypes from different feedlot based systems.

| | L* | a* | b* | HA | SI | pH ₂₄ | TL% | CL% | WBSF |
|------------------|----|----------|----------|----------|----------|------------------|---------|--------|----------|
| L* | - | -0.271** | 0.380*** | 0.631*** | -0.004 | -0.196 | 0.284** | -0.051 | -0.080 |
| a* | | - | 0.521*** | -0.205* | 0.917*** | -0.079 | 0.060 | -0.030 | -0.033 |
| b* | | | - | 0.719*** | 0.817*** | -0.206* | 0.298** | -0.089 | -0.059 |
| HA | | | | - | 0.194 | -0.166 | 0.271** | -0.092 | -0.058 |
| SI | | | | | - | -0.151 | 0.184 | -0.068 | -0.058 |
| pH ₂₄ | | | | | | - | -0.176 | -0.187 | 0.213* |
| TL% | | | | | | | - | -0.189 | -0.045 |
| CL% | | | | | | | | - | 0.420*** |
| WBSF | | | | | | | | | - |

Correlation significance: *P b 0.05, **P b 0.01; ***P b 0.001; NS– not significant at P N 0.05.

L*– lightness; a*– redness; b*– yellowness; HA– Hue angle; SI– saturation index; pH₂₄– meat pH; TL%– Thawing loss percentage; CL%– cooking loss percentage; WBSF– Warner Bratzler Shear Force (Newtons).

A) (Moloto et al., 2015). Strydom et al. (2015) argued that age, as used in the SA classification system, does not guarantee tenderness. The current results also coincide with Strydom et al. (2015) as meat tenderness from the same muscle was discovered to be different among animals of the same age but different genotypes.

The Angus and Simmental genotypes had the least tender meat (40.29 ± 11.62 and 38.71 ± 9.33), while the Non-descript and Fleckvieh had the most tender meat (31.53 ± 12.62 and 32.00 ± 7.92) in the current study. These results are similar to those reported by Reuter, Wulf, and Maddock (2002) stating that tenderness varies among genotypes, muscles and cuts. The SA carcass classification system, therefore, needs to adopt a classification system that will measure and rank the meat quality attributes across genotypes. Table 3 shows correlations among meat quality attributes of the C2 carcass class.

Some meat quality traits did not correlate (P N 0.05) with CL%, pH₂₄ and WBSF. However, positive correlations (P b 0.001) were found between tenderness (WBSF) and CL%. Aaslyng, Bejerholm, Ertbjerg, Bertram, and Andersen (2003) reported that changes in meat juiciness are closely associated with CL%, while juiciness is closely associated with tenderness, explaining the relationship for the Non-descript genotype which had the lowest CL% (11.41 ± 5.43) and more tender meat than other genotypes in the current study. Most significant positive correlations (P b 0.001) were among the meat colour characteristics such as lightness (L*), redness (a*), yellowness (b*), HA and SI.

4. Conclusion

In this study, meat quality traits were more similar among steers with 6 (B2), 7(C2) and 8 (C2) incisors within genotypes than among genotypes, with notable differences observed within the C-class animals. Further evaluation of C-class animals provided evidence that although animals might be falling within the same C-class, the number of incisors present at slaughter might distinguish the meat and carcass quality. This study therefore has shown that genotype and bovine dentition have an effect on some carcass and meat quality traits. There is, therefore, a need to rank carcasses within a class by dentition and genotype. A different age-classification with eight rankings to represent each number of incisors should therefore be developed to evaluate carcass and meat quality attributes in each of these classes.

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