THE EFFECT OF BREED TYPE AND SLAUGHTER AGE ON CERTAIN PRODUCTION PARAMETERS OF BEEF CATTLE IN THE ARID SWEET BUSHVELD

by

IZAK DU PLESSIS

Thesis in partial fulfilment for the degree of

MASTER OF SCIENCE IN AGRICULTURE (MScAgric)

(ANIMAL SCIENCE)

At the University of Stellenbosch

Study Supervisor: Prof. L.C. Hoffman

April 2004

Stellenbosch

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any other university for a degree.

Signature:_____________________ Date:____________________

SUMMARY

The aim of this study was to provide scientifically founded guidelines to enhance the understanding of beef production from natural pastures in arid sweet veld regions. Cattle from four breed types ranging from large to small frame sizes (Simmentaler cross > Bonsmara cross > Afrikaner > Nguni) were compared in terms of cow production and efficiency as well as the growth performance, carcass and meat quality of steers slaughtered at 18, 24 and 30 months of age. Eighteen and 30 month old steers were slaughtered at the end of the wet summer season, while the 24 month old steers were slaughtered at the end of the dry winter season.

The Afrikaner herd (59.8 ± 9.0 %) had lower ($p < 0.05$) pregnancy rates than the Simmentaler cross (79.3 ± 12.2 %), Bonsmara cross (76.5 ± 11.1 %) and Nguni herds (86.1 ± 5.8 %). Breed differences ($p < 0.05$) for weaning weight and preweaning gain were observed (Simmentaler cross > Bonsmara cross > Afrikaner > Nguni). The Nguni cow herd (46.5 ± 5.7 kg/100 kg mated) was more ($p < 0.05$) efficient than the Simmentaler cross (36.2 ± 5.5 kg/100 kg mated), Bonsmara cross (37.7 kg/100 kg mated) and Afrikaner herds (29.5 ± 5.9 kg/100 kg mated).

During the dry winter season steers gained 23.4 ± 1.5 kg from 7 to 12 months of age and from 18 to 24 months of age they gained 20.9 ± 2.0 kg. During the wet summer season steers gained 109.7 ± 1.8 kg from 12 to 18 months and 120.3 ± 4.1 kg from 24 to 30 months of age. The best ($p > 0.05$) fat classification codes were attained at 30 months of age and the worst ($p < 0.05$) at 24 months of age. Simmentaler cross steers attained the lowest ($p < 0.05$) fat classification at all three age classes. At 30 months of age, 15 of the 63 steers slaughtered had 3 or 4 permanent incisors, while 47 steers had 2 permanent incisors.

The total amount as well as the percentage kidney and omental fat were the highest ($p < 0.05$) at 30 months of age and the lowest ($p < 0.05$) at 24 months. Back fat thickness followed the same pattern.

Although breed differences for some meat quality parameters were observed, slaughter age had a much more pronounced effect on meat quality parameters. The percentage cooking loss was the lowest ($p < 0.05$) at 30 months of age. The meat was also darker ($p > 0.05$) and more red ($p < 0.05$) at 30 months than at 18 or 24 months of age. The pH_{24} was higher ($p < 0.05$) at 24 (5.68 ± 0.05) and 30 months (5.65 ± 0.03) than at 18 months of age (5.48 ± 0.04). A trained sensory panel only detected that *Longissimus* muscle samples from 18 month old steers were more tender ($p < 0.05$) than that from 30 month old steers. Similar results were found for Warner-Bratzler shear force values.

Marketing steers at 30 months of age resulted in higher production outputs for all the breed types than marketing weaners. For marketing both weaners and 30 month old steers the Nguni herd produced more marketable kilograms live weight than the Simmentaler cross, the Bonsmara cross and the Afrikaner herds.

Different marketing systems suitable to the Arid Sweet Bushveld were identified. Each marketing system is discussed in terms of its application, advantages, disadvantages and adaptability to arid regions. It is maintained throughout that a conservative approach to grazing as well as cattle management is critical to ensure stable production systems in arid regions with erratic rainfall patterns.

OPSOMMING

Die oogmerk van hierdie studie is om wetenskaplik gefundeerde riglyne daar te stel wat die begrip van beesvleis produksie vanaf natuurlike weidings in ariede soetveld streke sal verbeter. Beeste van vier ras tipes wat wissel van groot- tot kleinraam tipes (Simmentaler kruis > Bonsmara kruis > Afrikaner > Nguni) is vergelyk in terme van koeiproduksie en effektiwiteit sowel as die groei prestasie, karkas- en vleiskwaliteit van osse op 18-, 24- en 30-maande ouderdom. Osse wat op 18 en 30 maande ouderdom geslag is, is aan die einde van die nat somerseisoen geslag, terwyl osse wat op 24 maande ouderdom geslag is, aan die einde van die droë winterseisoen geslag is.

Die Afrikaner kudde (59.8 ± 9.0 %) het ’n laer ($p < 0.05$) reproduksietempo as die Simmentaler kruis (79.3 ± 12.2 %), Bonsmara kruis (76.5 ± 11.1 %) en die Nguni kuddes (86.1 ± 5.8 %) gehandhaaf. Ras verskille ($p < 0.05$) ten opsigte van speenmassas en voorspeense groeitempo’s is waargeneem (Simmentaler kruise > Bonsmara kruise > Afrikaners > Ngunis). Die Nguni koei kudde (46.5 ± 5.7 kg/100 kg gedek) was meer ($p < 0.05$) effektief as die Simmentalerkruis (36.2 ± 5.5 kg/100 kg gedek), Bonsmarakruis (37.7 kg/100 kg gedek) en die Afrikaner kuddes (29.5 ± 5.9 kg/100 kg gedek).

Gedurende die droëwinter seisoen het die osse vanaf 7 to 12 maande ouderdom 23.4 ± 1.5 kg in liggaamsmassa toegeneem en vanaf 18 tot 24 maande ouderdom het hulle 20.9 ± 2.0 kg toegeneem. Gedurende die nat somerseisoen het die osse vanaf 12 tot 18 maande ouderdom 109.7 ± 1.8 kg in liggaamsmassa toegeneem en van 24 tot 30 maande ouderdom het hulle 120.3 ± 4.1 kg toegeneem. Die beste ($p < 0.05$) vetklassifikasie kodes is op 30 maande ouderdom verkry en die swakste ($p < 0.05$) op 24 maande ouderdom. Simmentalerkruisosse het by alle ouderdomsgroepe die swakste ($P < 0.05$) vetklassifikasie kodes behaal. Op 30 maande ouderdom het 15 van die 63 osse wat geslag is 3 of 4 permanente snytande gehad, terwyl 47 osse 2 permanente snytande gehad het.

Die totale hoeveelheid sowel as die persentasie nier- en omentumvet was die hoogste ($p < 0.05$) op 30 maande ouderdom en die laagste ($p < 0.05$) op 24 maande ouderdom. Rugvetdikte het dieselfde patroon gevolg.

Alhoewel rasverskille vir sommige vleiskwaliteitsparameters waargeneem is, het slagouderdom’n groter effek hierop. Die persentasie kookverlies was die laagste ($p < 0.05$) op 30 maande ouderdom. Die vleis was ook donkerder ($p < 0.05$) en meer rooi ($p < 0.05$) op 30 maande ouderdom as op 18 en 24 maande ouderdom. Die pH_{24} was hoër ($p < 0.05$) op 24 (5.68 ± 0.05) en 30 maande ouderdom (5.65 ± 0.03) as op 18 maande ouderdom (5.48 ± 0.04). Behalwe vir sagtheid, is geen ander ras- of slagouderdomsverskille in die *longissimus* spiermonsters vir enige van die sensoriese eienskappe wat geëvalueer is, waargeneem nie. ’n Opgeleide sensoriese paneel het slegs waargeneem dat die *longissimus* spiermonsters van 18 maand oue osse sagter ($p < 0.05$) was as dié van 30 maand oue osse. Soortgelyke resulte is vir die Warner-Bratzler snyweerstand gevind.

Die bemarking van 30 maand oud osse het hoër produksie uitsette vir al die ras tipes opgelewer as die bemarking van speenkalwers. Met die bemarking van beide speenkalf en 30 maand oue osse, het die Nguni

kudde meer bemarkbare kilogram lewendige massa as die Simmentalerkruis, die Bonsmarakruis en die Afrikaner kuddes geproduseer.

Verskillende bemarkingstelsels wat as geskik vir die Ariede Soet Bosveld beskou word, is geïdentifiseer. Elke bemarking stelsel is in terme van sy toepassing, voor- en nadele asook die toepaslikheid daarvan in ariede streke bespreek. Dit word deurgaans aanbeveel dat ’n konserwatiewe benadering tot beide weidings- en kuddebestuur, krities is om stabiele produksiestelsels in ariede streke met wisselvalige reënvalpatrone te verseker.

ACKNOWLEDGEMENTS

On completion of this thesis, I would like to express my appreciation and gratitude to the following people and institutions:

Prof. Louw Hoffman, my study supervisor, for providing me with the opportunity to enrol for this study as well as for his friendly, yet professional guidance;

The Limpopo Province Department of Agriculture for allowing me to use the data without reservations for study purposes;

Dr. Piet Venter for the unconditional use and unlimited access of his abattoir facilities to collect the carcass data without which this study would not have been possible;

The technical personnel at Mara Research Station for the collection of the animal production data. In particular: Anita Meyer, Pieter Erasmus and Amos Chauke;

The personnel at the University of Stellenbosch for conducting the sensory evaluations, laboratory analysis and statistical analysis, especially: Erica Moelich, Resia van der Watt, Gail Jordaan and Petro du Buisson;

Frikkie Calitz from the ARC for assisting with the statistical analysis of the sensory panel data;

Cornelis van der Waal, my colleague, for his advice and assistance;

Brian Kritzinger, fellow student and friend for his help with the collection of the carcass data;

Santie du Plessis, my wife, for assisting with the collection and capture of carcass data, loving support, motivation and devotion.

CONTENTS

		Page
DECLARATION		ii
SUMMARY		iii
OPSOMMING		iv
ACKNOWLEDGEMENTS		vi
CONTENTS		vii
LIST OF ABBREVIATIONS		xiii
NOTES		xiv
CHAPTER 1		1
1.1	**GENERAL INTRODUCTION**	1
1.1.1	SCOPE AND DEFINITIONS	1
1.1.2	ECOLOGICAL BACKGROUND AND ANIMAL HUSBUNDRY PRACTICES IN THE ARID SWEET BUSHVELD	2
	LITERATURE REVIEW ON:	
1.2	**REPRODUTION AND PRODUCTION PERFORMANCE OF THE BEEF COW HERD**	4
1.2.1	INTRODUCTION	4
1.2.2	REPRODUCTION PERFORMANCE OF THE BEEF COW HERD	4
1.2.2.1	AGE AT PUBERTY	4
1.2.2.2	CALVING RATE	4
1.2.2.3	NEONATAL LOSSES	5
1.2.2.4	PREWEANING LOSSES	5
1.2.3	EFFICIENCY OF THE COW HERD	6
1.3	**GROWTH RATES**	6
1.3.1	INTRODUCTION	6
1.3.2	BIRTH WEIGHT, PREWEANING GROWTH RATE AND WEANING WEIGHT	7
1.3.3	POST WEANING GROWTH PERFORMANCE	7

1.3.3.1 GROWTH RATES 8
1.3.3.1.1 INFLUENCE OF BREED OR FRAME SIZE AND SEX 8
1.3.3.1.2 INFLUENCE OF FEEDING REGIME 8
1.3.3.2 FEED CONVERTION RATES 9
1.3.3.2.1 INFLUENCE OF BREED 9
1.3.3.2.2 INFLUENCE OF FEEDING REGIME 10

1.4 CARCASS TRAITS 10
1.4.1 INTRODUCTION 10
1.4.2 LIVE AND CARCASS WEIGHT 11
1.4.2.1 INFLUENCE OF SEX 12
1.4.2.2 INFLUENCE OF BREED AND FRAME SIZE 12
1.4.2.3 INFLUENCE OF FEEDING REGIME 13
1.4.3 DRESSING PERCENTAGE 14
1.4.4 CARCASS MEASUREMENTS 15
1.4.5 *LONGISSIMUS* MUSCLE AREA 15
1.4.6 MUSCLE, BONE AND FAT CONTENT 16

1.5 CARCASS FAT CONTENT, DISTRIBUTION AND PARTITIONING 19
1.5.1 INTRODUCTION 19
1.5.2 FAT THICKNESS 19
1.5.2.1 INFLUENCE OF SEX 19
1.5.2.2 INFLUENCE OF BREED AND FRAME SIZE 19
1.5.2.3 INFLUENCE OF FEEDING REGIME 20
1.5.3 CARCASS FAT CONTENT 21
1.5.3.1 INTRAMUSCULAR FAT AND MARBLING 21
1.5.3.1.1 INFLUENCE OF SEX 21
1.5.3.1.2 INFLUENCE OF BREED AND FRAME SIZE 22
1.5.3.1.3 INFLUENCE OF FEEDING REGIME 22
1.5.3.2 TOTAL DISSECTIBLE FAT AND CARCASS FAT CONTENT 23
1.5.3.2.1 INFLUENCE OF BREED OR FRAME SIZE AND SEX 23
1.5.3.2.2 INFLUENCE OF FEEDING REGIME 24

1.5.4 PARTITIONING OF FAT BETWEEN THE DIFFERENT FAT DEPOTS 24

1.6 PHYSICAL CHARACTERISTICS OF MEAT 26
1.6.1 INTRODUCTION 26
1.6.2 COLOUR 26
1.6.2.1 INFLUENCE OF BREED AND SEX 26
1.6.2.2 INFLUENCE OF FEEDING REGIME 27
1.6.2.3 INFLUENCE OF *POST-MORTEM* AGEING OF MEAT 27
1.6.3 pH 28
1.6.3.1 INFLUENCE OF BREED AND SEX 28
1.6.3.2 INFLUENCE OF FEEDING REGIME 28
1.6.4 TEMPERATURE 29
1.6.4.1 INFLUENCE OF BREED 29
1.6.4.2 INFLUENCE OF FEEDING REGIME AND FAT COVER 29
1.6.5 DRIP AND COOKING LOSS 30
1.6.5.1 INFLUENCE OF BREED AND SEX 30
1.6.5.2 INFLUENCE OF FEEDING REGIME 30
1.6.5.3 INFLUENCE OF KIDNEY FAT 30
1.6.6 COLLAGEN 30
1.6.6.1 INFLUENCE OF BREED AND SEX 31
1.6.6.2 INFLUENCE OF ANIMAL MATURITY 32
1.6.6.3 INFLUENCE OF MUSCLE TYPE 32
1.6.7 SHEAR FORCE 32
1.6.7.1 INFLUENCE OF BREED 32
1.6.7.2 INFLUENCE OF FEEDING REGIME 33
1.6.7.3 INFLUENCE OF FAT 34
1.6.7.4 INFLUENCE OF pH 34
1.6.7.5 INFLUENCE OF ANIMAL AGE, MATURITY AND SEX 35
1.6.7.6 INFLUENCE OF *POST-MORTEM* AGING OF MEAT 35
1.6.8 SENSORY EVALUATION 35
1.6.8.1 INFLUENCE OF BREED 35
1.6.8.2 INFLUENCE OF FEEDING REGIME 36
1.6.8.3 INFLUENCE OF ANIMAL MATURITY AND SEX 37

1.6.8.4 INFLUENCE OF FAT 37
1.6.9 RELATIONSHIPS 38

1.7 CHEMICAL COMPOSITION OF MEAT 38
1.7.1 INTRODUCTION 38
1.7.2 MOISTURE CONTENT 38
1.7.2.1 INFLUENCE OF BREED AND SEX 38
1.7.2.2 INFLUENCE OF FEEDING REGIME 39
1.7.3 CRUDE PROTEIN CONTENT 39
1.7.4 ASH AND MINERAL CONTENT 40

1.8 GENERAL CONCLUSIONS AND OBJECTIVES 40

1.9 REFERENCES 41

CHAPTER 2 50
REPRODUCTION AND PRODUCTION PERFORMANCE OF COW HERDS OF FOUR BREED TYPES GRAZING NATURAL SWEET PASTURES 50
ABSTRACT 50
INTRODUCTION 50
MATERIALS AND METHODS 51
RESULTS 53
DISCUSSION 55
CONCLUSIONS 56
REFERENCES 57

CHAPTER 3 59
EFFECT OF CHRONOLOGICAL AGE OF BEEF STEERS OF DIFFERENT MATURITY TYPES ON THEIR GROWTH AND CARCASS CHARACTERISTICS WHEN FINISHED ON NATURAL PASTURES IN THE ARID SUB-TROPICS OF SOUTH AFRICA 59

ABSTRACT 59
INTRODUCTION 60
MATERIALS AND METHODS 60
RESULTS AND DISCUSSION 62
CONCLUSIONS 70
REFERENCES 70

CHAPTER 4 74

THE EFFECT OF SLAUGHTER AGE AND BREED ON THE CARCASS TRAITS AND MEAT QUALITY OF STEERS GRAZING NATURAL SWEET PASTURES 74

ABSTRACT 74
INTRODUCTION 74
MATERIALS AND METHODS 75
RESULTS 77
DISCUSSION 84
CONCLUSIONS 86
REFERENCES 86

CHAPTER 5 91

EFFECT OF MARKETING STRATEGY ON THE PRODUCTION PERFORMANCE OF CATTLE HERDS FROM FOUR DIFFERENT BREED TYPES IN THE ARID SWEET BUSHVELD 91

ABSTRACT 91
INTRODUCTION 91
MATERIALS AND METHODS 92
RESULTS 93
DISCUSSION 97
CONCLUSIONS 98
REFERENCES 98

CHAPTER 6 99

FINAL CONCLUSIONS AND APPLICATIONS 99

INTRODUCTION 99

SUMMARY OF RESULTS 100

GENERAL RECOMMENDATIONS 101

ADAPTABLE PRODUCTION SYSTEMS 102

Purchasing weaners and marketing long weaners 102

Purchasing weaners and marketing 30 month old steers 103

Producing and marketing steers at 18 months from a nucleus cow herd 104

Producing and marketing steers at 30 months from a nucleus cow herd 106

FUTURE RESEARCH 107

REFERENCES 108

LIST OF ABBREVIATIONS

ADG	Average daily gain
AF	Afrikaner
BFT	Back fat thickness
BX	Bonsmara cross
BW	Birth weight
CCOMP	Carcass compactness
CCW	Cold carcass weight
CE	Cow efficiency
CL	Cooking loss
CW	Cow weight
DL	Drip loss
DP	Dressing percentage
HE	Herd efficiency
HWE	Herd weaning efficiency
KF	Kidney fat
KPH	Kidney, pelvic and heart fat
LSU	Live stock unit
LW	Live weight
NG	Nguni
NM	Number of cows mated
OF	Omental fat
PR	Pregnancy rate
SX	Simmentaler cross
TG	Total gain
WBS	Warner-Bratzler shear force
WW	Weaning weight

NOTES

The language and style in this thesis are in accordance with the requirements of the scientific journal, South African Journal of Animal Science. This dissertation represents a compilation of manuscripts where each paper is an individual entity and some repetition between the chapters has, therefore been unavoidable.

Results from this study have been presented at the following Congresses/Symposia:

1. Du Plessis, I. & Hoffman, L.C., 2002. Effect of chronological age on growth and carcass characteristics of four different frame sized steers. In: Proc GSSA/SASAS Joint Congress, Christiana Aventura, 13-16 May 2002.

2. Du Plessis, I. & Hoffman, L.C., 2003. Effect of marketing strategy on the production performance of cattle herds from four different breed types in the arid sweet Bushveld. In: Proc SASAS-DAIG Congress, University of Limpopo, 20-23 October 2003.

3. Du Plessis, I. & Hoffman, L.C., 2004. Effect of chronological age of beef steers of different maturity types on their growth and carcass characteristics when finished on natural pastures in the arid sub-tropics of South Africa. *S. Afr. J. Anim. Sci*. 34, 1-12.

4. Du Plessis, I. & Hoffman, L.C., 2004. Effect of marketing strategy on the production performance of cattle herds from four different breed types in the Arid Sweet Bushveld. SA-Anim. Sci. 5,1-7.

CHAPTER 1

1.1 General introduction

1.1.1 Scope and definitions

This review will mainly concentrate on how sex, breed/frame size and feeding regime affect the reproductive performance of the beef cow herd, the production of steers as well as the carcass and meat characteristics of the steers. Although references to the effects of other factors such as stress and manipulations to enhance meat quality are sometimes made, it is not the intention to study it in detail.

In the general context of this review the following terms are used and are accordingly defined:

- "Maturity rate" refers to the time needed for various physiological processes (growth, reproduction, fattening, etc.) to be completed.
  - In early maturing animals the physiological processes are completed at an early age, i.e. heifers reach puberty at an earlier age and animals start fattening at an earlier age.
  - In late maturing animals the physiological processes are completed at a late age, i.e. heifers reach puberty at a later age and animals start fattening at a later age.
- "Frame size" refers to the physical size of the animals and is in most cases defined in terms of either hip height, weight or both.
  - Small framed animals are shorter and lighter than large framed animals.
  - Large framed animals are taller and heavier than small framed animals.
- "Backgrounding", this term is frequently used in the *Journal of Animal Science* and refers to the treatment animals received before being fed in a feedlot. This usually entails a period on a pasture with or without supplementation.
- "Sweet and sour veld" refers to the nutritional quality of the pasture during the dry winter season and Scott (1947) defined it as follows: "Sweet veld is veld which remains palatable and nutritious when mature, whereas sour veld provides palatable material only in the growing season".

In most instances small framed and early maturing animals exhibit the majority of traits in a similar fashion than do large framed and late maturing animals. This is because small framed animals tend to be early maturing while large framed animals tend to be late maturing.

1.1.2 Ecological background and animal husbandry practices in the Arid Sweet Bushveld

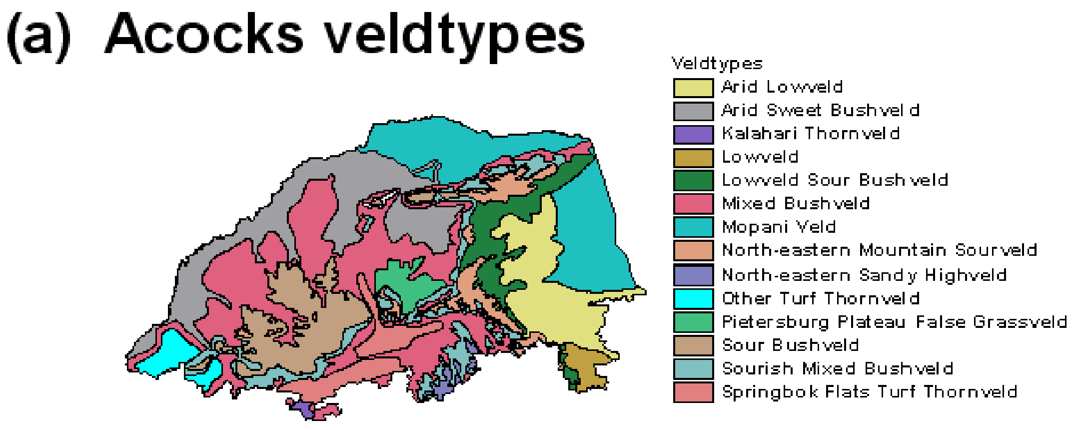
The long term (20 years+) mean annual rainfall for most parts of the Limpopo Province is less that 500 mm(Figure 1). Thus, most of the Limpopo Province consists of arid rangeland with a range of extensive farming systems being practiced. In the past, crops were planted on marginal areas, but this practice has largely been reduced to crops (especially maize) planted in rural areas on a subsistence scale only. In some small areas with substantial subsurface water cash crops (potatoes, tomatoes, onions, etc) and fruit trees (citrus, nuts etc.) are being cultivated. In the high rainfall areas other fruits (mangos, avocados, bananas, etc) are also cultivated.

In 1998 game fenced farms already occupied 26 % of the total area of the Limpopo Province (Van der Waal & Dekker, 2000). Game ranching is an ever increasing farming enterprise, especially in the driest parts of the Province, thus this percentage can presently be expected to be higher. The results of Robinson & Lademann (1998), indicating that cattle numbers have declined by as much as 84 % from 1975 to 1998, supports this observation. Game farming is a capital intensive enterprise, thus many (24 % according to Van der Waal & Dekker, 2000) professional people who are not solely dependent on the income from farming, purchase cattle farms and convert these to game farms.

Coetzee (1971) described the Arid Sweet Bushveld of the north western Transvaal as being ecologically vulnerable. He also identified overgrazing and rigid, inadaptable production systems as the main reasons for the low economical results obtained with cattle farming. Coetzee (1971) also concluded that the average farmer is approximately 50 years old and that it is very difficult for young farmers to enter the farming community if they do not inherit a farm. Although there are no results available on the current status of the farming community in the Province, it can be expected that the situation worsened since 1971 with the mean age of farmers increasing even more and very few new entrants into farming.

In general, cattle production enterprises revolves around weaner production with the animals being sold to feedlots. However, there is an increasing tendency for cattle farmers to raise steers. Various production practices are followed with this production system. In general light steers (< 200 kg) are bought and raised to between 290 kg and 300 kg and then sold directly to feedlots. This practice can involve various levels of supplementation ranging from no supplementation to production supplements on the veld. Some producers also raise steers on the natural pastures and finish them off in an on-farm feedlot for a short period (approximately two months).

Although producing steers, which allows flexibility in stocking rate adjustments, has been recommended by most scientists for a considerable period of time, producers are reluctant to adapt this production system as is the case with many scientific principals (Coetzee, 1971). It is difficult to pinpoint the reasons for this, but it probably stems from a lack of a convincing display of benefits of new principals. Economic pressures and the examples set by prominent farmers probably also act as deterrents to adapt new technologies and principals.



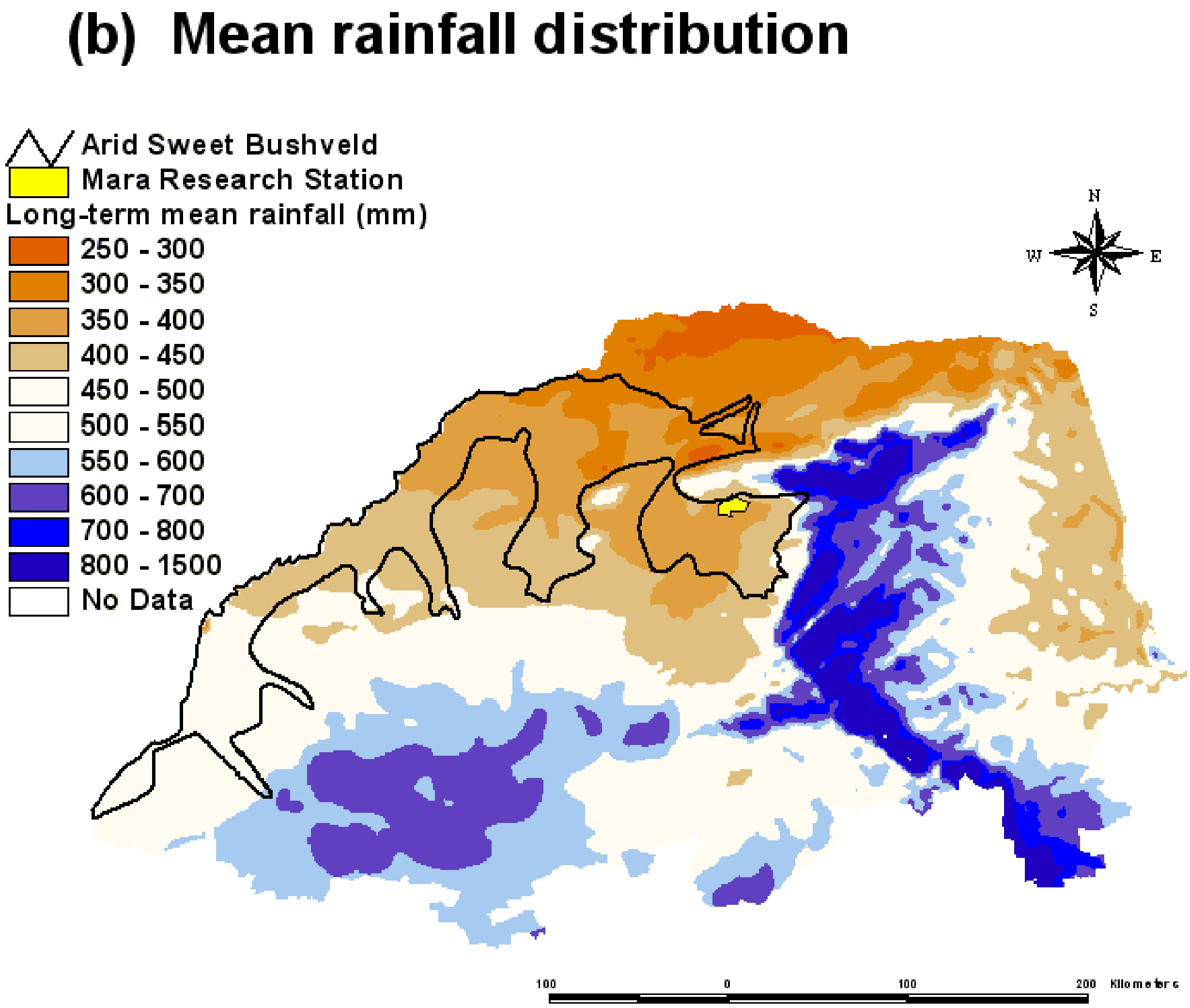


Figure 1 Veld types (a) (Acocks, 1988) and mean long term annual rainfall (b) maps for the Limpopo Province

1.2 Reproduction and production performance of the beef cow herd

1.2.1 Introduction

Beef cow herds are maintained primarily for reproduction and to convert forage into products useful to man (Klosterman, 1981). With calf production as the primary objective of the beef cow herd, it follows that the reproductive rate of the cow herd plays a major role in the overall productivity of the beef production enterprise. The pregnancy rates of the female as well as the survival rates of the calves are of critical importance in assessing the production efficiency of the cow herd. Although the growth rate of the calves also plays an important role in the production efficiency of the herd, it only contributes significantly if the reproductive performance of the herd is at a high level.

This section will concentrate on differences in productivity between breed/frame size types as most cow herds are kept on natural pastures. Therefore the major nutritional differences between cow herds depend on the locality i.e. whether the cow herd grazes sweet or sourveld pastures.

1.2.2 Reproduction performance of the beef cow herd

1.2.2.1 Age at puberty

In a review, Schoeman (1989) indicated that smaller framed, earlier maturing Nguni heifers reached puberty at a significantly ($p < 0.01$) younger age (349.9 days in feedlot and 399.9 days extensive) and lower weight (238.2 kg in feedlot and 234.9 kg extensive) compared to larger framed, later maturing Drakensberger (407.2 days and 298.7 kg) and Bonsmara heifers (419.0 days and 341.4 kg). McGregor & Swanepoel (1992) however, suggested much heavier target weights (ranging from 410 to 420 kg) for Bonmsara heifers mated between one and three years of age. Small, medium and large framed Brahman heifers reached puberty at 633, 626 and 672 days respectively (Vargas *et al.*, 1999).

The age at which puberty in heifers is reached, is dependent on the frame size of the heifers with smaller framed, earlier maturing breed types reaching puberty at an earlier age than larger framed, later maturing breed types. In practice heifers are mated for the first time between 18 and 24 months of age, depending on the breeding practices of the producer. All breed/frame size type cattle will reach puberty before 24 months of age. Breed and frame size differences should thus have little influence on the pregnancy and calving rates of first calf heifers.

1.2.2.2 Calving rate

Tawonezvi *et al.* (1988) reported that calving rates ranged from 54.4 % in Afrikaner x Nkone cattle to 78.0 % in Sussex x Brahman cattle. Collins-Lusweti (2000) reported calving rates of 87 %, 69 % and 70 % for Nguni, Afrikaner and Bonsmara cattle respectively. In agreement with these results, Schoeman (1989) reported that Sanga cows (89.6 %) attained a higher mean calving rate compared to Afrikaner (74.6 %), Hereford (77.9 %), Santa Gertrudis (79.6 %) and Simmentaler cows (77.6 %).

When heifers are mated for the first time at 2 years of age, no differences in calving rates are likely to be observed, as the majority of heifers will have reached puberty at this stage (Vargas *et al.*, 1999). However, these researchers reported that the calving rates of second parity cows were on average 63.1 %, with 41.0 % for large framed cows, 65.8 % for medium framed and 69.0 % for small framed cows that weaned their first calf the previous year. In mature cows the mean pregnancy rate is 90.3 %. Significantly more ($p < 0.01$) small framed cows (93.5 %) became pregnant than medium (78.5 %) or large framed cows (79.8 %).

Lepen *et al.* (1993) reported calving rates of 73.3 % (mated at 13 months of age) and 75.9 % (mated at 16 months of age) for feedlot and pasture reared Nguni heifers respectively. The reconception rates were 83.3 and 78.3 % respectively.

Grosskopf (1973) studied five herds (Afrikaner crosses at different locations) and reported a positive relationship between the preweaning growth rates of calves and the reconception rates of the respective cow herds. This author deduced that differences in weaning weights between cow herds and thus also the reconception rates of the cows, are due to differences in nutrition. In addition, McGregor & Swanepoel (1992) reported that the weight at the end of the breeding season accounted for most of the variation in conception rates.

Calving rate is influenced in a similar fashion to age at puberty, with smaller framed, earlier maturing breeds attaining higher calving rates than larger framed, late maturing breeds. The exception to this observation is Afrikaner cows that have lower than expected calving rates. Taking into account the history of the breed, starting out as primarily a draught animal (Van Marle, 1974), a low fertility rate may be an intrinsic characteristic of the Afrikaner breed.

1.2.2.3 Neo-natal losses

Neo-natal losses ranging from 1.33 % to 7.24 % for Santa Gertrudis and Simmentaler cattle respectively were reported by Schoeman (1989). Vargas *et al.* (1999) found that calf survival rate was only affected by frame size in first parity heifers. Significantly less ($p < 0.01$) calves from large framed Brahman heifers (47.9 %) than calves from medium (83.4 %) or small framed (80.7 %) heifers survived (Vargas *et al.*, 1999).

The most probable explanation for this observation, as proposed by Vargas *et al.* (1999), is that more difficult births are experienced by large framed breeds than by the smaller framed breeds. In the case of Vargas *et al.* (1999) weak calf syndrome and susceptibility to cold weather may also have contributed.

1.2.2.4 Preweaning losses

Preweaning losses of 6.28, 9.43, 3.61, 4.52 and 6.17 % were reported for Afrikaner, Hereford, Sanga, Santa Gertrudis and Simmentaler calves, respectively (Schoeman, 1989). However, no differences in the survival rates among the calves from different breed crosses were observed by Tawonezvi *et al.* (1988).

Frame size affected ($p < 0.05$) weaning rates only in first and second parity dams (Vargas *et al.*, 1999). Small and medium framed heifers and cows attained higher weaning rates than large framed heifers and cows.

It is a well known fact that breeds indigenous to southern Africa are more resistant to diseases. Thus it is more likely that breed rather than frame size will influence weaning rate.

1.2.3 Efficiency of the cow herd

Weight of calf weaned per cow mated is more important than weaning weight *per se* and is a function of calving rate, calf survival rate and calf weaning weight (Vargas *et al.*,1999).

Tawonezvi *et al.* (1988) reported that Afrikaner cows mated with Brahman bulls (34.7 kg) weaned the most kilograms per 100 kg cow mated, while the reciprocal cross weaned the least (24.9 kg). While Schoeman (1989) reported the following results for Afrikaner (26.9 kg), Hereford (25.9 kg), Sanga (38.9 kg), Santa Gertrudis (33.7 kg) and Simmentaler cows (29.0 kg). He explained that the low production rate of the Afrikaner cows was probably due to their lower weaning rate.

Vargas *et al.* (1999) reported overall production per cow of 148.4, 113.1 and 161.7 kg calf for first-, second- and third or greater parity Brahman dams, respectively. For all dam parity groups, large frame sized dams weaned less kg calf per cow mated than small and medium frame sized dams.

Schoeman (1996) defined cow efficiency as (calf weaning weight/cow weight$^{0.75}$) x calving rate. He reported that Afrikaner cows had the lowest and Shorthorn the highest efficiencies which is in contradiction with the findings of Vargas *et al.* (1999) that breed mature size did not influence cow efficiency.

Breed and frame size have a similar influence on the herd efficiency and the reproduction rate of the cows, as herd efficiency is closely linked to reproductive performance. Due to the lower calving and weaning rates of larger framed breeds, they also have lower herd efficiencies than smaller framed breeds.

However when steers are produced, growth rates and efficiency of feed conversion can not be ignored, as these factors play an increasingly important role in the efficiency of the production system.

1.3 Growth rates

1.3.1 Introduction

Growth rates are influenced by breed (which is a function of the frame size of the breed) nutrition and sex. Cattle are finished for slaughtering either intensively in feedlots, semi-intensively by feeding concentrates on pastures or extensively from pastures only. The suitability of a breed or breed type to be used under prevailing nutritional conditions is mainly determined by its ability to sustain a reasonable growth rate and to finish off to a marketable degree. In fact, Schoeman (1996) concludes that there is no “best breed” suitable to all environmental conditions.

1.3.2 Birth weight, preweaning growth rate and weaning weight

Birth weight increases with increasing frame size between as well as within breeds. The birth weight of large framed Charolais x Angus males were respectively 6 and 8 kg heavier than the birth weight of small framed Angus males in two experiments conducted by O'Mary *et al.* (1979). Dadi *et al.* (2002a) also reported that Charolais sired calves were 5 kg heavier than Hereford sired calves at birth. Similarly, the smaller framed Afrikaner x Mashona calves (30.7 kg) were significantly lighter than the other breed types studied by Tawonezi *et al.* (1988), while the larger framed Charolais x Sussex calves (36.5 kg) were the heaviest. Collins-Lusweti (2000) observed birth weights of 30.3, 30.2 and 31.3 kg for Nguni, Afrikaner and Bonsmara calves respectively. Birth weight also increased ($p < 0.05$) with increasing frame size in first, second as well as third or greater parity Brahman dams (Vargas *et al.*, 1999).

Larger framed breeds tend to grow at faster rates than smaller framed breeds. Calves of Brahman and Charolais crosses had the highest growth rates, while calves of Mashona and Nkone crosses had the lowest growth rates i.e. live weight gains (Tawonezi *et al.*, 1988). Similarly, Dadi *et al.* (2002b) reported that preweaning growth rates increased as the genetic proportion of Charolais:Angus increased. Growth rates of calves increased ($p < 0.05$) with increasing frame size (Vargas *et al.*, 1999). From the literature cited Vargas *et al.* (1999) explained that these differences likely reflect a positive phenotypic correlation between milk production and body size of the cow, the inherent growth pattern of large framed calves and the ability of fast-gaining calves to consume enough forage to meet their increased nutritional demands for growth.

Due to faster preweaning growth rates large framed breeds usually have higher weaning weights. Weaning weight was 21 kg ($p < 0.05$) and 62 kg ($p < 0.001$) heavier for large framed Charolais x Angus males than for small framed Angus males in two separate experiments (O'Mary *et al.*, 1979). Charolais sired calves were also 20 kg heavier at weaning than Hereford sired calves (Dadi *et al.*, 2002a). The smaller framed Afrikaner x Mashona calves were the lightest at weaning, while the larger framed calves from Brahman and Charolais crosses were the heaviest (Tawonezi *et al.*, (1988). Weaning weights (200 days) of 135.6, 173.6 and 150.6 kg for Nguni, Afrikaner and Bonsmara calves respectively, were noted (Collins-Lusweti, 2000).

The results of Vargas *et al.* (1999) that large framed first parity heifers and third or greater parity cows weaned heavier calves than medium and small framed heifers and cows, summarise the influence of breed/frame size on preweaning growth rate and weaning weight to a large extent.

1.3.3 Post weaning growth performance

The post weaning environment plays a more important role in the growth performance of animals than the preweaning environment. This section will concentrate on how breed or frame size, sex and nutritional plane as well as their interactions affect post weaning growth performance.

1.3.3.1 Growth rates

1.3.3.1.1 Influence of breed or frame size and sex

It is often expected that large framed breeds will grow at faster rates than small framed breeds, but the expression of breed effects is often dependent on the nutritional plane the animals are subjected to. Charolais x Angus steers had faster ($p < 0.05$) average daily gains (1.34 kg/day) than Angus (1.21 kg/day) steers up to 150 days on feed (O'Mary *et al.*, 1979). Correspondingly, Charolais sired steers had the fastest growth rates, while Longhorn and Nellore sired steers had the slowest growth rates (Wheeler *et al.*, 1996). These results are supported by the results of Block *et al.* (2001). Studying the Angus and Hereford compared to Tuli, Boran and Brahman on a limited feed intake regime, Sprinkle *et al.* (1998) found that the Tuli-sired steers grew at a slower rate than the British breeds, but no other differences were observed. On an *ad libitum* feed intake regime the British- and Brahman-sired steers attained higher growth rates than Tuli- or Boran-sired steers. On the contrary, large and small framed steers achieved similar growth rates from 11 to 19 months of age (Cianzio *et al.*, 1982). Swanepoel *et al.* (1990) observed no differences in growth rates of Afrikaner, Nguni and Pedi bulls fed intensively. Short *et al.* (1999) observed no differences in average daily gain between steers from high and low growth potential breeds. Schoeman (1996) summarized the growth performance of bulls from 16 breeds that participated in the Standardised Growth Test of the National Beef Cattle Performance Testing Scheme (Anon, 1994). He indicated that growth rate was correlated ($r = 0.686$) with mature cow weight.

As pertaining to sex, bulls achieved significantly higher growth rates than steers, due to the effect of higher testosterone production in bulls (Strydom *et al.*, 1993).

1.3.3.1.2 Influence of feeding regime

Growth rates of animals are particularly affected by the diet and especially the energy content of the diet. Average daily gain increased ($p < 0.05$) by approximately 0.1 kg/head/day between small type cattle fed low and medium energy levels and between those fed medium and high energy levels (Prior *et al.*, 1977). Similarly Danner *et al.* (1980) reported that the average daily gain increased with increasing levels of maize (0 %, 40 % and 85 %) in the diet for steers fed as yearling or as calves. Average daily gain was similar between large type cattle fed medium and high dietary energy levels, but higher ($p < 0.05$) than for cattle fed low dietary energy levels (Danner *et al.*, 1980). Comparing steers fed forage, forage with late grain supplementation, forage with early grain supplementation and a feedlot diet, Newsome *et al.* (1985) observed that average daily gains increased ($p < 0.05$) with increasing grain feeding periods. These results are in accordance with the results of Van der Merwe *et al.* (1975) as well as Bennet *et al.* (1995). Van Koevering *et al.* (1995) reported that the average daily gain on a carcass adjusted basis was higher ($p < 0.05$) at 119 days (1.44 kg/day) in the feedlot than at 105 days (1.36 kg/day) in the feedlot, but did not differ significantly from average daily gains at 133 (1.41 kg/day) and 147 days (1.41 kg/day) in the feedlot. May *et al.* (1992)

slaughtered steers every 28 days from 28 to 196 days in a feedlot and detected no differences in average daily gain among slaughter groups.

Differences in growth rates were even observed for cattle grazing different pastures. Van Niekerk *et al.* (1986) observed that Simmentaler and Afrikaner heifers fed in stalls in the sweet Lowland Thornveld in KwaZulu-Natal, had an advantage of 13.5 and 26.8 % respectively over Simmentaler and Afrikaner heifers fed in the Highland Sourveld of KwaZulu-Natal. This was probably due to differences in environmental temperatures, as the sourveld experienced colder temperatures over a longer period than the sweet veld region (7 vs. 4 months). However, on the pasture itself Simmentaler heifers grazing the sourveld had an advantage of 8.9 %, while Afrikaner heifers had an advantage of 18.8 % over heifers grazing the sweetveld. The reasons for this were not clear.

Phillips *et al.* (2001) reported that although growth rates did not differ between native prairie grazing and winter wheat grazing, it was 50 % higher during spring than during winter. These authors did not observe any compensatory growth during spring for the animals consuming native prairie grazing. The winter wheat group maintained higher growth rates during winter resulting in higher overall growth rates. However Short *et al.* (1999) found that steers fed in the feedlot from yearling age exhibited compensatory growth compared to steers fed as calves.

Growth rates improve with increasing levels of grain in the diet. Compensatory growth may occur in animals fed high energy diets from an older age. Irrespective of whether the influence of feeding regime, breed, etc. is studied, growth rates tend to slow down with increasing age of the animals (Prior *et al.*, 1977; Swanepoel *et al.*, 1990; Van Koevering *et al.*, 1995; Wheeler *et al.*, 1996).

1.3.3.2 Feed conversion rates

1.3.3.2.1 Influence of breed

O'Mary *et al.* (1979) reported that the feed efficiency did not differ between large framed, late maturing Charolais x Angus (7.52 kg feed/ kg gain) and small framed, early maturing Angus steers (7.83 kg feed/ kg gain) up to 120 days in a feedlot, but differed significantly ($p < 0.05$) when fed up to 150 days (7.95 vs. 8.55 kg feed/kg gain). From 120 to 150 days in a feedlot, the feed efficiency of Charolais x Angus steers was 9.55 kg feed/kg gain compared to the 13.9 kg feed/kg gain for Angus steers, indicating that the Angus steers were finishing during this feeding phase (O'Mary *et al.*, 1979). Similarly, large framed Simmentaler heifers were more efficient grazing sweet Thornveld as well as Highland sourveld pastures than Afrikaner heifers (Van Niekerk *et al.*, 1986). Swanepoel *et al.* (1990) reported that intensively fed Afrikaner, Nguni and Pedi bulls did not differ in terms of feed efficiency. Block *et al.* (2001) observed no significant differences between Charolais x Hereford steers, steers on a short (70 days) or long (126 days) backgrounding period or between steers fed to a 6 mm or a 12 mm backfat thickness. In a review Schoeman (1989) indicated that the feed efficiency rate of Nguni cattle were better than most other breeds. On the other hand, Short *et al.* (1999) reported no difference in the feed efficiency between steers from high and low growth potential breeds.

Compared at similar carcass fat endpoints, feed conversion rates are not likely to differ significantly between large framed, late maturing and small framed, early maturing breeds. However, small framed breeds start putting on fat at an earlier age than large framed breeds. At that stage the feed conversion rates of small framed breeds start to deteriorate. Comparing large and small framed breeds at similar age or weight endpoints will result in large framed breeds having better feed conversion rates than small framed breeds.

1.3.3.2.2 Influence of feeding regime

Feed efficiency was the highest for both large and small type cattle fed at a high dietary energy level than for cattle fed at low and medium dietary energy levels (Prior *et al.*, 1977). Loveday & Dikeman (1980) reported that steers fed the high energy diet used 8.2 kg dry matter/kg gain compared to 9.8 kg dry matter/kg gain ($p < 0.05$) for steers fed the low energy diet. Danner *et al.* (1980) also reported that feed efficiency increased with increasing levels of maize in the diet. Steers tended to be more effective in feed conversion on a carcass adjusted basis at 199 days in a feedlot than at 105, 133 or 147 days in a feedlot (Van Koevering *et al.*, 1995).

Simmentaler and Afrikaner heifers grazing sweet thornveld pastures were more efficient in converting pasture to meat than Simmentaler and Afrikaner heifers grazing Highland sourveld pastures (Van Niekerk *et al.*, 1986).

High dietary energy levels result in improved feed conversion rates due to more nutrients being available for growth at high dietary energy levels than at low dietary energy levels. Apart from influencing growth and feed conversion rates, breed, sex as well as post weaning feeding regimes also exert major influences on carcass and meat quality parameters.

1.4 Carcass traits

1.4.1 Introduction

Various intrinsic and extrinsic factors that have an influence on the growth and/or the carcass traits of cattle have been investigated. These factors include the effect of sex (Fortin *et al.*, 1981a, b; Meaker & Liebenberg, 1982; Crouse *et al.*, 1985a; Fortin *et al.*, 1985) breed and types of cattle (Prior *et al.*, 1977; Koch *et al.*, 1982; Swanepoel *et al.,* 1990; Tatum *et al.*, 1990; Wheeler *et al.,* 1996; Strydom *et al.*, 2001), feeding regime (Bowling *et al.*, 1977; Schroeder *et al.*, 1980; Newsome *et al.*, 1985; Bidner *et al.*, 1986; Schaake *et al.*, 1993; Bennett *et al.*, 1995; Van Koevering *et al.*, 1995; Harris *et al.*, 1997), frame size and muscle thickness (Cianzio *et al.*, 1982; Tatum *et al.*, 1986a, b, c; Dolezal *et al.*, 1993; Camfield *et al.*, 1997), and post weaning growth rate (Smith *et al.*, 1976).

1.4.2 Live and carcass weight

In practice, cattle in South Africa are usually finished in feedlots or intensively on grass and slaughtered at an age of 400 to 600 days (13 to 18 months), while in the USA cattle are slaughtered at older ages and at heavier live weights. A summary of approximate age at slaughter, final live weight as well as the carcass weight at the final slaughter end point as reported by various authors are presented in Table 1.

Table 1 Approximate age at slaughter, final live weight and carcass weight at final slaughter end points.

Slaughter age (months)	Final live weight (kg)	Carcass weight (kg)	Grain (G) / Forage fed (F)	Reference
12 – 18	237 – 582	139 – 365	G	Charles & Johnson (1976)
~ 16	432 – 493	260 – 304	G	Koch *et al.* (1976)
~ 18 – 21	309 – 408	141 – 198	F/I	Reyneke (1976)
~ 13	419 – 470		G	Smith *et al.* (1976)
		154 – 317	F	Bowling *et al.* (1977)
		172 - 334	G	Bowling *et al.* (1977)
15 – 18	495 – 676	306 – 436	G	Prior *et al.* (1977)
~ 15	485	285	G	Young & Kauffman (1978)
~ 16	496	274	F	Young & Kauffman (1978)
~ 18	525	289	F	Young & Kauffman (1978)
14- 19	437 – 493	272 – 311	G	Koch *et al.* (1979)
21 – 22	413 – 493	258 – 310	G	O'Mary *et al.* (1979)
15 – 16	517 – 531		G	Danner *et al.* (1980)
~ 16	506		F	Danner *et al.* (1980)
~ 16		182	F	Schroeder *et al.* (1980)
19 – 20		306 – 313	F/G	Schroeder *et al.* (1980)
7 – 24		156 – 229	G	Fortin *et al.* (1981a)
11 -19	455 – 530	284 – 334	G	Cianzio *et al.* (1982)
~ 15	445 – 477	285 - 308	G	Koch *et al.* (1982)
12 – 13	332 – 358	171 – 187	F	Meaker & Liebenberg (1982)
~ 13	390 – 504	263 – 393	G	Crouse *et al.* (1985a)
18		294	F	Lee & Ahsmore (1985)
18		237	F	Lee & Ahsmore (1985)
17		191 – 215	F	Newsome *et al.* (1985)
17 – 24		251 – 281	F/G	Newsome *et al.* (1985)
18		248	G	Newsome *et al.* (1985)
31	488	262.0	F	Bidner *et al.* (1986)
21	477	272	G	Bidner *et al.* (1986)
~ 13	386 – 548		G	Tatum *et al.* (1986b)
16 – 17	387 – 394	220 – 238	G	Swanepoel *et al.* (1990)
12 – 15	506 – 525	299 – 131	G	Tatum *et al.* (1990)
16 – 21	515 – 590	323 – 370	G	Dolezal et at. (1993)
18 – 21		282 – 291	F	Schaake *et al.* (1993)
22 – 23		323 – 341	F/G	Schaake *et al.* (1993)
~ 14		349	G	Schaake *et al.* (1993)
~ 14	560	346	G	Bennett *et al.* (1995)
~ 15	506	280	F	Bennett *et al.* (1995)
20 – 21	413 – 435	235 – 245	G	Gertenbach *et al.* (1995)
16	245 – 328	100 – 160	F	Gertenbach & Van H. Henning (1995a)
14	458 – 573	283 – 355	F	Wheeler *et al.* (1996)
~ 12		244	F	Camfield *et al.* (1997)
13 – 15		241 – 275	G	Camfield *et al.* (1997)
~ 15	433 – 512	267 – 330	G	Harris *et al.* (1997)
~ 10 – 12	295 – 421	168 – 242	G	Strydom *et al.* (2001)

1.4.2.1 Influence of sex

It seems that castration does not affect growth, final live weight and carcass weight adversely up to 12 months of age. Steers castrated at three months of age, however tended to grow more slowly than those castrated at birth, six months of age or intact males (Meaker & Liebenberg, 1982). However if bulls and steers are compared at an older age or equal fat content, bulls tend to grow faster and have heavier carcasses than steers (Crouse *et al.*, 1985a; Fortin *et al.*, 1981a). These results suggest that bulls are larger and more masculine than steers at these end points (Crouse *et al.*, 1985a).

1.4.2.2 Influence of breed and frame size

Many authors (Charles and Johnson, 1976; Koch et al, 1976; O'Mary *et al.*, 1979; Crouse *et al.*, 1985a; Wheeler *et al.*, 1996; Camfield *et al.*, 1999) showed that larger framed breeds tend to grow faster and are heavier than smaller framed breeds, whether the end point is a constant age or a constant fat parameter (back fat thickness, carcass fat content, etc.). Charolias, Simmentaler and Chianina cattle invariably outgrew and were heavier than most other breeds.

Little difference was reported in the growth rate and final weight of breeds like Piedmontese, South Devon, Limousine and Gelbvieh (Smith *et al.*, 1976; Tatum *et al.* 1990) while breeds like Angus and Hereford tended to have the lowest growth and live weights (Charles and Johnson, 1976; Koch *et al.*, 1979; O'Mary *et al.*, 1979; Crouse *et al.*, 1985a). Brahman crosses also tended to be heavier than other crosses or purebred cattle (Koch *et al.*, 1982; Bidner *et al.*, 1986), most probably due to the strong heterosis effect exhibited by Brahman crosses.

Under limited feeding conditions, Tuli-sired steers were lighter at approximately 420 days of age than British-sired steers, whilst no breed differences occurred in carcass weights (Sprinkle *et al.*, 1998).

Differences in growth rate and final live weight reported by Swanepoel *et al.* (1990) for bulls of intensively fed South African indigenous breeds namely, Afrikaner, Pedi and Nguni, were not significant. This is to be expected as these breeds are similar in terms of frame size and expected mature live weight. Similarly, the final live and carcass weight of bulls from different strains of the same breed (five Bonsmara and two Nguni) did not differ significantly (Strydom *et al.*, 2001).

Higher growth rates and final live weight for larger framed cattle were reported when they were separated into frame size groups, irrespective of breed type, according to live weight and body measurements (Dolezal *et al.*, 1993; Camfield *et al.*, 1997).

However, small framed breeds tended to maintain very similar growth rates to that of large framed breeds until the small framed breeds reached physiological maturity. From this point onwards they tended to grow at slower rates, probably because they were accumulating fat, while the larger breeds were still growing muscle and relatively less fat. O'Mary *et al.* (1979) reported that the growth rate of small framed Angus steers slowed down when they started to finish after 120 days of a 150 day feeding period, while the large framed Charolais steers maintained a high growth rate throughout the feeding period. Differences in final live weight of cattle from different frame sizes are due to the accumulative effect of birth weight, weaning weight, feedlot growth and in most cases a longer feedlot period (O'Mary *et al.*, 1979). However, Sullivan *et al.* (1999) reported that trends for rates of gain were generally higher for lighter breeds.

Most of the above mentioned growth rate comparisons took the whole growth period into account, reported only a mean growth rate spanning the whole feeding period and did not differentiate between the high-growth-rate growing phases and the slower-growth-rate finishing phases of small framed cattle. This discriminates against smaller breed types and usually does not focus on the possible benefit of selling better finished off cattle at an earlier age.

Larger framed, late maturing breeds grow faster and are heavier than smaller framed, earlier matured breeds at constant age end points. These differences are however more pronounced if diets with a high energy content are used. Smaller framed breeds seem to be able to maintain growth rates similar to that of larger framed breeds until the smaller framed breeds starts to accumulate fat.

1.4.2.3 Influence of feeding regime

Numerous reports focusing on various feeding regimes can be found (Table 1) and include studies comparing cattle grazing natural veld or planted pastures with intensively fed cattle (Schroeder *et al.*, 1980; Lee & Ashmore, 1985; Bidner *et al.*, 1986; Bennett *et al.*, 1995), comparisons of forage feeding (silage, haylage, etc.) with grain feeding of cattle (Bowling *et al.*, 1977; Prior *et al.*, 1977; Young & Kauffman, 1978), comparisons between feedlot diets varying in energy content (Fortin *et al.*, 1981a, Fortin *et al.*, 1983; Crouse *et al.*, 1985a), a combination of forage feeding with incremental increases in the energy or grain content of the diet (Danner *et al.*, 1980) and concentrate feeding from different ages or for different periods of time (Harris *et al.*, 1997; Newsome, *et al.*, 1985; Schaake *et al.*, 1993; Camfield *et al.*, 1997).

Large framed cattle seem to benefit more from diets with a higher energy content than smaller framed cattle (Prior *et al.*, 1977). The main reason for this appears to be that larger framed animals have higher maintenance requirements than smaller framed animals. Crouse *et al.* (1985a) reported that the energy intake (Mcal ME/d) of Simmentaler cattle was higher ($p < 0.01$) than that of Angus cattle on a high-energy diet, but apparently similar on a low-energy diet. Contradictory to this, Prior *et al.* (1977) suggests that on low-energy diets, the energy intake of small framed cattle may be limited by bulk fill, but not that of large framed cattle.

If steers were first put on a diet with a low energy content and later switched to a diet with a high energy content, they tend to grow faster during the phase on the diet with the high energy content than steers fed high energy rations from an earlier age (Harris *et al.*, 1997; Dikeman *et al.*, 1985a, b). These authors ascribe these findings to compensatory growth. Compensatory growth may be facilitated by the fact that although steers did not gain weight during the grazing phase, they grew in height (116 to 120 cm) during the same period (Harris *et al.*, 1997).

Van Koevering *et al.* (1995) indicated that live and carcass weights increased (linear term; $p < 0.01$) with increasing length of feedlot feeding, but it happened at a decreasing rate, resulting in a quadratic response ($p < 0.06$).

The effect of protein level in the diet seems to be less pronounced than that of energy. According to Harris *et al.* (1997) cattle should receive diets with higher protein levels for the first 63 days of a feedlot period or up to the weight of approximately 325 kg in small framed cattle and 348 kg in large framed cattle. It also seems that the carcasses of small framed cattle tend not to be affected by higher levels of protein in the diet. However, large framed cattle on the high crude protein diet had the highest dressing percentage and fat thickness.

The energy content of the diet has a more pronounced effect on final live weight and carcass weight than the protein content. Increasing the energy content of the diet will result in increased live and carcass weights. Delaying intensive feeding to an older age, may result in compensatory growth.

1.4.3 Dressing percentage

Relative differences in the hide weight, fat content and conformation are usually presented as reasons for differences in dressing percentage between different cattle breeds (Koch *et al.*, 1979; Swanepoel *et al.*, 1990; Wheeler *et al.*, 1996).

However, most authors reported no or only slight differences in dressing percentage between different breeds and breed types, with a range of usually less than 2 %, not withstanding the fact that hide weight and fatness may in some instances differ significantly (Koch *et al.*, 1976; Prior *et al.*, 1977; O'Mary *et al.*, 1979; Bidner *et al.*, 1986; Tatum *et al.*, 1990).

Although Dolezal *et al.* (1993) and Camfield *et al.* (1999) reported significant differences in dressing percentage between different frame sized cattle, the difference between large and small framed groups were still less than 2 %.

Koch *et al.* (1982) reported that Brahman and Sahiwal crosses had higher dressing percentages than other British cattle breeds in spite of their relative heavy hides. The breed with the lowest dressing percentage was Pinzgauer with 62.0 % and the highest were Brahman and Sahiwal crosses with 63.8 and 64.0 % respectively. This higher dressing percentage of Brahman cattle is ascribed to the lower weights of their gastrointestinal tract and its contents than in other breeds (Carpenter *et al.*, 1961).

It can be deduced that although breed may, irrespective of the type of end point, have an effect on dressing percentage, this effect is limited and will probably not be more than 2 to 3 %.

Larger differences in dressing percentage occurred if cattle were fed diets varying in concentrate:roughage ratio. Cattle on forage-fed diets had much lower dressing percentages (~ 55 % vs. 58+ %) than cattle on high concentrate diets (Prior *et al.*, 1977; Young & Kauffmann, 1978; Schroeder *et al.*, 1980; Bidner *et al.*, 1986; Bennet *et al.*, 1995; Keane & Allen, 1998). The main reasons for this are that the cattle are usually fatter on concentrate diets and there is more gut fill in forage fed cattle.

Carcasses from forage-fed cattle tended to have a more cooler shrinkage than carcasses from grain fed cattle (Schroeder *et al.*, 1980). Schroeder *et al.* (1980) speculate that this may be due to the lower fat cover of forage fed cattle, resulting in a higher moisture loss.

According to Harris *et al.* (1997), the dressing percentage of cattle that were fed from an older age, tended to be lower than that of cattle fed from an earlier age.

Various factors influence dressing percentage including breed (due to differences in the weight of the hide and gastro-intestinal tract) and feeding regime. On diets with high energy levels, dressing percentage seems to be higher than on diets with low energy levels (all forage diets and pastures).

1.4.4 Carcass measurements

A strong correlation (r = 0.96) between hip height and frame size and low correlations (ranging from 0.09 to 0.48) between other body measurements (body length, width and girth) and frame size were reported by Tatum *et al.* (1986a). They indicated that although all body measurements increased with an increase in frame size, body length, width and girth were not always proportional to corresponding differences in heights. Large framed animals thus tended to be disproportionately tall with relative short and narrow bodies, compared to small framed cattle that were short, but relatively highly developed in length, width and girth.

Swanepoel *et al.* (1990) defined carcass compactness as a ratio of weight per length and reported significant differences between breeds in terms of carcass compactness ($p < 0.05$) as well as for hindquarter compactness ($p < 0.01$). Nguni bulls had more compact carcasses (0.101 kg/cm) than Afrikaner (0.92 kg/cm) and Pedi bulls (0.93 kg/cm) at 390 kg final live weight. Nguni bulls also had more compact hindquarters than Afrikaner and Pedi bulls (0.77, 0.68 and 0.69 kg/cm respectively). Strydom *et al.* (2001) reported similar results for five different strains of Bonsmara bulls, but much lower carcass and hindquarter compactness for two strains of Nguni bulls.

Koch *et al*. (1982) reported significant breed differences for carcass length. Six sire breeds were used on Hereford and Angus cows. Tarentaise and Pinzgauer crosses had the longest carcasses. Carcass measurements ranged from 123.8 cm for Tarentaise crosses to 121.1 cm for Hereford x Angus steers at a constant carcass weight of 288 kg. Although significant differences in chest depth were reported, it was small. Tarentaise crosses had more chest depth than Hereford x Angus, Brahman and Sahiwal crosses. The round length reported by Koch *et al.* (1982) and described by Koch & Dikeman (1977) is a similar measurement to the length of the hindquarter (from anterior end of aitchbone to the line of the epiphyseal plate at the distal end of the tibia-fibula). Brahman (67.4 cm) and Sahiwal (67.0 cm) crosses had significantly more round length, while Hereford x Angus crosses (63.6 cm) had significantly less round length than Tarentaise (65.8 cm) and Pinzgauer crosses (65.5 cm).

Although differences in body measurements occur between breeds the most important measurement that differentiates between cattle of different frame sizes, seems to be hip height.

1.4.5 *Longissimus* muscle area

Longissimus muscle areas of cattle ranging from 60 to 99 cm^2 for constant age, weight and fat end points are reported in the literature. Sex (Crouse *et al.*, 1985a) as well as breed/frame size (Prior *et al.*, 1977; Koch *et al.*, 1982; Tatum *et al.*, 1990; Wheeler *et al.*, 1996; Camfield *et al.*, 1997; Camfield *et al.*, 1999;

Block *et al.*, 2001) apparently affects *longissimus* muscle area. Bulls had larger *longissimus* muscle areas than steers, while small framed breeds had smaller *longissimus* muscle areas than large framed breeds. Different strains within a breed did not affect *longissimus* muscle area (Strydom *et al.*, 2001).

Energy level of the diet did not affect *longissimus* muscle area (Prior *et al.*, 1977; Young & Kauffmann, 1978; Crouse *et al.*, 1985a; Bidner *et al.*, 1986; Harris *et al.*, 1997). Neither did length of the feeding period (Van Koevering *et al.*, 1995).

Smaller *longissimus* muscle areas were reported for forage finished steers than for grain finished steers (Bowling *et al.*, 1977; Schroeder *et al.*, 1980; Schaake *et al.*, 1993; Bennet *et al.*, 1995).

In a few instances the opposite were also reported, i.e. *longissimus* muscle area becoming smaller with increased level of nutrition (Danner *et al.*, 1980; Newsome *et al.*, 1985).

Most of the above quoted authors indicated high correlation coefficients for *longissimus* muscle area and carcass yield.

While it seems that bulls and large framed cattle have larger *longissimus* muscle areas than steers and small framed cattle, feeding regime does not seem to have a significant influence on *longissimus* muscle area.

1.4.6 Muscle, bone and fat content

Nguni bulls, slaughtered at different live weights (160 to 390 kg), had the highest percentage bone (15.20 %), differing significantly ($p < 0.05$) from Afrikaner bulls (14.54 %) (Swanepoel *et al.*, 1990). At a constant age a marginally higher percentage bone (bone, cartilage and tendons) of 16.1, 17.4 and 16.8 % were reported for Piedmontese, Gelbvieh and Red Angus sired steers respectively (Tatum *et al.*, 1990). Koch *et al.* (1979) reported a mean percentage bone (including major tendons and excised ligaments) of 12.78 %, ranging from 11.3 % for Angus steers to 14.2 % for Chianina crosses, at a constant carcass weight of 288 kg. Koch *et al.* (1982) reported differences between breeds for percentage bone, although it was less than 1.0 %. Small, but significant differences in percentage bone (15.6, 15.6 and 15.0 %) was reported by Dolezal *et al.* (1993) for steers that were grain finished from 8, 12 and 18 months of age respectively and slaughtered at a constant backfat thickness, but not for frame size groups. This is contrary to the results of Cianzio *et al.* (1982) that large framed steers had 2.5 % more bone than small framed steers. Breed differences for percentage bone were also reported by Fortin *et al.* (1981a). Schroeder *et al.* (1980) reported that steers finished only on pasture had a higher ($p > 0.05$) percentage bone (16.5, 18.7 and 19.3 %) than steers finished on grain after the pasture phase (14.0 and 14.1 %). These results are in agreement with those reported by Schaake *et al.* (1993).

At a constant slaughter age, Swanepoel *et al.* (1990) reported that Afrikaner bulls (69.56 %) had the highest percentage muscle, differing significantly ($p < 0.05$) from both Nguni (66.00 %) and Pedi bulls (66.25 %). Separable muscle percentages of Piedmontese, Gelbvieh and Red Angus sired steers differed significantly ($p < 0.05$) from each other and were 64.0, 61.6 and 57.5 % respectively (Tatum *et al.*, 1990). In contrast, no significant differences in percentage muscle were reported between steers of different age classes (Dolezal *et al.*, 1993), frame size classes (Dolezal *et al.*, 1993; Cianzio *et al.*, 1982) or breeds (Fortin *et al.* (1981a, b).

Steers finished on pastures had significantly higher muscle percentages of approximately 70 % compared to the only 55.3 and 57.5 % of steers finished in the feedlot after the pasture phase (Schroeder *et al.*, 1980). This was due to the lower ($p < 0.05$) fat content of pasture fed steers (~ 6 %) compared to grain fed steers (> 24 %). There is an inverse relationship between carcass muscle and fat content (Tatum *et al.*, 1990). Similar results were found by Schaake *et al.* (1993).

At a constant age, Pedi bulls (18.37 %) had the highest percentage fat, differing significantly ($p < 0.05$) from Afrikaner (15.35 %) and Nguni bulls (15.20 %) (Swanepoel *et al.*, 1990). Tatum *et al.* (1990) reported that Red Angus (29.3 %) sired steers had a significatly higher ($p < 0.05$) separable fat percentage than Piedmontese (22.7 %) and Gelbvieh (23.9 %) sired steers at 299.2, 312.1 and 312.9 kg carcass weight respectively. Angus cattle had more fat than Friesian cattle (Fortin *et al.*, 1981a). Most authors agree that differences in fat content between breeds and sexes fed high energy diets are not due to differences in the growth rate of the fat, but rather due to differences in the onset of rapid fattening. Smaller framed, early maturing cattle breeds start rapid fattening at an earlier age than larger framed, late maturing cattle breeds (Fortin et al, 1981a). On low energy diets it however appears that in addition to differences in the onset of rapid fattening, the growth rate of the fat may also contribute to differences in carcass fat content among breeds (Fortin *et al.*, 1981a). The same principal seems to apply to steers and bulls, with steers starting to become fat at an earlier age than bulls (Fortin *et al.*, 1981a).

Dolezal *et al.* (1993) reported that although no differences in percentage fat were found between different frame sizes, differences in the partitioning of fat between the different fat depots (see section 1.5) were found. Cianzio *et al.* (1982) also reported no significant differences in fat percentage between steers of different frame sizes, but they did not find significant differences in the relative distribution of fat between depots. Charles & Johnson (1976) on the other hand reported differences in total dissectible fat. Early maturing breeds (Hereford and Angus) were fatter at 15 and 18 months of age than late maturing breeds (Friesian and Charolais crosses).

Gwartney *et al.* (1996) concluded that it is possible to maintain marbling and eating quality while reducing subcutaneous and intermuscular fat by using expected progeny differences for marbling when selecting sires. Steers with high expected progeny differences for marbling exhibited similar carcass traits than small framed/early maturing steers. They had smaller *longissimus* muscle area, lighter carcasses, greater fat thickness (days on feed and carcass weight only) and more kidney, heart and pelvic fat, irrespective of the end point. Selecting for sires with high expected progeny differences for marbling will most probably result in selecting for smaller framed/early maturing animals.

Forage finished steers had much lower fat percentages ranging from 5.0 to 7.0 % compared to the 24.3 and 27.9 % of grain finished steers (Schroeder *et al.*, 1980) while Schaake *et al.* (1993) reported fat percentages of 12.8 and 14.4 % for pasture finished steers compared to 18.0 to 25.9 % for steers finished for various periods on grain. Significant differences in fat content (31.9, 32.2 and 33.2 %) were reported by

Dolezal *et al.* (1993) for steers that were grain finished from 8, 12 and 18 months of age respectively and slaughtered at a constant backfat thickness, but not for frame size groups. Restricting the energy intake reduced the rate of fattening in Angus steers and increased the growth rate of muscle, but the same response was not detected for Friesian cattle (Fortin *et al.*, 1981a).

Tatum *et al.* (1986b) reported that the percentage separable muscle, bone, and fat differ significantly between all frame size groups if they are slaughtered at a constant weight. Muscle-to-bone ratios did not differ between frame size groups and ranged from 3.68 to 3.73.

Bone percentage is normally inversely related to fat percentage and muscle-to-bone ratio, where as muscle percentage is negatively correlated with fat percentage and positively correlated with muscle-to-bone ratio (Berg & Butterfield, 1966 in Tatum *et al.*, 1990).

According to Tatum *et al.* (1990) carcass muscularity is most effectively evaluated, using means for muscle-to-bone ratio. Muscle-to-bone ratio was not affected by days on feed indicating, according to Tatum *et al.* (1990), that the primary influence of days on feed was exerted on the fat component of the carcass.

Schroeder *et al.* (1980) reported lean-to-fat ratios of 10.0, 11.1 and 14.6 respectively for three treatment groups that were finished on different pasture types, compared to 2.4 and 3.9 for treatment groups that were grain finished for 104 days after the pasture phase. This large difference between pasture finished and grain finished animals is due to the greater amounts of trimmable fat in the grain finished animals.

Percentages of separable carcass components and ratios were influenced by sire breed (Tatum *et al.*, 1990) and frame size (Tatum *et al.*, 1986b), but not by strain or subpopulation of the same breed (Strydom *et al.*, 2001).

Differences in percentage bone seems to be very small if compared at a comparable physiological end point and probably has little application in practice, especially as no significant differences in muscle percentage and muscle-to-bone ratio were found for the different age classes as well as the different frame size groups by Dolezal *et al.* (1993). However, at approximately the same chronological age, differences in percentage bone tended to be more pronounced. Percentages of muscle, bone and fat differ vastly between different frame sizes if compared at the same weight. Tatum *et al.* (1986b) concluded that the primary effect of frame size on the relative proportions of muscle, bone and fat was exerted through the fattening process.

Guenther *et al.* (1965) found that bone weight increased with age and was not affected by level of nutrition. This lead Dolezal *et al.* (1993) to conclude that the growth of bone relative to increases in live weight was slower for steers fed from 18 months of age than for steers fed from 8 months of age. The findings of Tatum *et al.* (1990) that increased time on feed was associated with an increase in separable fat percentage and a decrease in separable muscle and bone percentages support these conclusions.

The proportions of muscle and fat in carcasses varied the most among breeds and feeding regime, while the proportion of bone varied the least. As animals become fatter, muscle is replaced by fat, resulting in an inverse relationship between muscle and fat content in carcasses. Smaller framed, earlier maturing breeds and animals on high energy diets have proportionately more fat and proportionately less muscle than larger framed, later maturing breeds and animals on a low energy diet. In addition, fat deposition follows somewhat different patterns than bone and muscle growth. Fat is deposited in different depots and at different rates, only happening rapidly from the time that muscle growth ceases.

1.5 Carcass fat content, distribution and partitioning

1.5.1 Introduction

Various authors reported that the colour of fat from cattle finished on high roughage diets tends to be more yellow than the fat from cattle finished on high grain diets (Young & Kauffman, 1978; Bidner *et al.*, 1986; Schaacke *et al.*, 1993; Bennett *et al.*, 1995). However, Fortin *et al.* (1985) found no significant differences in the fat colour of forage-fed and barley-supplemented cattle. The general conclusion is that the yellow colour is insufficient to result in consumer resistance towards beef from cattle fed the high roughage diets. This issue will thus not receive further attention in this review, which will rather concentrate on the factors that have an influence on the fat cover, fat content of the carcass and the composition of the fat.

1.5.2 Fat thickness

Unless otherwise stated, references to fat thickness is by implication the measurement of back fat thickness, usually measured at the 12^{th} rib approximately 5 cm from the median plane.

1.5.2.1 Influence of sex

Meaker & Liebenberg (1982) reported that at the same age, bulls had significantly ($p < 0.05$) thinner fat thicknesses than steers (4.1 mm vs. 7.0 mm). Crouse *et al.* (1985a) reported significantly ($p < 0.05$) thicker fat thicknesses for bulls (0.97 cm) than for steers (0.76 cm), the bulls were approximately 90 kg heavier than the steers at the slaughter end point.

At a slaughter age of 15 to 17 months, Whipple *et al.* (1990) observed that the fat thickness of heifers (1.55 cm) was significantly ($p < 0.05$) thicker than that of steers (1.16 cm).

At a similar age or weight bulls tend to have thinner fat thicknesses than steers and heifers, while heifers tend to have the thickest fat.

1.5.2.2 Influence of breed and frame size

At a constant weight, no differences in fat thickness were observed between Nguni, Pedi and Afrikaner bulls (Swanepoel *et al.*, 1990). According to Sprinkle *et al.* (1998), the fat thickness of British-sired (Angus and Hereford) steers (1.54 cm) were significantly ($p < 0.05$) thicker than that of Tuli- (1.03 cm) and Boran-sired steers (0.82 cm), but the same as that of Brahman-sired steers (1.25 cm). Koch *et al.* (1979) also reported differences between various breeds in terms of fat thickness, ranging from 7.99 ± 0.41 mm for Chianina cross steers to 16.11 ± 0.47 mm for Hereford-Angus cross steers. Although O'Mary *et al.* (1979) varied the feeding period with the aim to slaughter Angus and Charolais x Angus steers at the same carcass composition, Angus steers still had a significantly ($p < 0.001$) thicker fat thickness than the Charolais crossed steers (1.57 ± 0.07 cm vs. 1.07 ± 0.09 cm). Tatum *et al.* (1990), also reported breed differences for fat thickness, comparing Piedmontese- (4.6 mm), Gelbvieh- (6.6 mm) and Red Angus-sired (9.9 mm) steers ($p < 0.05$). On the contrary, Dolezal *et al.* (1993) identified animals to be slaughtered at a predetermined fat thickness using a live animal fat probe and managed to produce carcasses exhibiting no significant differences in fat thickness from small-, medium- and large-framed steers.

No significant differences in fat thickness were reported between breeds, when the targeted endpoint was equal percentage rib fat (Crouse *et al.*, 1985a) or similar carcass weight (Bidner *et al.*, 1986). However, Wheeler *et al.* (1996) reported differences in fat thickness between various breeds at a constant weight as well as at a constant age. Cianzio *et al.* (1982) reported that for steers slaughtered at a similar age, the fat thickness of smaller framed steers (0.99 cm) was greater than that of larger framed steers (0.68 cm).

Frame size apparently affects fat thickness significantly. Fat thickness was the lowest ($p < 0.05$) for large-framed, late-maturing steers (0.3 cm) and highest ($p < 0.05$) for intermediate-framed, early-maturing (0.6 cm) and small-framed, early-maturing ($p < 0.05$) steers (Camfield *et al.*, 1999). These results are in agreement with the results of Block *et al.* (2001) that the fat thickness of large-framed Charolais steers was thinner than that of medium-framed Hereford and Angus steers. Camfield *et al.* (1997) reported that fat thickness was the thinnest for unfinished large-framed steers and the thickest for small-framed steers feedlot-finished for a period of 90 days. To reach the same fat thickness, large-framed breeds need to be fed for a longer period of time than small-framed breeds (O'Mary *et al.*, 1979). Although, Friesian and Hereford steers had approximately the same total dissectible fat at 12 months of age, their respective fat thickness measurements were 2.8 and 7.3 mm (Charles & Johnson, 1976).

Large-framed, late-maturing breeds tend to have thinner fat thicknesses than small-framed, early maturing breeds. However, the partitioning of fat between the different fat depots seems to differ between different breeds, resulting in unexpected results in certain cases. This topic will be reviewed in more detail later in this section.

1.5.2.3 Influence of feeding regime

Crouse *et al.* (1985a) reported no significant differences in fat thickness at a constant percentage rib fat between steers fed a high (0.86 cm) or low energy diet (0.86 cm). This is similar to the findings reported by Danner *et al.* (1980).

Due to the large difference in net energy between forage and grain, cattle finished on all forage diets had lower fat thicknesses than cattle finished on diets containing grain or finished in a feedlot after a backgrounding period on various pastures, irrespective of the end point used (Oltjen *et al.*, 1971; Bowling *et al.*, 1977; Young and Kauffman, 1978; Danner *et al.*, 1980; Bidner *et al.*, 1981; Newsome *et al.*, 1985; Bidner *et al.*, 1986; Schaake *et al.*, 1993; Bennett *et al.*, 1995; Keane & Allen, 1998).

Dolezal *et al.* (1993) reported no differences in fat thickness between steers fed a feedlot ration either as calves, yearlings or long yearlings. Although Harris *et al.* (1997) also reported no statistically significant differences in fat thickness between cloned calf and yearling fed steers, they observed that yearling-fed steers tended to have lower fat thicknesses. Schroeder *et al.* (1980) reported that steers finished in a feedlot after a 119 day grazing period, had significantly ($p < 0.05$) greater fat thicknesses than steers slaughtered at the end of the grazing period. Backgrounding cattle on either winter wheat pastures or dormant native prairie grass did not result in differences in terms of fat thickness at the end of the feedlot period (Phillips *et al.*, 2001). Block *et al.* (2001) reported that a long backgrounding period (126 days) resulted in significantly ($p < 0.05$) lower fat thicknesses compared to a short backgrounding period (70 days).

Smith *et al.* (1976), Prior *et al.* (1977) and Ferrell *et al.* (1978) observed that high energy diets increased fat deposition relative to protein deposition. With increased energy content of the diet, increased weight in small framed animals is normally the result of increased fat deposition (Prior *et al.*, 1977).

The fat thickness of steers fed a high roughage diet and gaining approximately 0.9 kg/day, increased significantly ($p < 0.05$) from 28 days (0.91 cm) to 56 days (1.29 cm) and to 84 days (1.67 cm) (Moody *et al.*, 1970). Van Koevering *et al.* (1995) also reported significant ($p < 0.01$) increases in fat thickness with increasing time (105 to 147 days) on a feedlot diet. The same tendency was reported by Camfield *et al.* (1997) for steers finished from 0 days to 90 days.

In general, increasing the energy content of feedlot diets, results in increases in fat thickness. On the other hand, delaying the intensive feeding phase, generally results in decreases in the fat thickness. Similarly, cattle finished from pastures have thinner fat thicknesses compared to cattle supplemented with grain or cattle finished in a feedlot.

1.5.3 Carcass fat content

In this section the terms inter- and intramuscular fat as well as marbling are often mentioned. Intermuscular fat refers to the fat portion that accumulates between individual muscles and forms part of the dissectible fat fraction. Intramuscular fat refers to the portion that accumulates within a muscle. Marbling is a subjective quantification of the amount of intramuscular fat and forms part of the USA carcass classification system. Objectively intramuscular fat is determined through ether extraction and expressed as total lipid content.

1.5.3.1 Intramuscular fat and marbling

1.5.3.1.1 Influence of sex

Intact males had significantly ($p < 0.05$) less marbling than castrates (Meaker & Liebenberg, 1982; Crouse *et al.*, 1985a). Similarly the ether extract of the *longissimus* muscle was significantly ($p < 0.05$) lower in intact bulls (0.71 %) than in early (1.09 %) or late (1.25 %) castrated steers (Destafanis *et al.*, 2003).

1.5.3.1.2 Influence of breed and frame size

Whipple *et al.* (1990) compared different combinations of Sahiwal and Hereford crosses and found no differences in marbling between the cross. This contradicts some other reports. Bidner *et al.* (1986) reported that Angus x Hereford steers had significantly ($p < 0.01$) higher marbling scores than Angus x Hereford x Brahman steers. Crouse *et al.* (1989) found that as percentage of Brahman or Sahiwal inheritance increased, marbling decreased. These findings are supported by Sprinkle *et al.* (1998) reporting that steers sired by British breeds had significantly ($p < 0.05$) better marbling than Tuli-, Boran- and Brahman-sired steers. Angus cattle had the greatest ($p < 0.05$) amount of marbling and Hereford the least (Newsome *et al.*, 1985). Similar results were reported by Koch *et al.* (1979). Tatum *et al.* (1990) found that Angus-sired steers had significantly ($p < 0.05$) more marbling than Piedmontese- and Gelbvieh-sired steers.

At a constant age, Wheeler *et al.* (1996) reported that the carcasses of Shorthorn-sired steers had the highest marbling and carcasses of Nellore-, Charolais- and Piedmontese-sired steers had the lowest marbling. The intramuscular fat percentage of the *longissimus* muscle was the highest for Hereford x Angus- and Shorthorn-sired steers, while it was the lowest for Piedmontese-, Gelbvieh-, Charolais-, Nellore-, Saler- and Longhorn-sired steers (Wheeler *et al.*, 1996).

Camfield *et al.* (1999) reported that large-framed steers (feedlot-fed) had significantly ($p < 0.05$) more marbling than intermediate-framed steers. For pasture-developed steers, carcasses of early maturing steers had significantly ($p < 0.05$) more marbling than late maturing steers (Camfield *et al.*, 1999).

In spite of contradicting reports, in general it seems that as the percentage of *B. indicus* in cattle increases, the intramuscular fat content or marbling tend to decrease. Similarly, smaller framed, earlier maturing breeds like Angus and Hereford tend to have a higher intramuscular fat content and marbling than larger framed, later matured breeds like Charolais and Piedmontese.

1.5.3.1.3 Influence of feeding regime

Schaake *et al.* (1993) reported that steers fed in a feedlot for either 75 or 170 days had higher marbling scores than steers kept on pastures or fed for only 45 days in a feedlot. This is partially in agreement with the results of Newsome *et al.* (1985) that cattle supplemented with grain for 138 days on fescue-clover pastures had significantly ($p < 0.05$) more marbling than cattle grazing only the pasture or cattle supplemented with grain for 92 days and even cattle fed intensively in a feedlot. A probable explanation offered by Newsome *et al.* (1985) states that the group fed for 138 days consumed 970 kg grain compared to the 886 kg for the intensively fed group and were also slaughtered at an older age (60 days). The results of Schroeder *et al.* (1980) ($p < 0.05$), Danner *et al.* (1980) and Bennett *et al.* (1995) ($p < 0.001$) that carcasses of grain-supplemented cattle had more marbling than that of cattle on all forage-diets, also support the previous findings. According to Bidner *et al.* (1986), grain-fed steers slaughtered at 21 months of age, had significantly ($p < 0.01$) more marbling than forage-fed steers, slaughtered at 31 months of age (at similar mean live weights).

Moody *et al.* (1970) observed a significant ($p < 0.05$) increase in the percentage ether extract of the *longissimus* muscle of steers fed a high roughage diet for 28 (3.3 % ether extract) and 56 days (4.0 % ether extract), but percentage ether extract did not increase beyond 56 days. May *et al.* (1992) also found no increases in marbling after intensive feeding for 112 days.

Pasture finished steers are reported to have a lower percentage of ether extract in the lean tissue of the 9-10-11th rib section than steers finished in a feedlot for 45, 75 or 170 days (Schaake *et al.* (1993). This is in agreement with the result of Schroeder *et al.* (1980). Van Koevering *et al.* (1995) reported that the total lipid percentage of the *longissimus* muscle of feedlot-fed steers increased significantly ($p < 0.01$) as time in a feedlot increased from 105 days (3.01 % lipid) to 119 days (3.66 % lipid), but no significant increase was found after 119 days. Keane &Allen (1998) reported that bulls fed intensively up to 19 months of age had 39 g/kg lipid in the *longissimus* muscle compared to 60 g/kg and 47 g/kg for steers fed intensively during their second winter (slaughtered at 24 months of age) and steers slaughtered after grazing pasture up to 29 months of age respectively. The lipid content of the 19 month old group was significantly ($p < 0.01$) lower than that of the 24 month old group.

Cattle supplemented with high energy feeds on pastures or intensively fed in feedlots, have more marbling and intramuscular fat than cattle finished from pastures. Intensive feeding seems to only increase intramuscular fat content up to 110 to 120 days on feed, thereafter little or no further increases in intramuscular fat could be detected.

1.5.3.2 Total dissectible fat and carcass fat content

1.5.3.2.1 Influence of breed or frame size and sex

Charles & Johnson (1976) compared carcasses of early-maturing Angus and Hereford steers with that of late-maturing Friesian and Charolais-cross steers. They were fed a high energy diet in a feedlot from eight months of age and slaughtered at either 12, 15 or 18 months of age. At 12 months of age no differences in terms of total dissectible fat were observed, except for Angus steers that had significantly ($p < 0.05$) more dissectible fat than Charolais-cross steers (21.4 vs. 17.4 %). At 15 months of age Angus steers had significantly more dissectible fat than all the other breeds and at 18 months of age the Hereford and Angus steers had more dissectible fat than the Friesian and Charolais-cross steers. However, at a similar age, no significant difference in fat content of the carcasses of smaller and larger framed steers was observed by Cianzio *et al.* (1982).

At the same fat thickness, Hereford and Angus steers had significantly less total dissectible fat than Friesian and Charolais-cross steers (Charles & Johnson, 1976). The Herefords also had significantly more subcutaneous fat than the other three breeds.

Swanepoel *et al.* (1990) reported that Pedi bulls had a significantly ($p < 0.05$) higher fat content than Afrikaner and Nguni bulls at 290 kg but not at heavier live weights. Sprinkle *et al.* (1998) reported that no breed differences occurred in carcass lipid weight on a limited-fed diet, but on the same diet fed *ad libitum*

British- (50.7 ± 2.4 kg) and Brahman-sired steers (48.1 ± 2.4 kg) had significantly ($p < 0.05$) higher carcass lipid weights than Boran- (37.8 ± 2.6 kg) and Tuli-sired steers (37.5 ± 2.4 kg).

Bulls produced carcasses with significantly more muscle ($p < 0.005$) and less total fat ($p < 0.005$) than steers (Strydom *et al.*, 1993).

Differences between breeds are mainly observed among *B. taurus* and *B. indicus* breeds, with *B. taurus* breeds having more dissectible carcass fat than *B. indicus* breeds. Also smaller framed, earlier maturing breeds like Angus and Hereford have more dissectible carcass fat than larger framed, later maturing breeds like Charolais, while bulls have less fat than steers.

1.5.3.2.2 Influence of feeding regime

Fortin *et al.* (1981a) observed that on high energy diets, differences between breeds in terms of carcass composition does not appear to be the result of different growth rates for the various tissues, but rather to be caused by differences in the onset of rapid fattening. However, on low energy diets it seems that in addition to differences in the onset of rapid fattening, the growth rates of the various tissues may also differ (Fortin *et al.*, 1981a). In early-maturing Saler bulls, restricted level of energy intake decreased the proportion of carcass fat considerably, whereas the restriction of energy intake did not change the proportion of fat in late-maturing Charolais bulls (Fortin *et al.* (1981a).

Steers on a limited energy diet, were unable to express any differences by breed in terms of fat content, but on an *ad libitum* diet, Brahman- and British-sired steers were similar but had significantly ($p < 0.05$) fatter carcasses than Tuli- and Boran-sired steers (Sprinkle *et al.*, 1998).

Danner *et al.* (1980) reported that at constant live weights, grain-fed cattle had fatter carcasses with no effect of energy level on carcass quality.

The energy level of the diet influences the onset of the rapid fattening period as well as the rate of fat accumulation. Late-maturing breeds seem to be less affected by the energy level of the diet, but this is probably because they already have low carcass fat levels even on higher energy diets.

1.5.4 Partitioning of fat between the different fat depots

Charles & Johnson (1976) reported breed (Angus, Hereford, Friesian and Charolais-cross steers) differences in the partitioning of total dissectible carcass fat between the subcutaneous, kidney and pelvic as well as intra-muscular fat depots. The greatest differences occurred in the proportions (of total dissectible fat) of the subcutaneous and kidney and pelvic fat depots, while intra-muscular fat varied little between the breeds. Hereford (36.7 %) and Angus steers (32.7 %) had significantly more subcutaneous fat and less kidney and pelvic fat than the Friesian (27.9 %) and Charolais-cross steers (26.9 %). Koch *et al.* (1979) reported similar results with similar breeds. Charles & Johnson (1976) also stated that for Hereford, Angus and Friesian steers there was an inverse relationship between subcutaneous fat and kidney and pelvic fat percentages as total dissectible fat increased. In Charolais-cross steers, however, the percentages of both the subcutaneous and the kidney and pelvic fat depots increased while intra-muscular fat percentage decreased

($p < 0.01$) as total dissectible fat increased. The percentage of kidney, pelvic and heart fat was lower in Piedmontese-, Hereford x Angus-, Galloway- and Gelbvieh-sired steers at a constant age (Wheeler *et al.*, 1996). At a constant weight, the percentage kidney, pelvic and heart fat tended to be lower in Piedmontese-, Charolais Hereford x Angus-and Gelbvieh steers. However, at a constant fat thickness Hereford x Angus-sired steers had the lowest percentage kidney, pelvic and heart fat with Galloway-sired steers intermediate and Charolais- and Longhorn-sired steers had the highest percentages (Wheeler *et al.*, 1996). On a limited-fed diet no differences occurred between breeds for kidney, pelvic and heart fat as well as omental fat, but on the same diet fed *ad libitum*, British-sired steers had more omental fat than Boran- and Tuli-sired steers, while Brahman- and Tuli-sired steers had more omental fat than Boran-sired steers (Sprinkle *et al.*, 1998). Tatum *et al.* (1990) reported no differences in the partitioning of fat for Piedmonteses-, Gelbvieh- and Angus-sired steers.

Camfield *et al.* (1999) reported that large-framed, late-maturing steers had the least ($p < 0.05$) kidney, pelvic and heart fat compared to steers of the other faster maturing breed types studied. On the contrary, large-framed steers had the lowest ($p < 0.05$) percentage of subcutaneous fat and the highest ($p < 0.05$) percentage of internal fat, compared to medium- and small-framed steers fed to the same backfat thickness (Dolezal *et al.*, 1993) or at a constant degree of marbling in the *longissimus* muscle (Tatum *et al.*, 1986).

Although steers that were feedlot-fed from 18 months of age had significantly ($p < 0.05$) heavier weights of subcutaneous, intermuscular and internal fat than steers feedlot-fed from 8 or 12 months of age, no significant differences were observed in the percentage of each depot (Dolezal *et al.*, 1993). Although grain-finished steers were selected to have the same degree of marbling than grass-finished steers, the carcasses of grain-finished steers had significantly ($p < 0.05$) higher percentages of kidney, pelvic and heart fat (Bowling *et al.*, 1977). Moody *et al.* (1970) reported that the percentage kidney fat increased significantly between 56 (1.0 %) and 84 days (2.1 %) on a high roughage diet, but not between 84 and 112 days (2.0 %). Similarly, intensively fed steers showed significant ($p < 0.05$) increases in kidney, pelvic and heart fat weights up to 112 days on feed, but not thereafter (May *et al.*, 1992).

Fat thickness accounted for 67 % of the variation in total separable fat in the body, 55 % of the variation in marbling score and 45 % of the variation in visceral fat content (Cianzio *et al.*, 1982). Cianzio *et al.* (1982) concluded that a lower fat thickness does not necessarily predict reduced marbling or lesser amounts of visceral fat.

It is traditionally maintained that fat is firstly deposited in the viscera and kidneys depots followed by the subcutaneous and intermuscular fat depots and finally fat is deposited intramuscularly. However, it is clear from this review that it is not that simple to separate the chronological deposition of fat into these four fat depots. Although differences in the partitioning of fat between the various depots exist, the expression of these differences is highly dependent on the energy content of the diet. Differences are more profoundly expressed on diets with higher energy levels. The differences among breeds occur mainly in the subcutaneous and kidney and pelvic fat depots. The percentage of intra-muscular fat differs least between breeds. In general, smaller framed, earlier maturing breeds tend to have higher percentages of subcutaneous fat and lower percentages of kidney, pelvic and heart fat than larger framed, later maturing breeds. Relative to total fat, only minor differences are generally found between breeds.

The fat cover of a carcass, through its insulating effects, affects the *post-mortem* physiological processes that govern the aging and tenderisation of meat. Furthermore, the fat content of muscles (intramusclular fat) influences the quality of meat, affecting, colour, tenderness and sensory panel palatability.

1.6 Physical characteristics of meat

1.6.1 Introduction

Various properties of meat influence the consumer's perception of meat. These include colour, texture, flavour, juiciness, breed, age, sex, type of muscle, *ante mortem* handling and feeding and *post-mortem* electrical stimulation. Although most characteristics give an indication of the status, especially the stress that an animal was under prior to slaughter, some influence the acceptability to consumers, some influence the palatability and some the tenderness of the meat. In this chapter attention will only be given to the traits that have an effect on the consumer's perception of the meat.

1.6.2 Colour

Colour is the critically important visual characteristic of meat which gives the important first impression and is largely determined by the relative proportions and distribution of oxymyoglobin and metmyoglobin (Gašperlin *et al.*, 2000).

Low muscle glycogen levels at slaughter are directly responsible for dark-cutting beef (McVeigh & Tarrant, 1982). The pH of dark-cutting meat is above 5.8 (MacDougall *et al.*, 1979) and results in reduced shelf life, undesirable dark colour (Young *et al.*, 2004) and weak beef flavour (Immonen *et al.*, 2000). Furthermore, dark-cutting meat will not bloom when exposed to air (Gašperlin *et al.*, 2000). In a review Naudé (1985) indicated that there is consumer resistance towards dark cutting meat.

The grazing background of animals also determines the colour stability of the meat as well as the stability of the fatty acids (Ponnampalam *et al.*, 2001; Maher *et al.*, 2004). These authors concluded that grazing lambs consumed enough antioxidants (β-carotene and α-tocopherol) to prevent the oxidation of the fatty acids that may affect the colour stability of the meat.

1.6.2.1 Influence of breed and sex

At a similar degree of finish, Whipple *et al.* (1990) found no differences in the colour of meat from *B. indicus* and *B. taurus* cattle. Destefanis *et al.* (2003) also reported no significant differences in lightness, chroma or hue among the *longissimus* muscle of intact males, early and late castrated steers.

The L*, a* and b* colour values of the *longissimus* muscle were similar for young bulls, steers and older heifers, but the L* colour value was significantly higher for intensively fed young heifers (Gerhardy, 1995). Although consumers could not detect colour differences between steaks from bullocks and steers, trained panellists could detect differences (Shackelford *et al.*, 1992). This is probably due to higher levels of marbling in the latter.

1.6.2.2 Influence of feeding regime

The *longissimus* muscle colour of forage-finished cattle is darker than that of grain-finished cattle (Bowling *et al.*, 1977; Crouse *et al.*, 1984; Bidner *et al.*, 1986; May *et al.*, 1992; Keane & Allen, 1998). One reason suggested from the literature (Bowling *et al.*, 1977) is that forage-finished cattle may be more susceptible to stress than grain-finished cattle. Grain-finished cattle are usually handled more regularly and they therefore become more used to people and being handled than forage-finished cattle. This specifically has an effect during lairage and the slaughtering process.

Beef from grain-fed cattle were also shown to have a higher reflectance (L*) value than beef from grass-fed cattle (Newsome *et al.*, 1985). The reason for this seems to be that fatter carcasses exhibits more marbling and had greater moisture retention and thus reflect more light than beef from grass-fed cattle. The Hunterlab a* and b* colour values of steers slaughtered from pastures at 29 months of age were significantly ($p < 0.05$ and $p < 0.001$) lower than the values for intensively fed bulls slaughtered at 19 months of age and steers fed intensively during their second winter and slaughtered at 24 months of age (Keane & Allen, 1998). Although feeding regime may influence the colour of the meat through the effects of intramuscular fat, it can not be denied that the increased activity of pasture reared animals may increase the myoglobin levels of the muscles and thus also contribute to the differences in colour between grass and grain fed animals.

1.6.2.3 Influence of *post-mortem* ageing of meat

Bowling *et al.* (1977) observed that the muscle colour of forage-finished cattle deteriorated more rapidly under retail sales conditions than that of grain-finished cattle. The colour (1 = dark red and 8 = bleached red) of steaks for grass-fed (3.14 to 5.19) as well as grain-fed cattle (3.64 to 5.19) darkened with increasing time on display (Crouse *et al.*, 1984). After five days the meat was deemed unacceptable to consumers. Initially Shackelford *et al.* (1992) found no differences between L* and a values of meat from bullocks and steers but, b* values were higher for steaks from steers ($p < 0.05$). After 3 days on display, L and b values were the same and a values were higher for steaks from steers.

None of the authors cited in the discussion of colour, indicated whether the darker meat colour of forage-fed cattle were offensive to consumers. Furthermore, it seems that consumers are not likely to detect subtle differences in colour of meat, although it may be statistically significant. It is thus concluded that as long as *ante-mortem* and *post-mortem* treatment of animals and meat does not induce excessive stress, cold toughness etc., the differences in colour caused by sex, breed and/or feeding regime will be small and not of practical importance.

1.6.3 pH

Muscle glycogen is the main metabolic substrate responsible for *post-mortem* lactic acid accumulation and thus normal pH decline (Immonen *et al.*, 2000). These authors also indicated that about 45 mmol glycogen is needed to lower the pH of 1 kg meat from 7.2 to 5.5. The muscle glycogen concentration at slaughter varies considerably depending on the muscle, species, nutritional status of the animal, but most of all, on level of pre-slaughter stress (Immonen *et al.*, 2000).

If a pH of less than 6.0 is reached sooner and at higher temperatures it will influence meat tenderness by preventing cold shortening of the various fibres. The most desirable range for muscle pH that results in the best properties for table cuts, is 5.4 to 5.6 (Young *et al.*, 2004).

Rees *et al.* (2003) indicated that the rate of pH and temperature decline can influence tenderness due to two main factors. Cold shortening occurs when the temperature falls below 10 ºC while muscle pH is still above 6.0. If the temperature declines slowly and pH rapidly, protein denaturation may occur. This will reduce the proteolytic processes necessary for tenderization of meat.

1.6.3.1 Influence of breed and sex

No breed differences were observed in the pH at any time period by Whipple *et al.* (1990). They reported that the three hour pH for the *longissimus* muscle was 6.4, while the ultimate pH was 5.5.

As in the case with results derived from different breeds, Destefanis *et al.* (2003) found no significant differences in the pH of the *longissimus* muscle of intact males (5.54), early (5.50) or late (5.50) castrated steers at 24 hours *post-mortem*. Similar results were reported by Ruiz de Huidobro *et al.* (2003) comparing young bulls and heifers. In contrast, Shackelford *et al.* (1992) observed that after three days on display the pH of steaks from steers were significantly ($p < 0.05$) lower than that of bullocks. The pH values ranged from 5.38 to 5.43 and from 5.41 to 5.51 for steers and bullocks respectively. These values however, were within the range considered normal.

The ultimate pH of muscles from cattle of different breeds or sexes will at most only differ slightly, but will be within acceptable norms.

1.6.3.2 Influence of feeding regime

Moody *et al.* (1970) reported that the 1-hour (ranging from 6.3 to 6.6) as well as the 96-hour (ranging from 5.6 to 5.7) pH of the *longissimus* muscle varied slightly for steers fed from 28 to 112 days. According to May *et al.* (1992), the 24-hour muscle pH tended ($p < 0.05$) to be higher for steers within the earlier slaughtering groups (0 and 84 days in a feedlot). The pH_{24} of steers slaughtered at 0 days were 5.78 compared to 5.69 for steers slaughtered after 84 days of feedlot feeding and 5.53 for steers slaughtered after 196 days of feedlot feeding. This was possibly due to a more rapid temperature decline due to poor insulation of the carcass resulting from a poor subcutaneous fat cover and a slower glycolytic rate for the carcasses in the early slaughter groups. Similar results were reported for trimmed and untrimmed carcasses (May *et al.*, 1992). Untrimmed carcasses (5.61) had significantly ($p < 0.05$) lower *longissimus* muscle pH values than trimmed carcasses (5.67) at 24-hours *post-mortem*. They however, concluded that this difference was small and of unpractical importance. Differences in pH measurements among different feeding regimes seem to be a measure of the effect of the fat cover on temperature decline and glycolitic rate.

Although breed, feeding regime and fat cover may have a slight influence on pH, it is in general practically unimportant. *Ante-mortem* (stress levels) and *post-mortem* (temperature decline and electrical stimulation) conditions are more important because they have stronger influences.

1.6.4 Temperature

1.6.4.1 Influence of breed

Few authors who investigated differences between breeds indicated the rate of temperature decline. Whipple *et al.* (1990) did not observe any differences in the temperature between carcasses from *B. taurus* and *B. indicus* breeds at any time period. However, the temperature of the *semitendinosus* muscle was initially lower than that of the *longissimus* muscle, but from six hours the temperature was higher in the *semitendinosus* muscle. Although no reasons for this was presented by Whipple *et al*. (1992), the location and activity of the respective muscles may have resulted in the different rates of *post-motrem* temperature decline.

1.6.4.2 Influence of feeding regime and fat cover

May *et al.* (1992) also reported that carcasses of steers fed for 0 to 56 days chilled at similar rates, while carcasses of steers fed from 112 to 140 days chilled at similar rates. The tendency was that carcasses from steers fed for shorter periods chilled faster than carcasses from steers fed for longer periods. May *et al.* (1992) concluded that carcass fatness and weight altered the chilling rates between slaughter groups.

The temperature of the *psoas major* muscle of conventionally treated carcasses remained above 13 ºC for approximately 25 hours *post-mortem*, while the temperature of carcasses with kidney and pelvic fat removed, remained above 13 ºC for approximately 11 hours *post-mortem* (de Felicio *et al.*, 1982). Similar results were reported by May *et al.* (1992) for the temperature decline of the *longissimus* muscle between trimmed and untrimmed carcasses.

In pork, conditioning muscles at 14 ºC produced muscles that were lighter and had less drip loss than muscles conditioned at either 0, 7 or 21 ºC (Rees *et al*., 2002). This is ascribed to the prevention of cold shortening at the low temperatures or protein denaturation at the high temperatures.

The influence of the feeding regime on the rate of temperature decline is usually expressed in terms of differences in subcutaneous fat cover. In most cases slower rates of temperature decline associated with a feeding regime are most probably due to differences in the subcutaneous fat cover. Animals with less subcutaneous fat will lose heat faster than animals with more subcutaneous fat.

1.6.5 Drip and cooking loss

1.6.5.1 Influence of breed and sex

The cooking loss of $^{5}/_{8}$ Sahiwal x Hereford crosses was significantly ($p < 0.05$) higher (31.6 %) than for Hereford x Angus crosses at one day *post-mortem*, but at 14 days post-mortem no differences were observed (Whipple *et al.*, 1990).

No differences in the drip loss from the *longissimus* muscle were observed among intact males, early or late castrated steers (Destefanis *et al.*, 2003). However, late castrated steers (20.38 %) had a significantly ($p < 0.05$) higher cooking loss than early castrated steers (17.61 %), while neither differed from the cooking loss of bulls (19.28 %).

1.6.5.2 Influence of feeding regime

Cooking losses of beef from grain-finished cattle did not differ significantly from that of forage-finished cattle (Bowling *et al.*, 1977; Crouse *et al.*, 1984). According to Bowling *et al.* (1977) it ranged from 27.5 to 29.8 %. Van Koevering *et al.* (1995) reported that as time in a feedlot increased, the percentage of cooking loss decreased (linear term; $p < 0.02$) at a decreasing rate (quadratic term; $p < 0.04$).

1.6.5.3 Influence of kidney fat

De Felicio *et al.* (1982) found no differences in drip as well as cooking loss of the *psoas major* muscle between beef from carcasses where the kidney fat was removed before chilling and that of conventionally treated carcasses.

1.6.6 Collagen

Collagen in meat consists of fibrous connective tissue and it can be differentiated into three types namely, the endomysium around individual muscle fibres, the larger layers of perimysium around bundles of muscle fibres and the thick, strong epimysium on the surface of individual muscles. It is commonly believed that collagen plays an important role in the tenderness of meat.

Hill (1966) concluded that when biochemical explanations for toughness in meat are considered, the degree of solubility of the collagen as well as the total amount of collagen should be considered. Bailey (1985) confirmed this conclusion in a review article. Young & Braggins (1993) however, concluded that collagen in ovine *semimembranosus* muscle is so insoluble throughout a sheep's life that solubility hardly matters; instead for that muscle it is the concentration of collagen that is more relevant. For muscles of which the collagen is more soluble throughout life, and/or where the range of solubility change is relatively wide, solubility may be more important. Furthermore, Ludwig *et al.* (1997) suggested that when interpreting collagen content of muscles it must be kept in mind that collagen is often not uniformly distributed within a muscle and also that higher concentrations of collagen are generally found near the origin and insertion regions of the relevant muscle. McCormick (1994) stated in a review that the effects of growth rate on muscle collagen characteristics have been studied extensively and have resulted in a great deal of confusion and some contradictory findings. He highlighted the role of dilution of collagen content associated with high growth rate as well as the role of cross linkages.

Although the suggestion of Hill (1966) is widely accepted in practice, it is clear from later studies that explaining toughness in meat using collagen concentration and solubility is not straight forward. All factors contributing to the attributes of collagen in a specific muscle should be considered in interpreting meat toughness in terms of collagen traits.

1.6.6.1 Influence of breed and sex

No differences were found by Whipple *et al.* (1990) in total as well as soluble collagen content between Hereford x Angus steer/heifers and Hereford x Sahiwal steers/heifers at one day or 14 days *post-mortem*. They concluded that neither collagen content nor solubility of the collagen contributed to differences in meat tenderness among the breeds they investigated. The results reported by Tatum *et al.* (1990) support these conclusions.

Collagen content of beef from Bonsmara bulls was significantly ($p < 0.05$) lower than beef from Brown Swiss, Afrikaner and Nguni bulls, but solubility of the collagen did not differ between the different breeds (Strydom *et al.*, 2000).

According to Destefanis *et al.* (2003) the hidroxyproline levels of intact males (536.55 μg/g) were higher than the levels of early (372.32 μg/g, $p < 0.01$) or late castrated steers (438.48 μg/g, $p < 0.05$). The steers groups did not differ significantly in hydroxiproline content. Collagen solubility did not differ between intact males and steer (Destefanis *et al.*, 2003). Similarly, Gerhardy (1995) reported that the collagen content of the *longissimus* muscle of young bulls (2.64 %) was higher ($p < 0.01$) than the collagen content of intensively fed 13 month old heifers (1.95 %), 32 month old steers (1.95 %) and 23 month old heifers (1.77 %). The collagen content for the steers and the two heifer groups did not differ significantly. The solubility of the collagen was similar for the young bulls (12.81 %), steers (11.64 %) and older heifers (10.81 %), but significantly ($p < 0.01$) higher for the intensively fed young heifers (18.99 %) (Gerhardy, 1995).

Differences in collagen content among the different sex classes are more likely to be due to differences in age rather than due to sex differences. Quoting various authors in their discussion, Strydom *et al.* (2000) indicated that variation in collagen content is influenced mainly by the specific muscle, animal species and gender, while thermal solubility of collagen depends mostly on species, age, gender and growth rate. A basic model including collagen solubility alone, explained only 35 and 25 % of the variation in shear force resistance and sensory tenderness of the *longissimus* muscle respectively. Furthermore, collagen solubility only influenced tenderness significantly when age variation was very wide, for example less than 18 months, more than 30 months and mature culled animals.

1.6.6.2 Influence of animal maturity

Field *et al.* (1997) reported that the collagen concentrations for A and C maturity heifer carcasses (1.89 % vs. 1.85 %) from animals of similar chronological age were similar.

Strydom *et al.* (2000) reported that collagen content declined significantly ($p < 0.05$) for bulls slaughtered from 75 % of their expected 112 day Standerdised Growth Test of the National Beef Cattle Performance Testing Scheme (Anon, 1994) weight to 105 % of their expected 112 day weight. They attributed the decline to the dilution effect of fat and myofibrillar tissue on collagen content. Tatum *et al.* (1990) found that the collagen content of the *longissimus* muscle was not affected by days fed.

1.6.6.3 Influence of muscle type

Collagen concentration was unrelated to age for the *semimembranosus* and *gluteus* muscles in sheep (Young & Braggins, 1993). In contrast Hill (1966) reported that collagen content of the *sternomandibularis* muscle in cattle was the highest at eight to nine weeks of age, probably due to poor muscle development at this stage. While Young & Braggins (1993) indicated that the collagen solubility of ovine *semimembranosus* muscles varied little with age, Hill (1966) indicated that in the *sternomandibularis* muscle of cattle the collagen solubility decreased with increasing age. The *longissimus* muscle had a lower ($p < 0.005$) collagen content (2.0 % vs. 3.1 %) and higher collagen solubility (11.2 % vs. 9.2 %) than the *semimembranosus* muscle (Gerhardy, 1995).

1.6.7 Shear force

Tenderness of meat is often expressed as the force (kg) needed to shear a cylinder of cooked meat of known diameter (usually 12.7 mm). When only peak shear force was used, 50 % of variation in overall tenderness was explained and when peak load as well as other parameters of the shear force profile was used, 66 % of the variation in overall tenderness was explained (Shackelford *et al.*, 1995). They concluded that shear force does not properly measure differences in tenderness among muscles and that shear force values of *longissimus* muscles were not highly related to shear force values of other muscles. Shear force, however, stays an easily obtainable, inexpensive and objective measure of the toughness of meat.

1.6.7.1 Influence of breed

Knapp *et al.* (1989) found no significant differences for shear force values of beef from English, European continental, Holstein, less than 50 % *B. indicus* and more than 50 % *B. indicus* breed type cattle. Casey *et al.* (1990) also did not find differences in shear force values between Afrikaner, Nguni and Pedi bulls. Only Santa Gertrudis bulls had higher shear force values than the other breeds, including Sanga and *B. taurus* breeds, studied by Strydom *et al.* (2000). These results are in contrast with the findings of Tatum *et al.* (1990), Whipple *et al.* (1990) and Wheeler *et al.* (1996) who noted breed differences for shear force values.

Longissimus steaks from Red Angus-sired steers had lower ($p < 0.05$) shear force values than steaks from Gelbvieh-sired steers (Tatum *et al.*, 1990). Whipple *et al.* (1990) reported that Warner-Bratzler shear force values increased significantly ($P < 0.05$) as the percentage Sahiwal increased. It ranged from 7.0 kg for Hereford x Angus crosses, 9.3 kg for $^3/_8$ Sahiwal x Hereford crosses to 9.6 kg for $^5/_8$ Sahiwal x Hereford crosses at one day *post-mortem* and 4.7 kg for Hereford x Angus crosses, 6.4 kg for $^3/_8$ Sahiwal x Hereford crosses to 7.7 kg for $^5/_8$ Sahiwal x Hereford crosses at 14 days *post-mortem*. Warner-Bratzler shear force values of more than 5.0 kg were deemed to be unacceptable. Wheeler *et al.* (1996) reported similar results for Nellore-sired steers compared to Pinzgauer and Piedmontese steers.

Shackelford *et al.* (1995) observed a genotype with muscle interaction for shear force values of steaks as well as roasts. Shear force values were higher for *longissimus* muscles of *B. indicus* than for the other muscles, whereas for *B. taurus* shear force values were lower for *longissimus* muscles than for *semimembranosus* muscles.

Although conflicting reports were found, it seems that in general the shear force values increase as the percentage of *B. indicus* increases.

1.6.7.2 Influence of feeding regime

According to Bowling *et al.* (1977), *longissimus* muscles from conventionally chilled forage-finished cattle had higher ($p < 0.05$) shear force values than that of conventionally chilled grain-finished cattle. These results are supported by the results of Schroeder *et al.* (1980) and Bennett *et al.* (1995). Similar shear force values were observed for steaks from grass-fed and grain-fed heifers (Crouse *et al.*, 1984). Shear force values were significantly higher ($p < 0.05$) for steaks from high-temperature chilled, forage-finished cattle (Bowling *et al.*, 1977). Similar results were reported by Lee & Ashmore (1985) who concluded that high *post-mortem* temperature treatment or delayed chilling can decrease meat tenderness of well finished beef carcasses, whereas delayed chilling at 10 to 15 ºC can increase meat tenderness of grass fed cattle. In South Africa where cattle are slaughtered at a leaner stage than in the USA, the tenderness of all meat may be enhanced by delayed chilling.

Mean Warner-Bratzler values tended ($p < 0.07$) to decrease with increasing time in the feedlot (Tatum *et al.*, 1990; Van Koevering *et al.*, 1995). Mean shear force values decreased from 4.45 kg after 105 days in a feedlot to 4.16 kg after 147 days in a feedlot (Van Koevering *et al.*, 1995). Similar results were reported by Short *et al.* (1999) for steers fed from either 6 or 18 months of age. May *et al.* (1992) reported that shear force values did not decrease after 56 days in a feedlot and slightly increased (quadratic term; $p < 0.01$) after 112 days in a feedlot. Short *et al.* (1999) reported that shear force values decreased steadily (linear term; $p < 0.01$) with increasing time in a feedlot (until 270 days) for steers fed from 6 months of age, but rapidly until 90 days in a feedlot and then not further for steers fed from 18 months of age (quadratic term; $p < 0.05$). In addition, Van Koevering *et al.* (1995) reported that the percentage of steaks being considered tough (> 4.54 kg) decreased ($p < 0.05$) with longer times in a feedlot. Steers fed in a feedlot for 105 days had a higher percentage of tough steaks than steers fed in a feedlot for 147 days (46 % vs. 28 %). On the contrary, Moody *et al.* (1970) did not find significant differences in shear force values in *longissimus* muscles of steers fed in a feedlot for 28, 56, 84 or 112 days. When cattle were slaughtered at the same degree of fatness, Prior *et al.* (1977) as well as Bidner *et al.* (1986) reported that dietary energy level had very little effect on the shear force values of beef. Similarly, Keane & Allen (1998) found no differences in the shear force values of the *longissimus* muscle of intensively fed bulls slaughtered at 19 months of age, steers fed intensively during their second winter (slaughtered at 24 months of age) and steers slaughtered after grazing pasture up to 29 months of age, respectively.

Increasing time on high energy diets will result in lower shear force values as well as lower percentages of steaks being tough. Delaying chilling under South African production and slaughtering systems will also increase the tenderness of the meat.

1.6.7.3 Influence of fat thickness

The fat thickness of the carcass is believed to be associated with a part of the differences in tenderness between forage-finished and grain finished cattle. Sarcomere length and panel tenderness ratings increased, while shear force values decreased when fat thickness increased from 1.27 mm to 8.9 mm (Bowling *et al.*, 1977). However, beyond a fat thickness of 10.2 mm, sarcomere length did not increase. Similar results were reported by De Felicio *et al.* (1982) for shear force values of steaks that were insulated by the kidney and pelvic fat and that of steaks where the kidney and pelvic fat was removed before chilling.

Steaks from conventionally chilled carcasses (2.26 kg) had significantly ($p < 0.01$) lower Warner-Bratzler shear force values than steaks from carcasses with kidney and pelvic fat removed (2.49 kg) before chilling (De Felicio *et al.*, 1982). They concluded that although differences between the treatments were statistically significant, palatability will probably not be affected.

Shear force was 8 % lower for bulls slaughtered at 105 % of the mean 112 day weight obtained in the Standardised Growth Test of the National Beef Cattle Performance Testing Scheme (Anon, 1994) than for bulls slaughtered at 75 % of the 112 day weight (Strydom *et al.*, 2000).

Shear force values will decrease as the fat thickness increases to approximately 10 mm, but not beyond 10 mm.

1.6.7.4 Influence of pH

Devine *et al.* (1993) reported that as the ultimate pH values of the *longissimus* muscles of lambs increased from 5.5 to 5.9, the shear force values increased from 8 kg to 13 kg. With further increases in the ultimate pH the shear force values decreased to around 6 to 8 kg. Devine *et al.* (1993) discussed the effect of moderate ultimate pH on tenderness of meat elaborately and concluded that it is often the main factor causing differences in tenderness between various treatments studied and that it is a likely unrecognized factor that results in tough meat in a variety of situations. Examples are, differences in the tenderness of meat from bulls and steers, the ability of well fed animals to buffer stress factors and higher muscle glycogen levels that may lead to lower ultimate pH values as well as differences in the tenderness of meat from *B.*

indicus and *B. taurus*. There is not a clear explanation for how moderate ultimate pH increases meat toughness.

1.6.7.5 Influence of animal age, maturity and sex

According to Field *et al.* (1997) shear force values tended ($p > 0.05$) to be higher for steaks from C maturity heifer carcasses (9.82 kg) than for A maturity heifer carcasses (9.02 kg).

Destefanis *et al.* (2003) found no differences in the shear force values among the *longissimus* muscles from intact males (6.97 kg), early (6.18 kg) or late castrated steers (7.15 kg). Similarly, Gerhardy (1995) observed no differences in the shear force values of the *longissimus* muscle of intensively fed young heifers, young bulls, steers, and older heifers.

1.6.7.6 Influence of *post-mortem* ageing of meat

The extent of *post-mortem* proteolysis of key myofibrillar proteins determines the final tenderness of meat (Shackelford *et al.*, 1994). The calpain proteolytic system plays a major role in the improvement of meat tenderization during *post-mortem* storage (Koohmaraie, 1992).

Shear force values of raw *semitendinosis* muscles decreased rapidly until 10 days post-mortem and gradually thereafter (Nishimura *et al.*, 1998). These authors concluded that the rapid decrease until 10 days post-mortem was mainly due to the weakening of the myofibril structures and after 10 days the gradual decrease is due to the structural weakening of the endomysium and the perimysium.

Shackelford *et al.* (1997) indicated that the mean *longissimus* muscle shear force values of all tenderness classes decline ($p < 0.01$) between one day and two days *post-mortem* and 14 days *post-mortem*. The magnitude of the decline was the greatest for the "tough" class and the least for the "intermediate" class.

1.6.8 Sensory evaluation

1.6.8.1 Influence of breed

Knapp *et al.* (1989) reported little differences in sensory evaluation between the various breeds they compared. In contrast, Whipple *et al.* (1990) reported that *longissimus* muscles of Hereford x Angus crosses had significantly ($p < 0.01$) higher scores for ease of fragmentation, connective tissue amount and overall tenderness than that of Sahiwal x Hereford steers/heifers. Similarly, Piedmontese and Pinzgauer-sired steers produced *longissimus* muscles with the highest tenderness ratings and Nellore-sired steers the lowest *longissimus* tenderness ratings (Wheeler *et al.*, 1996). Breed differences for sensory panel attributes were also found by Tatum *et al.* (1990). Comparing Afrikaner, Nguni and Pedi bulls, Casey *et al.* (1990) found that the meat of Afrikaner bulls tended ($p < 0.10$) to be slightly more tender and flavoursome with less residue than that of Nguni bulls. No breed differences occurred in juiciness. Although Koch *et al.* (1979) also found significant differences in tenderness of beef from various breeds, they indicated that breeds were scored within the range of moderately tender. No breed differences for juiciness and flavour were observed.

The most prominent differences in tenderness among breeds are, like in the case with shear force, between *B. indicus* and *B. taurus* breeds. It can however, be concluded that in animals raised under the same feeding and management conditions, differences in palatability among breed groups will be small.

1.6.8.2 Influence of feeding regime

Although no significant differences between grain- and forage-finished cattle was reported for initial juiciness, sustained juiciness or flavour intensity, beef from forage-finished cattle was less ($p < 0.05$) desirable in flavour and palatability than grain-finished cattle (Bowling *et al.*, 1977; Schroeder *et al.*, 1980; Crouse *et al.*, 1984; Fortin *et al.*, 1985; Bennett *et al.*, 1995; Camfield *et al.*, 1997). Bowling *et al.* (1977) as well as Camfield *et al.* (1997) proposed that the composition of the intra-muscular lipids and/or the concentration of the nitrogenous extractives in the muscle may be responsible for the reduced desirability in flavour of forage-finished cattle. Short *et al.* (1999) reported that flavour intensity increased non-linearly ($p < 0.01$) as time in a feedlot increased for steers fed from either six or 18 months of age. Flavour, juiciness, tenderness and acceptability were not affected by dietary energy level when cattle of different frame sized breeds were compared at similar degrees of fatness (Prior *et al.*, 1977; May *et al.*, 1992). In contrast, Bidner *et al.*, (1986) reported that beef from forage finished cattle were rated higher for juiciness than beef from grain-finished cattle. This difference however, was small.

Taste panel tenderness scores improved up to 84 days of feedlot feeding, while extending the feedlot feeding period up to 168 days did not improve taste panel tenderness scores any further (May *et al.*, 1992). They also reported that ease of fragmentation did not improve after 56 days in a feedlot and slightly decreased (quadratic term; $p < 0.01$) after 112 days in a feedlot. Tatum *et al.* (1990) and Camfield *et al.* (1997) reported similar results. Short *et al.* (1999) however, reported linear responses for ease of fragmentation for steers fed from six months of age ($p < 0.05$) and for steers fed from 18 months of age ($p < 0.01$). Panel tenderness of the *longissimus* muscle did not differ between 28, 56, 84 and 112 days of feeding nor were there definite trends in any of the other organoleptic traits with time in a feedlot (Moody *et al.*, 1970). Similar results were reported by Young & Kauffman (1978) as well as Fortin *et al.* (1985). On the other hand, Crouse *et al.* (1985b) reported that beef from cattle fed on a low-energy diet was more ($p < 0.01$) tender and easier to fragment than beef from a high-energy diet.

According to Bowling *et al.* (1977), *longissimus* muscles from conventionally chilled forage-finished cattle were less ($p < 0.05$) tender and had a greater ($p < 0.05$) amount of organoleptic detectable connective tissue than that of conventionally chilled grain-finished cattle. Similar results for tenderness ratings were reported by Schroeder *et al.* (1980) and Bennett *et al.* (1995). In contrast, Crouse *et al.* (1984) did not observe any differences in tenderness ratings for steaks from grass-fed compared to steaks from grain-fed heifers. Muscle fibre tenderness and the amount of organoleptic detectable connective tissue were similar for beef from conventionally chilled grain-finished and high temperature chilled, forage-finished cattle (Bowling *et al.*, 1977). In agreement with these findings, Keane & Allen (1998) found no differences in sensory panel traits of the *longissimus* muscle of intensively fed bulls slaughtered at 19 months of age, steers fed intensively during their second winter (slaughtered at 24 months of age) and steers slaughtered after grazing pasture up to 29 months of age respectively.

The major effects of feeding on sensory attributes of meat revolve around the type of feeding (forage vs. grain) and the time on grain feeding. Forage feeding mainly alters the flavour and palatability of meat, while grain-feeding animals improve tenderness ratings of meat.

1.6.8.3 Influence of animal maturity and sex

Field *et al.* (1997) reported that panellists comparing meat from carcasses of heifers similar in chronological age tended ($p > 0.05$) to rate meat from A maturity carcasses (6.43) to be less tender than meat from C maturity carcasses (5.97). The American carcass maturity classification is based on the colour and hardness of the bones (Lawrence *et al.*, 2001). This system results in animals similar in chronological age to be classified into different maturity classes. The opposite is also true; animals varying widely in chronological age are classified in the same maturity classes.

No significant differences were observed between intact males, early and late castrated steers for any of the sensory traits (Destefanis *et al.*, 2003).

1.6.8.4 Influence of fat

May *et al.* (1992) found that meat tenderness in steers did not improve when fattened beyond 7.6 mm fat thickness. In fact, sensory panel tenderness scores decreased for steaks from steers fed for 196 days to a fat thickness of 21.08 mm. The possible reason for the decreased tenderness forwarded by May *et al.* (1992) is that these steers had the highest ($p < 0.05$) early post mortem temperatures. This may have led to rapid glycolitic activity, rapid pH decline, resulting in denaturation of the enzymes responsible for proteolitic activity. It may also have been related to carcass maturity.

Sensory panel ratings did not differ for any of the traits between animals with high or low expected progeny differences for marbling (Gwartney *et al.*, 1996). These results are to be expected in the light that Wheeler *et al.* (1994) indicated that marbling has a low association with meat palatability and only explains at most 5 % of variation in palatability. They also concluded that increasing marbling from 3 to 7 % intramuscular fat contributes to palatability and that higher levels of marbling did not contribute to increased palatability.

Tenderness ratings will improve with fat thickness increasing up to approximately 10 mm but at thicker fat thicknesses, meat may become tougher. On the other hand marbling influences palatability of meat only within a narrow band.

1.6.9 Relationships

Shear force correlated highly (- 0.61) with tenderness (Casey *et al.*, 1990). Shear force and tenderness rating were also highly correlated (r = 0.92) in the study conducted by Wheeler *et al.* (1996). Devine *et al.* (1993) reported a linear relationship (r = 0.71) between shear force values and panel tenderness ratings for *longissimus* muscles of lambs.

The 2.5-hour temperature was highly correlated (r = 0.54) with tenderness (May *et al.*, 1992).

Shear force correlated highly (0.74) with residue, while juiciness correlated negatively with percentage cooking loss (- 0.57), but poorly with percentage free water (Casey *et al.*, 1990).

Strydom *et al.* (2000) found no significant linear relationship between any meat tenderness attribute and collagen content and solubility. Similarly, Crouse *et al.* (1985b) found low correlations between collagen content and solubility with tenderness and shear force. Young & Braggins (1993) indicated that in ovine *semimembranosus* muscle, sensory panel tenderness was weakly correlated (r = 0.38; p < 0.05) with collagen solubility, but collagen content on a wet basis was significantly (r = -0.53; p < 0.001) related to tenderness as determined by a taste panel. In contrast, shear force values were better correlated with solubility (r = -0.41; p < 0.05) than with concentration (r = 0.16).

Ease of fragmentation accounted for a greater proportion of the variation in overall tenderness among muscles than did amount of connective tissue (Shackelford *et al.*, 1995). They also indicated that ease of fragmentation accounted for a greater proportion of the within-muscle variation in overall tenderness than did amount of connective tissue.

1.7 Chemical composition of meat

1.7.1 Introduction

In meat studies the moisture, protein and lipid contents are usually reported. This is mainly due to the relationships between these components and their relationship with sensory evaluation. This section will only focus on the factors affecting the moisture, protein, mineral and ash content of meat. The lipid or fat content of muscles has been discussed in Chapter 5 and will not be discussed again.

1.7.2 Moisture content

1.7.2.1 Influence of breed and sex

Tatum *et al.* (1990) reported that the moisture content of meat did not differ significantly between breeds (72.3 %, 72.5 % and 71.9 % for Piedmontese, Gelbvieh and Red Angus respectively). In contrast, Wheeler *et al.* (1996) reported that the raw *longissimus* muscles of Hereford x Angus and Shorthorn-sired steers had the highest lipid content and the lowest moisture content, while the *longissimus* muscles of

Piedmontese, Gelbvieh, Charolais Nellore Salers and Longhorn- sired steers had the lowest lipid content and the highest moisture content.

As pertaining to the influence of sex, Destefanis *et al.* (2003) reported that *longissimus* muscles of intact males (75.39 %) had significantly ($p < 0.01$) higher moisture levels than early (74.60 %) or late castrated steers (74.73 %). However, Gerhardy (1995) reported no significant differences in the moisture content of the *longissimus* muscle of young bulls slaughtered at 18 months of age, (73.58 %) when compared to steers slaughtered at 32 months of age (72.07 %) and heifers slaughtered at 33 months of age (72.35 %). However, the *longissimus* muscle of intensively fed heifers slaughtered at 13 months of age had a significantly higher moisture content than the *longissimus* muscle of the bulls, steers and older heifers.

1.7.2.2 Influence of feeding regime

Moisture content of the soft tissue decreased significantly ($p < 0.05$) for smaller, earlier maturing type steers with increased energy content of the diet when compared at a constant weight (Prior *et al.*, 1977). Tatum *et al.* (1990) and Van Koevering *et al.* (1995) also reported that the moisture content of the *longissimus* muscle decreased significantly ($p < 0.01$) with increasing time in a feedlot. The reason for this seems to be that moisture is displaced by fat as the fat content increased with increasing energy levels or time in a feedlot (Prior *et al.*, 1977).

The results reported by Keane & Allen (1998) supports the above findings. They reported moisture contents of 720, 702 and 718 g/kg for the *longissimus* muscle of intensively fed bulls slaughtered at 19 months of age, steers fed intensively during their second winter (slaughtered at 24 months of age) and steers slaughtered after grazing pasture up to 29 months of age, respectively. The moisture content of the 24 month old group was significantly ($p < 0.01$) lower than the moisture content of the other two groups.

Due to the inverse relationship between moisture and fat content, differences between animals of different breeds, frame sized, maturity types, sex classes as well as feeding regimes will likely only be detected if animals are not compared at a constant fat parameter.

1.7.3 Crude protein content

Comparing steers at a constant weight, Prior *et al.* (1977) reported that the protein content of the *longissimus* muscle of smaller, earlier maturing type steers decreased with increasing levels of energy in the diet. Van Koevering *et al.* (1995) reported that the protein content of the *longissimus* muscle decreased with increasing time on a high energy feed.

The meat of intact males (22.35 %) had a significantly ($p < 0.05$) lower protein percentage than early castrated steers (22.80 %), but these values did not differ from that of late castrated (22.49 %) steers (Destefanis *et al.*, 2003).

Keane & Allen (1998) observed no significant differences in the protein content of the *longissimus* muscle of intensively fed bulls slaughtered at 19 months of age (228 g/kg) compared to steers fed intensively during their second winter (slaughtered at 24 months of age, 228 g/kg) and steers slaughtered after grazing pasture up to 29 months of age (226g/kg).

The crude protein content of meat, like the moisture content and for the same reason, is likely to be similar for animals of different breeds, frame size, maturity types, sex classes as well as feeding regimes when they are compared at similar carcass fat parameters.]

1.7.4 Mineral and ash content

The mineral content of different fibre types may be related to the tenderness of meat (Whipple *et al.*, 1990). Especially the Ca^{2+} is of interest as it is required to activate calpain. Whipple *et al.* (1990) determined the water-soluble free Ca^{2+} one day *post-mortem* and found no differences between breed types. They also did not find differences in the Zn^{2+} concentration one day *post-mortem* between the different breeds. Calcium content ranged from 8.6 to 10.8 µg/g muscle and the zinc content ranged from 8.5 to 9.5 µg/g muscle.

Ash contents of 11, 10 and 10 g/kg *longissimus* muscle were reported by Keane & Allen (1998) for the *longissimus* muscles of intensively fed bulls slaughtered at 19 months of age, steers fed intensively during their second winter (slaughtered at 24 months of age) and steers slaughtered after grazing pasture up to 29 months of age, respectively.

1.8 General conclusions and objectives

Breed type as determined by frame size or maturity type has a major influence on the efficiency of a production system. This influence is modified by the feeding regime. With increasing levels of dietary energy, larger framed, later maturing breed types become more competitive than smaller framed, earlier maturing breed types. In terms of reproduction and growth traits, larger breed types in general benefit more from increased dietary energy levels than small framed breed types. In respect to carcass quality and fat parameters at constant age or weight endpoints, large framed cattle exhibit only minor differences between high and low levels of dietary energy, while smaller framed animals are more pronouncedly affected.

Pastures are the main scource of nourishment for the majority of the world's ruminants (McDonald, 1971). He further concluded that our knowledge of understanding of pastoral ecosystems, especially in the tropical arid regions is lacking. Scientific knowledge of pastoral ecosystems has expanded dramatically since McDonald published his findings. However, in South Africa, most research pertaining to growth and carcass studies were conducted in the sourveld regions on irrigated and fertilized planted pastures (Gertenbach *et al*, 1995; Gertenbach & Henning, 1995b; Le Roux *et al*, 1999a, b; De Villiers & Van Ryssen, 2001) or in feedlots (Meaker & Barnard, 1988; Swanepoel *et al*, 1990; Gertenbach & Henning, 1995a; Strydom *et al.*, 2001). Manipulation of low quality forages and crop residues (Brand *et al.*, 1989; Snyman & Joubert, 2002; Taute *et al.*, 2002) also received considerable attention. In fact, only one study (Van Niekerk *et al.*, 1986) was found pertaining to a sweet veld region. Various studies concerning production from natural pastures were conducted at the Mara Research Station, but surprisingly all these studies primarily concentrated on the performance and efficiency of the cow herd (Venter, 1977; Van Zyl, 1990; Lademann, 1992; Meaker, 1993).

The objective of this study was to broaden the knowledge base and understanding of beef production as well as to provide scientifically founded guidelines for production systems in the Arid Sweet Bushveld (Acocks, 1988).

The production and reproduction parameters of four cow herds varying in frame size and represented by Simmentaler cross, Bonsmara cross, Afrikaner and Nguni breeds, were established, while the post weaning growth rates as well as carcass production and characteristics together with the meat quality of each breed type were also studied. The production potential for the different breed types were calculated from the production and carcass data collected in the study.

1.9 References

Acocks, J.P.H., 1988. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 57.

Anon., 1994. National Beef Cattle Performance and ProgenyTesting Scheme: 1980-1992 results, Compiled by D.J. Bosman. Livestock Improvement Schemes, Irene, Republic of South Africa.

Bailey, A.J., 1985. The role of collagen in the development of muscle and its relationship to eating quality. *J. Anim. Sci.* 60, 1580-1587.

Berg, R.T. & Butterfield, R.M., 1966. Muscle:bone ratio and fat percentage as measures of beef carcass composition. *Anim. Prod.* 8, 1-11.

Bennett, L.L., Hammond, A.C., Williams, M.J., Kunkle, W.E., Johnson, D.D., Preston, R.L. & Miller, M.F., 1995. Performance, carcass yield and carcass quality characteristics of steers finished on Rhizoma peanut (*Arachis glabrata*) – Tropical grass pasture or concentrate. *J. Anim. Sci.* 73, 1881-1887.

Bidner, T.D., Schupp, A.R., Montgomery, R.E. & Carpenter, J.C., 1981. Acceptability of beef finished on all-forage, forage-plus-grain or high energy diets. *J. Anim. Sci.* 53, 1181.

Bidner, T.D., Schupp, A.R., Mohamad, A.B., Rumore, N.C., Montgomery, R.E., Bagley, C.P. & Mcmillin, K.W., 1986. Acceptability of beef from Angus-Hereford or Angus-Hereford-Brahman steers finished on all-forage or a high-energy diet. *J. Anim. Sci.* 62, 381-387.

Block, H.C., McKinnon, J.J., Mustafa, A.F. & Christensen, D.A., 2001. Manipulation of cattle growth to target carcass quality. *J. Anim. Sci.* 79, 133-140.

Bowling, R.A., Smith, G.C., Carpenter, Z.L., Dutson, T.R. & Oliver, W.M., 1977. Comparison of forage-finished and grain-finished beef carcasses. *J. Anim. Sci*. 45, 209-215.

Brand, A.A., Cloete, S.W.P. & Coetzee, J., 1989. Urea ammoniation of wheat, oat and barley straw and oat hay. 1. A laboratory investigation into the effect of urea and moisture level and treatment period on chemical composition and *in vitro* digestibility. *S. Afr. J. Anim. Sci*. 19, 4-10.

Camfield, P.K., Brown, A.H., Jr., Lewis, P.K., Rakes, L.Y. & Johnson, Z.B., 1997. Effects of frame size and time-on-feed on carcass characteristics, sensory attributes and fatty acid profiles of steers. *J. Anim. Sci.* 75, 1837-1844.

Camfield, P.K., Brown, A.H., Jr., Johnson, Z.B., Brown, C.J., Lewis, P.K. & Rakes, L.Y., 1999. Effects of growth type on carcass traits of pasture- or feedlot-developed steers. *J. Anim. Sci.* 77, 2437-2443.

Carpenter, J.W.A., Palmer, A.Z., Kirk, W.G., Peacock, F.M. & Koger, M., 1961. Slaughter and carcass characteristics of Brahman and Brahman-Shorthorn crossbred steers. *J. Anim. Sci*. 20, 336.

Casey, N.H., Swanepoel, J., de Bruyn, J.F. & Naudé, R.T., 1990. Meat studies of indigenous Southern African cattle. II. Textural evaluation of ribcut samples from carcasses of Afrikaner, Nguni and Pedi bulls fed intensively. *S. Afr. J. Anim. Sci.* 20, 188-192.

Coetzee, J.J., 1971. Die Landboupotensiaal van die Noordwes-Transvaalse Soetbosveld. D. Agric (Inst. Agrar) Thesis. University of Pretoria. pp 245.

Charles, D.D. & Johnson, E.R., 1976. Breed differences in amount and distribution of bovine carcass dissectible fat. *J. Anim. Sci*. 42, 332-341.

Cianzio, D.S., Topel, D.G., Whitehurst G.B., Beitz, D.C. & Self, H.L., 1982. Adipose tissue growth in cattle representing two frame sizes: Distribution among depots. *J. Anim. Sci.* 55, 305-312.

Collins-Lusweti, E., 2000. Performance of Nguni, Afrikander and Bonsmara cattle under drought conditions in the North West Province of Southern Africa. *S. Afr.J.Anim Sci*. 30. 33.

Crouse, J.D., Cross, H.R. & Seideman S.C., 1984. Effects of a grass or grain diet on the quality of three beef muscles. *J. Anim. Sci.* 58, 619-625.

Crouse, J.D., Ferrel, C.L. & Cundiff, L.V., 1985a. Effects of sex condition, genotype and diet on bovine growth and carcass characteristics. *J. Anim. Sci.* 60, 1219-1227.

Crouse, J.D., Cross, H.R. & Seideman S.C., 1985b. Effects of sex condition, genotype, diet and carcas electrical stimulation on the collagen content and palatibility of two bovine muscles. *J. Anim. Sci.* 60, 1228-1234.

Crouse, J.D., Cundiff, L.V., Koch, R.M., Koohmaraie, M., & Seideman, S.C., 1989. Conparisons of Bos indicus and Bos taurus inheritance for carcass beef characteristics and meat palatability. *J. Anim. Sci.* 67, 2661-2668.

Dadi, H., Schoeman, S.J., Jordaan, G.F. & Van der Westhuysen, 2002a. The influence of Charolais and Hereford sires and straightbred and crossbred dams on pre-weaning growth performance of calves. *S. Afr. J. Anim. Sci*. 32, 38-43.

Dadi, H., Schoeman, S.J., Jordaan, G.F. & Van der Westhuysen, 2002b. The influence of Charolais and Angus breeding levels on pre-weaning growth performance traits in crossbred calves. *S. Afr. J. Anim. Sci*. 32, 201-207.

Danner, M.L., Fox, D.G. & Black, J.R., 1980. Effect of feeding system on performance and carcass characteristics of yearling steers, steer calves and heifer calves. *J. Anim. Sci*. 50, 394-404.

De Felicio, P.E., Kastner, C.L. & Allen, D.M., 1982. removal of kidney fat before chilling – effect on beef tenderloin yield, color and tenderness. *J. Anim. Sci.* 54, 72-75.

Destefanis, G., Brugiapaglia, A., Barge, M.T. & Lazzaroni, C., 2003. Effect of castration on meat quality in Piedmontese cattle. *Meat Sci*. 64, 215-218.

De Villiers, J.F. & Van Ryssen, J.B.J., 2001. Performance responses of lambs of various ages to Italian ryegrass (*Lolium multiflorum*) fertilized with various levels of nitrogen. *S. Afr. J. Anim. Sci*. 31, 142-148.

Devine, C.E., Graafhuis, A.E., Muir, P.D. & Chrystall, B.B., 1993. The effect of growth rate and ultimate pH on meat quality of lambs. *Meat Sci*. 35, 63-77.

Dikeman, M.E., Dayton, A.D., Hunt, M.C., Kastner, C.L., Axe, J.B. & Ilg, H.J., 1985a. Conventional versus accelerated beef production with carcass electrical stimulation. *J. Anim. Sci.* 61, 573-583.

Dikeman, M.E., Nagele, K.N., Myers, S.M., Schalles, R.R., Kropf, D.H., Kastner, C.L. & Russo, F.A., 1985b. Accelerated versus conventional beef production and processing. *J. Anim. Sci.* 61, 137-150.

Dolezal, H.G., Tatum, J.D. & Williams, F.L., Jr., 1993. Effects of feeder cattle frame size, muscle thickness and age class on days fed, weight and carcass composition. *J. Anim. Sci.* 71, 2975-2985.

Ferrell, C.L., Kohlmeier, R.H.,Crouse, J.D. & Glimp, H., 1978. Influence of dietary energy, protein and biological type of steer upon rate of gain and carcass characteristics. *J. Anim. Sci.* 46, 255-.

Field, R., McCormick, R., Balasubramanian, V., Sanson, D., Wise, J., Hixon, D., Riley, M. & Russell W., 1997. Tenderness variation among loin steaks from A and C maturity carcasses of heifers similar in chronological age. *J. Anim. Sci.* 75, 693-699.

Fortin, A., Reid, T.J., Maiga, A.M., Sim, D.W. & Wellington, G.H., 1981a. Effect of energy intake level and influence of breed and sex on the physical composition of the carcass of cattle. *J. Anim. Sci.* 51, 331-339.

Fortin, A., Reid, T.J., Maiga, A.M., Sim, D.W. & Wellington, G.H., 1981b. Effect of level of energy intake and influence of breed and sex on muscle growth and distibution in the bovine carcass. *J. Anim. Sci.* 51, 1288-1296.

Fortin, A., Veira, D.M., Froehlich, D.A., Butler,G. & Proulx, J.G., 1985. Carcass characteristics and sensory properties of Hereford x Shorthorn bulls and steers fed different levels of grass silage and high moisture barley. *J. Anim. Sci.* 60, 1403-1411.

Gašperlin, L., Žlender, B. & Abram, V., 2000. Colour of normal and high pH beef heated to different temperatures as related to oxygenation. *Meat Sci*. 54, 391-398.

Gerhardy, H., 1995. Quality of beef from commercial fattening systems in Northern Germany. *Meat Sci*. 40, 103-120.

Gertenbach, W.D., Van H. Henning, P.W. & Van Schalkwyk, A.P., 1995. Performance of beef steers on Smuts finger grass and Nile grass pasture in Northern Natal. 1. Effect of over wintering level and summer stocking rate. *S. Afr. J. Anim. Sci.* 25, 95-100.

Gertenbach, W.D. & Van H. Henning, P.W., 1995a. Performance of beef steers on Smuts finger grass and Nile grass pasture in Northern Natal. 2. Feedlot performance following summer grazing. *S. Afr. J. Anim. Sci.* 25, 101-104.

Gertenbach, W.D. & Van H. Henning, P.W., 1995b. Energy supplementation of yearling steers at different stocking rates on Nile grass pasture. *S.Afr. J. Anim. Sci*. 25, 105-108.

Grosskopf, J.W.J., 1973. Die korrelasie tussen die gemiddelde daaglike toename van kalwers en die herbesetting van hulle moers as hulpmiddel by die ondersoek na vrugbareheidsprobleme in vleisbeeskuddes. *S. Afr. J. Anim. Sci*. 3, 87-90.

Guenther, J.J., Bushman, D.H., Pope, L.S. & Morrison R.D., 1965. Growth and development of the major carcass tissues in beef calves from weaning to slaughter weight, with reference to the effect of plane of nutrition. *J. Anim. Sci.* 24, 1184-1191.

Gwartney, B.L., Calkins, C.R., Rasby, R.J., Stock, R.A., Vieselmeyer, B.A. & Gosey, J.A., 1996. Use of expected progeny differences for marbling in beef: II. Carcass and palatability traits. *J. Anim. Sci.* 74, 1014-1022.

Harris, J.J., Lunt, D.K., Smith, S.B., Mies, W.L., Hale, D.S., Koohmaraie, M. & Savell, J.W., 1997. Live animal performance, carcass traits and meat palatability of calf- and yearling-fed cloned steers. *J. Anim. Sci.* 75, 986-992.

Hill, F., 1966. The solubility of intramuscular collagen in meat animals of various ages. *J. Food Sci*. 31, 161-166.

Immonen, K., Ruusunen, M. & Puolanne, E., 2000. Some effects of residual glycogen concentration on the physical and sensory quality of normal pH beef. *Meat Sci*. 55, 33-38.

Keanne, M.G. & Allen, P., 1998. Effects of production system intensity on performance, carcass composition and meat quality of beef cattle. *Livest. Prod. Sci*. 56, 203-214.

Klosterman, E.W., 1981. measuring beef production in the cow herd. *S. Afr. J. Anim Sci*. 11, 195-198.

Knapp, R.H., Terry, C.A., Savell, J.W., Cross, H.R., Mies W.L. & Edwards, J.W., 1989. Characterization of cattle types to meet specific beef targets. *J. Anim. Sci.* 67, 2294-2308.

Koch, R.M. & Dikeman, M.E., 1977. Characterization of biological types of cattle. V. Carcass wholesale cut composition. *J. Anim. Sci*. 45, 30-42.

Koch, R.M., Dikeman, M.E., Allen, D.M., May, M., Crouse, J.D. & Campion, D.R., 1976. Characterization of biological types of cattle. III. Carcass composition, quality and palatability. *J. Anim. Sci.* 43, 48-62.

Koch, R.M., Dikeman, M.E., Lipsey, R.J., Allen, D.M. & Crouse, J.D., 1979. Characterization of biological types of cattle – Cycle II: III. Carcass composition, quality and palatability. *J. Anim. Sci.* 49, 448-460.

Koch, R.M., Dikeman, M.E., & Crouse, J.D., 1982. Characterization of biological types of cattle (Cycle III). III. Carcass composition, quality and palatability. *J. Anim. Sci.* 54, 35-45.

Koohmaraie, M., 1992. Effect of pH, temperature and inhibitors on autolysis and catalytic activity of bovine skeletal muscle u-calpain. *J. Anim. Sci.* 70, 3071-3080.

Lademann, E.E., 1992. Faktore wat die herkonsepsie van vleisraskoeie in die Noord-Transvaalse Soetbosveld beïnvloed. M.Sc. (Agric) Thesis, University of Pretoria. pp 249.

Lawrence, T.E., Whatley, J.D., Montgomery, T.H. & Perino, L.J., 2001. A comparison of the USDA ossification-based maturity system to a system based on dentition. *J. Anim. Sci.* 79, 1683-1690.

Lee, Y.B. & Ashmore, C.R., 1985. Effect of early post mortem temperature on beef tenderness. *J. Anim. Sci.* 60, 1588-1596.

Lepen, J.M., Schoeman, S.J. & Venter, H.A.W., 1993. Influence of first calving age and nutrition on the performance of early mated Nguni heifers. *S.Afr. J. Anim. Sci*. 23, 204-206.

Le Roux, C.J.G., Swart, J.S., Oosthuysen, E., Trethewey, C., Pittaway, C. & Daines, T., 1999a. Prediction of cattle performance on Coastcross 2 at different fertilizer and stocking rates. *S. Afr. J. Anim. Sci.* 29, 64-68.

Le Roux, C.J.G., Swart, J.S., Oosthuysen, E., Trethewey, C., Pittaway, C. & Daines, T., 1999b. Factors affecting cattle performance on Coastcross 2 at different stocking and fertilizer rates. *S. Afr. J. Anim. Sci.* 29, 69-73.

Loveday, H.D. & Dikeman, M.E., 1980. Diet energy and steer type effects on adipose composition, lopogenesis and carcass composition. *J. Anim. Sci.* 51, 78-88.

Ludwig, C.J., Claus, J.R., Marriot, N.G., Johnson, J. & Wang, H., 1997. Skeletal alteration to improve beef *longissimus* muscle tenderness. *J. Anim. Sci.* 75, 2404-2410.

MacDougall, D.B., Shaw, B.G., Nute, G.R. & Rhodes, D.N., 1979. Effect of Pre-slaughter handling on the quality and microbiology of venison from farmed young red deer. *J. Sci. Food Agric*. 30, 1160-1167.

Maher, S.C., Mullen, A.M., Molomey, A.P., Buckley, D.J. & Kerry, J.P., 2004. Quantifying the extent of variation in the eating quality traits of the *M. longissimus dorsi* and *M. semimembranosus* of conventionally processed Irish beef. *Meat Sci*. 66, 351-360.

May, S.G., Dolezal, H.G., Gill, D.R., Ray, F.K. & Buchanan, D.S., 1992. Effects of days fed, carcass grade traits and subcutaneous fat removal on post mortem musle characteristics and beef palatibility. *J. Anim. Sci.* 70, 444-453.

McCormick, R.J., 1994. The flexibility of the collagen compartment of muscle. *Meat Sci*. 30, 79-91.

McGregor, R.G. & Swanepoel, F.J.C., 1992. The relationship between body mass and fertility in Bonsmara breeding females. *S. Afr. J. Anim. Sci*. 22, 64-69.

McDonald, I.W., 1971. Animal Production – *Quo vadis*? *S. Afr. J. Anim. Sci.* 1, 149-158.

McVeigh, J.M. & Tarrant, P.V., 1982. Glycogen content and repletion rates in beef muscle, effect of feeding and fasting. *J. Nutr*. 112, 1306-1314.

Meaker, M.J., 1993. The effect of genotype on cow efficiency in extensive beef production in the northern Transvaal sweet Bushveld. M.Sc. (Agric) Thesis, University of Pretoria. pp 179.

Meaker, H.J. & Barnard, J.C., 1988. Beef steers implanted with short, medium, and long-acting anabolic compounds grazing natural pastures and finished in feedlot. *S. Afr. J. Anim. Sci.* 18, 68-71.

Meaker, H.J. & Liebenberg, G.C., 1982. Live and carcass characteristics of bulls and steers castrated at three different ages. *S. Afr. J. Anim. Sci.* 12: 375-378.

Moody, W.G., Little, J.E., Jr., Thrift, F.A., Cundiff, L.V. & Kemp, J.D., 1970. Influence of length of feeding a high roughage ration on quantitative and qualitative characteristics of beef. *J. Anim. Sci.* 31, 866-873.

Naudé, R.T., 1985. Biological effects on the quality of red meat with special reference to South African conditions. *S.Afr. J. Anim.Sci*. 15, 109-115.

Newsome, R.L., Moody, W.G., Lanlois, B.E., Gay, N., Mcmillan, M. & Fox, J.D., 1985. Effects of cattle-finishing systems on carcass traits and aging methods on loin shrinkage and steak color. *J. Anim. Sci.* 60, 1208-1218.

Nishimura, T., Liu, A., Hattori, A. & Takahashi, K., 1998. Changes in mechanical strength of intramuscular connective tissue during post mortem aging of beef. *J. Anim. Sci.* 76, 528-532.

Oltjen, R.R., Rumsey, T.S. & Putnam, P.A., 1971. All forage diets for finishing beef steers. *J. Anim. Sci.* 32, 327-333.

O'Mary C.C., Martin, E.L. & Anderson D.C., 1979. Production and carcass characteristics of Angus and Charolais x Angus steers. *J. Anim. Sci.* 48, 239-245.

Phillips, W.A., Brown, M.A., Brown, A.H., Jr. and Coleman, S.W., 2001. Genotype x environment interactions for post weaning performance in crossbred calves grazing winter wheat pasture or dormant native prairie. *J. Anim. Sci.* 79, 1370-1377.

Ponnampalam, E.N., Trout, G.R., Sinclair A.J., Egan, A.R. & Leury, B.J., 2001. Comparison of color stability and lipid oxidative stability of fresh and vacuumed packaged lamb muscle containing elevated omega-3 and omega-6 fatty acid levels from dietary manipulation. *Meat Sci.* 58, 151-161.

Prior, R.L., Kohlmeier, R.H., Cundiff, L.V., Dikeman, M.E. & Crouse, J.D., 1977. Influence of dietary energy and protein on growth and carcass composition in different biological types of cattle. *J. Anim. Sci.* 45, 132-146.

Rees, M.P., Trout G.R. & Warner R.D., 2002. Tenderness of pork m. longissimus thoracis et lumbborum after accelerated boning. Part I. Effect of temperature conditioning. *Meat Sci*. 61, 205-214.

Rees, M.P., Trout G.R. & Warner R.D., 2003. The influence of the rate of pH decline on the rate of ageing for pork. I: interaction with method of suspension. *Meat Sci*. 65, 791-804.

Reyneke, J., 1976. Supplementation of energy and/or protein to steers grazing summer veld. *S. Afr. J. Anim. Sci.* 6, 59-66.

Robinson, B.H. & Lademann, E.E., 1998. The fall in cattle numbers in the arid Bushveld of the Northern Province. Presented at the Arid Zone Ecology Forum, 14-17 September1998, Aventura Tshipise, South Africa.

Ruiz de Huidobro, F., Miguel, E., Onega, E, Blázquez, B., 2003. Changes in meat quality characteristics of bovine meat during the first 6 days *pos- mortem*. *Meat Sci*. 65, 1439-1446.

Schaake, S.L., Skelley, G.C., Halpin, E., Grimes. L.W., Brown, R.B., Cross, D.L. & Thompson, C.E., 1993. Carcass and meat sensory traits of steers finished on fescue and clover, summer forage, or for different periods in drylot. *J. Anim. Sci.* 71, 3199-3205.

Shackelford, S.D., Purser, D.E., Smith, G.C., Griffin, C.L., Stiffler, D.M. & Savell J.W., 1992. Lean color characteristics of bullock and steer beef. *J. Anim. Sci.* 70, 465-469.

Shackelford, S.D., Koohmaraie, M., Cundiff, L.V., Gregory, K.E., Roher, G.A. & Savell, J.W., 1994. Heritibilities and phenotypic and genetic correlations for bovine *postrigor* calpastatin activity, intramuscular fat content, Warner-Bratzler shear force, retail product yield and growth rate. *J. Anim. Sci.* 72, 857-863.

Shackelford, S.D., Wheeler, T.L. & Koohmaraie, M., 1995. Relatioship between shear force and trained sensory panel tenderness ratings of 10 major muscles from *Bos indicus* and *Bos taurus* cattle. *J. Anim. Sci.* 73, 3333-3340.

Shackelford, S.D., Wheeler, T.L. & Koohmaraie, M., 1997. Tenderness classification of beef: I. Evaluation of beef longissimus shear force at 1 or 2 days post-mortem as a predictor of aged beef tenderness. *J. Anim. Sci.* 75, 2417-2422.

Schoeman, S.J., 1989. Recent research into the production potential of indigenous cattle with special reference to the Sanga. *S. Afr. J. Anim. Sci.* 19, 55-61.

Schoeman, S.J., 1996. Characterization ofbeef cattle breeds by virtue of their performance in the National Beef Performance and Progeny Testing Scheme. *S. Afr. J. Anim. Sci.* 26, 15-19.

Schroeder, J.W., Cramer, D.A., Bowling, R.A. & Cook, C.W., 1980. Palatability, shelf life and chemical differences between forage- and grain finished beef. *J. Anim. Sci.* 50, 852-859.

Scott, J.D., 1947. Veld management in South Africa. Bull. Dept. Agric. S. Afr. No. 28. (cited by Tainton, 1999).

Short, R.E., Grings, E.E., MacNeil, M.D., Heitschmidt, R.K., Williams, C.B. & Bennett, G.L., 1999. Effects of sire growth potential, growing-finishing strategy and time on feed on performance, composition and efficiency of steers. *J. Anim. Sci.* 77, 2406-2417.

Smith, G.M., Laster, D.B., Cundiff, L.V. & Gregory, K.E., 1976. Characterization of biological types of cattle. II. Postweaning growth and feed efficiency of steers. *J. Anim. Sci.* 43, 37-47.

Snyman, L.D. & Joubert, H.W., 2002. The chemical composition and in vitro dry matter digestibility of untreated and ammoniated crop residues. *S. Afr. J. Anim. Sci.* 32, 83-87.

Sprinkle, J.E., Ferrel, C.L., Holloway, J.W., Warrington, B.G., Greene, L.W., Wu, G. & Stuth, J.W., 1998. Adipose tissue partitioning of limit-fed beef cattle and beef cattle with *ad libitum* access to feed differing in adaptation to heat. *J. Anim. Sci.* 76, 665-673.

Strydom, P.E., De Bruyn, J.F. & Naudé, R.T., 1993. Growth response, sexual development, carcass and meat quality of zinc tannate treated bulls. *S. Afr. J. Anim. Sci.* 23, 151-158.

Strydom, P.E., Naudé, R.T., Smith, M.F., Scholtz, M.M. & van Wyk, J.B., 2000. Characterisation of indigenous African cattle breeds in relation to meat quality traits. *Meat Sci*. 35, 79-88.

Strydom, P.E., Naudé, R.T., Smith, M.F., Kotze, A., Scholtz, M.M. & van Wyk, J.B., 2001. Relationships between production and product traits in subpopulations of Bonsmara and Nguni cattle. *S. Afr. J. Anim. Sci*. 31, 181-194.

Sullivan, P.G., Wilton, J.W., Miller, S.P. & Banks, L.R., 1999. Genetic trends and breed overlap derived from multiple-breed genetic evaluations of beef cattle for growth traits. *J. Anim. Sci.* 77, 2019-2027.

Swanepoel, J., Casey, N.H., de Bruyn, F.J. & Naude, R.T., 1990. Meat studies od indigenous southern African cattle. I. Growth preformance and carcass characteristics of Afrikaner, Nguni and Pedi bulls fed intensively. *S. Afr. J. Anim. Sci.* 20, 180-187.

Tainton, N.M., 1999. The ecology of the main grazing lands of South Africa. In: Veld management in South Africa. Ed. N.M. Tainton. University of Natal press, 48.

Tatum, J.D., Dolezal, H.G., Williams, F.L., Jr., Bowling, R.A. & Taylor R.E., 1986a. Effects of feeder-cattle frame size and muscle thickness on subsequent growth and carcass development. I. An objective analysis of frame size and muscle thickness. *J. Anim. Sci.* 62, 109-120.

Tatum, J.D., Dolezal, H.G., Williams, F.L., Jr., Bowling, R.A. & Taylor R.E., 1986b. Effects of feeder-cattle frame size and muscle thickness on subsequent growth and carcass development. II. Absolute growth and associated changes in carcass composition. *J. Anim. Sci.* 62, 121-131.

Tatum, J.D., Dolezal, H.G., Williams, F.L., Jr., Bowling, R.A. & Taylor R.E., 1986c. Effects of feeder-cattle frame size and muscle thickness on subsequent growth and carcass development. III. Partitioning of seperable carcass fat. *J. Anim. Sci.* 62, 121-131.

Tatum, J.D., Gronewald, K.W., Seideman, S.C. & Lamm W.D., 1990. Composition and quality of beef from steers sired by Piedmontese, Gelbvieh and Red Angus bulls. *J. Anim. Sci.* 68, 1049-1060.

Taute, A., Van Niekerk, W.A., Rethman, N.F.G. Coertze, R.J., 2002. An evaluation of Nitrogen fertilised *Panicum maximum* cv. Gatton at different stages of maturity during autumn: 1. Dry matter yield and certain qualitative parameters. *S. Afr. J. Anim. Sci*. 32, 208-216.

Tawonezvi, H.P.R., Ward, H.K., Trail, J.C.M. & Light, D., 1988. Evaluation of beef breeds for rangeland weaner production in Zimbabwe. *Anim. Prod*. 47, 361-367.

Van der Merwe, H.J., Von La Chevallerie, M. & Van Schalkwyk, A.P., 1975. Verskillende verhoudings van kuilvoer en kragvoer vir die afronding van vleisbeeste. *S. Afr. J. Anim. Sci* 5, 223-227.

Van der Merwe, H.J., Pienaar, A., Vermaak, L.M. & Van Rensburg, L.J.J., 1983. 'n Vergelyking tussen mielie- en sorghumgraam as bronne van kragvoer in afrondingsdiete vir vleisbeeste. *S. Afr. J. Anim. Sci* 13, 102-106.

Van der Waal, C. & Dekker, B., 2000. Game ranching in the Northern Province of South Africa. S. Afr. J. Wildl. Res. 30, 151-156.

Van Koevering, M.T., Gill, D.R., Owens, F.N., Dolezal, H.G. & Strasia, C.A., 1995. Effect of time on performance of feedlot steers, carcass characteristics and tenderness and composition of *longissimus* muscles. *J. Anim. Sci.* 73, 21-28.

Van Marle, J., 1974. The breeding of beef cattle in South Africa: Past, present and future. *S. Afr. J. Anim. Sci.* 4, 297-304.

Van Niekerk, A, Lishman, A.W. & Lesch, S.F., 1986. The reproductive responses of two breeds of cows and the performance of their progeny in two contrasting environments. *S. Afr. J. Anim. Sci* 16, 209-214.

Van Zyl, J.G.E., 1990. Studies on the performance and efficiency of pure and crossbred cattle in an arid Bushveld environment. Ph. D. (Agric) Thesis, University of Pretoria. pp 183.

Vargas, C.A., Olsen, T.A., Chase, C.C. Jr., Hammond, A.C. & Elzo, M.A., 1999. Influence of frame size and body condition score on performance of Brahman cattle. *J. Anim. Sci.* 77, 3140-3149.

Venter, H.A.W., 1977. Die invloed van voorspeense groei by sekere vleis-, dubbeldoel- en kruisrasse in die Noord-Transvaalse Soetbosveld. D.Sc. (Agric) Thesis, University of Pretoria. pp 331.

Wheeler, T.L., Cundiff, L.V., Koch, R.M., 1994. Effect of marbling degree on beef palatability in *Bos taurus* and *Bos indicus* cattle. *J. Anim. Sci.* 72, 3145-3151.

Wheeler, T.L., Cundiff, L.V., Koch, R.M. & Crouse, J.D., 1996. Charcterization of biological types of cattle (Cycle IV): Carcass traits and *longissimus* palatability. *J. Anim. Sci.* 74, 1023-1035.

Whipple, G., Koohmaraie, M., Dikeman, M.E., Crouse, J.D., Hunt, M.C. & Klemm, R.D., 1990. Evaluation of attributes that affect longissimus muscle tenderness in *Bos taurus* and *Bos indicus* cattle. *J. Anim. Sci.* 68, 2716-2728.

Young, O.A. & Braggins, T.J., 1993. Tenderness of ovine *semimembranosus*: Is collagen concentration or solubility the critical factor? *Meat Sci*. 35, 213-222.

Young, A.W. & Kauffman, R.G., 1978. Evaluation of beef from steers fed grain, corn silage or haylage-corn silage diets. *J. Anim. Sci.* 64, 41-47.

Young, O.A., West, J., Hart, A.L. & van Otterdijk, F.F.H., 2004. A method for early determination of meat ultimate pH. *Meat Sci*. 66, 493-498.

CHAPTER 2

Reproduction and production performance of cow herds of four breed types grazing natural sweet veld pastures

I du Plessis[1,2#], LC Hoffman[2]
[1] Limpopo Province Department of Agriculture, Mara Research Station, Private Bag X2467, Makhado (Louis Trichardt), 0920, South Africa
[2] Department of Animal Sciences, University of Stellenbosch, P. Bag X1, Matieland, 7602, South Africa

Abstract

Reproduction and weaner production traits of Simmentaler cross (SX), Bonsmara cross (BX), Afrikaner (AF) and Nguni (NG) cow herds were compared under natural sweet veld conditions. The respective cow herds were selected to differ in frame size. The AF cows, young (13 to 15 month old) heifers and herd had significantly lower pregnancy rates than the SX, BX and NG cows, young heifers and herds. No significant differences in weaning rates were observed. Weight and growth parameters differed significantly between breed types (SX > BX > AF > NG). Cow efficiency was lower for the AF cows than for the SX, BX and NG cows. The NG herd was more efficient than the other three herds, while the AF herd was the least efficient. This was mainly due to differences in the reproduction rates of the respective herds. Management practices should maximize the reproduction rate of the females including the young heifers to maximize herd efficiency.

Keywords: Pregnancy rate, survival rate, herd efficiency, preweaning growth rate

[#] Correspondinge author. E-mail: iduplessis@lantic.net

Introduction

The application and purpose for keeping meat animals changes constantly. In the early days, a beef animal was a draft animal first and secondly a provider of beef, which was killed at an advanced age when it had a thick layer of fat which was used for food preservation and candles (Van Marle, 1974). In the early 1970's, the introduction of feedlots and export markets changed the beef production scene dramatically and the more recent demand for organic foods is again influencing the objectives of beef producers. Undoubtedly, the demand for beef produced from free ranging cattle grazing natural pastures is increasing. This demand does not only focus on the finishing of beef animals, but inevitably includes the weaner production system followed by the cow herd. These changing demands in conjunction with the ever changing economic environment warrants the constant evaluation of the suitability and efficiency of breed types and production systems for differing environments. Furthermore, most sweet veld regions are vulnerable grazing areas (Coetzee, 1971), situated far from grain producing regions, making transportation of grain costly. Thus, whereas beef is produced from semi-intensive systems in grain producing regions, beef producers in sweet veld regions have to rely mainly on natural pastures to produce beef. The aim of this study is to compare the weaning production and efficiency of different breed type cows varying in frame size under extensive, natural sweet veld grazing conditions.

Materials and methods

The study was conducted from 1995 to 2003 on approximately 4 387 ha on the eastern side of the Mara Research Station (23° 05' S and 29° 25' E; 961 m.a.s.l). The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988). The vegetation in the study area includes the woody species *Acacia tortilis*, *Commiphora pyracanthoides, Boscia albitrunca* and *Grewia* spp. and the grass species *Eragrostis rigidior, Panicum maximum, Urochloa mosambicensis* and *Digitaria eriantha* (Dekker *et al.*, 2001). The long term mean rainfall is 452 mm. During the study period, the mean annual rainfall (measured from July to June) was 480 mm, ranging from 232 mm to 846 mm (Table 1), of which approximately 80 % occurs from November to March. The mean daily maximum temperature ranged from 22.6 °C in June to 30.4 °C in January.

The four breed types studied were Simmentaler cross, Bonsmara cross, Afrikaner and Nguni. The Simmentaler and Bonsmara cross cows originated from a two way Simmentaler x Afrikaner crossbreeding study. Cows consisting of approximately $^{2}/_{3}$ Simmentaler were mated with Simmentaler bulls and represented large framed breed types (SX). Cows of the reciprocal cross were mated with Bonsmara bulls and represent medium framed breed types (BX). Afrikaner (AF) and Nguni (NG) cows represented small-medium and small framed breed types respectively. Cows were selected throughout the trial period to comply with weight criteria and early maturing Bonsmara bulls were used to ensure that differences in frame size occurred between the steers of the different breed types. The weight criteria as well as the actual mean *post partum* weight of all the cows (heifers as well as mature cows) are summarized in Table 2.

Table 1 Annual rainfall during the study period

Year	Rainfall (mm)
1995/1996	447
1996/1997	533
1997/1998	589
1998/1999	232
1999/2000	343
2000/2001	846
2001/2002	368
Mean	**480**

The different herds were kept in separate, but adjacent camps. To reduce possible camp effects, camps were not allocated in blocks but randomly and evenly dispersed over the whole study area, ensuring that all the grazing area of each herd was dispersed evenly over the study area. As far as it was practically possible cow herds were kept in close proximity to each other. The metabolic weight (Meisner *et al*, 1983) of the cows was used to balance the stocking rates and care was taken not to let the stocking rate exceed 12 ha/LSU.

Table 2 Mature weight criteria and cow numbers used to select cows and to balance stocking rates as well as actual mean *postpartum* weight of cows

Breed type	Abbreviation	Mature weight criteria (kg)	Number of cows	*Postpartum* weight (kg)
Simmentaler cross	SX	> 500	30	486 ± 73
Bonsmara cross	BX	450 – 500	32	455 ± 78
Afrikaner	AF	400 – 450	34	431 ± 57
Nguni	NG	< 400	38	337 ± 49

Cows and heifers (13 to 15 months old) were mated from January 1st for 63 days. Pregnancy diagnosis were done by the end of May through rectal palpation. Calves were born from the end of October until the middle of December. All calves were physically weaned when the youngest calf in the study reached 205 days of age. Castration took place during the weaning phase. Other herd management practices (e.g. dipping, vaccination) were standardised for all breeds. No supplementary feeding or licks were supplied.

Live weights were recorded at 28-day intervals after withholding food and water for at least 12 hours. Weaning weights were corrected to a 205 day weight by interpolation of the weight before and after 205 of age was reached. Pregnancy rate (PR), weaning rate (WR) as well as cow (CE) and herd efficiencies (HE) were calculated using the following equations:

$$PR = \frac{\text{Number of cows pregnant}}{\text{Number of cows mated}} \times 100$$

$$WR = \frac{\text{Number of calves weaned}}{\text{Number of calves born}} \times 100$$

$$CE = \frac{\text{Corrected WW}}{\textit{Pos tpartum}\ \text{CW}} \times 100$$

$$HE = \frac{\text{NM x PR x WR x WW}}{\text{NM x }\textit{Pos tpartum}\ \text{CW}} \times 100$$

Where:
- PR = pregnancy rate
- WR = weaning rate
- WW = weaning weight
- CW = cow weight
- NM = number of females mated

Pregnancy (PR) and weaning rates (WR) were statistically analysed using the least squares procedure of a one way ANOVA of SPSS. Birth weight (BW), weaning weight (WW), average daily gain (ADG) total gain (TG) and cow efficiency were analysed by least squares ANOVA using the GLM procedure. Only breed was included as the main effect. The data did not allow for the inclusion of year of birth or dam age as main effects. The data is reported as least squares means ± standard deviation.

Results

No data is available for NG and SX cows for 1995 as the NG cows and some SX cows were transferred to the Mara Research Station during 1995, thus no initial data was available for the NG herd and due to adaptation problems the SX herd had a low PR. The AF cattle were transferred from Mara Research Station at the end of 2000 and therefore no further data (after 2000) is available for this breed.

PR (Table 3) was similar ($p > 0.05$) for the larger frame sized SX and BX and the smaller frame sized NG cows, heifers as well as for their respective herds. The AF cows, heifers and herd on the other hand, maintained a significantly ($p < 0.05$) lower PR than the other three breed types. Lower calving rates have been reported previously for AF cows (Schoeman, 1989) and AF crosses (Tawonezvi *et al*., 1988). Schoeman (1989) reported that although the calving rate of the AF cows did not differ significantly from the calving rates of the Simmentaler cows, NG cows had a significantly ($p < 0.01$) higher calving rate than both breeds. Reproductive results, similar to that of the current study, were reported by Marincowitz (1978), Van Niekerk *et al*. (1985), De Brouwer *et al*. (1993), Lademann & Schoeman (1994) and Collins-Lusweti (2000).

Vargas *et al*. (1999) also reported that small framed Brahman cows had significantly ($p < 0.01$) higher calving rates than medium or large framed cows, while Steenkamp & Van der Horst (1974) reported that large and medium beef cows had significantly higher calving rates than small beef cows.

Van der Merwe & Schoeman (1995) reported calving rates for Simmentaler heifers mated at 14 months of age (60.8 %) that is similar to the PR observed for the SX in the present study. However, Scholtz *et a*l. (1991) reported a lower PR for early mated NG heifers (37 %), while Lepen *et al*. (1993) reported higher PR values of 79.3 % and 80.0 % for pasture and intensively reared, early mated NG heifers respectively.

Table 3 Means (± S. D.) for pregnancy rates by breed type for cows, heifers and herd

	Cows		Heifers		Herd	
Breed	n Mated	% Pregnant	n Mated	% Pregnant	n Mated	% Pregnant
Simmentaler cross	143	$83.4^{ab} \pm 12.7$	44	$61.6^{ab} \pm 23.2$	187	$79.3^{ab} \pm 12.2$
Bonsmara cross	195	$81.9^{ab} \pm 11.2$	67	$51.9^{ab} \pm 23.3$	262	$76.5^{ab} \pm 11.1$
Afrikaner	163	$76.6^{b} \pm 15.5$	53	$7.6^{b} \pm 14.3$	216	$59.8^{b} \pm 9.0$
Nguni	184	$93.5^{a} \pm 5.4$	64	$61.3^{a} \pm 16.3$	248	$86.1^{a} \pm 5.8$

[a,b] Column means with different superscripts differ ($p < 0.05$).

Although no significant ($p > 0.05$) differences were observed in WR (Table 4) among the respective breed types, the WR of SX cows tended ($p = 0.08$) to be lower than that of AF cows. These results are in accordance with the results of Tawonezvi *et al*. (1988) and Vargas *et al*. (1999) who also reported no significant differences in WR among various breed types and frame sized cows respectively. However, Schoeman (1989) reported lower preweaning losses of 6.17, 6.28 and 3.61 % for Simmentaler, AF and NG cows respectively. AF cows in Highland Sourveld conditions weaned less calves than Simmentaler cows (62.6 % vs. 76.6 %), but the WR was noted to be similar (91.1 % vs. 93.4 %) among the two breeds in Lowveld Thornveld conditions (Van Niekerk *et al*., 1985).

Table 4 Mean (± S. D.) for the percentage calves weaned by breed type

Breed type	Number of calves born	% of calves weaned
Simmentaler cross	153	$80.4^{a} \pm 7.9$
Bonsmara cross	195	$85.0^{a} \pm 7.3$
Afrikaner	92	$90.3^{a} \pm 10.3$
Nguni	242	$87.9^{a} \pm 11.3$

[a] Column means with different superscripts differ ($p < 0.05$).

As expected, breed type affected all preweaning weight and growth rate parameters (Table 5) significantly (SX > BX > AF > NG, $p < 0.05$). Similarly, Van Zyl (1990) as well as Meaker (1993) also reported significant ($p < 0.05$) differences in weaning weight between Simmentaler, Bonsmara and AF calves. The results of Dadi *et al*. (2002a) that larger framed Charolais-sired calves were significantly ($p < 0.001$) heavier at birth (38.4 vs. 33.4) and weaning (197.1 vs. 177.5) than the smaller framed Hereford-sired calves supports the results observed in the present study. These authors also indicated that larger framed Bonsmara cows gave birth to and weaned significantly ($p < 0.05$) heavier calves than smaller framed Hereford and Angus cows. Dadi *et al*. (2002b) also reported that the BW, WW, ADG increased as the proportion of Charolais in calves increased and the proportion of Angus decreased. Medium and large AF cows weaned heavier calves than small AF cows (Steenkamp & Van der Horst, 1974). Similar results were reported for Brahman cows differing in frame size (Vargas et al., 1999). Heavier BW and WW for larger frame sized breed types compared to smaller frame sized breed types are widely reported (Venter, 1977; Mentz et al., 1979; Tawonezvi et al., 1988; Schoeman, 1989, 1996; Van Zyl et al., 1992; De Brouwer et al., 1993; Collins-Lusweti, 2000). Venter (1977) reported gains from birth to weaning similar to that observed in the present study for Bonsmara and AF calves, but a lower gain of 172.37 kg for Simmentaler calves, while Hereford calves had gains similar to the NG calves.

The AF cows had a significantly ($p < 0.05$) lower CE (cow efficiency – Table 6) than the SX, BX and NG cows. Schoeman (1989) also reported that AF cows had a lower CE than Simmentaler and Sanga cows. Tawonezvi *et al*. (1988) reported similar results for several cow productivity parameters for various AF cross bred cows. Lepen *et al*. (1993) reported similar CE values to that observed in the present study for NG heifers mated at either 13 months (47.1) or 15 months of age(43.5). On the contrary, Meaker (1993) reported that CE indexes (expressed as WW to $CW^{0.75}$) for purebred Simmentaler cows were significantly ($p < 0.05$) higher than for Bonsmara and AF cows.

Table 5 Means (± S.D.) for birth weight, weaning weight, average daily gain, total preweaning gain

Breed type	Birth weight (kg)	Weaning weight (kg)	Average daily gain (g/day)	Total gain (kg)
Simmentaler cross	$41.1^{a} \pm 6.4$	$241^{a} \pm 35$	$977^{a} \pm 156$	$200^{a} \pm 32$
Bonsmara cross	$36.1^{b} \pm 5.9$	$214^{b} \pm 32$	$869^{b} \pm 146$	$178^{b} \pm 30$
Afrikaner	$32.1^{c} \pm 4.1$	$181^{c} \pm 23$	$730^{c} \pm 103$	$150^{c} \pm 21$
Nguni	$26.2^{d} \pm 4.1$	$162^{d} \pm 21$	$666^{d} \pm 95$	$137^{d} \pm 20$

^{a,b,c,d} Column means with different superscripts differ ($p < 0.05$).

Table 6 Means (± S. D.) for cow and herd efficiencies by breed

Breed type	Cow efficiency (%)	Herd efficiency (kg/100 kg mated)
Simmentaler cross	$49.4^{a} \pm 8.2$	$36.2^{a} \pm 5.5$
Bonsmara cross	$47.6^{a} \pm 8.9$	$37.7^{a} \pm 9.4$
Afrikaner	$43.0^{b} \pm 6.8$	$29.5^{a} \pm 5.9$
Nguni	$48.9^{a} \pm 7.8$	$46.5^{b} \pm 5.7$

Although the HE (herd efficiency – Table 6) of the AF cow herd was lower than the HE of the SX and the BX cow herds the difference was not significant. However, the HE of the NG cows was significantly ($p < 0.05$) higher than that of the SX, BX and AF cows. Similar results were reported by Schoeman (1989) as well as Tawonezvi *et al*. (1988).

Discussion

The low PR observed for AF cows and heifers is most probably due to inherent breed characteristics, as various reports also indicated low reproduction rates in AF cattle (Schoeman, 1989; De Brouwer *et al*., 1993), even in comparisons to breed types of similar frame size (Tawonezvi *et al*., 1988).

PR at 13 to 15 months of age was low and variable. Simmentaler heifers at 24 months of age had a significantly ($p < 0.01$) higher calving rate than heifers mated at 14 months (Van der Merwe & Schoeman, 1995). Similar results were reported for AF x Sussex heifers (Meaker *et al*., 1980) and NG heifers (Scholtz *et al*. (1991). While Van der Merwe & Schoeman (1995) also reported lower reconception rates for early mated Simmentaler heifers, Scholtz *et al*. (1991) did not find significant differences in the reconception rates of early and late mated NG heifers. Vargas et al. (1999) observed that the calving rates of first parity heifers (24 months) did not differ significantly. The main reason for these observations lies in the age at which puberty is reached.

Age at puberty (first oestrus) varies according to breed (Lepen *et al*., 1991), frame size (Vargas et al., 1999), management (Van der Merwe & Schoeman, 1995) and nutrition (Lepen *et al*., 1993). According to Lepen *et al*. (1991) the age at which puberty is reached, varied from 344 days (~ 11 months) for Nguni heifers to 418 days (~ 13.5 months) for Bonsmara heifers and according to Vargas *et al*. (1999) between 633

(~ 21 months) for small framed Brahman heifers to 672 days (~ 22 months) for large framed Brahman heifers. Although there is a large difference between these reports, both indicate that puberty is reached during the mating season if the heifers are mated at 13 to 15 months of age, but in most cases puberty was reached before mating took place at 2 years of age. These results provide reasons for the low and variable PR for young heifers. Nutritional fluctuations between years were also responsible for the variation in the PR of especially the young heifers. Klosterman (1981) indicated that breeding immature heifers assists in reducing the feed costs of cattle production systems. However, if heifers are to be mated at this young age, provision of adequate supplementary feeding should be made available from weaning to mating in order to enssure acceptable conception rates in young heifers.

The differences in preweaning growth rate parameters were expected as various reports indicated that larger frame sized breed types tend to gain weight at faster rates than smaller frame sized breed types (Tawonezi *et al.*, 1988; Dadi *et al.* 2002a, b). Vargas *et al.* (1999) explained that these differences likely reflect a positive phenotypic correlation between milk production and body size of the cow, the inherent growth pattern of large framed calves and the ability of fast-gaining calves to consume enough forage to meet their increased nutritional demands for growth.

As the larger frame sized calves grew faster and weaned heavier than the smaller frame sized calves, the CE values of the different breed types were similar, but according to Vargas *et al.* (1999) the weight of calf weaned per cow mated is more important than weaning weight *per se* and is a function of calving rate, calf survival rate and calf weaning weight. Breed and frame size has a similar influence on HE as to what it has on the reproduction rate of the cows, as herd efficiency is closely linked to reproductive performance. From HE values observed in this study, it is evident that the reproductive and calving rates are the most important factors in determining HE as notwithstanding the fact that NG calves grew at the slowest rates, the NG herd was the most effective. This observation is in agreement with previous reports that profitability of the cow herd is greatly dependent on the reproduction rate (Lamond, 1970; Venter & Luitingh, 1980).

Conclusions

The reproduction rates of the cow herd as well as the survival rates of the calves are the most important factors that determine the efficiency of the cow herd. Simmentaler- and Bonsmara type as well as Nguni cattle maintained acceptable productivity levels grazing natural sweet veld pastures without supplements. The inherent characteristics (maintenance requirements, susceptibility to diseases, etc) of each breed should however be taken into account and the management practices adapted to maximize the reproduction rate as well as the calf survival rate and thus the production efficiency of the specific breed. Market preferences should also receive consideration. Large frame sized breed types produce calves that grow faster and wean heavier than smaller frame sized breed types, which may be more acceptable to feedlots. On the other hand, smaller frame sized, indigenous Sanga breeds like the Nguni with its known difficulties to adapt readily to feedlot environments, may be better suited for extensive finishing systems. Investigations into the ability and efficiency of different breed types to finish from natural pastures and thus to supply in the demand for organically produced meat, should be investigated further.

References

Acocks, J.P.H., 1988. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 57.

Coetzee, J.J., 1971. Die landbou potensiaal van die Noordwes-Transvaalse Soetbosveld. D. Agric. (Inst. Agrar) Thesis, Universiteit van Pretoria. pp 245.

Collins-Lusweti, E., 2000. Performance of Nguni, Afrikander and Bonsmara cattle under drought conditions in the North West Province of Southern Africa. *S. Afr.J.Anim Sci*. 30. 33.

Dadi, H., Schoeman, S.J., Jordaan, G.F. & Van der Westhuysen, 2002a. The influence of Charolais and Hereford sires and straightbred and crossbred dams on pre-weaning growth performance of calves. *S. Afr. J. Anim. Sci*. 32, 38-43.

Dadi, H., Schoeman, S.J., Jordaan, G.F. & Van der Westhuysen, 2002b. The influence of Charolais and Angus breeding levels on pre-weaning growth performance traits in crossbred calves. *S. Afr. J. Anim. Sci*. 32, 201-207.

De Brouwer, C.H.M., Visser, C.B., Schutte, A.R. & Postma, M., 1993. Biological and economical effects of different supplements given to beef cows on summer grazing. *S. Afr.J.Anim Sci*. 23. 31-37.

Dekker, B., Kirkman K.P. & Du Plessis, S.I., 2001. Use of the dry-weight-rank method of botanical analysis in semi-arid savanna communities. *Afr. J. Range For. Sci*. 19, 63-68.

Klosterman, E.W., 1981. Measuring beef production in the cow herd. *S. Afr. J. Anim. Sci*. 11, 195-198.

Lademann, E.E. & Schoeman, S.J., 1994. Factors influencing recalving rate in lactating beef cows in the sweet dry Bushveld of northern Transvaal. *S. Afr. J. Anim. Sci*. 24, 30-33.

Lamond, D.R., 1970. The influence of undernutrition on reproduction in the cow. *Anim. Breed. Abstr*. 38, 359.

Lepen, J.M., Schoeman, S.J. & Venter, H.A.W., 1991. Vie invloed van voedingspeil op puberteitsbereiking by Nguni, Bonsmara en Drakensbergerverse. *S.Afr. J. Anim. Sci*. 21, 43-47.

Lepen, J.M., Schoeman, S.J. & Venter, H.A.W., 1993. Influence of first calving age and nutrition on the performance of early mated Nguni heifers. *S.Afr. J. Anim. Sci*. 23, 204-206.

Marincowitz, G., 1978. Vrugbaarheid van vleisbeeste op die Soutpan beesplaas. *S. Afr. J. Anim. Sci.* 8, 119-123.

Meaker, M.J., 1993. The effect of genotype on cow efficiency in extensive beef production in the northern Transvaal sweet Bushveld. M.Sc. (Agric) Thesis, University of Pretoria. pp 179.

Meaker, H.J., Coetsee, T.P.N. & Lishman, A.W., 1980. The effects of age at first calving on the productive and reproductive performance of beef cows. *S. Afr. J. Anim. Sci.* 10, 105-113.

Meissner, H.H., Hofmeyer, H.S., Van Rensburg, W.J.J. & Pienaar, J.P., 1983. Classification of livestock for realistic prediction of substitution values in terms of a biologically defined Large Stock Unit. Technical Communication No. 175, Department of Agriculture, Republic of South Africa.

Mentz, A.H., Els, D.L. & Coetzer, W.A., 1979. Crossbreeding with Africander dam as basis. 2. Weaning performance of progeny of various sire breeds. *S. Afr. J. Anim. Sci.* 9, 205-208.

Schoeman, S.J., 1989. Recent research into the production potential of indigenous cattle with special reference to the Sanga. *S. Afr. J. Anim. Sci.* 19, 206-209.

Schoeman, S.J., 1996. Characterization of beef cattle breeds by virtue of their performance in the National Beef Performance and Progeny Testing Scheme. *S. Afr. J. Anim. Sci.* 26, 15-19.

Scholtz, M.M., Lombard, P.E. & Enslin, C.B., 1991. A note on the early mating of beef heifers. *S. Afr. J. Anim. Sci.* 21, 55-61.

Steenkamp, J.D.G. & Van der Horst, C., 1974. The relationship between size and efficiency in the beef cow. *S. Afr. J. Anim. Sci.* 4, 81-91.

Tawonezvi, H.P.R., Ward, H.K., Trail, J.C.M. & Light, D., 1988. Evaluation of beef breeds for rangeland weaner production in Zimbabwe. *Anim. Prod.* 47, 361-367.

Van der Merwe, P.S. & Schoeman, S.J., 1995. Effect of early calving of Simmentaler heifers under an extensive management system. *S. Afr. J. Anim. Sci.* 25, 36-39.

Van Marle, J., 1974. The breeding of beef cattle in South Africa: Past, present and future. *S. Afr. J. Anim. Sci.* 4, 297-304.

Van Niekerk, A., Lishman, A.W. & Lesch, S.F., 1985. The reproductive responses of two breeds of beef cows and the performance of their progeny in two contrasting environments. *S. Afr. J. Anim. Sci.* 16, 209-214.

Van Zyl, J.G.E., 1990. Studies on the performance and efficiency of pure and crossbred cattle in an arid Bushveld environment. Ph. D. (Agric) Thesis, University of Pretoria. pp 183.

Van Zyl, J.G.E., Schoeman, S.J. & Coertze, R.J., 1992. Sire breed and genotype of dam effects in crossbreeding beef cattle in the subtropics. 1. Birth and weaning mass of calves. *S. Afr. J. Anim. Sci.* 22, 161-165.

Vargas, C.A., Olsen, T.A., Chase, C.C. Jr., Hammond, A.C. & Elzo, M.A., 1999. Influence of frame size and body condition score on performance of Brahman cattle. *J. Anim. Sci.* 77, 3140-3149.

Venter, H.A.W., 1977. Die invloed van voorspeense groei by sekere vleis-, dubbeldoel- en kruisrasse in die Noord-Transvaalse Soetbosveld. D.Sc. (Agric) Thesis, University of Pretoria. pp 331.

Venter, H.A.W. & Luitingh, H.C., 1980. 'n Beesvleisproduksiestrategie vir die Transvaalse Bosveld en Noord-Kaap. *S. Afr. J. Anim. Sci.* 10, 311-322.

CHAPTER 3

Effect of chronological age of beef steers of different maturity types on their growth and carcass characteristics when finished on natural pastures in the arid sub-tropics of South Africa

I du Plessis[1,2#] & LC Hoffman[2]

[1] Limpopo Province Department of Agriculture, Mara Research Station, Private Bag X2467, Makhado (Louis Trichardt), 0920, South Africa

[2] Department of Animal Sciences, University of Stellenbosch, P. Bag X1, Matieland, 7602, South Africa

---

Abstract

In the arid sweetveld regions of South Africa, producers are marketing beef steers increasingly as long weaners (*ca.*12 months of age) or finishing them on the natural grazing to a ready-to-slaughter stage at between 18 and 30 months of age. Limited production norms in this regard are available since most growth and carcass studies have been conducted in the sourveld regions of the country. In this study steers from four different beef maturity types which differ in body frame size were used, *viz.* Simmentaler crosses (large, >500 kg mature weight), Bonsmara crosses (large-medium, 450–500 kg mature weight), the Afrikaner (small-medium, 400–450 kg mature weight) and the Nguni (small, <400 kg mature weight). After weaning the steers in each type were randomly allocated to three groups, *viz.* groups slaughtered at 18, 24 or 30 months of age after razing them on natural sweer pasture. Live weight, cold carcass weight, carcass fat classification code and number of visible incisors were recorded. Growth rates from weaning to 24 months of age were similar for the different maturity types, though the Afrikaner steers gained significantly less than the Bonsmara crossbreds. Periods where high growth rates occurred (at 12 to 18 months and 24 to 30 months of age) coincided with the rainy season. Relatively low dressing percentages were noted and could be attributed to the fact that all internal organs and fat were removed at slaughtering, as well as a possible high level of gut fill. Due to genetic variation within maturity types it was not possible to predict the market readiness of a particular individual from its live weight. The carcass weights were heavier for steers slaughtered at 24 months of age than those at 18 months of age, but had a lower fat classification code. This seems to be due to the fact that these steers were slaughtered at the end of the winter period when the quality of the grazing was at its lowest. The carcasses of all maturity types had the highest fat classification codes at 30 months of age. However, the carcasses of 77.8% of the Simmentaler crossbreds were graded 1 (lean) in the fat classification. Furthermore, at 30 months of age, 23.8% of all steers had more than two permanent incisors. This increases their carcass age classification, which lowers their carcass grading according to the South African grading standards, and thus the price per kg relative to the younger ages. The results of this investigation indicated that steers of all frame sizes would have to be fed additional energy to ensure that they finished with a fat classification code of at least 2 before the age of 30 months to ensure optimal financial returns.

Keywords: Growth, carcass traits, maturity type, steers, age, natural pasture, carcass classification, incisors
Corresponding author. E-mail: iduplessis@lantic.net

Introduction

Scott (1947) classified the natural grazing in South Africa as sweet and sour veld. He defined "sweetveld" as natural grazing which remains palatable and nutritious throughout the year, even when mature, whereas the "sourveld" provides palatable material only in the growing season. Animal growth during the winter period in sourveld regions is predominantly negative, while in the sweetveld positive animal growth can occur in winter.

Most growth and carcass related studies conducted in South Africa have been restricted to the sourveld areas (Reyneke, 1976; Van der Merwe *et al*., 1980; Gertenbach & Henning, 1995a) and due to the animal husbandry practices in these regions, this inevitably lead to investigations into animal growth and/or carcass characteristics from cultivated pastures (Gertenbach *et al*, 1995; Le Roux *et al*, 1999a; b;), in feedlots (Swanepoel *et al*, 1990; Gertenbach & Henning, 1995b; Strydom *et al*., 2001;) or in feedlots where the animals received growth stimulating implants (Meaker & Barnard, 1988). The enhancement of poor quality roughages (especially crop residues) also received attention (Brand *et al*., 1989; Snyman & Joubert, 2002; Taute *et al*., 2002). However, little if any scientific research have apparently been published on the finishing of steers on natural pastures in the sub-tropical sweetveld regions of southern Africa.

Production systems where beef steers are marketed at 18 to 30 months of age rather than as weaners have been suggested to be better suited to arid environmental conditions (Coetzee, 1971). This management practice introduces more flexibility to the producer's marketing strategy, by allowing for timely control of animal numbers in relation to erratic rainfall patterns. Thus, the risk involved in farming with cattle in arid regions would be reduced. In practice, producers use different maturity types to produce meat from natural pastures. The aim of this study was to define criteria for growth and carcass characteristics for maturity types which varies in frame size, at the end of the wet (18 and 30 months of age) and dry seasons (24 months of age) of the year, so that decisions can be made, based on optimal production and marketing of steers directly from natural sweet pastures.

Materials and methods

The study was conducted from 1995 to 2001 on *ca*. 4 387 ha on the eastern side of the Mara Research Station (23° 05' S and 29° 25' E; 961 m.a.s.l) which is situated in the Arid Sweet Bushveld (Acocks, 1988) of the Limpopo Province of South Africa. The vegetation in the study area includes the woody tree species, *Acacia tortilis*, *Commiphora pyracanthoides*, *Boscia albitrunca* and *Grewia* spp. and the grass species, *Eragrostis rigidior*, *Panicum maximum*, *Urochloa mosambicensis* and *Digitaria eriantha* (Dekker *et al*., 2001). The long term mean rainfall is 452 mm but during the study period, the mean annual rainfall (measured from July to June) was 498 mm, ranging from 232 mm to 846 mm, of which approximately 80%

occurred from November to March. The mean daily maximum temperature ranged from 22.6 °C in June to 30.4 °C in January.

The Simmentaler crossbred (SX) steers were bred from cows originating from a two way Simmentaler x Afrikander crossbreeding study. Cows consisting of approximately two thirds Simmentaler were mated with a Simmentaler bull, representing large-framed maturity types. The cows of the reciprocal cross were mated to Bonsmara bulls to represent the large-medium framed maturity types (BX). Purebred Afrikander (AF) and Nguni (NG) steers represented small-medium and small-framed maturity types, respectively. Cows were selected throughout the trial period to comply with the weight criteria and early maturing Bonsmara bulls were used to ensure that differences in frame size occurred between the steers of the different maturity types.

Due to logistical constraints, the different steer groups were allocated in separate but adjacent camps for the entire study period. To reduce possible camp effects, the stocking rates (ha/LSU) were balanced according to the metabolic body weight (Meissner *et al.*, 1983) of the animals. Stocking rates were managed to ensure that they did not exceed 12 ha/LSU.

Calves were born from the end of October to the middle of December. All steers were weaned simultaneously when the last steer reached 205 days of age (mean age = 237±22 days). Castration took place during the weaning phase. Other herd management practices (e.g. dipping, vaccination) were standardised for all breeds. No supplementary feeds or licks were supplied.

Steers born during a specific calving season were randomly divided per maturity type into three groups and slaughtered at 18, 24 or 30 months of age, respectively. Steers were born from October to December and slaughtered either in May (18 and 30 months of age) of November (24 months of age). Live weights were recorded at 28 day intervals after withholding food and water for at least 12 hours. Live weights at 18, 24 and 30 months of age (548, 730 and 912 days of age, respectively) were either interpolated or extrapolated from the 28 day weighing records, depending on whether the steers were slaughtered before or after reached the slaughtering age. Cold Carcass weight was determined 24 hours post mortem and was used to calculate dressing percentage from the actual live weight. Carcass weight at a specific age was then calculated as the product of the corrected live weight and the dressing percentage. The carcasses were classified according to the official carcass classification system (Government notice no. R. 1748, 26 June 1992) as summarised in Table 1. No fat thickness measurements were taken. The number of visible permanent incisors was also recorded.

Live weight, carcass weight, dressing percentage as well as weight gain and relative weight gains were analysed with the univariate analysis of variance of the GLM procedures (SPSS, 2002). Age at slaughter, maturity type and year of birth were included as main effects. Al two-way interactions were included in the model. Actual age at slaughter was included as a covariate in all applicable cases. Significant differences between means were computed, using the Bonferoni procedure (SPSS, 2002). Frequency distributions of fat classification codes and number of visible permanent incisors for age at slaughter and maturity type were analysed, using the Kruskal-Wallis test (SPSS, 2002). Differences in frequency distributions were computed, using the Mann-Whitney test (SPSS, 2002).

Table 1 Summary of the age and fat classification codes used to classify carcasses (Government notice no. R. 1748, 26 June 1992)

Age* description	Age class code	Fat description	Thickness of subcutaneous fat layer (mm)	Fat class code
0 Teeth	A	No fat	0	0
1–2 Teeth	AB	Very lean	< 1	1
3–6 Teeth	B	Lean	1–3	2
>6 Teeth	C	Lean	> 3–5	3
		Fat	> 5–7	4
		Over fat	> 7–10	5
		Excessively over fat	> 10	6

* Number of permanent incisors

Results and discussion

The periods from 7 to 12 months of age and from 18 to 24 months of age coincided with the winter season, while the periods from 12 to 18 months of age and from 24 to 30 months of age coincided with the summer season. During the winter seasons the growth rates of all steers were lower ($p < 0.05$) than during the summer seasons (Figure 1). This is mainly due to high quality, easily digestible grazing available during summer, and the low quality and digestibility of the vegetation during winter (Relling *et al*., 2001).

It is noticeable that steers of the different maturity types maintained similar growth rates up to 24 months of age (Figure 1). Weights used in compiling Figure 1 were not corrected for age. Although there were significant ($p < 0.05$) differences (Table 2) in the mean live weight gain of the respective breed types from weaning to 12 months of age and from 18 to 24 months of age, these differences were small in terms of the absolute growth rates and from 12 to 18 months of age growth rates were similar for all maturity types. The mean live weight gain from weaning to 24 months were similar for all breeds except for the BX steers (162.6 kg) that gained significantly ($p < 0.05$) more than the AF steers (139.6 kg). Results reported by Cianzio *et al*. (1982) support these findings. They reported that the growth rates of large and small framed steers on a growing-finishing diet were similar from 11 to 19 months of age. The similar growth rates of the large framed SX, BX, and the small framed NG steers in the present study imply that the growth rate of immature steers under the grazing conditions in this study was limited to a maximum threshold. This viewpoint is supported by Crouse *et al*. (1985), reporting that the energy intake (Mcal ME/d) of Simmentaler cattle was higher ($p < 0.01$) than that of Angus cattle on a high-energy diet, but similar on a low-energy diet. In contrast, Prior *et al*. (1977) suggests that on low-energy diets energy intake may be limited by bulk fill in smaller framed steers, but not in large framed steers. The low energy diets in thier study contained between 45 and 52% maize. On an all forage diet, as in the present study, it can be assumed that bulk fill could have limited energy intake in all breeds to the extent that only minor differences in growth rates between maturity types of different frame sizes could be manifested. Nguni and AF steers had ($p < 0.05$) lower growth rates from 24 to 30 months of age than the SX and BX steers (Table 2). Similarly, O'Mary *et al.* (1979) reported that the growth rate of small-framed Angus steers slowed down when they started to finish after 120 days of a 150 day feeding period, while the large-framed Charolais steers maintained a high growth rate throughout the feeding period. This could be due to the fact that especially NG steers have reached maturity in terms of live weight gain and were finishing off. Fortin *et al.* (1981) observed that differences between breeds in terms of carcass composition dids not appear to be the result of different growth rates for the various tissues, but were rather due to differences in the onset of rapid fattening, with small-framed, early maturing maturity types starting to deposit fat at an earlier age than large-framed, late maturing maturing types.

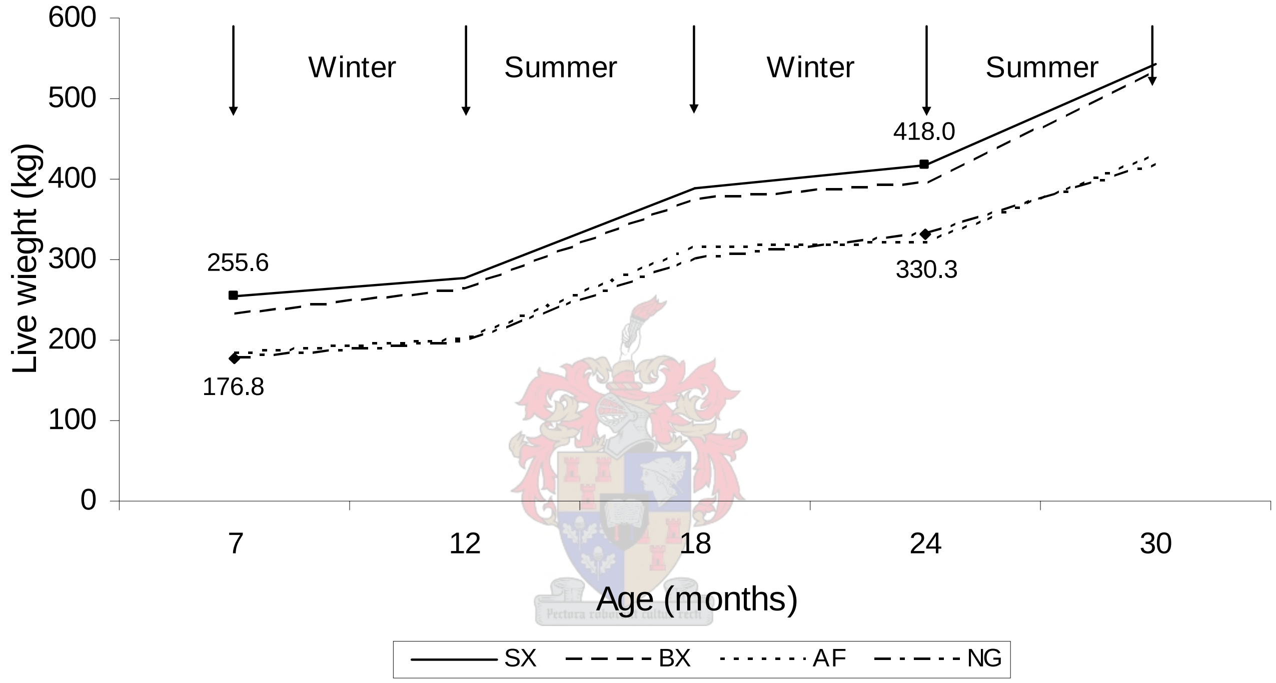


Figure 1 Postweaning growth of Simmentaler crossbred (SX), Bonsmara crossbred (BX), Afrikaner (AF) and Nguni (NG) steers

If growth rates are expressed relative to either live weight or expected adult weight (Table 2), NG and BX steers maintained higher ($p < 0.05$) relative growth rates from seven to 12 months of age than the AF steers, while NG steers maintained significantly higher relative growth rates than the SX, BX and AF steers from 18 to 24 months of age. From 18 to 24 months of age the AF steers maintained the lowest relative growth rate ($p < 0.05$). Both periods coincided with the dry winter periods when the nutritional status of the natural pasture is low. From 12 to 18 months (summer period) the NG and AF steers had higher ($p < 0.05$) relative growth rates than the SX and BX steers. Although NG steers had the lowest ($p < 0.05$) relative growth rate between 24 and 30 months of age, their relative growth rates were similar to those of the other maturity types during the other growing periods.

Table 2 Live weight gain as well as live weight gain relative to live weight and expected mature weight (± s.e.) for Simmentaler crossbred, Bonsmara crossbred, Afrikaner, and Nguni steers

Breed type	Expected adult weight (kg)	Live weight gain (kg)			
		7 to 12 months (winter)	12 to 18 months (summer)	18 to 24 months (winter)	24 to 30 months (summer)
Simmentaler cross		21.8^{abc} ± 2.5	112.3 ± 3.9	21.5^{a} ± 2.6	128.1^{a} ± 9.6
Bonsmara cross		30.6^{b} ± 3.1	110.9 ± 3.6	21.9^{a} ± 4.5	139.3^{a} ± 5.5
Afrikaner		15.8^{c} ± 2.4	113.9 ± 2.0	6.3^{b} ± 3.5	114.4^{ab} ± 6.2
Nguni		21.1^{anc} ± 2.6	102.3 ± 3.3	32.0^{a} ± 3.2	94.2^{b} ± 5.8
Total		**23.4^{d} ± 1.5**	**109.7^{e} ± 1.8**	**20.9^{d} ± 2.0**	**120.3^{e} ± 4.1**
		Live weight gain relative to live weight			
Simmentaler		0.0893 ± 0.0109	0.4105^{a} ± 0.0164	0.0562^{a} ± 0.0072	0.3093 ± 0.0254
Bonsmara		0.1391 ± 0.0154	0.4305^{a} ± 0.0190	0.0594^{a} ± 0.0128	0.3579 ± 0.0179
Afrikaner		0.0906 ± 0.0145	0.5805^{b} ± 0.0194	0.0195^{a} ± 0.0110	0.3424 ± 0.0350
Nguni		0.1266 ± 0.0155	0.5253^{b} ± 0.0200	0.1096^{b} ± 0.0117	0.2920 ± 0.0176
Total		**0.1150^{d} ± 0.0079**	**0.4791^{e} ± .00109**	**0.0622^{f} ± 0.0062**	**0.3268^{g} ± 0.0124**
		Live weight gain relative to expected adult weight			
Simmentaler	575	0.0402^{abc} ± 0.0046	0.2069^{a} ± 0.0044	0.0396^{a} ± 0.0048	0.2359 ± 0.0178
Bonsmara	550	0.0575^{b} ± 0.0058	0.2082^{a} ± 0.0068	0.0412^{a} ± 0.0084	0.2615 ± 0.0103
Afrikaner	460	0.0367^{c} ± 0.0056	0.2638^{b} ± 0.0047	0.0147^{a} ± 0.0082	0.2668 ± 0.0145
Nguni	440	0.0506^{abc} ± 0.0062	0.2449^{b} ± 0.0079	0.0765^{b} ± 0.0077	0.2256 ± 0.0138
Total		**0.0458^{d} ± 0.0029**	**0.217^{e} ± 0.0037**	**0.0423^{d} ± 0.0040**	**0.2348^{e} ± 0.0068**

^{a,b,c,} Column means within weight gain groups with different superscripts differ ($p < 0.05$).
^{d,e,f,g} Row means within totals with different superscripts differ ($p < 0.001$)

Across maturity types absolute growth rates and growth rates relative to expected mature weight followed the same pattern, being lower ($p < 0.001$) during the winter periods than during the summer periods. Live weight gain relative to live weight differed ($p < 0.001$) between all growing periods. It was lowest between 18 and 24 months of age, most probably because the quality of the grazing was lower than during the summer grazing periods and that maintenance requirements are higher than for weaning, allowing very little nutrients for growth.

When compared on a constant age basis, various authors reported that large-framed breeds grew faster than small-framed breeds (Smith *et al*., 1976; Koch *et al*., 1979; Crouse *et al*., 1985). These comparisons, however, considered the whole growing period and did not differentiate between the high growth rate growing phases and the slower growth rate finishing phases of small-framed cattle. These reports obscured the possibility that small-framed breeds may grow at similar rates as large-frame breeds during the high-growth-rate phase before the onset of fattening starts the slow-growth-rate finishing phase (O'Mary *et al*., 1979).

Live weight, carcass weight and dressing percentage (Table 3) increased with increasing age (18 months <24 months <30 months; $p < 0.01$). For all three traits the maturity type x year of birth interaction was significant ($p < 0.05$), while for live weight and carcass weight the age at slaughter x maturity type interaction was significant ($p < 0.01$). For dressing percentage the age at slaughter x the year of birth interaction was significant ($p < 0.001$). These interactions were only significant for the treatment groups slaughtered at 30 months of age. Mainly all interactions involving breed type are mainly due to the AF steers performing contrary to expectations.

Differences in live weight (% gain above 18 month weight in parenthesis) for steers slaughtered at 18 and 24 months of age (dry winter season) were 52.9 kg (14.4%), 5.9 kg (1.5%), 9.1 kg (2.8%) and 58.1 kg (20.2%) for SX, BX, AF and NG steers, respectively. In contrast, the differences in live weight (% gain above 24 month weight in parenthesis) for steers slaughtered at 24 and 30 months of age (wet summer season) were ($p < 0.01$) higher, and were 155.0 kg (36.9%), 154.4 kg (39.0%), 129.5 kg (39.1%) and 92.8 kg (26.7%) for the SX, BX, AF and NG steers, respectively. Although no conclusive evidence exists, based on the findings of Dikeman *et al*. (1985a; b) and Harris *et al*. (1997) it can be assumed that at least a portion of the rapid increase in live weight that occurred from December to May during the rainy season, when abundant food was available, could be ascribed to compensatory growth.

The gain in carcass weight (% gain above 18 month weight in parenthesis) for steers slaughtered at 18 and 24 months of age was 36.6 kg (21.0%), 6.4 kg (3.4%), 5.7 kg (3.8%) and 33.5 kg (23.6%) for the SX, BX, AF and NG steers, respectively, while higher ($p < 0.01$) carcass weight gains were realized from 24 to 30 months of age (% gain above 24 month weight in parenthesis) and were 86.7 kg (41.1%), 88.0 kg (44.7%), 68.8 kg (43.9%) and 55.0 kg (31.4%) for SX, BX, AF and NG steers, respectively.

Dressing percentages (Table 3) in this study were lower than the 60% (Koch *et al*., 1976; May *et al*., 1992; Wheeler, *et al*., 1996; Pringle *et al*., 1997) or the 57% (Strydom *et al*., 2001) generally reported for grain-fed cattle. It is within expectations that the dressing percentage of the animals in this study will be lower than that of grain-fed cattle. It was however not expected that the dressing percentage would be less than that reported from other studies on forage-fed cattle. Schroeder *et al*. (1980) and Camfield *et al*. (1999) reported dressing percentages ranging from 53.4% to 58.0% and 55.3% to 56.9%, respectively for forage-finished cattle. Possible reasons could be the low degree of finish of the carcasses (low carcass fat classifications), especially at 18 and 24 months of age, and that all internal fat and organs (including kidneys and pelvic fat) were removed during slaughter and/or the phenomenon that the body fill in grass-fed cattle is higher than in grain-fed cattle (Young & Kauffman, 1978; Bidner *et al*., 1986; Bennett *et al*., 1995). Furthermore, cattle in the USA are slaughtered at a higher fat content in the carcass, resulting in comparatively higher dressing percentages.

Although AF steers tended to have a lower dressing percentage at all ages than the other groups, it was only significant ($p < 0.01$) at 30 months of age (Table 3). Dressing percentage increased ($p < 0.01$) with increasing age. An increase in dressing percentage with increasing age was also reported by Moody *et al*. (1970).

No breed differences in terms of mean live and carcass weights were found between different years of birth. Breed differences, however, occurred at 24 and 30 months of age for dressing percentage. It is not clear why, but especially steers born in 1996 had a significantly lower dressing percentage at 24 months of age than steers born in 1995, 1997 and 1998 and slaughtered at 24 months of age. The other cases may be due to natural genetic and environmental variations that occurred.

Table 3 Average live weight, carcass weight and dressing percentage (± s.e.) of Simmentaler crossbred, Bonsmara crossbred, Afrikaner and Nguni steers slaughtered at 18, 24 and 30 months of age

Age at slaughter (months)	Frame sixe type / Year of birth	n	Age at slaughter (days)	Live weight (kg)	Cold Carcass weight (kg)	Dressing %
18	Simmentaler cross	9	536	367.1^{ab} ± 11.6	174.4^{a} ± 7.6	47.42 ± 0.90
	Bonsmara cross	9	544	387.1^{a} ± 8.8	184.6^{ab} ± 7.2	47.66 ± 1.47
	Afrikaner	8	537	321.8^{bc} ± 8.6	150.9^{ac} ± 4.8	46.87 ± 0.74
	Nguni	10	559	289.8^{c} ± 14.5	141.7^{ac} ± 8.0	48.91 ± 1.70
	Mean	36	544	340.6^{h} ± 8.6	162.6^{h} ± 4.5	47.77^{h} ± 0.65
	1995	1	629	349.4	158.9	45.48
	1996	14	519	352.4 ± 15.8	166.2 ± 4.2	47.04 ± 1.06
	1997	16	536	333.3 ± 12.7	161.6 ± 6.3	48.60 ± 0.88
	1998	5	626	329.1 ± 15.8	156.8 ± 9.7	47.64 ± 1.80
24	Simmentaler cross	13	745	419.5^{a} ± 14.4	211.0^{a} ± 10.6	50.17 ± 1.43
	Bonsmara cross	17	726	395.3^{a} ± 17.1	196.7^{a} ± 8.3	49.96 ± 1.26
	Afrikaner	9	726	330.9^{b} ± 12.5	156.6^{b} ± 3.5	47.63 ± 1.25
	Nguni	12	721	347.9^{b} ± 10.0	175.2^{b} ± 5.7	50.46 ± 1.31
	Mean	51	729	378.9^{h} ± 8.7	188.2^{i} ± 4.9	49.72^{h} ± 0.67
	1995	9	707	382.6 ± 13.5	196.0 ± 8.4	51.19^{e} ± 3.11
	1996	16	721	381.1 ± 15.2	172.1 ± 6.8	45.22^{f} ± 0.54
	1997	15	757	355.0 ± 16.1	194.8 ± 11.1	54.56^{g} ± 0.97
	1998	11	722	405.6 ± 22.4	196.1 ± 10.6	48.47^{e} ± 0.82
30	Simmentaler cross	16	899	575.0^{a} ± 14.4	297.7^{a} ± 8.65	51.74^{a} ± 0.58
	Bonsmara cross	17	907	549.7^{b} ± 14.9	284.9^{b} ± 7.7	51.85^{a} ± 0.30
	Afrikaner	13	880	460.4^{c} ± 12.3	225.4^{c} ± 6.0	48.99^{b} ± 0.51
	Nguni	17	899	440.7^{d} ± 8.0	230.2^{c} ± 4.6	52.20^{a} ± 0.37
	Mean	63	897	508.3^{i} ± 9.6	261.1^{j} ± 5.3	51.33^{i} ± 0.27
	1995	16	885	492.1 ± 21.3	249.6 ± 11.5	50.69^{e} ± 0.53
	1996	18	875	525.6 ± 20.9	274.2 ± 11.3	52.12^{f} ± 0.39
	1997	18	914	497.2 ± 14.1	259.5 ± 8.0	52.15^{f} ± 0.43
	1998	11	921	521.5 ± 19.4	259.1 ± 11.1	49.62^{g} ± 0.62

^{a,b,c,d} Column means for breed types within the same age group with different superscripts differ ($p < 0.001$)
^{e,f,g} Column means for year of birth within the same age group with different superscripts differ ($p < 0.01$)
^{h,i,j} Column means for means within the same age group with different superscripts differ ($p < 0.01$)

Although the live and carcass weights were higher ($p < 0.01$) at 24 months of age than at 18 months of age, steers had less ($p < 0.01$) fat on the carcasses at 24 months of age (Table 4). This is expected as the steers reached the age of 24 months just after the winter dry season and the ages of 18 and 30 months just after the rainy summer season. Carcasses that received a 2 fat classification code were deemed to be finished to a marketable degree. The largest portion of the steers reached a marketable finishing standard at 30 months of age, except for the SX steers that were still not finished, according to the current carcass classification standards. The majority of SX carcasses received 1 fat classification codes (< 1 mm subcutaneous fat) at 30 months of age, but the fat covered mainly the dorsal areas of the carcasses and was not distributed down to the ventral parts and was also very unevenly distributed. The same fat classification code and the fat covering of the BX, AF and NG carcasses were more continuous and were distributed down to the ventral parts of the carcasses. According to Camfield *et al*. (1999) the differences in measures of carcass fatness are greater and more attainable in steers developed in feedlots than in steers developed on pastures. In feedlots nutrients are supplied in excess to what is needed for maximal bone and muscle growth and the surplus nutrients are used in the formation of fatty tissue. Although it seems as if the supply of nutrients might have been enough to allow for the accumulation of fatty tissue in BX, AF and NG steers, the excess supply might not have been sufficient for differences in rates of fatty tissue accumulation between breeds. Hence, no significant differences in the distribution of the BX, AF and NG carcasses receiving 1 and 2 fat classification codes were observed for all age groups. Also, the low numbers observed in this study, may have played a role in this observation.

Table 4 The frequency distribution of carcasses of Simmentaler crossbred, Bonsmara crossbred, Afrikaner and Nguni steers within the respective fat classification codes at 18, 24 and 30 months of age

Age at slaughter (months)	Frame size type	Fat classification code			
		0	1	2	3
18	Simmentaler cross[c]	7	1	1	
	Bonsmara cross[d]	1	4	4	
	Afrikaner[d]		3	5	
	Nguni[d]		5	5	
Total[a]		**8**	**13**	**15**	
24	Simmentaler cross[c]	9	4		
	Bonsmara cross[d]	3	9	5	
	Afrikaner[d]		9		
	Nguni[d]		8	4	
Total[a]		**12**	**30**	**9**	
30	Simmentaler cross[c]	3	12	1	
	Bonsmara cross[d]			13	4
	Afrikaner[de]		2	8	3
	Nguni[e]		1	16	
Total[b]		**3**	**15**	**38**	**7**
	Simmentaler cross[c]	19	17	2	
	Bonsmara cross[d]	4	13	22	4
	Afrikaner[d]		14	13	3
	Nguni[d]		14	25	
	Total	**23**	**58**	**62**	**7**

[a,b,c] Total for slaughter age groups with different superscripts differ ($p < 0.01$)
[d,e] Breeds within age groups with different superscripts differ ($p < 0.05$)

Carcass data (Tables 3 & 5) and fat classification results (Table 4) are in agreement with the results of Camfield *et al*. (1994, 1997) who found that at the same chronological age, large framed, slower maturing steers have heavier carcasses ($p < 0.01$) but are less finished ($p < 0.05$) than medium framed, faster maturing steers. Tatum *et al*. (1990) also reported that Piedmontese sired steers had the least fat thickness compared to Gelbvieh and Red Angus sired steers, when slaughtered at the same chronological age. Schaake *et al*. (1993) reported that although the fat thickness of steers on spring fescue-clover, summer pasture (640 days of age) and steers fed a feedlot diet for 45 days after the same grazing treatment (685 days of age), did not differ statistically, feedlot steers tended to have a greater fat thickness ($p = 0.07$) than pasture raised steers. The fat thickness of steers raised on pastures until 640 days of age and then finished in a feedlot for 75 days was greater than for pastures raised steers (640 days) (Schaake *et al*., 1993). The frequency distributions of carcasses in fat classification code classes were similar at 18 and 24 months of age, but at 30 months more ($p < 0.01$) carcasses achieved higher fat classification codes. In order to ensure better fat classification codes, it would be beneficial to feedlot-feed or supply a supplement on the natural pasture for all maturity type steers to be slaughtered at 18 or 24 months of age for a short period of time. A period of 45 to 75 days should suffice.

Table 5 Average weights (± s.d.) and weight ranges for Simmentaler crossbred, Bonsmara crossbred, Afrikaner and Nguni steers slaughtered at 18, 24 and 30 months of age

Age at Slaughter (months)	Frame size type		Live weight (kg) for fat code			
			Fat code 0	Fat code 1	Fat code 2	Fat code 3
18	Simmentaler cross	n	7	1	1	
		Mean (kg)	356.9 ± 47.2	336	350	
		Range (kg)	284 – 420			
	Bonsmara cross	n	1	4	4	
		Mean (kg)	408	392 ± 33.8	361 ± 31.9	
		Range (kg)		362 – 434	328 – 404	
	Afrikaner	n		3	5	
		Mean (kg)		294 ± 28.4	300 ± 16.6	
		Range (kg)		272 – 326	278 – 316	
	Nguni	n		5	5	
		Mean (kg)		316 ± 37.2	277 ± 43.6	
		Range (kg)		262 – 366	222 – 332	
24	Simmentaler cross	n	9	4		
		Mean (kg)	417 ± 44.0	400 ± 49.8		
		Range (kg)	372 – 510	330 – 466		
	Bonsmara cross	n	3	9	5	
		Mean (kg)	421 ± 72.5	381 ± 28.8	402 ± 74.0	
		Range (kg)	338 – 470	348 – 428	304 - 488	
	Afrikaner	n		9		
		Mean (kg)		332 ± 35.9		
		Range (kg)		286 – 374		
	Nguni	n		8	4	
		Mean (kg)		325 ±18.4	363 ± 27.0	
		Range (kg)		304 – 354	340 – 396	
30	Simmentaler cross	n	3	12	1	
		Mean	465 ± 41.2	559 ± 35.6	586	
		Min	420 – 501	486 – 620		
	Bonsmara cross	n			13	4
		Mean (kg)			527 ± 49.9	553 ± 18.1
		Range (kg)			440 – 600	530 - 570
	Afrikaner	n		2	7	4
		Mean (kg)		428 ± 39.6	435 ± 29.5	420 ± 21.6
		Range (kg)		400 – 456	400 – 462	390 – 440
	Nguni	n		1	16	
		Mean (kg)		420	416 ± 30.2	
		Range (kg)			350 - 472	

A clear relationship between live weight and fat classification code can not be identified (Table 5). In most cases, factors like normal genetic variation (Sullivan et al., 1999) and the low/medium quality of the available feed (natural pasture) make it difficult to establish significant relationships concerning growth and weight parameters. The large variation in live weight within each weight group, combined with the few animals in some weight-fat class groups, supports the above explanation. Due to the inability to identify a significant relationship between live weight and fat classification code (Table 5), it was not possible to predict the actual market readiness of these steers at a particular age from the live weight at that age. Other measurements such as condition scoring will have to be used to identify animals that are finished and ready to be marketed. At 18 months of age only one NG steer had one permanent incisor (Table 6). All the other animals had only temporary teeth. At 24 months of age 92.3% SX, 42.1% BX, 55.6% AF and 58.3% NG steers still had no permanent incisors. The rest of the steers had either one or two permanent incisors and were classified AB. It is evident that even at this young age many steers had already started to become physiologically mature. At 30 months of age only 7.7% of AF steers had no permanent incisor. Most steers already had 2 permanent incisors (SX 62.5%, BX 76.5%, AF 84.6%, and NG 76.5%), while a meaningful proportion was classified in the B age class for having either three or four permanent incisors. The frequency distributions for number of visible permanent incisors of the different breed types were similar between breeds at 18 months of age. At 24 months of age fewer ($p < 0.05$) SX steers had permanent incisors than the BX steers, while at 30 months of age more ($p < 0.05$) SX steers had three or four permanent incisors than the AF steers.

Table 5 The frequency distribution of Simmentaler crossbred, Bonsmara crossbred, Afrikaner and Nguni steers having 0 to 4 teeth at 18, 24 and 30 months of age

Age at slaughter (months)	Frame size type	Number of permanent incisors				
		0	1	2	3	4
18	Simmentaler cross	9				
	Bonsmara cross	9				
	Afrikaner	8				
	Nguni	9	1			
Total[a]		**35**	**1**			
24	Simmentaler cross[d]	12		1		
	Bonsmara cross[e]	7	1	9		
	Afrikaner[de]	5	3	1		
	Nguni[de]	7	1	4		
Total[b]		**31**	**5**	**15**		
30	Simmentaler cross[d]			10	1	5
	Bonsmara cross[de]			13	2	2
	Afrikaner[e]	1		11	1	
	Nguni[de]			13		4
Total[c]		**1**		**47**	**4**	**11**
	Simmentaler cross	21		11	1	5
	Bonsmara cross	16	1	22	2	2
	Afrikaner	14	3	12	1	
	Nguni	16	2	17		4
	Total	**67**	**6**	**62**	**4**	**11**

[a,b,c] Total for slaughter age groups with different superscripts differ ($p < 0.01$)
[d,e] Breeds within age groups with different superscripts differ ($p < 0.05$)

At 30 months of age 23.8% of all steers had three or four visible incisors. Even if this proportion is a true reflection of the population teething rate, the magnitude of the weight gain achieved from 24 months of age to 30 months of age, coupled with the inexpensive food source utilized, should more than compensate for losses due to the lower age classification of these carcasses.

Conclusions

In order to take maximum advantage of rapid weight gains, marketing steers from natural pastures in arid regions should be done at the end of the wet summer season (18- and 30 months of age in case of this study). Steers received better classification codes at the end of the wet season than at the end of the dry season and were the highest at 30 months of age. If marketing steers before the age of 30 months is considered, animals should be fed in a feedlot or supplemented on the natural pasture.

Bonsmara crossnreds, AF and NG steers received better fat classification codes than SX steers at all slaughtering ages. At 30 months of age SX steers still received mainly a 1 fat classification code. Thus it seems that large framed breeds (mean cow weight >500 kg) may need supplementation on natural pastures or be finished off in a feedlot to achceive a 2 fat classification code. None the less, the finishing of large framed breeds from natural pastures is not recommended.

Although 23.8% of all steers had more than two visible permanent incisors at 30 months of age, most steers were classified as the AB age class. Marketing at a marginal earlier age (27 months) may provide an opportunity to utilise the period of high growth and reduce the number of animals being classified in the B age class.

References

Acocks, J.P.H., 1988. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 57.

Bennett, L.L., Hammond, A.C., Williams, M.J., Kunkle, W.E., Johnson, D.D., Preston, R.L. & Miller, M.F., 1995. Performance, carcass yield and carcass quality characteristics of steers finished on Rhizoma peanut (*Arachis glabrata*) – Tropical grass pasture or concentrate. *J. Anim. Sci.* 73, 1881-1887.

Bidner, T.D., Schupp, A.R., Mohamad, A.B., Rumore, N.C., Montgomery, R.E., Bagley, C.P. & Mcmillin, K.W., 1986. Acceptability of beef from Angus-Hereford or Angus-Hereford-Brahman steers finished on all-forage or a high-energy diet. *J. Anim. Sci.* 62, 381-387.

Brand, A.A., Cloete, S.W.P. & Coetzee, J., 1989. Urea ammoniation of wheat, oat and barley straw and oat hay. 1. A laboratory investigation into the effect of urea and moisture level and treatment period on chemical composition and *in vitro* digestibility. *S. Afr. J. Anim. Sci*. 19, 4-10.

Camfield, P.K., Brown, A.H., Jr., Johnson, Z.B., Lewis, P.K., & Brown, C.J., 1994. Effect of growth type on weight-age and carcass data of beef developed on pasture and in the feedlot. *J. Anim. Sci.* 72 (Suppl. 2), 26.

Camfield, P.K., Brown, A.H., Jr., Lewis, P.K., Rakes, L.Y. & Johnson, Z.B., 1997. Effects of frame size and time-on-feed on carcass characteristics, sensory attributes and fatty acid profiles of steers. *J. Anim. Sci.* 75, 1837-1844.

Camfield, P.K., Brown, A.H., Jr., Johnson, Z.B., Brown, C.J., Lewis, P.K., & Rakes, L.Y., 1999. Effects of growth type on carcass traits of pasture- or feedlot-developed steers. *J. Anim. Sci.* 77, 2437-2443.

Cianzio, D.S., Topel, D.G., Whitehurst G.B., Beitz, D.C. & Self, H.L., 1982. Adipose tissue growth in cattle representing two frame sizes: Distribution among depots. *J. Anim. Sci.* 55, 305-312.

Crouse, J.D., Ferrel, C.L. & Cundiff, L.V., 1985. Effects of sex condition, genotype and diet on bovine growth and carcass characteristics. *J. Anim. Sci.* 60, 1219-1227.

Dekker, B., Kirkman K.P. & Du Plessis, S.I., 2001. Use of the dry-weight-rank method of botanical analysis in semi-arid savanna communities. *Afr. J. Range For. Sci*. 19, 63-68.

De Villiers, J.F. & Van Ryssen, J.B.J., 2001. Performance responses of lambs of various ages to Italian ryegrass (*Lolium multiflorum*) fertilized with various levels of nitrogen. *S. Afr. J. Anim. Sci*. 31, 142-148.

De Waal, H.O., Engels, E.A.N., Van Der Merwe, F.J. & Biel, L.C., 1981. Supplementing sheep with protein and phosphorus on native pasture of the central Orange Free State. 2. Feed intake, mass changes and wool production. *S. Afr. J. Anim. Sci*. 11. 217-228.

Dikeman, M.E., Dayton, A.D., Hunt, M.C., Kastner, C.L., Axe, J.B. & Ilg, H.J., 1985a. Conventional versus accelerated beef production with carcass electrical stimulation. *J. Anim. Sci.* 61, 573-583.

Dikeman, M.E., Nagele, K.N., Myers, S.M., Schalles, R.R., Kropf, D.H., Kastner, C.L. & Russo, F.A., 1985b. Accelerated versus conventional beef production and processing. *J. Anim. Sci.* 61, 137-150.

Fortin, A., Reid, T.J., Maiga, A.M., Sim, D.W. & Wellington, G.H., 1981. Effect of energy intake level and influence of breed and sex on the physical composition of the carcass of cattle. *J. Anim. Sci.* 51, 331-339.

Gertenbach, W.D., Van H. Henning, P.W. & Van Schalkwyk, A.P., 1995. Performance of beef steers on Smuts finger grass and Nile grass pasture in Northern Natal. 1. Effect of over wintering level and summer stocking rate. *S. Afr. J. Anim. Sci.* 25, 95-100.

Gertenbach, W.D. & Van H. Henning, P.W., 1995a. Energy supplementation of yearling steers at different stocking rates on Nile grass pasture. S.Afr. J. Anim. Sci. 25, 105-108.

Gertenbach, W.D. & Van H. Henning, P.W., 1995b. Performance of beef steers on Smuts finger grass and Nile grass pasture in Northern Natal. 2. Feedlot performance following summer grazing. *S. Afr. J. Anim. Sci.* 25, 101-104.

Government Notice No. R. 1748, 26 June 1992. Regulation Gazette No. 4890, Government Gazette No. 14060, Vol. 3245, p8.

Harris, J.J., Lunt, D.K., Smith, S.B., Mies, W.L., Hale, D.S., Koohmaraie, M. & Savell, J.W., 1997. Live animal performance, carcass traits and meat palatability of calf- and yearling-fed cloned steers. *J. Anim. Sci.* 75, 986-992.

Jacobsz, J.Z.H., Cronje, P.J., Baard, M.A. & Van Schalkwyk, A., 1971. Supplementation during winter of two types of Merino sheep on Cymbopogon-Themeda veld II. Influence on body weight and carcass qualities. *S. Afr. J. Anim. Sci.* 1, 33-37.

Koch, R.M., Dikeman, M.E., Allen, D.M., May, M., Crouse, J.D. & Campion, D.R., 1976. Characterization of biological types of cattle. III. Carcass composition, quality and palatability. *J. Anim. Sci.* 43, 48-62.

Koch, R.M., Dikeman, M.E., Lipsey, R.J., Allen, D.M. & Crouse, J.D., 1979. Characterization of biological types of cattle – Cycle II: III. Carcass composition, quality and palatability. *J. Anim. Sci.* 49, 448-460.

Le Roux, C.J.G., Swart, J.S., Oosthuysen, E., Trethewey, C., Pittaway, C. & Daines, T., 1999a. Prediction of cattle performance on Coastcross 2 at different fertilizer and stocking rates. *S. Afr. J. Anim. Sci.* 29, 64-68.

Le Roux, C.J.G., Swart, J.S., Oosthuysen, E., Trethewey, C., Pittaway, C. & Daines, T., 1999b. Factors affecting cattle performance on Coastcross 2 at different stocking and fertilizer rates. *S. Afr. J. Anim. Sci.* 29, 69-73.

May, S.G., Dolezal, H.G., Gill, D.R., Ray, F.K. & Buchanan D.S., 1992. Effects of days fed, carcass grade traits, and subcutaneous fat removal on post mortem muscle characteristics and beef palatability. *J. Anim. Sci.* 70, 444-453.

McDonald, I.W., 1971. Animal production: Quo vadis. S. Afr. *J. Anim. Sci.* 1, 149-158.

Meaker, H.J. & Barnard, J.C., 1988. Beef steers implanted with short, medium, and long-acting anabolic compounds grazing natural pastures and finished in feedlot. *S. Afr. J. Anim. Sci.* 18, 68-71.

Meissner, H.H., Hofmeyer, H.S., Van Rensburg, W.J.J. & Pienaar, J.P., 1983. Classification of livestock for realistic prediction of substitution values in terms of a biologically defined Large Stock Unit. Technical Communication No. 175, Department of Agriculture, Republic of South Africa.

Moody, W.G., Little, J.E., Jr., Thrift, F.A., Cundiff, L.V. & Kemp, J.D., 1970. Influence of length of feeding a high roughage ration on quantative and qualitative characteristics of beef. *J. Anim. Sci.* 31, 866-873.

O'Mary C.C., Martin, E.L. & Anderson D.C., 1979. Production and carcass characteristics of Angus and Charolais x Angus steers. *J. Anim. Sci.* 48, 239-245.

Pringle, T.D., Williams, S.E., Lamb, B.S., Johnson, D.D. & West, R.L., 1997. Carcass characteristics, the calpain proteinase system, and aged tenderness of Angus and Brahman crossbred steers. *J. Anim. Sci.* 75, 2955-2961.

Prior, R.L., Kohlmeier, R.H., Cundiff, L.V., Dikeman, M.E. & Crouse, J.D., 1977. Influence of dietary energy and protein on growth and carcass composition in different biological types of cattle. *J. Anim. Sci.* 45, 132-146.

Relling, E.A., Van Niekerk, W.A., Coerze, R.J. & Rethman, N.F.G., 2001. An evaluation of *Panicum maximum* cv. Gatton: 2. The influence of stage of maturity on diet selection, intake and rumen fermentation in sheep. *S. Afr. J. Anim. Sci.* 31, 85-91.

Reyneke, J., 1976. Supplementation of energy and/or protein to steers grazing summer veld. *S. Afr. J. Anim. Sci.* 6, 59-66.

Schaake, S.L., Skelley, G.C., Halpin, E., Grimes. L.W., Brown, R.B., Cross, D.L. & Thompson, C.E., 1993. Carcass and meat sensory traits of steers finished on fescue and clover, summer forage, or for different periods in drylot. *J. Anim. Sci.* 71, 3199-3205.

Schroeder, J.W., Cramer, D.A., Bowling, R.A. & Cook, C.W., 1980. Palatability, shelf life and chemical differences between forage- and grain finished beef. *J. Anim. Sci.* 50, 852-859.

Smith, G.M., Laster, D.B., Cundiff, L.V. & Gregory, K.E., 1976. Characterization of biological types of cattle. II. Postweaning growth and feed efficiency of steers. *J. Anim. Sci.* 43, 37-47.

Snyman, L.D. & Joubert, H.W., 2002. The chemical composition and in vitro dry matter digestibility of untreated and ammoniated crop residues. *S. Afr. J. Anim. Sci.* 32, 83-87.

Strydom, P.E., Naudé, R.T., Smith, M.F., Kotzé, A., Scholtz, M.M. & Van Wyk, J.B., 2001. Relationships between production traits in subpopulations of Bonsmara and Nguni cattle. *S. Afr. J. Anim. Sci.* 31, 181-194.

Sullivan, P.G., Wilton, J.W., Miller, S.P. & Banks, L.R., 1999. Genetic trends and breed overlap derived from multiple-breed genetic evaluations of beef cattle for growth traits. *J. Anim. Sci.* 77, 2019-2027.

Swanepoel, J. Casey, De Bruyn, J.F. & Naudé, R.T., 1990. Meat studies of indigenous South African cattle. I. Growth performance and carcass characteristics of Afrikaner, Nguni and Pedi bulls fed intensively. *S. Afr. J. Anim. Sci.* 20, 180-187.

Tainton, N.M., 1999. The ecology of the main grazing lands of South Africa. In: Veld management in South Africa. Ed. N.M. Tainton. University of Natal press, 48.

Tatum, J.D., Gronewald, K.W., Seideman, S.C. & Lamm W.D., 1990. Composition and quality of beef from steers sired by Piedmontese, Gelbvieh and Red Angus bulls. *J. Anim. Sci.* 68, 1049-1060.

Taute, A., Van Niekerk, W.A., Rethman, N.F.G. Coertze, R.J., 2002. An evaluation of Nitrogen fertilised *Panicum maximum* cv. Gatton at different stages of maturity during autumn: 1. Dry matter yield and certain qualitative parameters. *S. Afr. J. Anim. Sci.* 32, 208-216.

Wheeler, T.L., Cundiff, L.V., Koch, R.M. & Crouse, J.D., 1996. Characterization of biological types of cattle (Cycle IV): Carcass traits and *longissimus* palatability. *J. Anim. Sci.* 74, 1023-1035.

Young, A.W. & Kauffman, R.G., 1978. Evaluation of beef from steers fed grain, corn silage or haylage-corn silage diets. *J. Anim. Sci.* 64, 41-47.

CHAPTER 4

The effect of slaughter age and breed on the carcass traits and meat quality of steers grazing natural sweet pastures

I du Plessis[1,2#], LC Hoffman[2]
[1] Limpopo Province Department of Agriculture, Mara Research Station, Private Bag X2467, Makhado (Louis Trichardt), 0920, South Africa
[2] Department of Animal Sciences, University of Stellenbosch, Private Bag X1, Matieland, 7602, South Africa

Abstract

Simmentaler cross (SX), Bonsmara cross (BX), Afrikaner (AF) and Nguni (NG) steers were raised on natural sweet pastures and slaughtered at 18, 24 and 30 months of age. Slaughtering at 18 and 30 months of age occurred at the end of the wet summer season and at 24 months at the end of the dry winter season. Live weight and carcass traits were significantly influenced by breed and slaughter age. The amount as well as percentage kidney and omental fat differed significantly between the respective slaughter ages, but only between breeds at 30 months of age. Breed and slaughter age affected back fat thickness. All fat parameters were at their lowest at 24 months of age and at their highest at 30 months of age. Breed did not have a large influence on meat quality attributes, but slaughtering age did. Drip loss was higher at 24 months of age than at 18 or 30 months of age. The meat was darker and more red at 30 months of age than at 18 and 24 months of age. The pH_{24} of the l*ongissimus* muscle were 5.51, 5.73 and 5.67 at 18, 24 and 30 months of age respectively. No breed differences were detected for sensory panel attributes or Warner-Bratzler shear force values. Tenderness and Warner-Bratzler shear force values were higher in 30 months old steers than in 18 month old steers. Differences in meat quality are probably due to the combined effects of fatness, pH and collagen characteristics. It is concluded that small to medium framed steers can successfully be raised and slaughtered without supplementation from natural pastures in sweet veld areas. Slaughtering steers at younger ages may require supplementary feeding or feedlot finishing.

Keywords: Beef, carcass traits, meat quality, natural pasture.

[#] Correspondinge author. E-mail: iduplessis@lantic.net

Introduction

Beef is produced either intensively in feedlots or semi-intensively or extensively from pastures. The dietary effect on carcass and meat quality of cattle has been researched intensively. Thus, varying dietary energy levels (Prior *et al.*, 1977; Loveday & Dikeman, 1980; Crouse *et al.*, 1985a) as well as grain vs. forage based diets (Bowling *et al.*, 1977; Young & Kauffman, 1978; Schroeder *et al.*, 1980; Crouse *et al.*, 1984;

Fortin *et al.*, 1985; Newsome *et al.*,1985; Bidner *et al.*, 1986) or pasture vs. feedlot finishing (Schaake *et al.*, 1993; Bennett *et al.*, 1995; Camfield *et al.*, 1999) and breed types/frame size (Koch *et al.*, 1976; Cianzio *et al.*, 1982; Tatum *et al.*, 1986a; Tatum *et al.*, 1990; Dolezal *et al.*, 1993; Camfield 1997; Short *et al.*, 1999) were especially the focus of research studies abroad. In general, carcasses from feedlot-fed cattle are heavier and contain more fat than carcasses from forage-fed cattle. Beef from forage fed cattle is also darker and less tender than meat from feedlot-fed cattle.

In South Africa research concerning the utilization of forage revolved around nutritional, reproductive and growth responses of supplementation on sour veld pastures (Erasmus & Barnard, 1985; Gertenbach & Van H. Henning, 1995a), enhancing the nutritional value of planted pastures (Le Roux *et al.*, 1999; Taute *et al.*, 2002) as well as crop residues (Cloete & Kritzinger, 1985; Brand *et al.*, 1989; Snyman & Joubert, 2002). Most carcass and meat quality related research revolved around feedlots (Meaker & Barnard, 1988; Casey *et al.*, 1990; Swanepoel *et al.*, 1990; Gertenbach & Van H. Henning, 1995b; Strydom *et al.*, 2000; Strydom *et al.*, 2001). At Mara Research Station research from natural pastures focused on cow production and efficiency (Venter, 1977; Van Zyl, 1990; Lademann, 1992; Meaker, 1993).

Most studies reported were conducted in the USA where consumers prefer heavier carcasses exhibiting a substantial degree of marbling. In South Africa, consumers prefer lean meat with little visible fat. Here carcasses are produced to suite consumer preference and not trimmed. The possibility exists that beef can be produced from natural sweet pastures that can, apart from meeting consumer expectations, also be classified as organically produced. This enables the producer to add value to his product. However, no information on the effects of genotype and cattle age under sweetveld grazing conditions are available.

The objectives of this study were to identify breed types that will be suitable for finishing off on natural sweet pastures as well as the influence of slaughtering age on carcass and meat quality.

Materials and methods

The study was conducted from 1999 to 2003 on approximately 4 387 ha on the eastern side of the Mara Research Station (23° 05’ S and 29° 25’ E; 961 m.a.s.l). The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988). The vegetation in the study area include the woody species *Acacia tortilis*, *Commiphora pyracanthoides, Boscia albitrunca* and *Grewia* spp. and the grass species *Eragrostis rigidior, Panicum maximum, Urochloa mosambicensis* and *Digitaria eriantha* (Dekker *et al.*, 2001). The long term mean rainfall at the Mara Weather Station is 452 mm of which approximately 80 % occurs from November to March. The mean daily maximum temperature ranges from 22.6 °C in June to 30.4 °C in January. During the study period, the mean annual rainfall (measured from July to June) was 410 mm, ranging from 232 mm to 846 mm per annum.

In this investigation the productivity of four different breeds/frame sizes on sweet veld were evaluated. Cows consisting of approximately $^{2}/_{3}$ Simmentaler were mated with Simmentaler bulls, their offspring representing large framed breed types (SX) and the cows of the reciprocal cross were mated with Bonsmara bulls, their offspring representing medium framed breed types (BX) while Afrikaner (AF) and Nguni (NG) steers represented small-medium and small framed breed types respectively.

Calves were born from the end of October until the middle of December. All calves were weaned simultaneously when the youngest animal reached 205 days of age. Castration took place during the weaning phase. Other herd management practices (e.g. dipping, vaccination) were standardised for all breeds. No supplementary feeding or licks were supplied.

The live weights (LW) of the steers were recorded at 28-day intervals after withholding food and water for at least 12 hours. Steers born during a specific calving season were randomly divided into three groups and slaughtered at 18-, 24- or 30 months of age respectively. Steers born from October 1999 to December 2001 were slaughtered either in May 2002, November 2002 or May 2003. The slaughtering that occurred in May (18 and 30 month old steers) coincided with the end of the wet summer season, while the slaughtering in November (24 month old steers) coincided with the end of the dry winter season. Live weights at 18-, 24- and 30 months of age (548, 730 and 912 days of age respectively) were either interpolated or extrapolated from the 28 day weight records, depending on whether the steers were slaughtered before or after they reached the respective slaughter ages. Steers were transported for 35 km to the abattoir on the day of slaughter. Steers were slaughtered using standard South African techniques and conditions. Carcasses were quartered 48 hours *post-mortem*, whereafter all carcass measurements were recorded and all sampling conducted. Cold carcass weight (CCW) was also corrected for age. Dressing percentage (DP) was calculated as the proportion of the CCW of the LW. Carcass length was measured from the centre of the first rib to the centre of the pubic symphysis and used to calculate carcass compactness (kg/cm) as described by Swanepoel *et al*. (1990). Back fat thickness was measured at the 12th rib, approximately 5 cm from the dorsal midline. All kidney and omental fat were removed, weighed and expressed as a percentage of carcass weight.

The wing rib cuts (9th, 10th, and 11th ribs) were removed from both sides of the carcasses. The *M. longissimus dorsi* (*longissimus* muscle) from the left ribcut was immediately dissected, labelled and kept at 4 °C until drip losses were determined later the same day. Drip and cooking losses were determined according to the methods set out by Honikel (1998). Cooking losses (cooked for 1 hour at 80 °C) were determined 72 hours *post-mortem*. The cooked samples were cooled in running water at room temperature (~25 °C) prior to determining the final weight. To determine Warner-Bratzler shear force (WBS) values, five 12.7 mm diameter cores were cut perpendicular to the longitudinal axis of the muscle fibres at a crosshead speed of 299 mm/minute (Voisey, 1976). The average of the maximum shear force values of the five samples was calculated. Colour measurements (average of three random measurements) were taken from the surface of freshly cut steaks after a 20 minute blooming period (Stevenson *et al*., 1989) using a Color-guide 45°/0° colorimeter (BYK-Gardener, USA) with scales for lightness (L*) (0 = black, 100 = white), redness (a*) (+ = red, - = green) and yellowness (b*) (+ = yellow, - = blue). The remainder of the l*ongissimus* muscle was labeled, vacuum packed and frozen and stored at - 18 °C until the sensory evaluations were made.

Sensory evaluations were conducted on the *longissimus* muscle of the wing rib cut from the right side of steers slaughtered at 18- and 30 months of age in May 2003. As different age groups were slaughtered with intervals of six months, comparisons between groups slaughtered at different times of the year could not be made. Before the sensory evaluation, the *longissimus* muscle samples were thawed for 24 h at a temperature of 2 to 4 °C. Meat samples were cut to a uniform size and placed on foil covered metal racks. Each metal rack was placed in a coded cooking bag and a probe inserted into the center of the meat. The samples were roasted at 160 °C (Viljoen, *et al.,* 2001) to an internal temperature of 68 °C (American Meat Science Association, 1978). The meat was allowed to rest for 5 minutes, during which time an endpoint temperature of 72°C was reached. Cubed samples (1.5 cm x 1.5 cm) were taken from the middle of each *longissimus* muscle sample and individually wrapped in aluminium foil. The samples were placed in preheated glass ramekins marked with random three-digit codes and placed in a preheated oven at 100 °C and evaluated within 10 min.

Descriptive sensory analyses were performed on the meat samples. Five panelists were selected and trained in accordance with the guidelines for the sensory evaluation of meat (American Meat Science Association, 1978). The meat samples were evaluated for the following sensory attributes: beef aroma intensity, initial impression of juiciness, sustained juiciness, tenderness, residue and overall beef flavor by means of an eight-point structured scale. The meat was evaluated in 12 sessions, controlled for age per session. The panelists were seated in individual booths in a temperature and light-controlled room, receiving a set of three samples served in a complete randomized order.

Carcass and meat trait results were analyzed statistically with a univariate ANOVA using the GLM procedure. Breed and age at slaughter were included as the main effects. Least significant differences were determined between means. The experimental design of the sensory evaluation consisted of a randomized incomplete block design. The treatment design was a 3 x 2 factorial design with three breeds and two age groups as the main factors. Where appropriate, data were also pooled to test for the main effects of breed and age. Prior to analyses of variance, the sensory scores were transformed to ranks. Tukey's LSD was calculated at a 5% significance level to compare treatment means (SAS, 1990).

Results

An analysis of variance for all the observed traits is presented in Table 1. Age at slaughter had a highly significant influence ($p < 0.001$) on LW, CCW, carcass compactness, all the fat parameters, drip loss, cooking loss, colour parameters and pH 24 hours *post-mortem*. Slaughter age also had an influence ($p < 0.05$) on the WBS values of the meat. Breed had a highly significant ($p < 0.001$) influence on LW, CCW, carcass compactness, omental fat, percentage kidney fat and percentage omental fat. Breed also had a significant ($p < 0.05$) influence on kidney fat, WBS, and cooking loss.

Breed type had an effect on LW, CCW and carcass compactness ($p < 0.05$) at all slaughter ages (Table 2). The large framed SX steers were heavier ($p < 0.05$) and had heavier ($p < 0.05$) carcasses than the medium framed BX steers at 18 months of age, but not at 30 months of age. Both SX and BX steers were heavier ($p < 0.05$) and had heavier ($p < 0.05$) carcasses than the AF and the small framed NG steers at all three age groups. Heavier ($p < 0.05$) LW and carcass weights have been reported for large framed steers than for small framed steers at a constant age (Wheeler *et al.*, 1996; Camfield *et al.*, 1999; Short *et al.*, 1999) as well as at a constant carcass fat content (Tatum *et al.*, 1986b; Dolezal *et al.*, 1993; Wheeler *et al.*, 1996). Bidner *et al.* (1986) reported similar LW for pasture raised Angus x Hereford and Brahman cross steers at 31 months as was observed for SX and BX steers in the present study. Schaake *et al.*, (1993) however, reported appreciably higher hot carcass weights (281.9 and 291.4 kg) for steers slaughtered from pastures at approximately 18 months of age.

Table 1 Analysis of variance for live weight, carcass weight, dressing percentage, carcass length, hind leg length, carcass compactness, kidney fat, omental fat, back fat thickness, kidney fat percentage, omental fat percentage, shear force, drip loss, cooking loss, L-, a-, b-values and pH at 24 hours *post-mortem*.

Source of variation	df	F values: Live weight (kg)	Carcass weight (kg)	Dressing %	Carcass compactness (kg/cm)
Breed	3	22.73***	18.37***	0.31	16.59***
Slaughter age	2	107.13***	88.1***	2.86	81.5***
Mean (± s.e.)		365 ± 8	173 ± 4	47.6 ± 0.5	0.712 ± 0.013
CV		10.990	12.721	9.558	9.206
R^2 model (%)		77.8	74.3	7.3	72.8

Source of variation	df	Kidney fat (g)	Omental fat (g)	Back fat thickness (mm)	Kidney fat (%)	Omental fat (%)	Shear force (kg)
Breed	3	3.02*	9.12***	10.57***	7.19***	19.08***	3.17*
Slaughter age	2	64.01***	62.05***	19.45***	53.08***	63.23***	4.75*
Mean (± s.e.)		1541 ± 96	1842 ± 81	2.87 ± 0.26	0.83 ± 0.05	1.01 ± 0.04	2.83 ± 0.08
CV		39.462	27.702	67.090	37.793	26.621	26.869
R^2 model (%)		60.3	60.1	44.6	57.0	63.2	20.4

Source of variation	df	Drip loss (%)	Cooking loss (%)	L	a	b	pH_{24}
Breed	3	0.18	3.52*	0.43	2.48	1.98	1.94
Slaughter age	2	20.03***	11.65***	27.7***	17.21***	17.04***	7.99***
Mean (± s.e.)		1.84 ± 0.001	33.5 ± 0.3	35.6 ± 0.23	13.59 ± 0.16	9.19 ± 0.17	5.59 ± 0.02
CV		53.090	7.509	4.822	9.395	15.386	3.946
R^2 model (%)		33.8	30.3	42.3	33.2	29.4	19.0

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

DP was lower ($p < 0.05$) at the end of the dry winter season than at the end of the wet summer season (18 and 30 months old), whereas differences between breeds were small, only differing significantly ($p < 0.05$) at 24 months of age between the BX and NG and at 30 months between AF and NG. These results are in general agreement with the results of Bidner *et al.* (1986), but contrary to the findings of Prior *et al.* (1977), Dolezal *et al.* (1993) and Camfield *et al.* (1999) who reported higher ($p < 0.05$) DP for large framed steers than for small framed steers and Swanepoel *et al.* (1990) who noted that NG bulls had higher DP than AF and Pedi bulls, all under intensive feeding conditions. Higher DP have been reported for intensively fed cattle (Schroeder *et al.*, 1980; Bidner *et al.*, 1986; Swanepoel *et al.*, 1990; Bennett *et al.*, 1995; Keane & Allen, 1998; Strydom *et al.*, 2001) than for forage fed cattle. Although increased DP with increased age was observed in previous studies (Short *et al.*, 1999), DP of steers slaughtered at 18 and 30 months of age were similar and were significantly ($p < 0.05$) higher than that of the 24 month old steers.

SX steers had the highest ($p < 0.05$) carcass compactness at 18 and 30 months of age, while BX steers had higher ($p < 0.05$) carcass compactness than AF and NG steers at 24 and 30 months of age. Similarly, Swanepoel *et al.* (1990) reported that carcass compactness increased with increasing animal age. These authors also reported higher carcass compactness for NG bulls than for AF and Pedi bulls, which is contrary to the observations made in the present study. Strydom *et al.* (2001) reported higher carcass compactness for Bonsmara (0.91 to 0.94) and Nguni (0.74) bulls than was observed at 30 months of age in the present study.

Table 2 Least square means (± s.e.) for live weight, carcass weight, dressing percentage, and carcass compactness by breed at the respective slaughter ages

Slaughter age (months)	Breed type	N	Live weight (kg)	Carcass weight (kg)	Dressing %	Carcass compactness (kg/cm)
18	SX	5	$376^{a} \pm 17$	$182^{a} \pm 10$	48.4 ± 3.0	$0.767^{a} \pm 0.031$
	BX	15	$314^{b} \pm 10$	$155^{b} \pm 6$	49.9 ± 1.7	$0.654^{b} \pm 0.018$
	NG	17	$285^{v} \pm 9$	$134^{c} \pm 5$	47.0 ± 1.6	$0.621^{b} \pm 0.017$
	Mean	**37**	$\mathbf{309^{e} \pm 9}$	$\mathbf{149^{e} \pm 5}$	$\mathbf{48.3^{e} \pm 0.7}$	$\mathbf{0.654^{e} \pm 0.014}$
24	BX	5	$377^{a} \pm 12$	$165^{a} \pm 6$	$43.6^{a} \pm 0.8$	$0.664^{a} \pm 0.020$
	NG	12	$278^{b} \pm 8$	$127^{b} \pm 4$	$45.8^{b} \pm 0.5$	$0.561^{b} \pm 0.013$
	Mean	**17**	$\mathbf{307^{e} \pm 13}$	$\mathbf{138^{e} \pm 7}$	$\mathbf{45.2^{f} \pm 1.1}$	**0.614 ± 0.019**
30	SX	7	$496^{a} \pm 16$	$242^{a} \pm 9$	$48.6^{ab} \pm 0.9$	$0.907^{a} \pm 0.026$
	BX	11	$467^{a} \pm 13$	$220^{a} \pm 8$	$47.0^{ab} \pm 0.7$	$0.841^{b} \pm 0.021$
	AF	5	$415^{b} \pm 20$	$192^{b} \pm 11$	$46.2^{a} \pm 1.0$	$0.746^{c} \pm 0.031$
	NG	18	$405^{b} \pm 10$	$197^{b} \pm 6$	$48.6^{b} \pm 0.5$	$0.784^{c} \pm 0.016$
	Mean	**41**	$\mathbf{438^{f} \pm 8}$	$\mathbf{210^{f} \pm 4}$	$\mathbf{47.9^{e} \pm 0.7}$	$\mathbf{0.821^{g} \pm 0.011}$

[a,b,c] Column means for breed types within a slaughter age group with different superscripts differ ($p < 0.05$).
[e,f,g] Column means for means at the different slaughter ages with different superscripts differ ($p < 0.05$).

All the fat parameters (Table 3) were significantly ($p < 0.05$) higher at the end of the wet summer season (18 and 30 months of age) than at the end of the dry winter season (24 months of age). No significant differences among breeds for the amount of kidney and omental fat were observed at 18- and 24 months. However, the percentage kidney fat, omental fat and BFT were significantly ($p < 0.05$) higher for smaller framed NG steers than for larger framed SX and BX steers. At 30 months of age the weight, percentage and thickness of the fat parameters increased ($p < 0.05$) with decreasing frame size.

Similar age and sire effects were reported by Short *et al.* (1999) who also concluded that the effect of sire breed became more pronounced with increasing age. Breed differences in BFT were also reported by Koch *et al.* (1979), Loveday & Dikeman (1980) and Wheeler *et al.* (1996) at constant weight and age end points, while Camfield *et al.* (1999) observed increased ($p < 0.05$) BFT and KPH percentage for steers of smaller framed breed types compared to steers of larger framed breed types. Although Swanepoel *et al.*

(1990) did not observe any significant breed differences in BFT between intensively fed AF, NG and Pedi bulls, percentage kidney and channel fat were higher for Pedi bulls than for AF ($p < 0.05$) and NG bulls ($p < 0.01$). Although no significant differences in BFT, KPH and omental fat were observed among British, Tuli, Boran and Brahman steers with limited access to a corn based diet, differences were significant ($p < 0.05$) with *ad libitum* access to the diet (Sprinkle *et al.*, 1998). However, Tatum *et al.* (1990) observed breed differences ($p < 0.05$) in BFT between Piedmontese, Gelbvieh and Red Angus steers, but not in KPH fat percentage. Contrary to the present results Swanepoel *et al.* (1990) did not observe significant differences in omental fat percentage between the different breeds. Bidner *et al.* (1986) observed higher BFT for pasture raised Hereford Angus cross steers than was observed in the present study.

Increased grain feeding increased BFT as well as kidney fat percentage (Bowling *et al.*, 1977; Young & Kauffman, 1978; Danner *et al.*, 1980; Schroeder *et al.*, 1980; Newsome *et al.*, 1985; May *et al.*, 1992; Schaake *et al.*, 1993). BFT and KPH fat of small framed breeds increased significantly ($p < 0.05$) with increasing energy level in the diet, but not that of large framed breeds (Prior *et al.*, 1977). At equal BFT, Simmentaler cattle had significantly ($p < 0.05$) more KPH fat than Angus cattle (Crouse *et al.*, 1985a). Block *et al.* (2001) found no significant differences in body cavity fat percentage at equal BFT among Angus, Charolais and Hereford steers.

Table 3 Least square means ± s.e. for kidney fat, percentage kidney fat, omental fat, percentage omental fat and back fat thickness by breed and slaughtering age

Slaughter Age (months)	Breed type	N	Kidney Fat (g)	Kidney Fat (%)	Omental Fat (g)	Omental Fat (%)	Back fat thickness (mm)
18	SX	5	969 ± 126	0.54^{a} ± 0.09	1388 ± 159	0.77^{a} ± 0.12	0.97^{a} ± 0.64
	BX	15	1255 ± 73	0.84^{b} ± 0.05	1520 ± 92	1.00^{a} ± 0.07	1.76^{a} ± 0.37
	NG	17	1083 ± 68	0.81^{b} ± 0.05	1667 ± 86	1.26^{b} ± 0.07	2.75^{b} ± 0.35
	Mean	**37**	**1137^{e} ± 103**	**0.78^{e} ± 0.06**	**1570^{e} ± 94**	**1.09^{e} ± 0.06**	**2.11^{e} ± 0.36**
24	BX	5	507 ± 73	0.22 ± 0.03	1051 ± 136	0.46 ± 0.06	1.38 ± 0.31
	NG	12	583 ± 75	0.24 ± 0.02	1023 ± 88	0.43 ± 0.04	1.12 ± 0.20
	Mean	**17**	**561^{f} ± 152**	**0.24^{f} ± 0.08**	**1031^{f} ± 139**	**0.44^{f} ± 0.08**	**1.19^{f} ± 0.54**
30	SX	7	1707^{a} ± 321	0.71^{a} ± 0.16	1615^{a} ± 239	0.67^{a} ± 0.11	1.13^{a} ± 0.93
	BX	11	2101^{a} ± 256	0.95^{ab} ± 0.12	2344^{ab} ± 191	1.07^{b} ± 0.09	3.24^{a} ± 0.74
	AF	5	2183^{ab} ± 380	1.14^{bc} ± 0.18	2027^{b} ± 283	1.04^{b} ± 0.13	6.23^{b} ± 1.10
	NG	18	2709^{b} ± 200	1.38^{c} ± 0.10	2896^{c} ± 149	1.47^{c} ± 0.07	5.56^{b} ± 0.58
	Mean	**41**	**2311^{g} ± 98**	**1.12^{g} ± 0.05**	**2423^{g} ± 90**	**1.18^{e} ± 0.05**	**4.26^{g} ± 0.34**

^{a,b,c} Column means for breed types within a slaughter age group with different superscripts differ ($p < 0.05$).
^{e,f,g} Column means for means at the different slaughter ages with different superscripts differ ($p < 0.05$).

No significant differences among breed types were observed for drip loss (Table 4), while breed affected cooking loss only at 30 months of age when SX steers had a significantly ($p < 0.05$) higher cooking loss than BX, AF, and NG steers. Drip loss was the highest ($p < 0.05$) at 24 months of age, while cooking loss was the highest at 30 months of age. Although Keane & Allen (1998) observed no significant differences in drip loss due to feeding system, they noted differences ($p < 0.05$) among light and heavy slaughter groups. Crouse *et al.* (1984) reported cooking losses for grain as well as pasture raised steers that are similar to that observed in the present study. Camfield *et al.* (1997) reported that although cooking loss was similar for meat from steers fed for 0 and 90 days it was higher ($p < 0.05$) than from steers fed for 30 and 60 days. Comparing Afrikaner, Nguni and Pedi bulls, Swanepoel *et al.* (1990) observed no breed differences in the cooking loss of the *longissimus* muscle, but Whipple *et al.* (1990) observed that cooking loss increased as the percentage of *Bos indicus* increased.

No breed differences were observed for the L- and b-colour values (Table 4). At 18 months the a value was significantly ($p < 0.05$) higher for NG steers than for BX steers. L*- and a*-colour values increased ($p < 0.05$) with increasing animal age (became darker and more red), while b*-colour values were significantly ($p < 0.05$) higher at 24 months of age than at 18 or 30 months of age. Young & Kauffman (1978) and Newsome *et al.* (1985) reported very little dietary effects (forage vs. grain fed) on the subjectively evaluated lean colour of carcasses. However, Newsome *et al.* (1985) found that at 3 days *post-mortem* steaks from grain fed steers had more ($p < 0.05$) reflectance of light than the steaks from forage fed steers. Similarly, Schroeder *et al.* (1980), Bidner *et al.* (1986), Schaake *et al.* (1993) and Bennett *et al.* (1995) reported that forage-fed steers had darker meat (subjectively measured) than grain-fed steers. Similar results were reported by Keane & Allen (1998) for objectively measured Hunterlab L* values among *longissimus* muscle steaks from intensively and extensively reared steers. Keane & Allen (1998) also reported higher a* ($p < 0.05$) and b* colour values ($p < 0.001$) for *longissimus* muscle steaks from intensively raised steers than for *longissimus* muscle steaks from extensively raised steers.

The pH_{24} (Table 4) did not differ significantly among the breed types, but was significantly ($p < 0.05$) lower at 18 months of age than at 24 and 30 months of age.

Table 4 Least square means ± s.e. for percentage drip loss, percentage cooking loss, L*-, a*- and b*-colour values and pH at 24 hours *post-mortem* by breed and slaughter age

Slaughter age (months)	Breed type	N	Drip loss (%)	Cooking loss (%)	Colour			pH_{24}
					L*	a*	b*	
18	SX	5	1.6 ± 0.3	34.4 ± 0.6	36.4 ± 0.8	12.24^{ab} ± 0.51	9.51 ± 0.55	5.60 ± 0.14
	BX	15	1.7 ± 0.1	34.0 ± 0.4	36.9 ± 0.5	12.16^{a} ± 0.30	9.59 ± 0.32	5.54 ± 0.08
	NG	17	1.7 ± 0.1	34.4 ± 0.3	36.3 ± 0.5	13.19^{b} ± 0.29	9.74 ± 0.31	5.38 ± 0.08
	Mean	**37**	**1.6^{e} ± 0.2**	**34.2^{e} ± 0.4**	**36.6^{e} ± 0.3**	**12.62^{e} ± 0.22**	**9.65^{e} ± 0.24**	**5.48^{e} ± 0.04**
24	BX	5	2.7 ± 0.9	34.4 ± 0.8	38.0 ± 0.9	13.52 ± 0.57	6.97 ± 0.48	5.73 ± 0.05
	NG	12	3.5 ± 0.6	35.9 ± 0.5	37.1 ± 0.6	13.91 ± 0.37	7.71 ± 0.31	5.66 ± 0.03
	Mean	**17**	**3.3^{f} ± 0.2**	**35.5^{e} ± 0.6**	**37.3^{e} ± 0.4**	**13.80^{f} ± 0.32**	**7.49^{f} ± 0.35**	**5.68^{f} ± 0.05**
30	SX	7	1.5 ± 0.2	34.7^{a} ± 1.3	33.6 ± 0.6	13.71 ± 0.57	9.18 ± 0.69	5.64 ± 0.05
	BX	11	1.4 ± 0.2	32.3^{abc} ± 1.0	34.0 ± 0.5	14.47 ± 0.42	9.31 ± 0.51	5.68 ± 0.04
	AF	5	1.4 ± 0.3	29.4^{bc} ± 1.5	34.1 ± 0.7	13.87 ± 0.63	8.46 ± 0.76	5.71 ± 0.05
	NG	18	1.4 ± 0.1	31.5^{c} ± 0.8	34.2 ± 0.4	14.67 ±0.33	10.03 ± 0.40	5.61 ± 0.03
	Mean	**41**	**1.4^{e} ± 0.2**	**32.0^{f} ± 0.4**	**34.0^{f} ± 0.3**	**14.18^{g} ± 0.21**	**9.28^{e} ± 0.23**	**5.65^{f} ± 0.03**

^{a,b,c} Column means for breed types within a slaughter age group with different superscripts differ ($p < 0.05$).
^{e,f,g} Column means for means at the different slaughter ages with different superscripts differ ($p < 0.05$).

The only significant ($p < 0.05$) breed difference detected for any sensory trait (Table 5), was for sustained juiciness between meat from the BX and SX steers slaughtered at 30 months of age. No significant differences were detected between any of the age x breed combinations for tenderness (Table 5). However, when the data was pooled for age, the panel rated meat from steers slaughtered at 30 months of age significantly ($p < 0.05$) tougher than meat from steers slaughtered at 18 months of age. At 18 months of age, SX steers had higher ($p < 0.05$) WBS values (less tender) than BX steer, but no significant breed influence was evident at 24 and 30 months of age (Table 5). WBS were similar at 18 (2.62 ± kg) and 24 months of age (2.49 ± kg), but significantly ($p < 0.05$) higher at 30 months of age (3.15 ± kg).

Table 5 Rank means (means) for the sensory quality characteristics and least square means ± s.e for shear force values of the *Longissimus* muscle as influenced by different beef breed x age combinations for steers slaughtered at 18- and 30 months of age respectively.

	Breed x age combinations						LSD[a]
	SX 18	BX 18	NG 18	SX 30	BX 30	NG 30	
Aroma[c]	1.820 (5.960)	1.814 (5.857)	2.029 (6.057)	2.100 (6.133)	1.660 (5.920)	1.880 (6.160)	NS[b]
Initial juiciness[d]	2.120 (6.600)	1.829 (6.486)	1.800 (6.343)	2.000 (6.467)	1.920 (6.560)	1.680 (6.400)	NS[b]
Sustained juiciness[e]	1.880 (5.640)	1.971 (5.742)	1.829 (5.543)	2.033 (5.600)	2.060 (5.920)	1.520 (5.360)	NS[b]
Tenderness[f]	2.100 (6.400)	2.043 (6.629)	1.600 (6.114)	1.933 (5.200)	2.000 (5.720)	1.640 (5.480)	NS[b]
Residue[g]	2.120 (6.680)	2.000 (6.743)	1.629 (6.486)	1.833 (5.733)	2.060 (6.600)	1.640 (6.160)	NS[b]
Flavour[h]	2.020 (6.240)	1.757 (5.743)	1.943 (6.057)	1.900 (5.867)	1.980 (6.280)	1.680 (6.040)	NS[b]
Shear force	3.27[i] ± 0.34	2.37[j] ± 0.20	2.66[ij] ± 0.18	3.71 ± 0.32	2.98 ± 0.25	3.07 ± 0.20	

[a] LSD=Least significant difference (p=0.05)
[b] NS=Not significant (p>0.05)
[c] 1=Extremely bland; 8=Extremely intense
[d] 1=Extremely dry; 8=Extremely juicy
[e] 1=Extremely dry; 8=Extremely juicy
[f] 1=Extremely tough; 8=Extremely tender
[g] 1=Abundant; 8=None
[h] 1=Extremely unflavourable; 8=Extremely flavourable
[ij] shear force values with different superscripts differ significantly ($p < 0.05$)

The present results are in agreement with the results of Casey *et al.* (1990) who did not observe any breed differences in WBS values or sensory panel tenderness of the *longissimus* muscle of AF, NG and Pedi bulls. Similarly, Crouse *et al.* (1985a) did not find significant differences in WBS values or sensory panel tenderness of *longissimus* and *semimembranosus* steaks from Angus and Simmentaler cattle. Although Strydom *et al.* (2001) did not find significant differences in WBS values between different strains of Bonsmara or NG bulls, sensory panel tenderness differed ($p < 0.05$) among the different strains. In contrast, Strydom *et al.* (2000) reported in earlier research that although Santa Gertrudis bulls had higher ($p < 0.05$) WBS values than Bonsmara, Pinzgauer, Brown Swiss Afrikaner and NG bulls, sensory panel tenderness did not differ significantly between the various breeds. Similar results were reported by Koch *et al.* (1979), Knapp *et al.* (1989) and Wheeler *et al.* (1996). On the other hand, Whipple *et al.* (1990) reported that WBS values for *longissimus* muscle steaks increased ($p < 0.05$) and that sensory panel tenderness decreased ($p < 0.01$) as the percentage *B. indicus* increased, but not in steaks from the *semimembranosus* muscle.

Mixed results were reported for dietary effects (especially the effect of energy or grain content) on WBS and sensory panel traits of beef. Prior *et al.* (1977) reported little influence of dietary energy and protein level on WBS and sensory traits of meat from small framed Angus x Hereford and large framed Charolais and Chianina steers and concluded that all carcasses of both types of cattle had acceptable palatability. Significantly higher WBS values and lower tenderness ratings were observed for pasture-finished than for grain-finished steers (Bowling *et al.*, 1977; Schroeder *et al.*, 1980). Schaake *et al.* (1993) as well as Bennett *et al.* (1995) reported lower WBS values for *longissimus* muscle steaks of feedlot steers than for steaks of pasture raised steers, but steaks of pasture fed steers were rated more tender than steaks of feedlot fed steers by a trained sensory panel. Short *et al.* (1999) observed that WBS values decreased (became more tender) and that sensory panel tenderness increased ($p < 0.01$) with increasing time on a feedlot diet. Although the results of Camfield *et al.* (1997) and Keane & Allen (1998) also indicate a tendency for WBS values to decrease and sensory panel tenderness ratings to increase with increasing time in a feedlot, it was not significant. Crouse *et al.* (1984) and Bidner *et al.* (1986) reported no effect of diet on WBS values or sensory panel tenderness of the *longissimus* muscle. Although Crouse *et al.* (1985b) also observed no significant influence of diet on the WBS values of meat, the sensory panel rated meat produced on a low energy diet to be more tender ($p < 0.01$) than meat produced from a high energy diet.

Breed and age did not affect any of the other sensory traits evaluated significantly (Table 5). Similar results were reported by Koch *et al.* (1979), Knapp *et al.* (1989), Whipple *et al.* (1990), Wheeler *et al.* (1996) and Strydom *et al.* (2000) for juiciness and flavour. Breed differences ($p < 0.05$) for connective tissue amount and flavour intensity scores, but not for juiciness scores were observed by Tatum *et al.* (1990). Whipple *et al.* (1990) observed that connective tissue amount score (similar to residue in Table 5) decreased (became more) with increasing *B. indicus*, but similar to the results of the present study, Knapp *et al.* (1989) and Strydom *et al.* (2000) found no significant difference among breeds in the score for connective tissue amount with increasing *B. indicus*.

Casey *et al.* (1990) found no significant differences among breeds for juiciness, flavour and residue, but residue score decreased with increasing slaughter weight. Keane & Allen (1998) observed higher juiciness scores at higher slaughter weights. Juiciness scores also increased with increasing levels of marbling, but flavour intensity were not affected significantly (Wheeler *et al.*, 1996).

Although, Crouse *et al.* (1985a) also observed no breed effects for juiciness, flavour and connective tissue amount, but the meat from the low energy diet had a lower connective tissue content ($p < 0.01$) and flavour intensity score ($p < 0.05$) than beef from the high energy diet. Similar results were reported by Bowling *et al.* (1977), Schroeder *et al.* (1980), Bidner *et al.* (1986) and Bennet *et al.* (1995). Camfield *et al.* (1997) and Short *et al.* (1999) reported that connective tissue content and flavour intensity scores increased with increased time on feed, but juiciness was not affected by time in a feedlot. Similarly, May *et al.* (1992) observed that connective tissue content scores increased with increasing time in a feedlot, but juiciness and flavour intensity were not affected. In contrast, no significant differences in sensory panel scores were observed for beef from grain and pasture fed heifers (Crouse *et al.,* 1984) and varying levels of energy in the diet (Prior *et al.*, 1977). Inconsistent results for juiciness and connective tissue content for beef produced from pastures and various times in a feedlot were also reported by Schaake *et al.* (1993), while Young and Kauffman (1978) observed lower ($p < 0.05$) juiciness and higher ($p < 0.05$) flavour intensity scores for forage fed compared to grain fed steers.

Discussion

Differences in LW and CCW among the breed types used in this study are in general agreement with results from previous studies in that larger frame sized breed types attain heavier final weights and have heavier carcasses than smaller frame sized breed types. The observed differences in carcass compactness are in agreement with the results of Tatum *et al.* (1986b) who indicated that there is a strong correlation (r = 0.96) between hip height and frame size, but a low correlation (ranging from 0.09 to 0.48) between other body measurements (body length, width and girth) and frame size. They indicated that although all body measurements increased with an increase in frame size, body length, width and girth were not always proportional to corresponding differences in heights. Large framed animals thus tend to be disproportionately tall with relative short and narrow bodies, compared to small framed cattle that were short, but relatively highly developed in length, width and girth.

Even though the internal fat components measured were significantly ($p < 0.05$) higher for NG steers than for the other SX, BX and AF steers, they had similar dressing percentages than the SX and BX steers. The reason for this is possibly due to the relatively lighter hide (Swanepoel *et al.*, 1990) of NG as well as differences in fat partitioning. Swanepoel *et al.* (1990) reported that at a LW of 390 kg, hides from NG bulls weighed approximate 1.5 kg less that that of AF bulls. NG steers also accumulated more carcass fat than the other breeds as their BFT doubled from 18 to 30 months of age, while that of BX increased with 84 % and that of SX steers with 16 %. All fat parameters were the lowest ($p < 0.05$) at the end of the dry winter season (24 months of age) when the nutritional value of the natural pasture is at its lowest. This led to a higher gut fill, lower fat cover and possibly a higher cooler shrinkage and consequently, the combined effect resulted in the lower ($p < 0.05$) dressing percentage observed at 24 months of age. Although the effect of diet on gut fill and dressing percentage has been described for forage vs. grain diets (Prior *et al.*, 1977; Young & Kauffmann, 1978; Schroeder *et al.*, 1980; Bidner *et al.*, 1986; Bennet *et al.*, 1995; Keane & Allen, 1998), the same principal is likely to apply to high quality summer pastures with high moisture contents. Furthermore, Schroeder *et al.* (1980) indicated that carcasses from forage-fed cattle tended to have a higher cooler shrinkage than carcasses from grain fed cattle. They speculate that this may be due to the lower fat cover of forage fed cattle, resulting in a higher carcass moisture loss.

Although breed did not have a major effect on the meat quality attributes, slaughter age did. Meat quality was lower at 24 months of age than at 18- or 30 months of age. Although this could have been due to poor grazing conditions prior to slaughter at 24 months of age, it does not seem that a low muscle glycogen concentration was responsible for these results. The meat quality attributes followed an opposing pattern to that reported by Immonem *et al.* (2000) for different levels of residual muscle glycogen. The only similarity to the results of Immonen *et al.* (2000) is for the drip losses observed at the respective ages. Although not significant, beef with a low residual glycogen level had a higher drip loss than beef with higher glycogen levels similar to the higher ($p < 0.05$) drip loss observed for steers slaughtered at 24 months of age compared to steers slaughtered at 18- and 30 months. pH_{24} was not high enough to result in dark cutting meat. It appears that meat quality was probably influenced by carcass fatness than by muscle glycogen concentration.

Devine *et al.* (1993) observed that young lambs (7 months of age) have lower ($p < 0.05$) ultimate pH values than older lambs (14 months of age), which is similar to what was observed in the present study. Young *et al.* (2004) concluded that the most desirable range for muscle pH that results in the best properties for table cuts is 5.4 to 5.6. The results of Devine *et al.* (1993) support this conclusion as they reported that WBS increased as the ultimate pH increased from 5.5 to 5.9 and also that WBS values of meat from young and older animals with similar pH values were similar. Devine *et al.* (1993) concluded that age-related tenderness effects were minor compared to pH effects. Rees *et al.* (2003) indicated that the rate of pH and temperature decline can influence tenderness due to two main factors; (1) Cold shortening occurs when the temperature falls below 10 ºC while muscle pH is still above 6.0 and (2) if the temperature declines slowly and pH rapidly, protein denaturation may occur. The latter event leads to a reduction of the proteolytic processes necessary for tenderization of meat. The fat thickness of the carcass is believed to be associated with a part of the difference in tenderness of beef due to its effect on temperature decline and thus also pH decline. Bowling *et al.* (1977) reported that sarcomere length and panel tenderness ratings increased while shear force values decreased when fat thickness increased from 1.27 mm to 8.9 mm, while May *et al.* (1992) found no improvement in tenderness after steers reached a BFT of 7.6 mm. Although the role of pH can not be ignored completely, it is doubtful that pH had the major influence on the tenderness of the meat. Most probably, the natural aging processes and its effects on the content and properties of collagen as explained by Hill (1966), Bailey (1985) and McCormick (1994) played a more prominent role. Although the pH_{24} of the steers slaughtered at 24 and 30 months fell marginally outside the range defined by Young *et al.* (2004), the WBS values and sensory panel tenderness ratings were still within acceptable tenderness norms. WBS values higher than 5.0 kg (Whipple *et al.*, 1990) were deemed unacceptable, while panel tenderness scores between 6.82 and 7.44 (scale of 1 to 9) were deemed moderately tender by Koch *et al.* (1979). Although a trained sensory panel identified differences in tenderness among steers slaughtered at 18 and 30 months of age, these differences were not large and were within a moderately tender class. It is thus unlikely that consumers will discriminate against beef from 30 month old steers compared to beef from 18 month old steers.

Conclusions

While breed and slaughter age influenced LW and carcass traits significantly, slaughter age had a much more pronounced influence on meat quality traits than breed, possibly the result of the combined effects of fatness, pH and collagen characteristics. Although slaughtering steers from natural pastures in the sweet veld areas can successfully be done with small framed steers at 18 as well as with small to medium framed steers at 30 months of age, carcasses of small framed steers at 18 months of age may be too small to be readily accepted by the market. It may thus be more advantageous to supplement or even feedlot steers to be slaughtered before the age of 30 months of age. This aspect, however, requires further research to determine the nutritional and cost implications that may result of this practice. As WBS values and sensory panel tenderness scores were within moderately tender norms, it is doubtful that consumers will discriminate against beef from pasture raised steers slaughtered at 30 months of age. Rigid slaughtering ages at the end of the wet season were used in this study, undoubtedly the quality of the grazing were already in a decreasing phase. Thus steers may be in better condition prior to 18 and 30 months of age. Visual appraisal from 26 months of age onwards may identify animals suitable for slaughtering at a slightly younger age.

References

Acocks, J.P.H., 1988. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 57.

American Meat Science Association (1978). *Guidelines for cookery and sensory evaluation of me*at. Chicago, IL: American Meat Science Association, National Livestock and Meat Board.

Bailey, A.J., 1985 the role of collagen in the development of muscle and its relationship to eating quality. *J. Anim. Sci.* 60, 1580-1587.

Bennett, L.L., Hammond, A.C., Williams, M.J., Kunkle, W.E., Johnson, D.D., Preston, R.L. & Miller, M.F., 1995. Performance, carcass yield and carcass quality characteristics of steers finished on Rhizoma peanut (*Arachis glabrata*) – Tropical grass pasture or concentrate. *J. Anim. Sci.* 73, 1881-1887.

Bidner, T.D., Schupp, A.R., Mohamad, A.B., Rumore, N.C., Montgomery, R.E., Bagley, C.P. & Mcmillin, K.W., 1986. Acceptability of beef from Angus-Hereford or Angus-Hereford-Brahman steers finished on all-forage or a high-energy diet. *J. Anim. Sci.* 62, 381-387.

Block, H.C., McKinnon, J.J., Mustafa, A.F. & Christensen, D.A., 2001. Manipulation of cattle growth to target carcass quality. *J. Anim. Sci.* 79, 133-140.

Bowling, R.A., Smith, G.C., Carpenter, Z.L., Dutson, T.R. & Oliver, W.M., 1977. Comparison of forage-finished and grain-finished beef carcasses. *J. Anim. Sci*. 45, 209-215.

Brand, A.A., Cloete, S.W.P. & Coetzee, J., 1989. Urea ammoniation of wheat, oat and barley straw and oat hay. 1. A laboratory investigation into the effect of urea and moisture level and treatment period on chemical composition and *in vitro* digestibility. *S. Afr. J. Anim. Sci*. 19, 4-10.

Camfield, P.K., Brown, A.H., Jr., Lewis, P.K., Rakes, L.Y. & Johnson, Z.B., 1997. Effects of frame size and time-on-feed on carcass characteristics, sensory attributes and fatty acid profiles of steers. *J. Anim. Sci.* 75, 1837-1844.

Camfield, P.K., Brown, A.H., Jr., Johnson, Z.B., Brown, C.J., Lewis, P.K. & Rakes, L.Y., 1999. Effects of growth type on carcass traits of pasture- or feedlot-developed steers. *J. Anim. Sci.* 77, 2437-2443.

Casey, N.H., Swanepoel, J., de Bruyn, J.F. & Naudé, R.T., 1990. Meat studies of indigenous Southern African cattle. II. Textural evaluation of ribcut samples from carcasses of Afrikaner, Nguni and Pedi bulls fed intensively. *S. Afr. J. Anim. Sci.* 20, 188-192.

Cianzio, D.S., Topel, D.G., Whitehurst G.B., Beitz, D.C. & Self, H.L., 1982. Adipose tissue growth in cattle representing two frame sizes: Distribution among depots. *J. Anim. Sci.* 55, 305-312.

Cloete, S.W.P. & Kritzinger, N.M., 1985. A Laboratory assessment of various treatment conditions affecting the amoniation of wheat straw by urea. 2. The effect of physical form, moisture level, and prolonged treatment period. S. Afr. J. Anim. Sci. 15, 137-141.

Crouse, J.D., Cross, H.R. & Seideman S.C., 1984. Effects of a grass or grain diet on the quality of three beef muscles. *J. Anim. Sci.* 58, 619-625.

Crouse, J.D., Ferrel, C.L. & Cundiff, L.V., 1985a. Effects of sex condition, genotype and diet on bovine growth and carcass characteristics. *J. Anim. Sci.* 60, 1219-1227.

Crouse, J.D., Cross, H.R. & Seideman S.C., 1985b. Effects of sex condition, genotype, diet and carcas electrical stimulation on the collagen content and palatibility of two bovine muscles. *J. Anim. Sci.* 60, 1228-1234.

Dolezal, H.G., Tatum, J.D. & Williams, F.L., Jr., 1993. Effects of feeder cattle frame size, muscle thickness, and age class on days fed, weight, and carcass composition. *J. Anim. Sci.* 71, 2975-2985.

Danner, M.L., Fox, D.G. & Black, J.R., 1980. Effect of feeding system on performance and carcass characteristics of yearling steers, steer calves and heifer calves. *J. Anim. Sci*. 50, 394-404.

Dekker, B., Kirkman K.P. & Du Plessis, S.I., 2001. Use of the dry-weight-rank method of botanical analysis in semi-arid savanna communities. *Afr. J. Range For. Sci*. 19, 63-68.

Devine, C.E., Graafhuis, A.E., Muir, P.D. & Chrystall, B.B., 1993. The effect of growth rate and ultimate pH on meat quality of lambs. *Meat Sci*. 35, 63-77.

Dolezal, H.G., Tatum, J.D. & Williams, F.L., Jr., 1993. Effects of feeder cattle frame size, muscle thickness and age class on days fed, weight and carcass composition. *J. Anim. Sci.* 71, 2975-2985.

Erasmus, J.A. & Barnard, H.H., 1985. Supplementary winter feeding and reproduction of beef heifers on Dohne sourveld. *S. Afr. J. Anim. Sci*. 15, 162-164.

Gertenbach, W.D. & Van H. Henning, P.W., 1995a. Energy supplementation of yearling steers at different stocking rates on Nile grass pasture. S.Afr. J. Anim. Sci. 25, 105-108.

Gertenbach, W.D. & Van H. Henning, P.W., 1995b. Performance of beef steers on Smuts finger grass and Nile grass pasture in Northern Natal. 2. Feedlot performance following summer grazing. *S. Afr. J. Anim. Sci.* 25, 101-104.

Fortin, A., Veira, D.M., Froehlich, D.A., Butler, G. & Proulx, J.G., 1985. Carcass characteristics and sensory properties of Hereford x Shorthorn bulls and steers fed different levels of grass silage and high moisture barley. *J. Anim. Sci.* 60, 1403-1411.

Hill, F., 1966. The solubility of intramuscular collagen in meat animals of various ages. *J. Food Sci*. 31, 161-166.

Honikel, K.O., (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Sci*. 49, 447-457.

Immonen, K., Ruusunen, M. & Puolanne, E., 2000. Some effects of residual glycogen concentration on the physical and sensory quality of normal pH beef. *Meat Sci*. 55, 33-38.

Keanne, M.G. & Allen, P., 1998. Effects of production system intensity on performance, carcass composition and meat quality of beef cattle. *Livest. Prod. Sci*. 56, 203-214.

Knapp, R.H., Terry, C.A., Savell, J.W., Cross, H.R., Mies W.L. & Edwards, J.W., 1989. Characterization of cattle types to meet specific beef targets. *J. Anim. Sci.* 67, 2294-2308.

Koch, R.M., Dikeman, M.E., Allen, D.M., May, M., Crouse, J.D. & Campion, D.R., 1976. Characterization of biological types of cattle. III. Carcass composition, quality and palatability. *J. Anim. Sci.* 43, 48-62.

Koch, R.M., Dikeman, M.E., Lipsey, R.J., Allen, D.M. & Crouse, J.D., 1979. Characterization of biological types of cattle – Cycle II: III. Carcass composition, quality and palatability. *J. Anim. Sci.* 49, 448-460.

Lademann, E.E., 1992. Faktore wat herkonsepsie van vleisraskoeie in die Noord-Transvaalse Soetbosveld beïnvloed. M. Sc. Thesis, University of Pretoria. pp 249.

Le Roux, C.J.G., Swart, J.S., Oosthuysen, E., Trethewey, C., Pittaway, C. & Daines, T., 1999. Prediction of cattle performance on Coastcross 2 at different fertilizer and stocking rates. *S. Afr. J. Anim. Sci.* 29, 64-68.

Loveday, H.D. & Dikeman, M.E., 1980. Diet energy and steer type effects on adipose composition, lopogenesis and carcass composition. *J. Anim. Sci*. 51, 78-88.

May, S.G., Dolezal, H.G., Gill, D.R., Ray, F.K. & Buchanan, D.S., 1992. Effects of days fed, carcass grade traits and subcutaneous fat removal on post mortem musle characteristics and beef palatibility. *J. Anim. Sci.* 70, 444-453.

McCormick, R.J., 1994. The flexibility of the collagen compartment of muscle. *Meat Sci*. 30, 79-91.

Meaker, M.J., 1993. The effect of genotype on cow efficiency in extensive beef production in the northern Transvaal sweet Bushveld. M.Sc. (Agric) Thesis, University of Pretoria. pp 179.

Meaker, H.J. & Barnard, J.C., 1988. Beef steers implanted with short, medium and long-acting anabolic compounds grazing natural pastures and finished in feedlot. *S. Afr. J. Anim. Sci*. 18, 68-71.

Newsome, R.L., Moody, W.G., Lanlois, B.E., Gay, N., Mcmillan, M. & Fox, J.D., 1985. Effects of cattle-finishing systems on carcass traits and aging methods on loin shrinkage and steak color. *J. Anim. Sci.* 60, 1208-1218.

Prior, R.L., Kohlmeier, R.H., Cundiff, L.V., Dikeman, M.E. & Crouse, J.D., 1977. Influence of dietary energy and protein on growth and carcass composition in different biological types of cattle. *J. Anim. Sci*. 45, 132-146.

Rees, M.P., Trout G.R. & Warner R.D., 2003. The influence of the rate of pH decline on the rate of ageing for pork. I: Interaction with method of suspension. *Meat Sci*. 65, 791-804.

SAS (1990). *SAS/STAT User's guide, Version 6.* (4th Edition). Cary, NC: SAS Institute Inc.

Schaake, S.L., Skelley, G.C., Halpin, E., Grimes. L.W., Brown, R.B., Cross, D.L. & Thompson, C.E., 1993. Carcass and meat sensory traits of steers finished on fescue and clover, summer forage, or for different periods in drylot. *J. Anim. Sci.* 71, 3199-3205.

Schroeder, J.W., Cramer, D.A., Bowling, R.A. & Cook, C.W., 1980. Palatability, shelf life and chemical differences between forage- and grain finished beef. *J. Anim. Sci.* 50, 852-859.

Short, R.E., Grings, E.E., MacNeil, M.D., Heitschmidt, R.K., Williams, C.B. & Bennett, G.L., 1999. Effects of sire growth potential, growing-finishing strategy and time on feed on performance, composition and efficiency of steers. *J. Anim. Sci.* 77, 2406-2417.

Snyman, L.D. & Joubert, H.W., 2002. The chemical composition and in vitro dry matter digestibility of untreated and ammoniated crop residues. *S. Afr. J. Anim. Sci.* 32, 83-87.

Sprinkle, J.E., Ferrel, C.L., Holloway, J.W., Warrington, B.G., Greene, L.W., Wu, G. & Stuth, J.W., 1998. Adipose tissue partitioning of limit-fed beef cattle and beef cattle with *ad libitum* access to feed differing in adaptation to heat. *J. Anim. Sci.* 76, 665-673.

Stevenson, J.M., Seman, D.L.., Weatherall, I.L. & Littlejohn, R.P., 1989. Evaluation of venison color by an objective method using calieb values. *J. Food Sci.* 54, 1661-1662.

Strydom, P.E., Naudé, R.T., Smith, M.F., Scholtz, M.M. & van Wyk, J.B., 2000. Characterisation of indigenous African cattle breeds in relation to meat quality traits. *Meat Sci*. 35, 79-88.

Strydom, P.E., Naudé, R.T., Smith, M.F., Kotze, A., Scholtz, M.M. & van Wyk, J.B., 2001. Relationships between production and product traits in subpopulations of Bonsmara and Nguni cattle. *S. Afr. J. Anim. Sci*. 31, 181-194.

Swanepoel, J., Casey, N.H., de Bruyn, F.J. & Naude, R.T., 1990. Meat studies od indigenous southern African cattle. I. Growth preformance and carcass characteristics of Afrikaner, Nguni and Pedi bulls fed intensively. *S. Afr. J. Anim. Sci.* 20, 180-187.

Tatum, J.D., Dolezal, H.G., Williams, F.L., Jr., Bowling, R.A. & Taylor R.E., 1986a. Effects of feeder-cattle frame size and muscle thickness on subsequent growth and carcass development. II. Absolute growth and associated changes in carcass composition. *J. Anim. Sci.* 62, 121-131.

Tatum, J.D., Dolezal, H.G., Williams, F.L., Jr., Bowling, R.A. & Taylor R.E., 1986b. Effects of feeder-cattle frame size and muscle thickness on subsequent growth and carcass development. I. An objective analysis of frame size and muscle thickness. *J. Anim. Sci.* 62, 109-120.

Tatum, J.D., Gronewald, K.W., Seideman, S.C. & Lamm W.D., 1990. Composition and quality of beef from steers sired by Piedmontese, Gelbvieh and Red Angus bulls. *J. Anim. Sci.* 68, 1049-1060.

Taute, A., Van Niekerk, W.A., Rethman, N.F.G. Coertze, R.J., 2002. An evaluation of Nitrogen fertilised *Panicum maximum* cv. Gatton at different stages of maturity during autumn: 1. Dry matter yield and certain qualitative parameters. *S. Afr. J. Anim. Sci*. 32, 208-216.

Van Zyl, J.G.E., 1990. Studies on the performance and efficiency of pure and crossbred cattle in an arid Bushveld environment. Ph. D. (Agric) Thesis, University of Pretoria. pp 183.

Venter, H.A.W., 1977. Die invloed van voorspeense groei by sekere vleis-, dubbeldoel- en kruisrasse in die Noord-Transvaalse Soetbosveld. D.Sc. (Agric) Thesis, University of Pretoria. pp 331.

Viljoen, D. L., Muller, M., De Swart, J. B., Sadie, A. & Vosloo, M. C. (2001). Computerized electronic temperature control system for thermal efficiency during baking in food research. *International Journal of Consumer Studies, 25,* 30-42.

Voisey, P.W., 1976. Engenering assessment and critique of instruments used for meat tenderness evaluation. *J. Textural Studies*. 7, 11-13.

Wheeler, T.L., Cundiff, L.V., Koch, R.M. & Crouse, J.D., 1996. Charcterization of biological types of cattle (Cycle IV): Carcass traits and *longissimus* palatability. *J. Anim. Sci.* 74, 1023-1035.

Whipple, G., Koohmaraie, M., Dikeman, M.E., Crouse, J.D., Hunt, M.C. & Klemm, R.D., 1990. Evaluation of attributes that affect longissimus muscle tenderness in *Bos taurus* and *Bos indicus* cattle. *J. Anim. Sci.* 68, 2716-2728.

Young, A.W. & Kauffman, R.G., 1978. Evaluation of beef from steers fed grain, corn silage or haylage-corn silage diets. *J. Anim. Sci.* 64, 41-47.

Young, O.A., West, J., Hart, A.L. & van Otterdijk, F.F.H., 2004. A method for early determination of meat ultimate pH. *Meat Sci*. 66, 493-498.

CHAPTER 5

Effect of marketing strategy on the production performance of beef cattle herds from four different breed types in the Arid Sweet Bushveld

I du Plessis[1, 2#] & LC Hoffman[2]
[1] Limpopo Province Department of Agriculture, Mara Research Station, Private Bag X2467, Louis Trichardt, 0920, South Africa
[2] Department of Animal Science, University of Stellenbosch, P. Bag X1, Matieland, 7602, South Africa

Abstract

Various breed types and productions systems are used to produce beef from natural pastures. In arid regions with erratic rainfall patterns, flexible production systems will assist the sustainable use of land. Cattle breed types (Simmentaler cross, Bonsmara cross, Afrikaner and Nguni) differing in frame size were used to illustrate the effect of marketing strategy (weaners vs. 30 month old steers) on production performance. The actual pregnancy, weaning and growth rates determined for the respective breed types were used to calculate production performance. For all breed types marketing steers at 30 months of age resulted in more kilograms live weight marketed than when marketing weaner calves. Differences in kilograms live weight produced were also observed between the various breed types (Nguni > Bonsmara cross > Simmentaler cross > Afrikaner). The reproduction rate of the cows and the survival rates of the calves had a more pronounced influence on production efficiency than the growth rate of the calves. The characteristics of the respective breed types must be taken into account when deciding on a breed type as well as the production and marketing system to be followed.

Introduction

Producers use different breeds of cattle differing in frame size combined with different production and marketing strategies to produce meat from natural pastures in arid regions.

In arid regions the rainfall is erratic and unreliable. Pressure on land-users to use land sustainably, is increasing. Adjustments in various aspects of land use are necessary to accomplish this. Using breed types and production systems that are adapted to a specific environment and the climatic conditions prevalent in that environment becomes increasingly important.

The choice of the most suitable production system should not be based on what short term benefits the one holds over the other, but rather the long term benefits and sustainability thereof. The aim of this study is to provide production guidelines for two marketing strategies (weaners or 30 month old steers) that can be followed with various breed types of cattle and to highlight some of the benefits of the two marketing systems.

Materials and methods

The study was conducted from 1995 to 2002 on approximately 4 387 ha on the eastern side of the Mara Research Station (23° 05' S and 29° 25' E; 961 m.a.s.l). The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988). The vegetation in the study area include the woody species *Acacia tortilis*, *Commiphora pyracanthoides, Boscia albitrunca* and *Grewia* spp. and the grass species *Eragrostis rigidior, Panicum maximum, Urochloa mosambicensis* and *Digitaria eriantha* (Dekker *et al.*, 2001). The long term mean rainfall is 452 mm of which approximately 80 % occur from November to March. During the study period, the mean annual rainfall (measured from July to June) was 453 mm (Table 1). The mean daily maximum temperature ranged from 22.6 °C in June to 30.4 °C in January.

Table 1 Annual rainfall during the study period

Year	Rainfall (mm)
1995/1996	447
1996/1997	533
1997/1998	589
1998/1999	232
1999/2000	343
2000/2001	846
2001/2002	368
2002/2003	263
Mean	**453**

In this investigation the productivity of four different breeds/frame sizes on sweet veld was evaluated. Cows consisting of approximately $^{2}/_{3}$ Simmentaler were mated with Simmentaler bulls, they and their offspring representing large framed breed types (SX). Cows (*ca.* $^{2}/_{3}$ Afrikaner) were mated with Bonsmara bulls. They and their offspring representing medium framed breed types (BX). Purebred Afrikaner (AF) and Nguni (NG) cattle represented small-medium and small framed breed types respectively. Cows were selected throughout the trial period to comply with weight criteria (Table 2). The different herds were kept in separate, but adjacent camps. To reduce possible camp effects, camps were not allocated in blocks but randomly and evenly dispersed over the whole study area. As far as it was practically possible cow herds were kept in close proximity to each other. The metabolic *postpartum* weight (Meisner *et al*, 1983) of the cows was used to balance the stocking rates and care was taken that stocking rates did not exceed 12 ha per LSU.

Mating took place from the 1st of January for 63 days. Heifers (13 to 15 months old) were also mated. Pregnancy testing was done during May or June. Calves were born from the end of October until the middle of December. All calves were weaned simultaneously when the last calves reached 205 days of age (June). Castration took place during the weaning phase. All losses were recorded. Other herd management practices (e.g. dipping, vaccination) were standardised for all breeds. No supplementary feeding or licks were supplied.

Table 2 Mature weight criteria and cow numbers used to select cows and to balance stocking rates

Breed type	Abbreviation	Mature weight criteria (kg)	Number of cows
Simmentaler cross	SX	> 500	30
Bonsmara cross	BX	450 – 500	32
Afrikaner	AF	400 – 450	34
Nguni	NG	< 400	38

Live weights of all animals were recorded at 28-day intervals after withholding food and water for at least 12 hours. Live weights of steers were determined up to 30 months of age and that of females throughout their life span in the herd. All calculations were based on the means in the tables for the respective breed types. The production potential of cow herds similar in metabolic weight and LSU (65 LSU) for each breed type subjected to a weaner (205 days) as well as a steer (30 months of age) marketing system was calculated. All references to year refer to the year that mating took place. Thus parameters like weaning percentage and weaning weights were calculated in relation with the cow data for the mating season that the calves were conceived in. Herd weaning efficiency (HWE) as summarised in Table 5 was calculated using the following equations:

$$HWE = \frac{\text{Kg weaned}}{\text{Kg mated}} \times 100$$

This gives an indication of the kg calf weaned per 100 kg cows mated. With this formula all factors contributing to preweaning losses (conception rate, abortions, illnesses, etc.) were taken into account.

Although the yearly performances of the different breed types are presented in the tables, it is not discussed in detail, as only the means are used in calculations. It thus serves to clarify how the mean values were calculated and to indicate year to year differences in performances.

Results

No data is available for NG and SX cows for 1995 as the NG cows and some SX cows were transferred to the Mara Research Station during 1995, thus no initial data was available for the NG herd and due to adaptation problems the SX herd had a low pregnancy rate. The AF cattle were transferred from the Mara Research Station at the end of 2000 and therefore no further data (after 2000) is available for this breed.

Pregnancy rates varied substantially between years for all breeds (Table 3). The pregnancy rates of NG differed the least between years. The overall pregnancy rates of SX and BX cows were close to the average performance of all animals over the trial period. Afrikaner cows had lower pregnancy rates for most years, while NG cows had the highest pregnancy rates. The pregnancy rates of the 13 to 15 month old heifers differed more than that of the cows. AF heifers performed the poorest, while SX heifers had the best conception rates.

Pregnancy rates for cows and heifers are presented separately to indicate possible explanations for differences between breed types. AF cows had lower conception rates than the other breeds, but the AF heifers had such a low pregnancy rate that the pregnancy rate of the herd became even lower compared to the other herds.

Table 3 Pregnancy rates of the Simmentaler cross, Bonsmara cross, Afrikaner and Nguni cow herds from 1995 to 2002.

		Cows			Heifers			Herd		
Breed	Year	n	Preg	%	n	Preg	%	n	Preg	%
Simmentaler cross	1995									
	1996	30	26	86.7	12	9	75.0	42	35	83.3
	1997	29	27	93.1	7	5	71.4	36	32	88.9
	1998	28	18	64.3	5	1	20.0	33	19	57.6
	1999	17	13	76.5	10	7	70.0	27	20	74.1
	2000	20	16	80.0	6	5	83.3	26	21	80.8
	2001	19	19	100.0	4	2	50.0	23	21	91.3
	2002	23	20	87.0	10	5	50.0	33	25	75.8
	Mean	**166**	**139**	**83.7**	**54**	**34**	**63.0**	**220**	**173**	**78.6**
Bonsmara cross	1995	32	23	71.9	6	1	16.7	38	24	63.2
	1996	29	24	82.8	12	7	58.3	41	31	75.6
	1997	32	28	87.5	11	8	72.7	43	36	83.7
	1998	28	19	67.9	5	2	40.0	33	21	63.6
	1999	21	18	85.7	16	7	43.8	37	25	67.6
	2000	23	23	100.0	8	7	87.5	31	30	96.8
	2001	30	25	83.3	9	4	44.4	39	29	74.4
	2002	38	35	92.1	15	2	13.3	53	37	69.8
	Mean	**233**	**195**	**83.7**	**82**	**38**	**46.3**	**315**	**233**	**74.0**
Afrikaner	1995	30	16	53.3	10	1	10.0	40	17	42.5
	1996	30	23	76.7	14	5	35.7	44	28	63.6
	1997	34	25	73.5	9	0	0.0	43	25	58.1
	1998	24	17	70.8	3	0	0.0	27	17	63.0
	1999	18	18	100.0	10	0	0.0	28	18	64.3
	2000	27	23	85.2	7	0	0.0	34	23	67.6
	2001									
	2002									
	Mean	**163**	**122**	**74.8**	**53**	**6**	**11.3**	**216**	**128**	**59.3**
Nguni	1995									
	1996	27	26	96.3	5	2	40.0	32	28	87.5
	1997	30	30	100.0	13	10	76.9	43	40	93.0
	1998	31	26	83.7	7	3	42.9	38	29	76.3
	1999	28	26	92.9	13	8	61.5	41	34	82.9
	2000	32	30	93.8	14	10	71.4	46	40	87.0
	2001	36	34	94.4	12	9	75.0	48	43	89.6
	2002	47	41	87.2	17	4	23.5	64	45	70.3
	Mean	**231**	**213**	**92.2**	**81**	**46**	**56.8**	**312**	**259**	**83.0**

Weaning rates as expressed in Table 4, includes losses such as abortions, distocia, illnesses, accidents and theft. In 1997 six NG calves were stolen which is why the weaning rate was so low in 1997. SX and AF herds weaned less than 80 % of the calves expected from the pregnancy rates, while BX and NG herds weaned more than 80 % of the expected calf crop.

Table 4 Weaning rates of the Simmentaler cross, Bonsmara cross, Afrikaner and Nguni cow herds from 1995 to 2001

	Simmentaler cross			Bonsmara cross			Afrikaner			Nguni		
Year	**A** n	**B** n	**C** %	**A** n	**B** n	**C** %	**A** n	**B** n	**C** %	**A** n	**B** n	**C** %
1995	21	16	76.2	24	22	91.7	17	12	70.6			
1996	35	25	71.4	31	28	90.3	28	17	60.7	28	27	96.4
1997	32	24	75.0	36	28	77.8	25	23	92.0	40	31	77.5
1998	19	16	84.2	21	20	95.2	17	14	82.4	29	28	96.6
1999	20	14	70.0	25	20	80.0	18	17	94.4	34	31	91.2
2000	21	13	61.9	30	26	86.7				40	35	87.5
2001	21	12	57.1	29	27	93.1				43	39	90.7
Mean	**169**	**120**	**71.0**	**196**	**171**	**87.2**	**105**	**83**	**79.0**	**214**	**191**	**89.3**

A – Number pregnant; B – Number weaned; C – Percentage weaned

The very low HWE (Table 5) of the AF herd is mainly due to poor reproductive performance, especially that of the heifers. Although growth rate is also reflected in HWE, it is not the major contributor to HWE. The NG herd with the lowest weaning weights, had the highest HWE with high pregnancy rates as well as survival rates of calves being the main contributors.

Mean live weights at 30 months of age is summarised in Table 6. This end point (30 months) was selected for calculations, because it is deemed to be the optimum age for marketing steers from natural sweet pastures. At this age they have grazed through two summer seasons during which the nutritional status of the natural pasture is high enough to sustain high growth rates. Fortunately animals do not routinely loose weight on natural sweet pastures during winter. In fact, they tend gain, but at a slow rate.

The following assumptions were made in calculating herd productivity for both the weaner (Table 7) and the 30 month old steer (Table 8) marketing systems:

- Post weaning losses are small and the same between the different herds and were not taken into account.
- To maintain the same grazing pressure on the pasture, 40 % more females can be kept in the herd if a weaner-marketing system is followed than when a 30-month-old-steer-marketing system is followed.
- The number of females mated includes the 13 to 15 month old heifers, as they were included in establishing the performance norms.
- A cow replacement rate of 20 % was used for all breed types and both marketing systems.
- For the steer marketing systems only animals to be marketed was taken into account, but it must be taken into account that although it takes a steer 30 months to be marketed, the cow herd is still producing offspring and that there will be weaners and 18 month old steers in the herd at the time of marketing.

Table 5 Herd weaning efficiency for Simmentaler cross, Bonsmara cross, Afrikaner and Nguni herds from 1995 to 2001

Breed type	Year	Cow weight	Weaning weight	Kg weaned/100 kg mated
Simmentaler cross	1995			
	1996	22 802	6 908	30.30
	1997	17 896	6 016	33.62
	1998	11 598	4 060	35.01
	1999	11 138	3 836	34.44
	2000	11 378	3 510	30.85
	2001	11 132	2 750	24.70
	Total	**85 944**	**27 080**	**31.51**
Bonsmara cross	1995	13 042	4 222	32.37
	1996	17 462	7 080	40.55
	1997	19 464	6 208	31.89
	1998	10 042	4 750	47.30
	1999	13 836	4 628	33.45
	2000	12 664	6 196	48.93
	2001	17 321	5 214	30.10
	Total	**103 831**	**38 298**	**36.88**
Afrikaner	1995	11 942	2 222	18.61
	1996	13 930	3 098	22.24
	1997	17 486	6 180	35.34
	1998	11 134	2 744	24.65
	1999	11 068	3 344	30.21
	2000			
	2001			
	Total	**65 560**	**17 588**	**26.83**
Nguni	1995			
	1996	8 884	4 344	48.90
	1997	14 512	5 456	37.60
	1998	9 156	4 864	53.12
	1999	12 256	5 846	47.70
	2000	13 096	6 092	46.52
	2001	15 662	6 420	40.99
	Total	**73 566**	**33 022**	**44.89**

Table 6 Mean live weight (± s.d.) of Simmentaler cross, Bonsmara cross, Afrikaner and Nguni steers at 30 months of age

Breed type	Abbreviation	Live weight (kg)
Simmentaler cross	SX	575.0 ± 57.7
Bonsmara cross	BX	549.7 ± 61.3
Afrikaner	AF	460.4 ± 44.3
Nguni	NG	440.7 ± 32.8
Mean		**508.3 ± 76.0**

Table 7 Calculations for total live weight (kg) produced annually per breed for the Simmentaler cross, Bonsmara cross, Afrikaner and Nguni cow herds marketing weaners

Kg weaned /100 kg mated	Factor	Kg produced /cow	n females mated	Total kg produced	Kg bull calves produced	n culled cows	Kg culled cows marketed	n culled heifers	Kg culled heifers marketed	Total kg marketed
Simmentaler cross herd										
31.51	5.25	165.4	50	8 270	4 135	8	4 200	6	1 560	9 895
Bonsmara cross herd										
36.88	4.75	175.2	54	9 461	4 731	9	4 275	8	1 792	10 798
Afrikaner herd										
26.83	4.25	114.0	58	6 612	3 306	10	4225	3	636	8 167
Nguni herd										
44.89	3.75	168.3	66	11 108	5 554	11	4 125	13	2 249	11 928

Table 8 Calculations for total live weight produced (kg) annually per breed for the Simmentaler cross, Bonsmara cross, Afrikaner and Nguni cow herds marketing 30 month old steers

n females mated	% Pregnant	n calves born	% Weaned	n steer marketed	Steer weight (kg)	Kg steers marketed	N culled cows	Kg culled cows marketed	N culled heifers	Kg culled heifers marketed	Total kg marketed
Simmentaler cross herd											
36	78.6	28	71.0	10	575	5 750	6	3 150	4	475	10 800
Bonsmara cross herd											
38	74.0	28	87.2	12	549	6 588	6	2 850	6	2 550	11 988
Afrikaner herd											
41	59.3	24	79.0	10	460	4 600	7	2 975	2	750	8 325
Nguni herd											
47	83.0	39	89.3	18	441	7 938	8	3 000	9	2 925	13 863

Discussion

Although actual data was used in all calculations, differences and similarities that occurred allow for comparisons between herds ignoring growth rate of the calves. Higher growth rates favouring the larger breed types did not result in changes in the rankings of the breed types in terms of kg to be marketed. Thus it is concluded that growth rate of the calves play a minor role in the production performance of the cow herd. The two factors that had the largest effect on the production performance of the cow herd were reproduction rate and calf survival rate.

The differences in production performance between the SX herd and the BX herd is mainly due to differences in their calf survival rate (71.0 % vs. 87.2%) as the pregnancy rates were similar (78.6 % vs. 74.0%). Differences in production performance between the BX and the NG herds are mainly due to differences in pregnancy rate (74.0 % vs. 83.0 %) as the calf survival rates (87.2 % vs. 89.3 %) were similar. The AF herd produced less than all the other herds due to its low pregnancy as well as calf survival rates.

There seems to be a 10 % advantage to the steer production system compared to the weaner marketing system (Tables 7 and 8). Possible reasons for this are that advantage was taken of the rapid growing phases during the wet summer months. The maintenance requirements of a reproducing and lactating cow herd are probably higher than for growing animals. It was not calculated whether this difference in production will be offset by the differences in price of the marketed products (weaners vs. steers).

Advantages of a weaner marketing system include earlier initial financial returns, reduced risk in losing animals after weaning and higher per kg prices. Disadvantages include less flexibility in marketing strategy, sentiments may develop towards productive cows and thus cows are not easily sold. Advantages of steer marketing systems include, flexible marketing strategies are possible, herd numbers can be more readily adapted to rainfall without reducing cow numbers. Disadvantages include, a longer initial lag time before financial returns are received, risk of losing animals after weaning and it takes longer after low rainfall and reduction of herd numbers to have marketable animals.

Conclusions

Although specific differences between breed types were observed for various traits under the study conditions, it will not necessarily be the case for different environmental conditions and management practices. A different feeding or supplementation strategy could also have enhanced the reproductive performance of the cows, especially the young heifers. If the reproductive performances of the respective herds are more comparable, the growth rate of the calves will start to play a more pronounced role in the production efficiency of the herds.

The characteristics of the respective breed types must also be taken into account when deciding on a breed type as well as the production and marketing system that is to be followed. For example, NG calves are not popular with feedlots, while Simmentaler steers do not finish well from pastures alone.

This study provided production norms that can be used to calculate economic returns for each individual producer. It was not done in this paper, as management and, specific on farm circumstances can differ a lot between producers.

References

Acocks, J.P.H., 1988. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa 57.

Dekker, B., Kirkman K.P. & Du Plessis, S.I., 2001. Use of the dry-weight-rank method of botanical analysis in semi-arid savanna communities. *Afr. J. Range For. Sci.* 19, 63-68.

Meissner, H.H., Hofmeyer, H.S., Van Rensburg, W.J.J. & Pienaar, J.P., 1983. Classification of livestock for realistic prediction of substitution values in terms of a biologically defined Large Stock Unit. Technical Communication No. 175, Department of Agriculture, Republic of South Africa.

CHAPTER 6

Final conclusions and applications

Introduction

Although it does not fall within the scope of this study, grazing management forms the crucial foundation of any cattle production system. This is especially true in the arid regions. The Arid Sweet Bushveld was identified in 1971 as a predominantly grazing area with little room for intensive farming practices (Coetzee, 1971). Coetzee (1971) also highlighted several reasons that create and aggravate the production stability of the region, namely:

- Farmers ignore the natural grazing capacity of the natural pastures.
- Farmers are overly optimistic about the climatic conditions.
- Farmers try to extract the maximum out of the natural pasture and thereby over utilize the pasture. This leads to lower pasture production. The problem is exacerbate when animal numbers are increased in an effort to increase financial returns.
- Grazing camps are primarily erected to graze the pasture more intensively and to assist with animal handling and not to assist with pasture management.
- Farm units are too small to be economically viable units.

Although no recent survey is available, it is safe to assume that none of the above have changed significantly and that the situation may even be worse today.

In arid regions with erratic rainfall patterns, the carrying capacity of an area is not constant, but varies considerably between years. Applying the correct grazing pressure for a specific rainfall season will undoubtedly have the most impact on the long term stability and profitability of any cattle enterprise. Applying beef production systems that are flexible, will assist in the application of suitable grazing management principals and maximizing animal production. Coetzee (1971) recommended that steer production systems are preferable for the more arid regions of the sweet Bushveld. Although more reasons may exist for farmers still preferring weaner production systems, the most important one is probably the economic situation of farmers, aggravated by the reasons stated above. Another reason is that no clear and scientifically founded production norms and guidelines exist to convince producers of the advantages of converting to steer production systems. Many studies regarding production efficiency were conducted at Mara Research Station, but all of them focussed on weaner production and did not include growth and carcass norms for producing steers. Many studies with regards to pastures and roughage were also conducted, but the focus was mainly on the enhancement of the nutritional value of the forage. With this study many of these shortcomings with regards to post weaning growth, carcass production and meat quality were addressed. The aim of this chapter is to put the results in context with beef production systems that are adapted to arid regions with sweet natural pastures.

Summary of results

The following results obtained from this study were used in calculations and in the drafting of flow diagrams for the various proposed production systems:

- Pregnancy rates of the cows and 13 to 15 month old heifers followed the same pattern across breed types and resulted in pregnancy rates of 79.3, 76.5, 59.8 and 86.1 % for Simmentaler (SX), Bonsmara cross (BX), Afrikaner (AF) and Nguni (NG) herds respectively.
- No significant differences in the preweaning survival rate of the different breed type calves were observed. (SX = 80.4 %, BX = 85.0 %, AF = 90.3 %, NG = 87.9 %).
- Birth and weaning weights were the heaviest for SX (41.1 kg and 241 kg), followed by BX (36.1 kg and 214 kg), AF (32.1 kg and 181 kg) and NG (26.2 kg and 162 kg).
- Live weights increased from 367.1, 387.1, 321.8 and 289.8 kg at 18 months of age to 419.5, 395.3, 330.9 and 378.9 kg at 24 months of age to 575.0, 549.7, 460.4 and 440.7 kg at 30 months of age for SX, BX, AF and NG respectively.
- Carcass weight increased from 174.4, 184.6, 150.9 and 141.7 kg at 18 months of age to 211.0, 196.7, 156.6 and 175.2 kg at 24 months of age to 297.7, 284.9, 225.4 and 230.2 kg at 30 months of age for SX, BX, AF and NG respectively.
- At 18 months of age 50 % of BX, AF and NG carcasses achieved a 1 fat classification code, whereas the rest of the carcasses achieved a 2 classification code. Most SX carcasses achieved a 0 fat classification code. At 24 months of age most BX, AF and NG carcasses achieved a 1 fat classification code, while most SX carcasses acheived a 0 fat classification code. At 30 months of age 78 % of BX, AF and NG carcasses achieved a 2 fat classification code and 15 % even a 3 fat classification code. SX carcasses achieved mainly (75 %) a 1 fat classification code.
- At 18 months of age most steers still had no permanent incisors, while at 24 months of age 60 % had no permanent incisors, 10 % had one permanent incisor and 30 % had 2 permanent incisors. At 30 months of age 75 % had two permanent incisors, and 24 % three or four permanent incisors.
- All fat parameters (amount and % of kidney and omental fat as well as back fat thickness) were at their lowest at 24 months of age after the dry winter season and at their highest at 30 months of age at the end of the wet summer season. At 18 months of age fat parameters were higher than at 24 months of age, but lower than at 30 months of age.

- The effect of breed and age on the meat quality parameters were not important, except that meat from 18 month old carcasses was more tender, judged by the Warner-Bratzler shear force values as well as sensory panel tenderness scores, than the meat of 30 month old steers.
- When the production and reproduction parameters obtained with this study were used to calculate production per herd, more marketable kg live weight was produced following a 30 month old steer marketing strategy than a weaner marketing strategy. With both marketing strategies the production order of the respective breed types was NG > BX > SX > AF. The best calculated production per herd was achieved with NG marketing steers at 30 months of age and the worst with AF marketing weaner calves.

General recommendations

- The influence of breed type is more pronounced on the production efficiency of the cow herd than on the finishing of steers and will thus play a more important role in production systems involving cows than in production systems involving only steers.
- Management practices, such as increased concentrate feeding, that could improve the reproductive performance of larger frame cows and could increase the production outputs of these breed types to be comparable with that of smaller frame size breed types. However, these management practices will increase the financial inputs into the herd. Whether this will also increase the financial returns from the herd is uncertain and falls outside the scope of this study.
- In terms of carcass quality and extra weight gained per animal, the worst time to slaughter steers from natural pastures is at 24 months of age after the dry winter season.
- Acceptable carcasses are produced at 18 as well as 30 months of age , but at 18 months of age carcasses may too light, especially if small framed breed types are used.
- Steers of large framed breed types with mature cow weights exceeding 500 kg will not finish from natural pastures and are best suited for production systems marketing weaners or long weaners to feed lots.
- Steers of small to medium framed breed types with mature cow weights of less than 500 kg, will finish from natural pastures at 30 months of age without supplementary feeding.
- Small to medium framed steers will need to be supplemented or feedlot fed for a short period if they are to be slaughtered at 18 months of age.
- Although some carcasses will be classified in the B age class at 30 months of age, Warner-Bratzler shear force values and sensory panel scores for various attributes, indicate that the beef of 30 month old animals will still be acceptable to consumers.
- Although this study was conducted in the Arid Sweet Bushveld, the results should to a large extent also apply to other arid regions where the natural pastures exhibit sweet veld characteristics (maintain a relatively high nutritional value during the dry winter season).

Adaptable production systems

In a weaner marketing system, the only animals to be sold are weaners and culled cows. If stocking rates have to be reduced due to climatic conditions, productive females have to be sold. This tends to discourage the timely reduction of animal numbers, rendering it a rigid marketing system not suited to the Arid Sweet Bushveld. The production of weaners is thus deemed to be more suitable to regions with reliable rainfall patterns, i.e. with a reliable source of food.

In arid regions a conservative approach to any beef production enterprise will ensure long term stability of the production system. Focussing on short term financial returns may initially result in relatively high returns, but the production system will become unstable in the long term. The following production systems were identified as being suitable to the Arid Sweet Bushveld, lending flexibility to rapidly adapt stocking rates to environmental conditions:

- Buying light weight weaners (< 200 kg) and selling long weaners at 290 kg.
- Buying weaners and marketing them at 30 months of age.
- Producing and marketing steers at 18 months of age from a nucleus cow herd.
- Producing and marketing steers at 30 months of age from a nucleus cow herd.

Only numbers applicable to BX cattle will be presented in the flow diagrams, but starting numbers will be stated for AF and NG. It is assumed for all systems that the breeding season is during the summer months as is the predominant practice in the Arid Sweet Bushveld. This results in calves being weaned May, June and July.

LSU for the different breed types for the different animal age and production classes were adapted from Meissner *et al*. (1983).

Purchasing weaners and marketing long weaners

Light weight weaners, not exceeding 200 kg in live weight, are purchased and kept on natural pastures until they reach 290 kg. Weaners are purchased during the early dry season (May, June and July). Although light weight weaners are purchased, they should still be the type of animals that the feedlot will be interested in at a later stage. Hence light weight weaners from large and medium frame size breeds that will adapt easily to feedlot conditions must still be purchased. In the arid regions and on fairly good pastures, the weaners should gain between 20 and 25 kg until the onset of the rainy period and should on average reach a live weight of 290 kg by March. The marketing date is however not rigid as the aim is to sell the long weaners to a feedlot before they reach 300 kg live weight. As the animals reach the target marketing weight, it becomes critically important that they are weighed at regular intervals and so to ensure that they do not overshoot the target weight. Marketing animals that weigh more than 300 kg will result in a lower price per kg. Animals will thus be marketed from February to April. Another crucial aspect of this marketing system is that a large enough area should be rested through the summer season to accommodate the replacement animals to be bought during the next winter season.

To stock 250 LSU's approximately 298 SX, 325 BX and 368 AF weaners can be purchased. NG type cattle are not recommended for marketing to feedlots as they tend to be discriminated against.

Advantages of this marketing system include:

- The forced summer resting of the natural pasture will benefit the pasture, animals and eventually the producer.
- Due to utilizing the pasture during the wet summer season, an indication of the condition of the winter grazing is obtained at an early stage.
- Animal numbers can rapidly be adapted to changing grazing conditions by changing firstly purchasing and then also marketing patterns.

Disadvantages of this marketing system include:

- Animals are purchased at a stage when the natural pasture can only sustain a very low growth rate. Animals have to be kept until the onset of the wet season before substantial gains are made.
- If animal numbers are not adapted to changes in grazing conditions, it may result in lower returns and in the worst case even financial losses.
- External factors (feed and price margins) can change the purchasing pattern of feedlots over a short period of time (weeks), increasing the risk of producing a product for which thereis no demand.
- Steers of the right type and age are not always readily available for purchase.

In terms of adaptability to arid environments, this marketing system is rated third best system due its speculative nature as well as the risk factors introduced by the erratic rainfall pattern and the unpredictable purchasing behaviour of feedlots. With the necessary caution it can however be practised successfully in all the arid regions.

Purchasing weaners and marketing 30 month old steers

In essence this marketing system rests on the same principals as selling long weaners, but animals are sold at a stage when they are ready to be slaughtered. To take full advantage of an inexpensive food resource, it is preferable to keep animals until they are approximately 30 months of age. During this time two periods of high growth are utilised, while an organic product that is still acceptable to consumers is produced.

Weaners are purchased during May to July and kept for approximately 18 months when they can be marketed directly through an abattoir. Although steers were only slaughtered at 30 months of age in this study, steers may be marketable at an earlier stage (>26 months). Regular visual appraisal for steers that are finished off will thus assist in identifying marketable animals and slaughtering at an optimal stage. It is not recommended that large framed animals be used for this marketing system as they do not achieve carcass finish on natural pastures. Small to medium frame size breed types will all be ready for slaughter with this marketing strategy. Steers of two age groups will always be accommodated on the farm, except when climatic conditions change purchasing and marketing strategies.

To stock 250 LSU's approximately 142 BX, 171 AF and 189 NG weaners can be purchased annually. An equal number of 18 month old animals were purchased the previous year, thus the total number of animals on the farm will be 284, 342 and 378 for BX, AF and NG respectively.

Advantages of this marketing system include:

- No cow herd to manage and maintain.
- The two periods when the growth rates are high, are utilised.
- Stocking rate can rapidly be adapted to prevailing climatic conditions through alterations in purchasing and marketing strategies.
- The production system is less speculative and more production orientated and thus more stable in nature.
- An acceptable lean, organically product is produced.

Disadvantages of this marketing strategy include:

- Due to the longer production period, the risk to lose animals due to diseases, accidents and theft.
- The need to market may arise during a period in the year that beef/animal prices are low.
- Steers are not always readily available for purchase.

In terms of adaptability to arid environments this marketing system is rated the best system, especially in regions with a highly erratic rainfall pattern and with a mean annual rainfall of less than 400 mm.

Producing and marketing steers at 18 months of age from a nucleus cow herd

In general, production systems involving cow herds are more suitable to regions with higher and more reliable rainfall. These include regions with a mean annual rainfall of more than 400 mm. These regions will seldom receive less than 250 mm rain during a specific year. With the correct stocking rates this should be enough to sustain at least the largest proportion of the cow herd. During dry seasons the stocking rate can be reduced by marketing more steers than usual, while with weaner marketing systems productive cows must be marketed. Thus if the need arises to reduce cow numbers with the steers production system, it is not necessary to reduce cow numbers substantially. The production nucleus of the system thus stays relatively intact. A summer mating season is applied at the Mara Research Station and is deemed to be best suited for arid environments as fluctuations in nutrient requirements of cows are then synchronised with the fluctuations in nutrient supply from the pasture.

Large frame size breed types will not be suited for this marketing system as they will not be ready for slaughter at 18 months of age. Small and medium frame size breed types will be better suited for this marketing system as a proportion of the steers will be finished off and be ready for marketing at this age. To ensure that all the steers are finished off, some additional feeding will be necessary.

To stock 250 LSU's the nucleus cow herd should consist of approximately 100 BX, 108 AF and 120 NG cows. A basic flow diagram as an example of the herd structure and outputs for the Bonsmara cross herd are presented in Figure 1. Reproduction and calf survival rates will influence the outcome of the flow diagram, but for the sake of following a conservative approach the low reproduction and calf survival rates obtained with this study were used in the calculations.

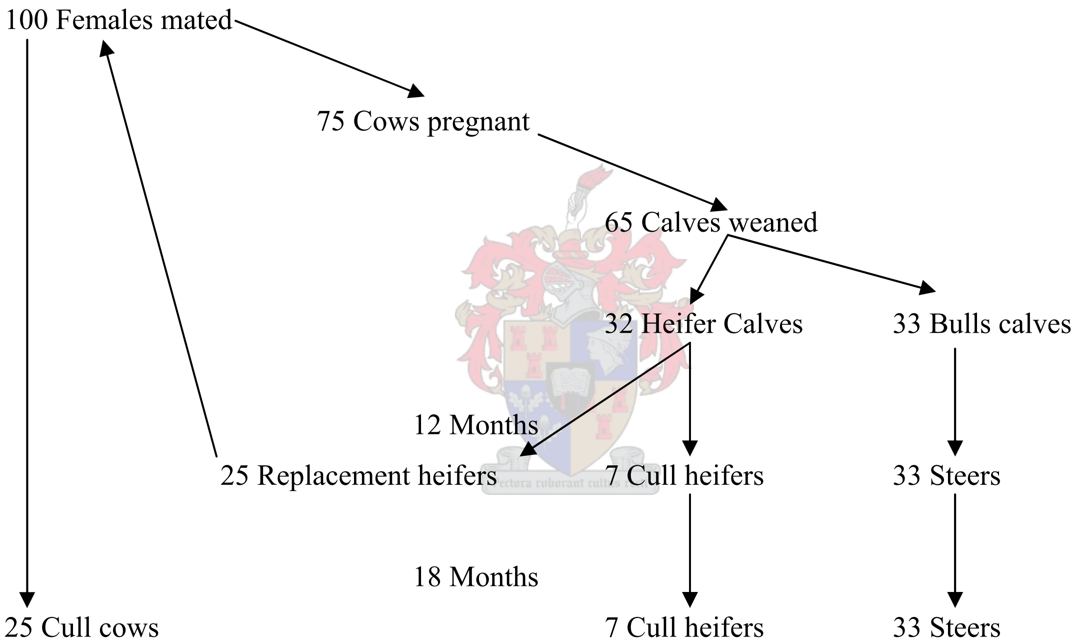


Figure 1 A flow diagram of the herd composition for the Bonsmara cross herd, marketing steers at 18 months of age

Advantages of this marketing strategy include:

- Stocking rates can be adjusted to rainfall without reducing cow numbers and, when necessary, with only a minor reduction in cow numbers.
- If cow numbers were reduced, the reproductive herd size will be back at the optimal level in a relatively short time.
- The marketing strategy has some flexibility.

Disadvantages of this marketing strategy include:

- Although steers may be finished off at 18 months, the carcasses are very small.
- It must be accepted that even with small frame size breed types some of the animals will not finish off from natural pastures at 18 months.
- The risk exists that some animals may be lost post weaning.
- The need to market may arise during a period in the year that beef/animal prices are low.

In terms of adaptability to arid environments this marketing system is rated the worst system of the four proposed systems. It is however still rated better than a weaner production system, but only recommended if the producer is prepared to invest in sufficient supplementary feeding to ensure that carcasses of acceptable weight are produced. Large and medium frame size breed types will be most suitable for this marketing system.

Producing and marketing steers at 30 months of age from a nucleus cow herd

When steers are marketed at 30 months of age instead of 18 months of age the nucleus cow herd will be even smaller, rendering it a more conservative marketing system than the 18 month marketing system. During severe droughts, even more LSU's in the form of steers are available to reduce the stocking rate. It will very seldom, if ever, be necessary to reduce cow numbers significantly in order to adjust the stocking rate to the available pasture material.

Some animals may be finished off before the age of 30 months. Regular visual appraisal for carcass finish from about 26 months (March) will assist in timely identifying marketable animals. These animals can be slaughtered sooner. This will result in more grazing being available to the remaining animals.

It is not recommended that large framed animals be used for this marketing system as they do not finish off on natural pastures. Supplementing large frame breed types to be finished off at 30 months may result in very heavy carcasses. Small to medium frame size breed types will all finish off with this marketing strategy.

Advantages of this marketing strategy include:

- Stocking rates can easily be adjusted to rainfall by reducing steers while it will seldom be necessary to reduce cow numbers significantly.
- Optimal cow herd size is reached within one or two years after a serious reduction of animal numbers.
- The use of the two high growth rate stages where at least a portion of that growth is due to compensatory growth.
- Animals finish off from the natural pasture without the need for extra supplementation.
- Marketing strategy can be very flexible.

Disadvantages of this marketing strategy include:

- With poor financial management, cash flow can be problematic after reduction of animal numbers.
- The risk exists that some animals may be lost post weaning.
- The need to market may arise during a period in the year that beef/animal prices are low.

To stock 250 LSU's the nucleus cow herd will consist of approximately 76 BX, 83 AF and 91 NG cows respectively. A basic flow diagram as an example of the herd structure and outputs for the Bonsmara cross herd are presented in Figure 2. Again a conservative approach is followed and the low pregnancy and calf survival rates obtained in this study were used in the calculations.

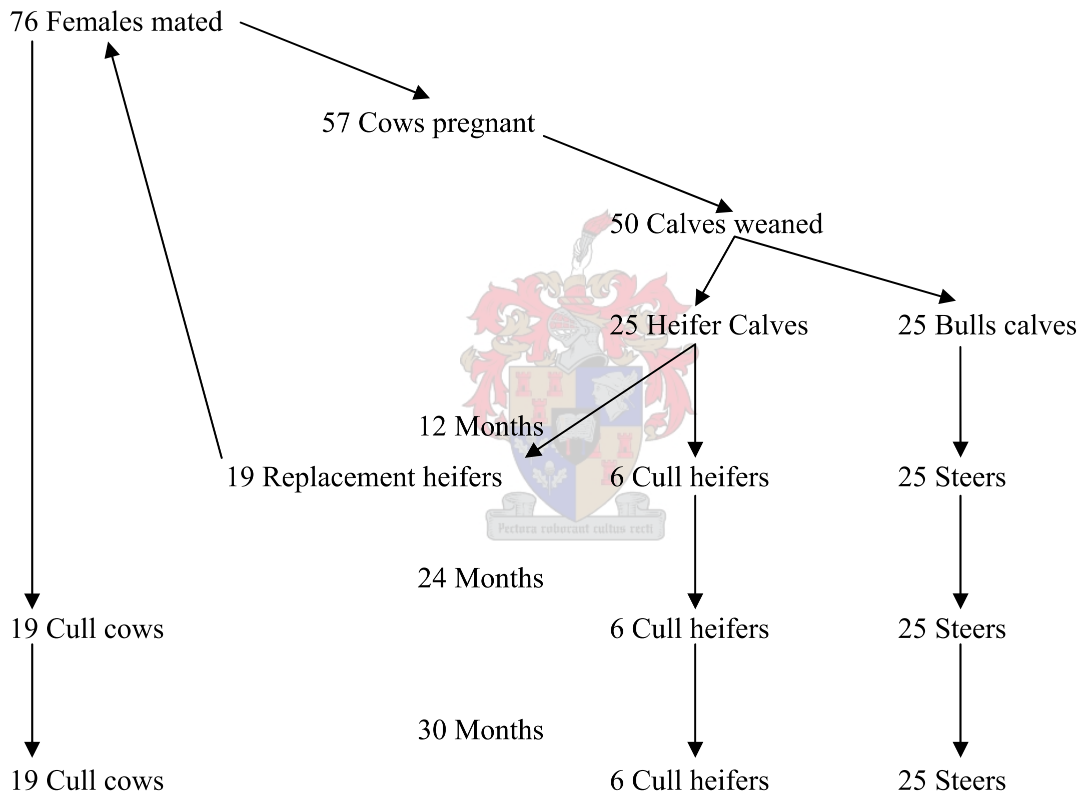


Figure 2 A flow diagram of the herd composition for the Bonsmara cross herd, marketing steers at 30 months of age

This marketing system is the preferred marketing system for arid regions with a long term mean annual rainfall of more than 400 mm. Although the rainfall in these areas are still erratic, forage production is stable enough that with good pasture management this smallish cow herd can be sustained even through dry years.

Future research

Although many aspects of raising and finishing steers from natural sweet pastures were addressed with this study, quite a few aspects still need to be researched and norms be set.

- This study only focussed on three fixed age end points at the end of the different seasons. It can be expected that the quality of the pasture is already deteriorating at that stage, thus the possibility that animals may be finished off earlier than 18 and 30 months of age, should be investigated.
- Sex effects were not researched, thus the growth and development as well as the carcass and meat quality of heifers and bulls raised on natural sweet pastures still need to be addressed.
- The role of supplementary feeding on growth and carcass quality of animals grazing natural sweet pastures is still unclear and only open to speculation. This aspect needs to be clarified.
- Although it is expected that results from this study could also be applicable to other arid environments, growth and carcass studies should also be conducted in other arid environments to verify the degree of applicability of results among the different arid regions.
- Producing beef from natural pastures opens up opportunities to enter into markets demanding organically produced agricultural products. The effect of the required management practices to meet organically produced status on the production efficiency of various production systems need to be researched.
- As there are indications that fat from pasture raised animals tends to contain more unsaturated fatty acids than beef produced from high energy diets, the effect of supplementation and possible changes in fatty acid composition with increasing age must be investigated.
- This study focussed only on the biological aspects of beef production. Models relating these biological aspects to financial returns need to be developed.

References

Coetzee, J.J., 1971. Die Landboupotensiaal van die Noordwes-Transvaalse Soetbosveld. D. Agric (Inst. Agrar) Thesis. University of Pretoria. pp 245.

Meissner, H.H., Hofmeyer, H.S., Van Rensburg, W.J.J. & Pienaar, J.P., 1983. Classification of livestock for realistic prediction of substitution values in terms of a biologically defined Large Stock Unit. Technical Communication No. 175, Department of Agriculture, Republic of South Africa.