Cattle production on communal rangelands of South Africa and the potential of *Acacia karroo* in improving Nguni beef production

By

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Submitted in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN ANIMAL SCIENCE

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August 2009

Declaration

I, Cletos Mapiye, declare that this dissertation has not been submitted to any University and that it is my original work conducted under the supervision of Prof. M. Chimonyo, Prof K. Dzama and Dr. P. E. Strydom. All assistance towards the production of this work and all the references contained herein have been duly credited.

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List of Abbreviations

*a**	redness of meat
ADF	acid detergent fibre
ADG	average daily gain
AG	albumin-globulin ratio
AK	*Acacia karroo*
ALP	alkaline phosphatase
ALT	alanine aminotransferase
AOAC	Association of Official Agricultural Chemists
AMSA	American Meat Science Association
AST	aspartate aminotransferase
*b**	yellowness of meat
BCS	body condition score
CIE	Commission International De IôEclairage
CK	creatinine kinase
CN	control diet
CP	crude protein
CPE	cattle production efficiency
CPP	cattle production potential
DM	dry matter
DMD	dry matter disappearance
ECDC	Eastern Cape Development Corporation
EDTA	ethylene diamine tetra acetic acid

FAO	Food and Agriculture Organisation of the United Nations
GC	gas chromatography
GGT	gamma glutamyltransferase
GLM	generalised linear model
*L**	lightness (brightness) of meat
LTL	*m. longissimus thoracis et lumborum*
LU	livestock unit
M	number of mature cattle consumed or sold
MBA	muscle bundle areas
MFA	muscle fibre areas
MFI	myofibrillar fragmentation index
MFL	myofibril fragment length
MUFA	monounsaturated fatty acids
n-3	omega-3 fatty acids
n-6	omega-6 fatty acids
NAD^+	nicotinamide adenine dinucleotide (oxidised form)
NADH	nicotinamide adenine dinucleotide (reduced form)
NDA	National Department of Agriculture, South Africa
NDF	neutral detergent fibre
NEFA	non-esterified fatty acids
NPL	non-pregnant and lactating
NPNL	non-pregnant and non-lactating
PCV	packed cell volume

PL	pregnant and lactating
PNL	pregnant non-lactating
PUFA	polyunsaturated fatty acids
SAS	Statistical Analysis Systems
SF	sunflower cake
SFA	saturated fatty acids
SIP	serum inorganic phosphorus
TP	total protein
UFH	University of Fort Hare
WBSF	Warner Bratzler shear force
WHC	water holding capacity
vs	Versus

Abstract

Cattle production on communal rangelands of South Africa and the potential of *Acacia karroo* in improving Nguni beef production

By

C. Mapiye

The broad objective of the current study was to evaluate cattle production on communal rangelands and the potential of *Acacia karroo* in improving Nguni beef production in the Eastern Cape Province of South Africa. A total of 218 structured questionnaires were administered to identify constraints of smallholder cattle farmers in the sweet and sour rangelands in the Eastern Cape, South Africa. As a follow up, 90 households were monitored over a year to determine the effect of season, rangeland type and herd size on cattle production potential (CPP) and cattle production efficiency (CPE) on communal rangelands in the Eastern Cape Province of South Africa. Body weight, body condition score (BCS) and serum concentrations of nutritionally-related metabolites were also determined seasonally in 100 Nguni and crossbred cattle raised on communal rangelands in the Eastern Cape, South Africa. The effects of supplementing *Acacia karroo* leaf meal on growth performance, blood chemistry, carcass traits, meat quality attributes, fatty acid composition and sensory characteristics of Nguni steers were also evaluated. In this experiment, thirty 19-month old Nguni steers were randomly assigned to *A. karroo* leaf meal (AK), sunflower cake (SF) and the control (CN) that consisted of natural pasture grazing. The *m. longissimus thoracis et lumborum* was sampled for meat quality, fatty acid composition and sensory quality analyses.

Despite the importance of constraints varying with production systems and rangeland types, the smallholder farmers ranked shortage of feed as the most important constraint. Even though the cattle production potential (CPP) was lower ($P < 0.05$) in the sweet rangelands, households in these areas had higher ($P < 0.05$) CPE, especially in the cool-dry season compared to those in the sour rangelands. Nguni cattle had lower ($P < 0.05$) serum cholesterol, non-esterified fatty acids (NEFA) and glucose concentrations, but higher ($P < 0.05$) phosphorus concentration in the hot-wet season than the crossbreds. The Nguni breed had lower ($P < 0.05$) albumin, urea and creatinine than the crossbreds, especially in the dry season. Steers that were supplemented with AK and SF diets had higher ($P < 0.05$) total protein, albumin, urea, NEFA, phosphorous, calcium, magnesium and iron concentrations, but lower ($P < 0.05$) glucose and cholesterol concentrations than those that received the CN diet. Even though steers that received the AK diet had higher ($P < 0.05$) body condition score (BCS), average daily gain, carcass weights, protein content and gross margin than those given the CN diet, they were out-performed by those that received the SF diet. The highest meat redness and colour saturation values were observed in steers that received AK diet. Beef from steers that received the AK diet had the highest Ŭ-linolenic acid, eicosopentaenoic acid, docosapentaenoic acid, poly-unsaturated fatty acids to saturated fatty acids ratio, and lowest omega-6 to omega-3 fatty acids ratio. Diet had no effect on beef sensory attributes. It was concluded that low feed quality, particularly low protein content in the dry season was the major factor limiting Nguni cattle production on communal rangelands. Protein deficiency in the dry season could, however, be rectifed by feeding *A. karroo* leaf meal, which can cheaply improve growth performance, carcass traits, beef quality and fatty acid profiles of Nguni cattle.

Acknowledgements

I express my utmost gratitude to my supervisors, Prof M. Chimonyo, Prof K. Dzama and Dr P. E. Strydom for their expert guidance and counselling in the development of this thesis. I also acknowledge Dr V. Muchenje for his invaluable comments and sustained interest in my work and Dr S. Dube for processing payments for my sample analyses. The technical staff in the Department of Livestock and Pasture Science: Messrs D. Pepe, W. Sibanga, M. Nyanga and F. Mhlanga also assisted in data collection. I thank the staff at the University of Fort Hare farm for their unwavering support in managing research animals. I will forever be grateful for the veterinary expertise of Dr M. C. Marufu who assisted with the assessment of body condition, health status and pregnancy status of research animals. I am greatly indebted to Dr F. Rumosa Gwaze (the post-doctoral student in the Department of Livestock and Pasture Science) and fellow postgraduate students M. Mwale, N. Nqeno, M. Mapekula, U. Marume, A. Bakare, L. Musemwa, Busani Moyo, Bethwell Moyo, M. Lesoli and J. Madzimure for their constructive criticism and encouragement. Prof. H. Hamudikuwanda, thank you so much, your critical comments greatly improved the quality of this thesis.

I thank the Eastern Cape Department of Agriculture for providing information and assisting with data collection in the field. My sincere gratitude goes to the farmers in the Eastern Cape who sacrificed their precious time for this study and availed their animals for research. Feed chemical analyses were carried out at Dohne Agricultural Development Institute. I am also grateful to Dr F. Nherera and Prof C.W. Cruywagen of Stellenbosch University for providing facilities and guidance in determining the *in vitro* digestibility of feeds. Serum samples were processed at the University of Pretoria Veterinary Clinical Pathology Laboratory, Pretoria. The steers were slaughtered at East London abattoir and meat samples were analysed at the Meat Industry Centre, Agricultural Research Council, Irene. I greatly appreciate the support of Prof A. Hugo of the University of Free State in providing facilities for the analyses of fatty acid composition of the feed and meat samples.

Special appreciation goes to Kellogg Foundation (Project 478), National Research Foundation (Project T063) and Cannon Collins Trust for funding my research and taking care of my welfare as I studied. Many thanks go to my parents, Mr and Mrs C. Mapiye, brothers (Moses, Aaron, Simbarashe, Obvious and Brighton), sisters (Miriam and Millicent) and the Mwerenga family for the inspiration and moral support. Lastly, all the praise goes to the Almighty GOD for giving me the opportunity, wisdom and strength to craft this thesis.

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CHAPTER 1: Introduction

1.1 Background

In South Africa, the livestock sector accounts for 75 % of national agricultural output, of which cattle farming is the largest sub-sector [National Department of Agriculture (NDA), 2008]. Despite its importance, cattle production is failing to meet the local beef market demand (Bester *et al.,* 2003). Currently, South Africa imports between 40 000 and 60 000 tonnes of beef, which is 10 to 15 % of its meat requirements per annum [Eastern Cape Development Corporation (ECDC), 2003]. Over 40 % of the total cattle population (14.1 million) in South Africa belong to the smallholder sector, which is composed of emerging and communal farmers (NDA, 2008). Cattle off-take from this sector is, however, markedly lower than that from the commercial sector (2-5 versus 20-25 % per annum) (Winter, 2007). Improvement of communal cattle production may, therefore, increase local beef off-take and improve food security and livelihoods of the resource-poor cattle producers.

At independence, policies to improve cattle production in communal areas were based on the use of imported breeds (Bester *et al.,* 2003). These imported breeds were preferred because they are perceived to possess genetically superior beef traits compared to indigenous breeds (Schoeman, 1989). Crossbreeding between indigenous and imported breeds generated non-descript breeds of cattle, which are now dominant in communal areas (Bester *et al.,* 2003). Performance and sustainability of these crossbreeds on communal rangelands is, however, not established. Performance of crossbred cattle is expected to be adversely influenced by harsh environmental and poor socio-economic conditions that are prevalent in most communal areas. For example, in the communal areas of the Eastern Cape Province, feed is scarce (Schoeman, 1989), nematodes (Ndlovu *et al.,* 2008), ticks (Muchenje *et al.,* 2008a) and tick-borne diseases are endemic (Marufu *et al.,* 2009) and intensity of cattle management is low (Bester *et al.,* 2003). Sustainable beef cattle production requires the use of breeds that are adapted to the local environmental and socio-economic conditions (Strydom, 2008).

To develop appropriate improvement strategies for cattle production, it is crucial to have knowledge of existing production systems, management practices and cattle herd dynamics (Bester *et al.,* 2003). Communal cattle farmersô objectives and constraints vary due to several factors, such as culture, beliefs, education and wealth, which influence rangeland and cattle management. Cattle herd dynamics across production systems and rangeland types are not clearly understood. Herd dynamics is a product of changes in reproductive, mortality and off-take rates, and factors influencing such changes (Amanor, 1995). Measures of herd dynamics include cattle production potential (CPP) and cattle production efficiency (CPE). Production potential is defined as the proportion of mature and growing animals in the herd, while production efficiency is the proportion of mature animals sold and consumed as a proportion of the production potential (Chiduwa *et al.,* 2008). Information on herd dynamics allows identification of factors that cause variations in the herd and development of appropriate intervention strategies (Amanor, 1995). Determining farmersô objectives and constraints, CPP and CPE in the communal areas is, therefore, fundamental.

Currently, in the communal areas of South Africa, there is growing interest in using Nguni cattle as food and cash generating assets (ECDC, 2003). This is largely ascribed to their positive attributes under low-input production systems. Such attributes include resistance to nematodes (Ndlovu *et al.,* 2008), ticks (Muchenje *et al.,* 2008a), tick-borne diseases (Marufu *et al.,* 2009), high fertility rates and low feed requirements for maintenance (Schoeman, 1989). In addition, Nguni cattle produce beef of comparable yield and quality to imported breeds (Muchenje *et al.,* 2008a, b; Strydom, 2008). It can be argued that indigenous breeds are largely unpopular due to lack of commercialisation of their invaluable traits under low-input production systems.

Development efforts are under way to repopulate the communal areas of South Africa with Nguni cattle and commercialise their production (Bester *et al.,* 2003). du Plessis and Hoffman (2004) and Muchenje *et al.* (2008a), however, reported that Nguni cattle fairly lose body weight and body condition in the dry season. This is attributed to low feed quality, particularly crude protein (CP) content, which is as low as 10 g/kg DM in the dry season (Mokoboki *et al.,* 2005). It is, therefore, imperative to devise nutritional strategies to improve cattle condition in the dry season. Prior to any nutritional improvement programme, it is, however, important to verify the types and levels of limiting nutrients across seasons and rangeland types. This can be more accurately achieved by assessing changes in the levels of nutritionally-related blood metabolites (Ndlovu *et al.,* 2009). There are no reference values for these metabolites for cattle raised on communal rangelands. This makes it difficult to design proper supplementary feeding strategies for cattle in semi-arid communal areas.

Dietary supplementation, particularly with locally available protein-rich feeds (du Plessis and Hoffman, 2004) in the dry season can improve the viability and sustainability of beef production on communal rangelands. One such potential supplement is the indigenous *Acacia* species, particularly *Acacia karroo*, which is adaptable, widely distributed and relatively available in the early dry season in Southern Africa (Mokoboki *et al.,* 2005). It has high CP (100 to 250 g/kg DM) and mineral (Mokoboki *et al.,* 2005) contents, and has antihelmintic properties (Xhomfulana *et al.,* 2009). Although the presence of thorns and phenolic compounds in fresh foliage limit its utilisation as ruminant feed, these factors can be minimised by use of protective clothing during harvesting and simple detannification processes based on drying treatments, respectively (Makkar, 2003). The effect of feeding *A. karroo* leaf meal on nutritional status, growth performance, beef yield and quality of indigenous cattle raised on communal rangelands has, however, not been evaluated. Since modern consumers have increased preference for natural/organic beef (Anderson *et al.,* 2005), the safety and healthiness of beef from indigenous cattle fed an organic substance such as *A. karroo* should be investigated.

1.2 Justification

It is crucial to empower extension officials to deliver informed advice, development agents to prioritise funding of appropriate technologies and policy-makers to implement policies that promote sustainable beef production and subsequently, improve livelihoods of resource-limited farmers. Lack of information on farmer constraints, management practices, cattle herd dynamics and production efficiency, and nutritional status of cattle in the communal areas, however, makes it difficult to formulate and implement proper cattle-based programmes that benefit the resource-poor farmers. Knowledge of cattle population dynamics, production potential and production efficiency improves the understanding of functional attributes and the development potential of beef production systems in the communal areas. Information on the nutritional status of cattle is essential in the management, budgeting and allocation of feed resources. It is also essential in developing recommendations for the adoption of breeds that are adapted to the local environmental and socio-economic conditions.

Despite that *A. karroo* is adaptable, widespread and abundantly available; there is little, if any, information on its value as a protein supplement for beef production in the communal areas of South Africa. Such information is important in devising cost-effective feeding strategies for improving beef yield and quality in the communal areas. Moreover, feeding locally adapted breeds, such as Nguni cattle with locally available feed resources has the potential to produce more acceptable and health-promoting beef products. The current study will generate information that will improve the nutritional status, beef yield and quality and, consequently production efficiency of Nguni cattle in the communal areas. This will ultimately contribute towards improving food security and income for resource-poor cattle producers and reducing beef imports in South Africa.

1.3 Objectives

The broad objective of the current study was to evaluate cattle production on communal rangelands and the potential of *A. karroo* in improving Nguni beef production in the Eastern Cape province of South Africa. The specific objectives were to:

1. Identify constraints faced by smallholder Nguni cattle farmers in the sweet and sour rangelands;
2. Determine the production potential and production efficiency of Nguni cattle on communal rangelands;
3. Assess the nutritional status of Nguni cattle on communal rangelands; and
4. Evaluate growth performance, beef yield, quality and fatty acid profiles of Nguni steers supplemented with *A. karroo* leaf meal.

1.4 Hypotheses

The null hypotheses tested were that:

1. Constraints faced by smallholder Nguni cattle farmers in the sweet and sour rangelands are similar;
2. Nguni cattle production potential and production efficiency in the sweet and sour communal rangelands are the same;

3. The nutritional status of Nguni cattle on sweet and sour communal rangelands are not different; and
4. Nguni steers supplemented with *A. karroo* leaf meal and those that entirely rely on rangelands have similar growth performance, beef yield, quality and fatty acid profiles.

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CHAPTER 2: Literature Review

[Part of the review was published in the *African Journal of Agricultural Research,* see Appendix 1]

2.1. Introduction

Utilisation of indigenous cattle breeds and locally available feed resources has potential to increase food security, reduce poverty and improve livelihoods of the resource-poor farmers (Ashley *et al.,* 1999). Repopulating communal areas with indigenous cattle breeds and promoting the use of locally available feed resources is, therefore, important. Successful implementation of these cattle-based developmental programmes, however, depends on understanding existing production systems, identification of farmersô objectives, constraints and management practices, and determination of cattle performance under the current production systems (Bebe *et al.,* 2003a). This review discusses the production systems, objectives for keeping cattle, constraints faced by cattle farmers and the potential of using locally available browse legumes to improve beef production on communal rangelands.

2.2 Cattle production systems in smallholder areas

In South Africa, cattle production in smallholder areas is composed of small-scale commercial and communal systems (Palmer and Ainslie, 2006). The small-scale production system is composed of individuals who are commercially oriented and their use of technology and external inputs is moderate (Ainslie *et al.,* 2002). Depending on land tenure system, small-scale farming can either be practised on private or communal land (Palmer and Ainslie, 2006). Cattle producers on private land are beneficiaries of government land reform programmes or lease state farms of between 200 and 500 ha (Ainslie *et al.,* 2002). These beneficiaries are usually found in groups as cooperatives and own between 40 and 100 cattle.

On the other hand, small-scale commercial cattle producers on communal land own less than 25 cattle and have farm sizes that range between 12 and 100 ha and do not have exclusive land tenure (Palmer and Ainslie, 2006). In the communal production system, farms are small (< 12 ha) and individuals have open access to natural resources, including rangelands (Moyo *et al.,* 2008). Communal farmers are subsistence oriented, own between one and 10 cattle, and have limited use of technology and external inputs (Palmer and Ainslie, 2006). Generally, there is little information on these systems, especially regarding cattle numbers and distribution, and levels of production (Ainslie *et al.,* 2002). This has often resulted in the implementation of irrelevant and inappropriate development technologies in rural areas.

The functions of cattle in the smallholder areas include draught power, meat, milk, dung, hides, cash and capital storage (Delali *et al.,* 2006). Cattle also play a vital role through their contribution to cultural and social life of smallholder farmers (Bayer *et al.,* 2004). The relative importance of each of these functions varies with production system, pedo-climatic conditions and socio-economic factors, such as gender, age, education and religion of the farmers (Nqeno, 2008). The differences in farmersô objectives and perspectives to communal cattle production largely determines the feasibility of interventions and development opportunities aimed at improving the livelihoods of the resource-poor farmers (Bayer *et al.,* 2004). Efforts to improve sustainability of smallholder cattle production should, therefore, prioritise the understanding of farmersô objectives, perceptions and experiences across production systems and rangeland types.

2.3 Constraints faced by beef cattle producers in the communal areas

Beef cattle productivity in the communal areas is low and inefficient (Ainslie *et al.,* 2002; Delali *et al.,* 2006). Understanding farmersô constraints in the communal areas is important before giving any advice for improving viability of beef production enterprises (Ashley *et al.,* 1999). The major constraints faced by beef cattle producers include lack of proper rangeland management principles, poor cattle health management practices, limited cattle production skills, lack of appropriate breeds, low off-take and existence of low quality and quantity feed resources (Bester *et al.,* 2003; Nqeno, 2008). The importance of each of these constraints could differ with production system, climate and farmersô socio-economic conditions, validation research could, therefore, be necessary. To improve rate and extent of adoption of livestock production technologies, holistic and participatory approaches which instill sense of ownership and responsibility for natural resources should be implemented (Francis and Sibanda, 2001).

2.3.1 Lack of proper rangeland management principles

Most rangelands in the communal areas are communally-owned, with grazing rights allocated by traditional leaders (Cousins, 1996). Under communal rangeland management systems, individuals have free access to rangeland resources (Moyo *et al.,* 2008). Consequently, it is often difficult to control grazing habits, stocking rates and diseases in the communal areas (Mapiye *et al.,* 2006). The high stocking rates observed in most communal areas have the consequence of degrading the rangelands and reducing the feed resource base for cattle (Scoones and Graham, 1994). This, in turn, adversely affects growth and reproductive performance, and ultimately cattle market value. Communal ownership of rangeland resources also complicates the introduction and adoption of improved rangeland management practices in the communal areas (Cousins, 1996). Constraints faced by communal farmers in the management of rangelands are poorly understood (Mapiye *et al.,* 2006). Information on farmerõs challenges and perceptions on rangeland management, which is useful in developing sustainable communal rangeland and cattle health management practices, is limited.

2.3.2 Poor health management practices

Livestock health issues are barriers to trade in cattle products whilst specific diseases lower production and increase mortality (Marufu *et al.,* 2009). Tick-borne diseases, especially babesiosis, anaplasmosis and ehrlichiosis are of economic significance in the communal areas (Mbati *et al.,* 2002; Marufu *et al.,* 2009). Generally, information on tick-borne diseases incidences, their geographical/seasonal distribution and dynamics in the communal areas of South Africa is not well documented. Currently, little is known about farmersô views on ticks and tick-borne diseases control practices in the communal areas. Lack of information on cattle health management and cattle production skills in general, makes it difficult to formulate and execute suitable control strategies that assist beef cattle producers in the communal areas.

2.3.3 Limited cattle production skills

In most communal areas, farmers lack knowledge on appropriate methods of cattle production and often there are poor systems for supplying farmers with technical assistance (Bester *et al.,* 2003; Bayer *et al.,* 2004). The farmer training needs are largely unknown and their importance could vary with production systems, rangeland types and socio-economic conditions. These factors should, therefore, be considered when ranking cattle producersô training needs in the communal areas.

2.3.4 Lack of appropriate cattle breeds and poor breeding management practices

Most beef cattle in the communal areas are non-descript crossbreds with small populations of local breeds, such as Nguni, Afrikaner and locally developed Bonsmara and Drankensberger (Palmer and Ainslie, 2006). The non-descript crossbred cattle are a product of indiscriminate crossbreeding and institutional policies that promote use of imported beef breeds in communal areas (Bester *et al.,* 2003). The situation is worsened by lack of records and uncontrolled mating systems used in these areas (Bayer *et al.,* 2004), which, in most cases, promote inbreeding (Bayer and Feldmann, 2001). These practices threaten the existence of local Nguni breeds (Ramsay *et al.,* 2000). Generally, there is limited information on the statistics and geographic distribution of different breeds kept by communal farmers.

To improve beef production for any community, it is critical to gather adequate information on the performance and sustainability of existing breeds (Bebe *et al.,* 2003a). Productivity of imported and non-descript cattle is most likely to be negatively influenced by harsh environmental conditions and poor breeding practices in the communal areas (Bester *et al.,* 2003). On the other hand, the small-framed Nguni cattle, which were perceived to have little or no commercial value as a source of beef, are now gaining popularity under low-input production systems due to their positive adaptation attributes (Ramsay *et al.,* 2000). The Nguni breed, a sub-type of the African Sanga cattle (*Bos taurus africanus*) exhibits resistance to nematodes (Ndlovu *et al.,* 2008; Xhomfulana *et al.,* 2009), ticks (Muchenje *et al.,* 2008a) and tick-borne diseases (Spickett *et al.,* 1989; Marufu *et al.,* 2009). Nguni cattle also have inherent capacity to produce relatively high beef yield and quality under both feedlot and rangeland conditions as indicated in Table 2.1. In addition, Nguni beef have favourable fatty acid profiles (Muchenje *et al.,* 2008c) and sensory attributes (Muchenje *et al.,* 2008d). There is, therefore, a possibility that beef produced from Nguni cattle raised on rangeland can meet both producer and consumer expectations.

Table 2.1: Carcass and meat quality attributes of Nguni cattle reared under feedlot and rangeland conditions

Attributes	**Feedlot**	**Natural pasture**
Carcass		
Average daily gain (g/day)	800-1200	100-250
Slaughter weight (kg)	240-450	200-350
Warm carcass weight (kg)	160-180	110-150
Dressing percentage	56-58	50-55
Meat quality		
Marbling (%)	0.55-0.75	1.12-1.15
Cholesterol (mg/100g)	-	41-42
Protein (%)	-	21-22
pH	5.5-6.1	5.5-6.4
Colour (L)	-	29-45
WBSF2 (N)	-	11-100
Drip loss (%)	-	1.5-3.5
Water holding capacity (%)	-	0.2-0.5
Sarcomere length (µm)	1.84-1.90	1.0-2.0
Cooking loss 2 (%)	-	15-54
Sources	Swanepoel (1990); Strydom *et al.* (2000; 2001); Strydom (2008).	du Plessis and Hoffman (2004; 2007); Muchenje *et al.* (2008a; 2008b).

The potential for organic beef production from Nguni cattle is high because of this breedøs ability to be raised with little or no chemicals, antibiotics, hormones and inorganic feed supplements (Ramsay *et al.,* 2000; Muchenje *et al.,* 2008a, b) and with use of pesticide, herbicide and fertiliser free rangelands. Organic beef costs are between USD 8.00 and 12.00/kg at retail prices, compared with at least half that amount for natural beef (ECDC, 2003). Different institutions are already working on repopulating Nguni cattle in the communal areas of South Africa (Bester *et al.,* 2003).

To enhance efficiency of the Nguni cattle repopulation programmes, farmersô cattle breeding objectives, preferences for different breeds and criteria used for the selection of breeding stock should be clearly understood (Bebe *et al.,* 2003a). Breeding strategies generally evolve in response to changes in production systems, vegetation type, production objectives, farmersô breed preferences and farmersô perceptions about breed characteristics and market opportunities (Amer *et al.,* 1998). Farmerøs perceptions should, therefore, be an integral part of breeding improvement efforts because farmers adopt and adapt genotypes to their needs and circumstances (Bayer and Feldmann, 2001).

Information about farmers' cattle breeding practices and breed preferences can help to identify the likely markets for existing cattle breeds. Market information reveals buyer preferences for different breeds and attributes, which may be useful in designing breed improvement schemes (Amer *et al.,* 1998). Furthermore farmers' knowledge about specific attributes of different breeds under communal conditions assist to focus scientific research on improving particular traits and identify needs for further farmer education through extension programmes (Bebe *et al.,* 2003a). Knowledge of traits of economic importance can be used to determine the incentives that may need to be put in place for farmers to be involved in conservation of threatened or endangered breeds that may not be supported by market forces (Ramsay, 2000).

2.3.5 Low cattle off-take

Cattle off-take rates refer to the number of cattle sold and/or slaughtered per annum as a proportion of total herd size (Montshwe, 2006). Generally, it represents the proportion of cattle annually exiting the herd due to slaughters, sales, purchases or other transactions such as exchanges, gifts and loans (Upton, 1989; Amanor, 1995). Despite large cattle numbers in the smallholder sector (5.7 million head) in South Africa, off-take to formal market ranges from 2 to 10 % of total herd size per annum (Montshwe, 2006; Winter, 2007). These off-take values are extremely low compared to commercial sector off-take rates, which vary between 20 and 25 % (Coetzee *et al.,* 2005).

The low off-take rates reported are chiefly due to lack of marketable cattle numbers per household and poor animal condition rather than lack of willingness to sell or multiple functions of cattle in the communal areas (Coetzee *et al.,* 2005; Musemwa *et al.,* 2008). The small herd sizes of one to 10 cattle per household translate into owners who are not in a position to market cattle regularly and who are, instead, constantly trying to build up their herds (Montshwe, 2006; Musemwa *et al.,* 2008). Poor condition of cattle mainly attributable to inadequate grazing, especially in the dry season, results in farmers being reluctant to sell their animals as they would receive low income (Makhura, 2001).

Increasing cattle off-take rates in the communal areas can enhance food security and income levels of the resource-poor farmers (Ashley *et al.,* 1999). Presently, ways of estimating and improving cattle off-take rates are subject to a high degree of inaccuracy, partly due to lack of reliable data on cattle population dynamics (Ainslie *et al.,* 2002). Herd dynamics involve short to long-term changes in numbers, body weight, structure, age, sex ratio, survivorship and fecundity of animals in one or several populations (Amanor, 1995). It is a product of the changes in reproductive, mortality and off-take rates and biological, environmental and socio-economic factors influencing such changes (Upton, 1989; Ezanno, 2005).

Studies on cattle population dynamics are useful in determining production potential and production efficiency. Production potential is the percentage of mature and growing animals in the herd/flock size (Muchadeyi *et al.,* 2005; Chiduwa *et al.,* 2008). The production potential reflects the number of potentially saleable or consumable animals in a given system. Under the communal production systems, juveniles are hardly consumed, purchased or sold, since they are highly prone extreme of weather conditions and drought (Chiduwa *et al.,* 2008). Production efficiency is the percentage of mature animals sold and/or consumed as a proportion of the production potential (Muchadeyi *et al.,* 2005; Chiduwa *et al.,* 2008). Evaluating herd dynamics can allow factors causing variations in herd productivity to be identified and appropriate rangeland and cattle management strategies to be developed (Amanor, 1995; Angassa and Oba, 2007). Herd dynamics reflect the extent of adaptation of cattle to the environment, degree of integration of farmers into the market, characteristic development of markets, trends towards specialization in particular branches of cattle production and the effects of market demand on local herd management (Amanor, 1995).

Changes in herd dynamics are associated with changes in the extreme climatic and socio-economic events (Bebe *et al.,* 2003b). For example, the alternation of a short rainy season and a long dry season generates periodic stresses for cattle and, thus, periodic variations in their demographic rates (Boone and Wang, 2007). The relationship between climatic variability and cattle population dynamics is crucial in adjusting cattle numbers per unit of time and space to match rangeland resources (Boone and Wang, 2007). Thus, besides gathering data on herd dynamics, it is also crucial to determine factors that influence nutritional status and, consequently, cattle production potential and efficiency of cattle on communal rangelands. Feed quantity and quality, for example, is directly related to the nutritional status of cattle and consequently its market value.

2.3.6 Low quality and quantity of feed resources

The most abundant feed resources for ruminants in the tropics are poor quality roughages, in particular rangeland grasses and crop residues (Devendra and Sevilla, 2002). The total amount and quality of these feed resources vary across seasons and agro-ecological zones, depending on the amounts, distribution and reliability of rainfall (Botsime, 2006; Boone and Wang, 2007). In South Africa, rangelands are categorized into ñsweetò and ñsourò based on the amount of rainfall received per annum and vegetation type (Tainton, 1999). Precipitation in sweet rangelands is less than 500 mm per annum and vegetation is comprised of perennial grasses that remain nutritious and palatable all year round (Ellery *et al.,* 1995). In contrast, sour rangelands receive between 600 and 800 mm of rainfall per annum and are mainly composed of annual grass species, which lose nutritive value and palatability in the dry season (Ellery *et al.,* 1995). Consequently, feed shortage in the dry season and its associated effects are more pronounced in sour rangelands than in sweet rangelands (Botsime, 2006). There is, however, little evidence to substantiate the impact of these differences in rangeland types on the nutritional status of cattle raised on communal rangelands.

The decline in feed quality, particularly crude protein content, which is as low as 10 g/kg DM in the dry season in both sour and sweet rangelands leads to loss of animal body weight and condition (Collins-Luswet, 2000; Muchenje *et al.,* 2008a). Loss of body weight and condition, subsequently, result in sub-optimal carcass and meat attributes (du Plessis and Hoffman, 2004; Muchenje *et al.,* 2008b) which leads to a reduction in income for cattle producers (Musemwa *et al.,* 2008). To improve beef production on communal rangelands, appropriate supplementary feeding strategies based on locally available feed resources should, therefore, be developed. Before any nutritional improvements are recommended, it is, however, important to verify the types and levels of nutrients that limit beef production. The levels of limiting nutrients can be achieved through monitoring changes in weight, body condition score and level of nutritionally-related blood metabolites in cattle on communal rangelands (Agenas *et al.,* 2006; Ndlovu *et al.,* 2007).

Body weight changes are commonly used to determine nutritional status of cattle (Ndlovu *et al.,* 2007; 2009) but are influenced by changes in gut and bladder fill, pregnancy and parturition (National Research Council, 1996). Furthermore, weight changes may reflect tissue hydration rather than significant alterations in body protein or fat content. In addition, most communal areas in South Africa, however, have no access to heavy-duty scales (Nqeno, 2008). This makes it difficult to use body weight changes as indicators of cattle nutritional status in the communal areas.

Body condition scoring (BCS) is a more sensitive and acceptable indicator of the nutritional status in cattle (Ndlovu *et al.,* 2007). The BCS of cattle influences carcass yield and quality (Apple *et al.,* 1999). While passing from óthinô to ónormalô then to ófatô condition the carcasses show better conformation score, a darker yellow colour, higher score of fatness and larger *longissimus dorsi* area with thicker cover-fat (Apple *et al.,* 1999). Regardless of the fact that the relationship between BCS and meat yield of communal herds can provide useful information required for the prediction of beef yield and quality, and prices of live cattle in the communal areas, this concept is poorly understood. Body condition scoring, however, suffers from the disadvantage that it responds slowly to short-term changes in the diet and is influenced by the physiological status of the animal (Agenas *et al.,* 2006).

Nutritionally-related blood metabolites, such as glucose, non-esterified fatty acids (NEFA), cholesterol, triglycerides, total proteins, albumin, urea, creatinine and macrominerals, are becoming important criteria in determining the nutritional status of beef cattle (Ndlovu *et al.,* 2009). Serum concentrations of these metabolites represent an integrated index of the adequacy of nutrient supply in relation to its utilisation that is independent of physiological state. The concentrations give an immediate indication of nutritional status at that point in time (Yokus and Cakir, 2006; Ndlovu *et al.,* 2007). Reference levels for these nutritionally-related metabolites across seasons and rangeland types in cattle raised under communal rangeland management systems are, however, not available, making it difficult to devise proper feeding management strategies in these areas. Variables such as breed, age, sex and physiological status of animals influence nutritionally related blood parameters (Grunwaldt *et al.,* 2005; Yokus and Cakir, 2006; Ndlovu *et al.,* 2009). Metabolite profiling provides information on types and amounts of limiting nutrients, and time of the year at which they are limited (Grunwaldt *et al.,* 2005). Such information determines types and amounts of supplementary nutrients to be supplied as well as the season in which they should be supplemented.

Use of metabolic profiles on beef cattle in the communal areas has not been adopted extensively due to lack of expertise for blood sampling and analyses, unavailability and high cost of sampling facilities (Ndlovu *et al.,* 2007). Moreover, similar values of some blood metabolites can have different meanings if the animal is gaining, losing or maintaining body condition (Calderia *et al.,* 2007; Ndlovu *et al.,* 2009). Furthermore, the changes in most nutritionally related metabolites occur in animals experiencing severe nutritional stress leading the body weight and BCS losses. Thus, blood profiles become more useful when combined with physical examinations such as changes body weight and BCS (Calderia *et al.,* 2007). The joint application of physical examination and blood metabolic profiles can produce nutritional status indices of broader potential value for the development of optimal feeding management strategies for sustainable beef production on communal rangelands.

2.4. Potential of *Acacia karroo* leaf meal as a protein supplement for beef cattle

Since protein is the most limiting nutrient in the dry season (Tainton, 1999; Devendra and Sevilla, 2002), provision of protein supplements when finishing beef cattle on rangelands is strongly recommended (du Plessis and Hoffman, 2007; Muchenje *et al.,* 2008a, b). Supplementation with high-protein diets increases body weight gains by between 0.1 and 0.8 kg/head/day and consequently higher carcass weights and better beef quality than low-protein diets (Rubanza *et al.,* 2005a; Baublits *et al.,* 2006). Smallholder farmers use several alternative protein supplementation strategies which include use of legume crop residues (such as straws and hulls), legume crop by-products (that include oilseed cakes) and mono-nutrient blocks/licks (urea and ammonia) (Devendra and Sevilla, 2002). Crop residues are, however, highly fibrous and low in protein, vitamins and critical minerals (Ngongoni *et al.,* 2007). Besides, crops in the arid and semi-arid areas require expensive inputs such as fertilizers, herbicides and pesticides. Mono-nutrient blocks are costly and generally unavailable in the communal areas (Devendra and Sevilla, 2002).

Protein supplementation with exotic herbaceous and browse legumes, such as *Acacia angustissima*, *Calliandra calothyrsus* and *Leucaena leucocephala* as fresh grazing and/or conserved fodder has been widely researched in the sub-tropics (Mullen, 1999; Hove *et al.,* 2001; Rubanza *et al.,* 2005a; 2007). Adoption of exotic leguminous plants has, however, been limited by scarcity and high cost of seed, inoculants and phosphate fertilizers. There are also difficulties associated with their establishment and maintenance, and their competition for land with food crops in the communal areas (Mapiye *et al.,* 2006). Furthermore, misuse of herbicides, pesticides and inorganic supplements increase consumersô worries about risk of chemical residues in beef products (Sundrum, 2001; Paull, 2006). Assessment of locally available protein supplements grown with little or no use of chemicals is, therefore, essential.

Indigenous legume trees found in Southern Africa include *Colophospermum mopane*, *Brachystegia spiciformis*, *Dichrostychs cinerea*, *Julbernadia globiflora* and the genera of *Acacia*, *Guibourtia*, *Piliostigma* and *Pterocarpus* (van Wyk *et al.,* 2000; Mlambo *et al.,* 2004). *Acacia* species have great potential as protein supplements because they are the most widespread and moderately available in the early dry season in semi-arid areas of Southern Africa (Aganga *et al.,* 1998; 2000; Mokoboki *et al.,* 2005). *Acacia karroo* Hayne, in particular, is gaining importance as a protein supplement for grazing ruminants due to its adaptability to harsh local environments and availability in the dry season (Osuga *et al.,* 2007; Nyamukanza and Scogings, 2008). More importantly, it has high crude protein content of between 100 and 250 g/kg DM (Mokoboki *et al.,* 2005). There is also a possibility that beef produced from natural pastures plus indigenous browse legume supplements can, apart from being classified as organic, meet both producer and consumer expectations. Information on utilisation of *A. karroo* as a protein supplement for indigenous beef cattle raised on communal rangelands is, however, scarce.

2.4.1 Nutritive value of Acacia karroo

In Southern Africa, *A. karroo* (sweet thorn) is a valuable source of forage for herbivores where feed quality and diversity are a production constraint (Ngwa *et al.,* 2002; Osuga *et al.,* 2007). *Acacia karroo* contains high levels of amino acids (Ngwa *et al.,* 2002), CP (Table 2.2) and minerals (Aganga *et al.,* 1998). Its crude protein levels are within the range of 130 to 150 g CP/kg DM, which is required for high producing beef animals (Mokoboki *et al.,* 2005). This makes it a potentially important protein supplement for beef cattle grazing low quality rangelands. In addition to high nutrient levels, the potential of *A. karroo* as a forage is enhanced by the presence of many complex chemical constituents that have antihelmintic properties (Kahiya *et al.,* 2003; Xhomfulana *et al.,* 2009). Xhomfulana *et al.* (2009), for example, observed that Nguni cattle supplemented with *A. karroo* leaf meal had the lowest nematode egg loads. Thus, *A. karroo* may possibly be used as a lower-cost and locally available substitute to commercially available anthelmintics to control the escalating problem of anthelmintic resistance and reduce consumer concerns about drug residues in beef.

Acacia karroo leaves have moderate levels of detergent fibres and relatively low *in vitro* apparent digestibility coefficient and degradability (Table 2.2). The *in vitro* DM degradability values for *A. karroo* are lower (320-480) (Aganga *et al.,* 1998; 2000) than 500 g/kg DM, which is adequate to meet the energy requirements for low output ruminant production systems (Mullen, 1999). The large variation in values of *A. karroo's* nutritive is attributed to differences in nature of assays used, seasons, soil type, age of the plant and plant parts (Aganga *et al.,* 1998; 2000; Scogings and Mopipi, 2008). Further research on the effect of seasons, soil type, age of the plant and plant parts on nutritive value could be important.

Table 2.2: Nutritive value of *Acacia karroo* leaves

Constituent (g/kg DM)	Source(s) of values: Mokoboki *et al.* (2005)	Source(s) of values: Aganga *et al.* (1998; 2000); Dube (2000); Nyamukanza and Scogings (2008); Scogings and Mopipi (2008).
Dry matter (DM)	945.4	
Organic matter (OM)	897.0	-
Crude protein (CP)	108.0	125 -256
Neutral detergent fibre (NDF)	504.6	389-590
Acid detergent fibre (ADF)	406.9	286-400
Ash	-	42-55.3
In vitro enzymatic DM degradability	460.9	320-480
OM degradability	428.9	-
Apparent digestibility coefficient of DM	-	390-600
Apparent digestibility coefficient of CP	-	500-530
Apparent digestibility coefficient of NDF	-	330-405
Apparent digestibility coefficient of ADF	-	300-350

2.4.2. Factors affecting utilisation of Acacia karroo

Although *A. karroo* has a high CP content, the plant contains high concentrations of bio-active groups of compounds, such as alkaloids and phenolics, particularly extractable condensed tannins (Dube *et al.,* 2001; Mokoboki *et al.,* 2005), which could undermine its utilisation as a protein supplement for beef cattle. Table 2.3 shows the concentration of phenolic compounds in *A. karroo* leaves. Condensed tannin concentrations above 60 g/kg DM confer bitterness and astringency resulting in low palatability and depression of voluntary feed intake (Rubanza *et al.,* 2005b). High concentrations also reduce degradability and digestibility of the feed and nutrient availability to the host animal (Abdulrazak *et al.,* 2001; Mlambo *et al.,* 2004).

On the other hand, Aganga *et al.* (1998) and Nyamukanza and Scogings (2008) reported relatively high (> 100 g/day) average daily gain for goats fed *A. karroo* diets. Feeds with moderate to high tannin content (20-60 g/kg DM) have been reported to produce lean (Priolo and Ben Salem, 2004; Vasta *et al.,* 2007) and light coloured meat in small ruminants, which is considered safe for human consumption (Priolo *et al.,* 1998). Dietary condensed tannins influence meat protein content, fatty acids composition and sensory quality and, consequently human health (Vasta *et al.,* 2007). In addition, supplementing sheep with condensed tannins-rich foliage increases the intensity of meat flavour (Priolo *et al.,* 2002). There are little, if any, studies that have incorporated *A. karroo* into feeding regimes and determined its utility for improving beef yield and quality, fatty acid composition and sensory attributes.

Table 2.3: Concentration of phenolic compounds [g/kg dry matter (DM)] in *Acacia karroo* leaves

	Source of values		
Constituent (g/kg DM)	Mokoboki *et al.* (2005)	Aganga *et al.* (1998; 2000)	Dube *et al.* (2001)
Total phenolics	31.3	20.2-25.5	-
Simple phenolics	8.9	-	-
Extractable phenolics	-	-	13
Extracted condensed tannin	80.7	90-110	-
Condensed tannin in neutral detergent fibre	38.9	-	2.28
Condensed tannin in acid detergent fibre	24.1	-	-
Ytterbium precipitable phenolics	-	-	124-428.0
Crude protein-bound proanthocyanidins	-	-	2.0
Fibre-bound proanthocyanidins	-	-	2.2-2.9
Radial diffusion assay (cm^2/g)	233.3	-	41.0

Presence of thorns in *A. karroo* is arguably the main factor that reduces its forage utilisation potential (Teague, 1989; Nyamukanza and Scogings, 2008). Thorns restrict leaf accessibility and retard rates of nutrient ingestion by restricting bite size of browsers (Teague, 1989). Dense thorny thickets suppress growth of grasses and limit movement by livestock (Teague, 1989; Nyamukanza and Scogings, 2008). According to Wilson and Kerley (2003), bushbucks and Boer goats attained larger bite sizes and high intake rates following manual removal of thorns from *A. karroo* branches. Removal of thorns is, however, not feasible, especially when feeding large flock/herd sizes. On the same note, harvesting of large quantities of *A. karroo* foliage has been deemed impractical due to presence of thorns (Dube, 2000; Mlambo *et al.,* 2004). Development of practical and low-cost strategies of harvesting and reducing the effects of phenolic compounds in *A. karroo* foliage at medium to large scale is, therefore, imperative.

2.4.3. Sun-air-drying as a method of minimising phenolic compounds

Several methods can be used to reduce the adverse effects of phenolic compounds in feeds. These methods include the use of metal ions, alkalis (urea, sodium hydroxide and potassium hydroxide), oxidising agents (such as potassium dichromate and potassium permanganate), wood ash/charcoal, microbial degradation, use of tannin-binding compounds (such as polyethylene glycol and polyvinyl-pyrrolidone), and drying (Makkar, 2003; Ben Salem *et al.,* 2005; Vitti *et al.,* 2005). The major disadvantages of using metal ions, alkalis and oxidising agents is the large losses of soluble nutrients and if mismanaged, can be poisonous to animals (Ben Salem *et al.,* 2005; Vitti *et al.,* 2005). Although effective, the cost and availability of microbial enzymes and tannin-binding compounds makes their use impractical and uneconomic under the communal beef production systems (Makkar, 2003; Ben Salem *et al.,* 2005). Wood ash and charcoal are inexpensive and locally available products (Ben Salem *et* *al.,* 2005), but may not be available in large quantities for sustainable utilisation in smallholder areas. Oven and freeze-drying methods require expertise, sophisticated equipment and electricity (Dzowela *et al.,* 1995), which are not available in most rural communities. Though moderately effective compared to other methods, sun-air-drying is a cheaper and user-friendly technique that makes use of locally and abundantly available resources (Dzowela *et al.,* 1995). Sun-air-drying can, therefore, be a more acceptable and feasible alternative for the resource-limited cattle producers (Dube, 2000).

Sun-air-drying improves degradability and digestibility of leguminous tree leaves (Lowry *et al.,* 1996; Hove *et al.,* 2001), and animal performance compared to fresh leaves (Vitti *et al.,* 2005; Rubanza *et al.,* 2005a; 2007). Improved performance of animals on dried tree legume diets can be attributed to increased nutrient concentration, improved utilisation of endogenous nitrogen in the rumen and change in the solubility of the protein increasing the bypass protein content, and amount and quality of post-ruminal amino acid absorption of the leaf meal (Ben Salem *et al.,* 1997; Rubanza *et al.,* 2007).

Leng (1997) reported that sun-air-drying improves palatability of some browse species. In practice, sun-air-drying reduces astringency of *Acacia* species, thus increasing its intake by ruminants (Ben Salem *et al.,* 2005). It is, however, important to prolong feed adaptation phase or mix *Acacia* species leaf meal with locally available palatable feed resources, such as natural pasture hay (milled or chopped) before feeding (Maasdorp *et al.,* 1999; Abdulrazak *et al.,* 2001). Further research is, however, required to ascertain the effect of feeding sun-air dried *A. karroo* leaf meal on beef cattle performance and, beef yield and quality.

2.4.4 Harvesting of Acacia karroo leaf meal

Despite its adaptability, abundant availability and high nutritive value, especially following a simple detanninification process, *A. karroo's* potential is mainly lowered by the existence of thorns, which makes accessibility and harvesting difficult. *Acacia karroo* leaf meal can, however, be conveniently prepared by cutting branches with an axe, hacksaw or diesel powered saw mill. Lopped branches should be stacked (1-1.5 m high) on plastic sheets of manageable size placed in the rangeland. The small trees should be cut at a slanting angle to prevent rotting of the stump and to promote coppicing (Dube, 2000). The leaves should be left to sun-dry for two to four days to reach a DM content of between 80 and 85 % (Dzowela *et al.,* 1995; Srivastava and Sharma, 1998). To minimise spoilage of leaves by rain during drying, *A. karroo* can be harvested in the post-rainy season (between February and April). Dried leaves should then be collected from the plastic sheet by shaking them off the branches. The dried leaves are passed through a 2 mm home-made sieve to separate them from thorns, twigs and exploded pods, which can inhibit intake (Maasdorp *et al.,* 1999). The leaf meal should be bagged and stored in a well-ventilated shade or storeroom until it can be used for supplementation in the subsequent winter. During harvesting and processing, protective clothing, such as thorn proof gloves, helmets and safety shoes should be worn for protection. Roughly, one tree (1-1.5 m tall) can produce 2.5-4.5 kg of leaf-meal per annum. *Acacia karroo* has a population density of between 500-1500 trees/ha in the False Thornveld of the Eastern Cape Province (van Wyk *et al.,* 2000). It also has high ability to coppice after cutting and grows fast in its early stages (Dube, 2000). These positive attributes suggests that harvesting of *A. karroo* is likely to have little impact on deforestation and carbon sequestration.

Currently, *A. karroo* is commonly considered an invader in most parts of Southern Africa (Dube, 2000; Mokoboki *et al.,* 2005; Scogings and Mopipi, 2008). The problem of *A. karroo* bush encroachment is most prevalent in the communal areas (Mokoboki *et al.,* 2005; Nyamukanza and Scogings, 2008). Hand-harvesting and sun-air drying of *A. karroo* leaf meal for animal feeding can, therefore, be a viable long-term solution to efficient utilisation and therefore, bush encroachment control in the semi-arid communal areas of Southern Africa.

2.5 Summary

Nguni cattle production on communal rangelands has the potential to produce high beef yield and quality. Nguni beef production is, however, limited by several constraints, chiefly low cattle off-take and poor nutrition in the dry season. Research on production potential, production efficiency, nutritional status of cattle on communal rangelands and the effect of supplementary feeding using locally available feed resources on cattle performance is, therefore, essential. Despite that *A. karroo* leaf meal has potential as a supplementary feed, its value for beef production from indigenous cattle grazing low quality rangelands has not been determined. The broad objective of the current study was to evaluate cattle production on communal rangelands and the potential of *Acacia karroo* in improving Nguni beef production in the Eastern Cape Province of South Africa.

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CHAPTER 3: Constraints to Nguni cattle production in the smallholder farming systems in the Eastern Cape, South Africa

(Published in *Livestock Science*, see Appendix 2)

Abstract

A total of 218 structured questionnaires were administered to identify constraints faced by smallholder Nguni cattle farmers in the sweet and sour rangelands in the Eastern Cape Province of South Africa. Cattle were mainly sold for cash, used for milk production, and slaughtered during ceremonies. Cattle herd sizes were larger ($P < 0.05$) in the small-scale (23 ± 5.2) compared to the communal (9 ± 3.1) areas. Most (75 %) of the cattle owners were adult males and were more involved in herd management than adult females and youths. Shortage of feed was ranked by farmers as the most important constraint. The logistic regression model showed that odds ratio estimates of households experiencing cattle feed shortage and disease/parasite challenges were highest in the communal area with a sweet rangeland. About 40 and 75 % of the respondents in the sour and sweet rangelands, respectively, reported that cattle body condition deteriorates in the dry season. Tick-borne diseases were the common causes of mortality, especially in summer. Non-descript crossbreds and Nguni were the common cattle breeds in the smallholder areas. African tradition worshippers had higher ($P < 0.05$) Nguni herd sizes (6 ± 3.2) than Christians (1 ± 0.5). Breeding season was undefined and mating system was largely uncontrolled in the communal areas. It was concluded that smallholder farmers ranked feed shortage in the dry season as the major constraint, especially in the sweet rangeland.

Key words: Cash, Communal farmers, Fencing, Rangelands, Tick-borne diseases

3.1 Introduction

Over 70 % of the resource-poor farmers in South Africa are situated in the harsh agro-ecological zones where cropping is unsuitable and, thus, rely on livestock for their livelihoods (Bester *et al.,* 2003; ECDC, 2003). The Eastern Cape Province has about 3.1 million beef cattle, comprising nearly a quarter of the total cattle population in South Africa (NDA, 2008). Out of that, over 65 % comes from smallholder sector (ECDC, 2003). Most smallholder farmers in South Africa depend on cattle for milk, meat, draught power, hides, manure, cash and socio-cultural uses (Shackleton *et al.,* 1999; Bayer *et al.,* 2004), but the relative importance of each function is likely to vary with production system, agro-ecological zone and farmersô socio-cultural factors (Chimonyo *et al.,* 1999; Simela *et al.,* 2006). Currently, the smallholder herd is an underutilised resource for beef production, although it has the potential to reduce beef imports, which are presently between 10 and 15 % of local production per annum (FAO, 2007; NDA, 2008). This calls for the need to increase output and off-take, which currently stands at 5 %, from the smallholder areas (ECDC, 2003).

Although the University of Fort Hare (UFH) and the Department of Agriculture, have embarked on repopulating Nguni cattle in the communal and small-scale areas of the Eastern Cape there are few, if any, studies that have shown linkages between constraints, production parameters, climatic conditions and farmers' socio-economic factors in the smallholder areas of South Africa. Such linkages are important in the designing and implementation of sustainable development programmes that benefit resource-poor farmers (Bester *et al.,* 2003; Bayer *et al.,* 2004; Simela *et al.,* 2006). To be viable and sustainable, initiatives to improve cattle production should directly address the objectives, constraints and opportunities of the farmers while promoting rational use of indigenous genetic resources (Amer *et al.,* 1998; Bayer and Feldmann, 2001; FAO, 2007). The objective of the current study was to identify constraints faced by smallholder Nguni cattle farmers in the sweet and sour rangelands in the Eastern Cape Province of South Africa. It was hypothesised that constraints faced by smallholder Nguni cattle farmers in the sweet and sour rangelands are similar.

3.2 Materials and Methods

3.2.1 Description of study sites and farmer selection procedure

The survey was conducted in 18 communities that benefited from UFH and Department of Agriculture Nguni Cattle projects in the Eastern Cape Province of South Africa (Table 3.1). Seven communal and two small-scale farming communities were selected from each rangeland type using the stratified random sampling technique, proportional to the number of communities within each production system. The small-scale farming communities which benefited from the land restitution programme, a relatively newly introduced system under the land reform programme of South Africa, were selected. Household heads owning Nguni cattle and willing to participate in the study were randomly selected.

3.2.2 Data collection

Data were obtained through personal observations and by interviewing 218 smallholder cattle farmers using pre-tested structured questionnaires (Appendix 3) between June and July 2007. The interviews were conducted in vernacular Xhosa language by five trained enumerators. Farmersô socio-demographic information, resource availability, livestock ownership, cattle feeding, health and breeding management practices were captured.

Table 3.1: Pedo-climatic conditions and the number of respondents for each community studied

Production System	Community	Rangeland type	Respondents	Annual rainfall (mm)	Mean annual temperature (°C)	Altitude (m)	Soil type
	Dyamala	Sweet	6	300-500	16	500-550	Loam
	Dyamdyam	Sweet	11	500-600	20	200-300	Sandy
	Ityali	Sweet	12	450-600	16	500-550	Loam
	Kwamasele	Sweet	26	450-600	16	400-600	Loam
	Kwezana	Sweet	6	450-600	16	500-550	Loam
	Mahobe	Sour	9	650-1000	14	600-1400	Sandy
	Magwiji	Sweet	15	400-600	10	1400-2000	Sandy
Communal	Melani	Sweet	14	450-600	16	500-550	Loam
	Msobombvu	Sweet	6	450-600	16	500-550	Loam
	Ncera	Sweet	13	450-600	16	500-550	Loam
	Ntselamanzi	Sweet	16	450-600	16	500-550	Loam
	Saphanduku	Sour	10	650-1000	14	600-1400	Sandy
	Tiwane	Sour	13	650-1000	12	600-1400	Sandy
	Upper Mnxe	Sour	18	650-1000	12	600-1400	Sandy
	Caba-mdeni	Sour	13	600-800	12	1250-2000	Sandy-Loam
Small-scale	Hex River	Sour	11	450-700	14	1350-1450	Sandy
	Masizame	Sweet	12	450-600	16	400-600	Loam
	Perkshoek	Sweet	7	300-450	20	100-200	Sandy-Loam

Source for pedo-climatic conditions: Acocks (1988)

3.2.3 Statistical analyses

All data were analysed using SAS (2003). Chi-square tests were computed to determine the association between production system and rangeland type with animal body condition and proportion of the farmers who provided supplementary feeding. The Generalised Linear Models (GLM) procedure was used to analyse the effects of farmersô socio-economic profiles, production system and rangeland type on herd/flock sizes and numbers of various cattle classes (calves, heifers, cows, steers, oxen and bulls). The linear model used was:

$$Y_{lmnopqrstuv} = \mu + A_l + B_m + AB_{lm} + C_n + D_o + E_p + F_q + G_r + H_s + I_t + J_u + \mathring{U}_{lmnopqrstuv}$$

Where $Y_{lmnopqrstuv}$= Herd/ flock sizes, numbers of various cattle classes and breed herd sizes;

μ = overall mean;

A_l = effect of rangeland type (l= sweet, sour)

B_m = effect of production system (m= communal, small-scale)

AB_{lm} = interaction of the l^{th} level of rangeland type and m^{th} level of production system

C_n = effect of age (n= < 30, 31-45, 45-60, >60)

D_o = effect of level of education (o= primary, secondary, tertiary)

E_p = effect of occupation of the head of household (p= unemployed, informally employed, formally employed)

F_q = effect of religion (q=Christian, African tradition, non-worshippers)

G_r = effect of sex of the head of household (r= male, female)

H_s = effect of marital status (s= married, single, divorced, widowed)

I_t = effect of household size (t= 0-5, 6-10, 11-15, >15)

J_u = effect of size of grazing land (u= 0-5ha, 6-10 ha, >10ha)

$\mathring{U}_{lmnopqrstuv}$ = residual error.

Pair-wise comparisons of the least square means were performed using the PDIFF procedure. The uses of cattle, breed selection criteria, farmersô constraints and training area were ranked using Kruskal-Wallis test (NPAR1WAY procedure of SAS). An ordinal logistic regression (PROC LOGISTIC procedure of SAS) was used to determine the odds of a household experiencing cattle feed shortages. The logit model fitted both production (rangeland type, production system, land size, cattle herd size, sheep and goats flock sizes) and socio-economic (gender, age, education, employment status and availability of extension services) factors. The logit model used for analysis was:

$\ln[P/1-P] = \beta_0 + \beta_1X_1 + \beta_2X_2 ... + \beta_{11}X_{11} + \mathring{U}$

Where:

P = probability of a household experiencing cattle feed shortage;

[P/1-P] = odds ratio, which referred to the odds of household experiencing cattle feed shortage;

β_0 = intercept;

$\beta_1X_{1...}\beta_{11}X_{11}$ = regression coefficients of production and socio-economic factors

$\mathring{U}$ = random residual error.

When computed for each estimator ($\beta_1 ... \beta_{11}$), the odds ratio was interpreted as the probability household to experience cattle feed shortages. A similar model was performed on the incidence of diseases/parasites and Nguni cattle ownership.

3.3 Results

3.3.1 Farmers' socio-economic profiles

The majority of the households in the communal (84 %) and small-scale (95 %) areas were male-headed. Mean household size across all the production systems was 7 ± 4 members. Most of the interviewees in communal (89 %) and small-scale (65 %) farms were unemployed. About 75 and 90 % of the farmers in the communal and small-scale areas, respectively, were Christians whilst 20 and 6 % African tradition worshipers. Most of the respondents in the communal (82 %) and small-scale (65 %) areas were over 50 years old and relied on pensions (55 and 50 %) for their livelihoods, respectively. The majority of the interviewees had at least primary school education (88 % communal and 72 % small-scale) and did not know how much land they owned (75 % communal and small-scale 65 %). Maize was the only reported major field crop grown (80 % of the farmers reported), largely for household consumption across production systems and rangeland types.

3.3.2 Livestock species kept, herd composition and reasons for keeping cattle

The farmers ranked cattle as the most important livestock species followed by goats, sheep and chickens. The average cattle herd size was larger ($P < 0.05$) in the sour rangeland (23 ± 6.2) than in the sweet rangeland (7 ± 3.1). Cattle herds and goats flock sizes were higher ($P < 0.05$) in the small-scale compared to communal areas (Table 3.2). Cattle herd sizes in the smallholder areas were mainly composed of cows. Respondents with secondary level qualifications had higher ($P < 0.05$) number of cattle (24 ± 5.2) compared to those with primary education (11 ± 3.1). Gender and occupation of the head of household, age, religion, marital status, household size and size of the grazing land did not affect cattle herd sizes across all production and rangeland types.

Reasons for keeping cattle varied with production systems and rangeland types (Table 3.3). Cash was ranked as the most important reason for keeping cattle across all production systems and rangeland types. Respondents in the communal areas ranked ceremonies as the second most important reason for keeping cattle, whilst those in the small-scale ranked milk.

Table 3.2: Mean herd/flock sizes of livestock species kept and numbers of various cattle classes

	Herd/flock sizes	
Livestock species	Communal area	Small-scale area
Cattle	9 ± 3.1^{a}	23 ± 5.2^{b}
Goats	7 ± 4.2^{a}	17 ± 5.4^{b}
Chickens	10 ± 7.3	11 ± 9.8
Sheep	15 ± 6.2	17 ± 9.2
Pigs	1 ± 0.6	1 ± 0.8
Horses	1 ± 0.4	1 ± 0.6
Donkey	1 ± 0.3	1 ± 0.4
Turkeys	1 ± 0.1	1 ± 0.2
Numbers of cattle classes		
Calves	2 ± 1.1	3 ± 2.1
Heifers	2 ± 1.0	2 ± 1.2
Steers	1 ± 0.5	1 ± 2.0
Oxen	1 ± 0.5	1 ± 1.1
Cows	4 ± 2.4	5 ± 3.2
Bulls	1 ± 0.5	1 ± 0.5

[a,b] Values with different superscripts, within row, are different ($P < 0.05$).

Table 3.3: Reasons for keeping cattle as ranked by respondents

	Rank (mean rank score)[a]					
	Production system			Rangeland type		
Reason	Communal	Small-scale		Sweet rangeland	Sour rangeland	
	n =175	n=43	Sig[1]	n = 144	n = 74	Sig[1]
Cash	1 (3.13)	1 (2.59)	*	1 (2.89)	1 (3.29)	*
Ceremonies	2 (3.67)	3 (4.28)	*	3 (3.70)	3 (3.96)	*
Milk	3 (3.75)	2 (2.85)	*	2 (3.65)	2 (3.41)	*
Manure	4 (4.91)	4 (5.06)	ns	4 (5.17)	4 (4.49)	*
Draught power	5 (5.30)	6 (6.08)	*	6 (5.74)	5 (4.91)	*
Meat	6 (5.48)	5 (5.35)	ns	5 (5.34)	6 (5.68)	*
Skin	7 (6.03)	7 (6.09)	ns	7 (5.78)	9 (6.54)	*
Dowry	8 (6.37)	9 (6.42)	ns	9 (6.42)	8 (6.43)	ns
Status	8 (6.37)	8 (6.28)	ns	8 (6.31)	7 (6.30)	ns
Sig[1]	*	*		*	*	

[a] The lower the rank (mean rank score) of a reason, the greater is its importance.

[1]Mean ranks of the different reasons (columns) and production system (rows) and rangeland types (rows) are different at P Ò0.05 (*).

Sig= Significance level; ns= not significant

3.3.3 Cattle ownership patterns and gender participation

Seventy-five percent of the cattle owners across all production systems and rangeland types were men, 18 % were women and 4 % children, respectively. Respondents acquired cattle through purchasing (70 %), inheritance (20 %) and other sources (10 %). Over 60 % of the respondents that inherited cattle were female widows. Adult males (75 %) dominated all cattle production activities (feeding, herding, breeding, milking, purchasing, treating, slaughtering and selling) across production systems. Male youths and hired labour participated in cattle production activities more than adult females, except in purchasing and selling. Female youths were minimally involved in all cattle production activities.

3.3.4 Constraints to cattle production

Farmers across both production systems and rangeland types ranked shortage of feed as the most important constraint, followed by diseases and parasites (Table 3.4). Poor breeding practice was ranked third in both communal and small-scale production systems. Ranking of other constraints varied with production systems and rangeland types (Table 3.4). Lack of production skills and poor breeding practices were ranked third in the sweet and sour rangelands, respectively. The fourth most important constraint in the communal area was lack of production skills, while in the small-scale it was inadequate marketing services. In the sweet rangeland, farmers ranked poor infrastructure as the fourth most important constraint whilst those in the sour rangeland ranked lack of production skills.

Table 3.4: Cattle production constraints as ranked by respondents

	Rank (mean rank score)[a]					
Constraints	Communal	Small-scale	Sig[1]	Sweet	Sour	Sig[1]
Feed shortage	1 (2.99)	2 (4.10)	*	1 (4.65)	1 (3.99)	*
Diseases and parasites	2 (3.77)	1 (3.47)	*	2 (5.08)	2 (5.39)	*
Poor breeding practices	3 (4.01)	3 (4.70)	*	5 (6.01)	3 (5.62)	*
Lack of production skills	4 (4.96)	6 (5.98)	*	3 (5.57)	4 (5.76)	*
Poor infrastructure	5 (5.79)	7 (6.17)	*	4 (5.81)	5 (5.80)	ns
Theft	6 (6.27)	5 (5.88)	*	7 (6.42)	7 (6.16)	*
Inadequate veterinary services	7 (6.32)	8 (6.41)	*	8 (6.45)	6 (5.99)	*
Inadequate marketing services	8 (6.67)	4 (5.57)	*	6 (6.38)	4 (5.76)	*
Poor extension services	9 (7.11)	9 (6.93)	*	9 (6.54)	8 (6.90)	*
Sig[1]	*	*		*	*	

[a] The lower the rank (mean rank score) of a constraint, the greater is its importance.

[1]Mean ranks of the different reasons (columns), production systems (rows) and rangeland types (rows) are significantly different at P Ò0.05 (*).

Sig= Significance level; ns= not significant.

The probability of experiencing cattle feed shortage was higher in the sweet rangelands (odds ratio 4.4) than in the sour rangelands. The odds ratio of 3.066 indicates that farmers who did not receive extension services had higher probability of experiencing cattle feed shortages than those who received extension services. The likelihood of farmers in the communal areas to experience feed shortages was greater than that of the small-scale areas (odds ratio 2.784). Youth-headed households had higher chances of experiencing feed shortages than households headed by adults. Households with uneducated heads were more likely to be challenged by feed shortages than households with educated heads (Table 3.5). The likelihood for a household to experience a disease and parasite problems were higher in the sour rangeland (odds ratio 4.693) than in the sweet rangeland (Table 3.5). Communal areas had higher chances of experiencing diseases/parasites problems than small-scale areas.

3.3.4.1 Feed shortages

Rangelands were the most common source of cattle feed. Grazing in the smallholder areas was shared, with more people sharing a given piece of grazing land in the communal areas compared to small-scale farming areas. In the communal areas, grazing rights were allocated by traditional leaders whilst in the small-scale they were allocated by a grazing committee. About 45 and 60 % of the farmers in the sour and sweet rangelands, respectively, described the condition of rangelands as having insufficient palatable biomass in winter. Biomass availability, species composition, basal and litter cover, soil erosion and animal body condition were used by respondents to evaluate condition of their rangelands.

Table 3.5: Odds ratio estimates of a household experiencing a feed shortage challenge and disease and parasite challenge in the smallholder areas

Feed shortage challenge	**Odds ratio**	**Lower CI**	**Upper CI**
Rangeland type (sweet vs* sour)	4.400	1.271	15.234
Production system (communal vs small-scale)	2.784	1.107	7.002
Herd size (large vs small)	1.038	0.989	1.089
Sheep flock sizes (large vs small)	0.997	0.989	1.006
Goat flock sizes (large vs small)	0.990	0.970	1.011
Land size (small vs large)	1.007	0.761	1.332
Age of the head of household (youth vs adults)	1.922	1.282	2.883
Gender of the head of household (female vs male)	1.087	0.398	2.970
Employment status (unemployed vs employed)	1.003	0.571	1.760
Education (uneducated vs educated)	1.920	1.194	3.088
Availability of extension services (no vs yes)	3.066	1.336	7.037
Disease and parasites challenge			
Rangeland type (sour vs sweet)	4.693	1.619	13.601
Production system (communal vs small-scale)	1.708	0.534	5.461
Herd size (large vs small)	1.004	0.974	1.035
Gender of the head of household (female vs male)	1.220	0.434	3.428
Education (uneducated vs educated)	0.930	0.616	1.403
Employment status (unemployed vs employed)	0.914	0.525	1.590
Availability of extension services (no vs yes)	0.692	0.339	1.411
Availability of veterinary services (no vs yes)	0.491	0.240	1.007

vs*-Versus

Rangeland type was significantly associated with animal body condition ($P < 0.05$). About 40 and 75 % of the respondents in the sour and sweet rangelands reported that cattle condition deteriorates during winter, respectively. Eighty percent of the interviewees associated the deterioration in animal body condition to poor grazing. Besides feed shortage, communities reported that they faced fencing (65 %), bush encroachment (15 %), water shortage (10 %), theft (5 %) and fire (5 %) challenges in the management of rangelands.

Although 40 and 55 % of the farmers practiced supplementary feeding in the communal and small-scale farms, respectively, they all reported that supplementary feeds were not sufficient. Seventy percent of the interviewees in the sour rangelands provided supplements to their cattle compared to 22 % in the sweet rangelands ($P < 0.05$). About 70 % of those who supplemented cattle feed used crop residues, 20 % hay and only 10 % bought-in supplementary feeds. Those farmers who did not supplement cited unavailability of money, lack of knowledge and inadequate availability of rangeland feed as reasons for not supplementing. Out of those who practiced supplementary feeding in the sour rangeland, 75 % supplemented their cattle at least once a day in winter. Respondents preferred supplementing cows first, followed by calves, heifers, steers, oxen and bulls, respectively. Cows were mainly supplemented to improve milk yield, calves to improve growth rate, and steers, oxen and bulls to improve body condition.

3.3.4.2 Diseases and parasites

Diseases and parasites (65 % of the respondents), extreme climate (12 %), predators (10 %), ageing (7 %), poor diet (6 %) and rangeland fires (5 %) were the causes of mortality across all production and rangeland types. Over 70 % of the farmers across both production systems treated and vaccinated their animals against diseases. About 30 and 12 % of the respondents used ethno-veterinary medicine in the communal and small-scale farming areas, respectively. *Aloe africanus*, *Elephantorrhiza elephantine*, *Aloe ferox*, *Asparagus africanus*, *Leonotis leonurus*, *Aloe boylei*, *Celtis africana*, *Cryptocarya woodii* and *Schotia afra* were the most commonly used medicinal plants.

All the respondents reported that ticks were the most common parasites. Ticks mainly occurred in summer (75 % responses) in the sour rangeland. Over 95 % of the respondents dipped cattle regularly to control ticks and less than 5 % dosed to control gastro-intestinal parasites. Cattle were mainly dipped every fortnight (80 % of the respondents) across production systems. Most communal farmers used plunge pool dips. Babesiosis and anaplasmosis were the most important diseases and mainly occurred in summer. Nearly 90 % of the smallholder farmers conducted post-mortems to diagnose the cause of their animalsô death. Less than 5 % of the farmers received veterinary or extension services on monthly basis both in communal and small-scale areas.

3.3.4.3 Poor breeding practices

Most respondents (70 %) reported that local crossbreds (indigenous x exotic) and the Nguni (50 %) breed were the most common cattle breeds across production systems and rangeland types. Other beef breeds available were Bonsmara, Hereford, Brahman and Drankensberger (> 20 % responses). There were more ($P < 0.05$) local crossbreds cattle in the small-scale farms (15 ± 8.4) than in the communal areas (5 ± 6.3). African tradition worshippers had higher ($P < 0.05$) Nguni herd sizes (6 ± 3.2) compared to Christians (1 ± 0.5) and non-worshippers (1 ± 0.5). Table 3.6 shows breeds and breeding stock selection criteria used by respondents. Education, gender, employment status, age, marital status, household size and size of the grazing land did not affect breed herd sizes ($P > 0.05$). The odds ratio estimates for household owning Nguni cattle were less than one for rangeland type, production system, land size gender, age, education, employment status and availability of extension services.

Adaptation to local production conditions, growth performance and milk yield were ranked as the most important traits used by farmers in choosing breeds to keep across production systems and rangeland types (Table 3.6). The majority of the farmers considered performance in bulls and health status in cows first when selecting their breeding animals. Most of the cows used for breeding were from the farmersô own herds. Breeding season was undefined and mating system was largely uncontrolled in the communal areas. More than 85 % of the farmers castrated their animals between 3 and 6 months of age. Respondents across production systems and rangelands used names (80 %), tags (6 %), brands (5 %) and ear notches (4 %) to identify their animals. Most of the farmers (85 %) did not keep records.

Interviewees across all production systems and rangeland types indicated that they experienced the problems of low bull numbers. Nearly 70 % of the respondents had full access to Nguni cattle project bulls and they used them for 2 to 3 years before exchanging them with other communities. It should be noted that 30 % of the farmers who had limited access to Nguni bulls, were not members of the project. These farmers were encouraged by other members to join the project so that they can improve their access to Nguni bulls. Most respondents (75 %) were willing to continue participating in the Nguni cattle projects. In addition, the interviewees obtained drugs and acquired cattle production skills from the Nguni project.

Table 3.6: Beef breed and breeding stock selection criteria used by respondents

Criteria	Rank (mean rank score)[a]					
Breed	Communal	Small-scale	Sig[1]	Sweet rangeland	Sour rangeland	Sig[1]
Adaptation	1 (3.38)	1 (3.06)	*	1 (3.50)	1 (2.94)	*
High growth rate	2 (4.12)	2 (3.87)	*	2 (4.10)	2 (4.01)	*
Milk yield	3 (4.72)	3 (3.88)	*	4 (4.66)	3 (4.33)	*
Availability	4 (4.57)	4 (5.06)	*	3 (4.53)	4 (4.94)	*
Meat quality	5 (5.06)	5 (5.22)	ns	5 (5.11)	5 (5.06)	ns
Affordability	6 (5.16)	6 (5.64)	*	6 (5.15)	6 (5.48)	*
Temperament	7 (5.82)	7 (5.76)	ns	8 (5.85)	7 (5.72)	*
Coat colour	8 (5.95)	8 (6.09)	*	7 (5.83)	8 (6.26)	*
Sig[1]	*	*		*	*	
Breeding stock	Bulls			Cows		
	Communal	Small-scale		Communal	Small-scale	
Performance	1 (1.61)	1 (1.83)	*	4 (3.82)	5 (3.87)	ns
Health status	2 (3.40)	3 (3.12)	*	2 (3.08)	2 (3.21)	*
Conformation	3 (3.41)	2 (2.94)	*	1 (2.83)	1 (2.38)	*
Body condition	4 (3.57)	4 (4.08)	*	3 (3.35)	3 (3.48)	*
Age	5 (4.22)	5 (4.42)	*	5 (3.73)	4 (3.86)	*
Sig[1]	*	*		*	*	

[a] The lower the rank (mean rank score), the greater the importance of the selection parameter.

[1] Mean ranks of the different reasons (columns), production systems (rows) and rangeland types (rows) are significantly different at P Ò0.05 (*).

Sig= Significance level; ns= not significant

3.3.5 Possible solutions to constraints on cattle production

The farmers recommended provision of fence, rangeland reinforcement, cattle herding, and, use of fireguards and enforcement of burning by-laws as solutions to rangeland management problems. The interviewees across all production systems and rangeland types suggested that provision of locally available feed supplements, pasture seed/planting material and rangeland management skills could minimise cattle feed shortages. Over 72 and 20 % of the respondents in the communal and small-scale areas, respectively, appealed for the construction of dams from the local municipalities and government to reduce water shortages.

All respondents indicated provision of drugs, construction and/or maintenance of dip tanks as solutions to diseases and parasite challenges. Interviewees urged the government to improve transport network and increase farmer-veterinarian and farmer-extension officer ratios, which are currently at 1:8000 and 1:500, respectively. Farmers also suggested that the government should desist from the top-down delivery system of agricultural information to a more participatory approach, which actively involves them and formulate policies that promote intervention by other stakeholders. Eighty percent of the respondents urged the development agencies to supply more Nguni bulls and heifers, and also asked for training (50 %) in cattle breeding management aspects. Workshops and on-farm research (95 % of the participants) were suggested as possible solutions to lack of cattle production skills.

The majority of interviewees in the communal areas claimed that construction of banking, marketing and training facilities and provision of credits would improve cattle production. All the respondents requested the local municipalities and government to provide more reliable and equity markets for cattle. Farmers reported that cattle theft can be reduced by establishing police satellite stations and instituting police night patrols in the communities.

They also recommended use of community rangers and provision of fence to reduce cattle theft in the smallholder areas. Most (70 %) of the participants reported that they prefer training in animal health followed by feeding, breeding and marketing management.

3.4 Discussion

The larger cattle herd size in the sour rangeland than in the sweet rangeland could be attributed to high rainfall which improves availability of fodder and grazing in the former, hence there is a positive correlation between rainfall, feed availability and herd size (Andrew *et al.,* 2003). Establishing long-term studies to determine the effects of rangeland type and seasonal changes on cattle herd dynamics, cattle production potential and cattle production efficiency in the communal areas could be essential. The fact that cattle herd sizes were highest for the most educated respondents is supported by earlier assertions in Nyangito (1986) that agricultural production and adoption of new technologies in agriculture are positively related to educational status of the farmers.

The observed low bull numbers can be ascribed to the fact that farmers usually castrate their male animals to make them docile for draught power purposes (Chimonyo *et al.,* 1999; Dovie *et al.,* 2006). Since farmers were using cattle for draught power, the observed low oxen to cow ratio can reflect a shortage of draught power, especially during the rainy season in the sour rangelands where crop production is prominent. The lower numbers of steers and oxen agrees with a previous affirmation by Musemwa *et al.* (2007) that farmers prefer selling steers and oxen to reproductively active animals. This could mean that farmers prefer retaining cows for breeding and milk production purposes.

The variation in reasons for keeping cattle across regions and production systems observed in the study are similar to previous reports (Shackleton *et al.,* 1999; Dovie *et al.,* 2006; Siegmund-Schultze *et al.,* 2007; Nqeno, 2008). Although farmers highlighted cash as the main reason for rearing cattle, it is not clear why sales are not proportionate to the large numbers of cattle found in the smallholder farming areas. Setting-up monitoring trials to determine herd dynamics, production potential and efficiency, and reasons for low cattle off-take in the smallholder areas of South Africa, is therefore, important.

Cattle ownership and management in the smallholder areas were dominated by men. Men are generally the owners of large stock (cattle, goats and sheep) while women are confined to producing livestock species close to the homesteads, such as chickens and pigs (Grandin *et al.,* 1991; Bank and Qambata, 1999; Andrew *et al.,* 2003). While widows may be the nominal owners of cattle after their husbandsô death as reported in this study, this is usually seen as a stewardship role in that these cattle are often regarded as the property of the eldest son, who will formally take them over upon his motherôs death (Grandin *et al.,* 1991; Andrew *et al.,* 2003). The observation that female-headed households were more susceptible to feed shortages and disease/parasites can be attributed to lack of capital and access to institutional credit, poor technical skills and lack of access to extension services (Bank and Qambata, 1999). These factors affect women more than men, and limit participation and reduce efficiency of women in cattle production (Grandin *et al.,* 1991; Bank and Qambata, 1999). There is need to investigate the control and access to resources and benefits of cattle production by different gender groups in the smallholder farming sector. An engendered approach to cattle development would improve production efficiency (Andrew *et al.,* 2003).

Farmers ranked feed shortage as the major constraint and, as shown by high odds ratio estimates, it was mainly experienced in communal areas in the sweet rangelands. On the same note, loss in animal condition which was also common in communal areas in the sweet rangelands was largely attributed to decline in feed quality, especially in the dry season. The observation that feed quality was more marked in the communal areas, where gazing lands are small and controlled by traditional leaders than in the small-scale communities, where grazing lands are large and controlled by grazing committees was also reported by Moyo *et al.* (2008). Research on the potential of various community institutions to manage the use of communally owned rangeland resources should, therefore be investigated. On the other hand, the marked drop in feed quality in the sweet rangelands during winter is accredited to low rainfall. Sweet rangeland receives low rainfall (< 500 mm per annum) compared to sour rangelands that receive moderate rainfall (600-800 mm). Rainfall received in the sour rangeland promotes excess herbage growth during the hot-wet season (Botsime, 2006), which is conserved as hay and crop residues for dry season supplementary feeding, particularly by small-scale farmers (Simela *et al.,* 2006). Small-scale farmersô purchase of feed resources and adoption of fodder conservation technology is high compared to communal farmers who are resource-limited (Andrew *et al.,* 2003; Mapiye *et al.,* 2006).

As feed supply is generally low during winter, utilisation of breeds with low maintenance feed requirements such as Nguni is advisable. Since availability of extension services and education have a strong influence on feed availability, educating farmers through extension, on cost-effective ways of harvesting, conserving and value-addition to grasses, tree foliage and crop residues to improve their nutritive value, palatability, digestibility and utilisation is important. Research on low-cost protein supplements from indigenous leguminous trees such as *Acacia* species in the sweet rangeland is essential. The indigenous leguminous tree leaves, seeds, pods or their combinations can be processed into meals or blocks to concentrate protein and reduce anti-nutritional factors and be fed to animals on rangelands. To improve utilisation efficiency of crop residues and low quality forages in the sour rangelands, poor quality feeds can be mixed with *Acacia* leaf meal (Dube, 2000). Screening, evaluation and utilisation of indigenous forage grasses in the sour rangelands for foggage and hay production deserves attention.

Although fencing is essential in reducing herding labour expenses and in controlling grazing, breeding, diseases, parasites, trespassing, theft and predation (Mapiye *et al.,* 2006), it is capital-intensive. Currently, the impact of fencing is undermined by vandalism, theft and the absence of local by-laws and if available, poor mechanisms of enforcing these by-laws (Moyo *et al.,* 2008; Nqeno, 2008). Research on how to appropriately design and effectively implement local by-laws to govern communal rangelands should, therefore, be prioritised. One option is for farmers to group their herds and take turns in herding, especially during the cropping season, and to rotationally graze animals on different sides of the mountains, where applicable. Use of indigenous browse species as live-fences with a double strand of plain wire can be viable, where fencing is an option.

Reports that cattle farmers experienced problems with ticks and tick-borne diseases, especially during summer in the sour rangeland are comparable to results found in the Eastern Cape by Perret *et al.* (2000) and Marufu *et al.* (2009), and in the Free State by Mbati *et al.* (2002). The reason could be that the Eastern Cape has semi-arid climatic conditions modified by proximity to the coast. These conditions promote growth of most ticks, especially during the hot-wet season (Muchenje *et al.,* 2008b; Marufu *et al.,* 2009). The observation that disease and parasite occurrence was influenced by rangeland type concurs with reports by

Coop and Holmes (1996) that in ruminants, a strong relationship exists between nutrition and disease/parasite infestation. Animals with higher levels of protein and/or energy are better able to control establishment of new diseases/parasites and reduce fecundity of existing pathogens/parasites (Coop and Holmes, 1996).

The observation that households in the communal areas had higher chances of experiencing disease and parasite problems than small-scale areas can be attributed to the uncontrolled grazing system practised in the communal areas. In the communal areas, herds from different households are allowed to graze together and mate irrespective of their health status and in some cases mix with wildlife. This is exacerbated by lack of proper disease and parasites control infrastructure in the communal areas. These conditions increase prevalence of disease and parasites under the communal production systems (Marufu *et al.,* 2009).

Use of breeds that are resistant to ticks and tick-borne diseases, such as Nguni provides a key entry point for increasing cattle productivity in the rural areas of the Eastern Cape (Scholtz, 2005; Marufu *et al.,* 2009). Research on the efficacy, dosage rates and application methods of locally available ethno-veterinary medicine, such as *Aloe* and *Elephantorrhiza* species is required to complement breed resistance in alleviating ticks and tick-borne diseases. Education of farmers through veterinary extension would ultimately result in improved disease diagnosis and, targeting and usage of drugs, and consequently animal health.

The observation that pure Nguni herds were rare among smallholder farmers concurs with the reports by Schoeman (1989), Rege *et al.* (1999) and FAO (2007) that the purity of Nguni cattle is under threat due to indiscriminate crossbreeding. Pure Nguni cattle numbers in South Africa are decreasing, for example, they declined from 1 800 000 in 1992 to 9 462 in 2003

(International Livestock Research Institute, 2008). Since farmers are keen to re-build their cattle herds with the Nguni breed and improve its production (Bester *et al.,* 2003), there is need to establish government multiplication farms to supply the breeding stock and formulate policies that minimise haphazard introduction of exotic cattle in the rural areas. An interchange of adapted Nguni breeding stock between villages and or even regions becomes a viable option when herds are more widespread. The UFH model, which gives communities two bulls and ten in-calf heifers to allow them to build up a Nguni nucleus herd and after five years the community gives back to the project two bulls and ten in-calf heifers that are then passed on to another community (Musemwa *et al.,* 2007), should be recommended to farming communities in other Provinces of South Africa.

Possession of large Nguni herd sizes by African tradition worshippers compared to Christians and non-worshippers could be attributed to use of indigenous cattle for traditional rituals. These rituals include funerals, circumcision, veneration and appeasing of ancestors, payment for service to traditional healers and installation of spirit-mediums and exorcism of evil spirits (ECDC, 2003; Dovie *et al.,* 2006; Nqeno, 2008). Cattle skins/hides are used to make drums and clothing for spirit mediums and traditional healers for use during traditional functions (Shackleton *et al.,* 1999). African tradition worshippers consider local crossbreds and exotic cattle as unacceptable offerings to ancestors, spirit mediums, evil spirits and traditional healers. Thus, traditionalists place a high cultural-value on indigenous cattle compared to Christians and non-worshipers. Consideration of religion and cultural beliefs of the beneficiaries in rural developmental strategies is, therefore, important.

The farmer selection criteria for breed (adaptation, milk yield and growth rate) and breeding stock (performance, conformation and health status) were in line with their major roles for keeping cattle namely, cash, milk and ceremonies. Breeding objectives are related to functions of animal keeping (Amer *et al.,* 1998; Bayer and Feldmann, 2001; Bebe *et al.,* 2003). Given the harsh pedo-climatic and socio-economic condition prevalent in smallholder farming areas in the Eastern Cape, the animals need to be adapted to the environment and capable of coping with rampant disease and low-input conditions (Collins-Luswet 2000; Andrew *et al.,* 2003). Since the Nguni breed is adapted to a harsh environment (Scholtz, 2005; Muchenje, *et al.,* 2008a, b; Ndlovu *et al.,* 2008); its population is likely to remain stable or increase under such conditions, if crossing with exotic breeds is reduced. Indigenous breeds are an important reservoir of genomes that may be used to produce hybrids or animals that will adapt to unseen future catastrophes (Omondi *et al.,* 2008a, b; Zander and Drucker, 2008). For example, Nguni cattle are currently being reared with little/no use of feed supplements, anthelmintics or acaricides (Muchenje *et al.,* 2008a, b; Ndlovu *et al.,* 2008; Marufu *et al.,* 2009). Encouraging farmers to keep the Nguni breed can, therefore, be cost-effective, and offer a chance for entry into an attractive organic beef niche market (FAO, 2007). Conservation with utilisation of Nguni cattle genetic resources is, therefore, of paramount importance.

The findings that breeding cows were generally selected from within the herd and bulls were obtained through communal grazing and exchange or transfers concur with previous reports (Bayer and Feldmann, 2001). Breeding season was undefined and mating system was largely uncontrolled in communal areas. Bayer *et al.* (2004) reported similar results in the communal areas. Since most of the farmers did not own bulls, an open nucleus breeding scheme or a bull-exchange scheme could be introduced to improve availability of bulls and avoid inbreeding in the smallholder sector (Bayer and Feldmann, 2001). At community level, a better cooperation between farmers could be sought with respect to the keeping of sires to provide breeding services.

Following the farmersô reports on lack of extension and veterinary services, research on the effectiveness of farmer-research-extension linkages, farmersô adoption rates, and willingness to pay for private veterinary and extension services is crucial. Documentation of cattle production information in local languages and its marketing through the print and electronic media can be useful in improving smallholder farmersô cattle production skills.

3.5 Conclusions

Although the importance of constraints varied with production systems and rangeland types, shortage of feed was ranked as the most important constraint, especially in the dry season. To better understand the implications of feed shortage on Nguni cattle production, monitoring cattle dynamics, production potential and production efficiency in communal areas is essential. Such studies can generate useful information required to devise feeding strategies that improve beef production under low-input production systems.

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Chapter 4: Seasonal dynamics, production potential and efficiency of Nguni cattle in the sweet and sour rangelands in the Eastern Cape, South Africa

(Published in *Journal of Arid Environments*, see Appendix 4)

Abstract

Monitoring cattle inflows and outflows over time in a herd provides a good indicator of herd productivity. Ninety households were monitored over a year to determine the effect of season, rangeland type and herd size on births, deaths, sales, purchases, exchanges, off-take, cattle production potential (CPP) and cattle production efficiency (CPE) on communal rangelands in the Eastern Cape, South Africa. Most births were recorded in large herds in the sour rangelands during the hot-wet season. Farmers with large herd sizes purchased more ($P < 0.05$) cattle compared to those with small herd sizes. Cattle sales were highest in the large herds in the cool-dry season. Most cattle died in the hot-wet and cool-dry seasons in the sour rangeland. Mortality was mainly caused by anaplasmosis (24 %) and babesiosis (20 %). Most cattle that died were cows (45 %). Households owning small herds in the sweet rangeland had the lowest CPP in the cool-dry season ($P < 0.05$). The CPE was highest in the cool-dry season in the households owning large herds on sweet rangelands ($P < 0.05$). It was concluded that households owning small herds in the sweet rangeland had the lowest births, purchases and CPP in the cool-dry season whilst those owning large herds in the sour rangeland had the higher sales, slaughters and deaths in the hot-wet and cool dry seasons, and CPE was high in the cool-dry season in the sweet rangeland.

Key words: Cattle sales, Communal, Herd dynamics, Household consumption, Mortality

4.1 Introduction

Feed shortage was identified as the most important factor limiting cattle production on communal rangelands (Chapter 3). The factors which influence feed shortage and their effects on cattle off-take, production potential and production efficiency on communal rangelands is, however, not well understood. Cattle off-take, production potential and production efficiency reflect the extent of adaptation of cattle to the local environment and the degree of integration of farmers into the market (Amanor, 1995; Ezanno, 2005). Knowledge of production efficiency improves the understanding of functional attributes and is useful in determining the constraints and the potential of communal beef cattle production systems. Cattle herd dynamics is a product of the changes in reproductive, mortality and off-take rates, and the pedo-climatic and socio-economic factors influencing such changes (Upton, 1989; Baptist, 1990). Understanding of herd dynamics is, therefore, useful in determining production potential and production efficiency and, consequently, the impact of feed shortage on CPE on communal rangelands.

Cattle herd dynamics on communal rangelands in the semi-arid areas is often determined by feed resource availability, which, in turn, is influenced by vegetation types and climatic factors (Botsime, 2006; Angassa and Oba, 2007). In the communal areas, cattle productivity is directly linked to the feed availability (Desta and Coppock, 2002; Kgosikoma, 2006). For example, intra-annual spatial and seasonal distribution of rainfall will cause fluctuations in forage quality and quantity, forage conservation and utilisation and consequently, changes in cattle condition indices and populations (Scoones, 1995; Fynn and O'Connor, 2000; Boone and Wang, 2007). The variations result in fluctuations in marketable cattle numbers, beef yield and quality, and beef market values (Coetzee *et al.,* 2005; Musemwa *et al.,* 2008). Information on the effect of vegetation type, seasonal changes on herd dynamics and management in communal areas is scarce, making it difficult to assess the efficiency of utilisation of communal rangelands, and predict cattle sales and consumption patterns in these areas. The objective of the current study was to determine the effect of season, rangeland type and herd size on births, deaths, sales, purchases, exchanges, off-take, CPP and CPE on communal rangelands in the Eastern Cape, South Africa. It was hypothesised that season, rangeland type and herd sizes do not affect births, deaths, sales, purchases, exchanges, off-take, CPP and CPE on communal rangelands in the Eastern Cape, South Africa.

4.2. Materials and Methods

4.2.1 Description of study sites

Two major rangeland types that are common in South Africa: the sweet and sour rangelands were selected. Two communities from each of the sweet and sour rangelands in the Eastern Cape Province of South Africa were selected based on the willingness of the communities to participate in the study. The sweet rangeland was represented by Melani community, located near Alice in the Amatole District Municipality and Magwiji, situated near Sterkspruit in the Ukahlamba District Municipality. Tiwane and Upper Mnxe communities, located near Cala town in the Chris Hani District Municipality, represented the sour rangeland.

Melani lies along longitude 32^0 78' E and latitude 26^0 85' S at an altitude of 450-500 m above sea level. It is in the False Thornveld vegetation characterised by mean annual rainfall of 480 mm and mean annual temperature of 18.7^oC. Most of the rains are received between November and April. Cattle graze on communal rangelands mainly composed of *Cynodon dactylon*, *Digitaria eriantha*, *Sporobolus* species and *Themeda triandra* grasses. *Acacia karroo*, *Scutia myrtina* and *Maytenus polyacantha* are the dominant tree species.

Magwiji (Sterkspruit) is situated 30^{o} 37′S and 27^{o} 22′E at an altitude of 1507 m above sea level. It has a semi-arid climate with most of the rainfall received between October and April (450 mm) and less than 50 mm falling between May and September. Ambient temperatures fluctuate between 10 and 20^{o}C, with minimum and maximum temperatures being recorded in July (9^{o}C) and January (22^{o}C), respectively. The most common grass species are *Elionurus muticus*, *Heteropogon contortus*, *Microchloa caffra* and *Setaria sphacelata*. The rangelands are dominated by *Euryops pyroides* and *A. karroo* invader woody species (Lesoli, 2008). In the sweet rangelands, cattle were grazed on communal rangelands throughout the year at a stocking rate of 10 ha per livestock unit (LU). Cattle were usually not enclosed at night and were only brought to the homesteads for routine practices, such as vaccination and dipping.

Tiwane and Upper Mnxe (Cala) communities are positioned 31^{o} 33′S and 27^{o} 36′E at an altitude of 1440 m above sea level. They receive rainfall of 600 to 800 mm between October and April, and 50-200 mm from May to September. Mean monthly minimum and maximum day temperatures are recorded in July (11^{o}C) and January (20^{o}C), respectively. The most common grass species were *T. triandra*, *H. contortus*, *S. africanus* and *Microchloa ciliate*. *Acacia karroo*, *E. pyroides*, *Chrysocoma ciliate* and *Dyspyros scrabrida* are the common bush species (Lesoli, 2008). In the sour rangelands, cattle were grazed on communal rangelands at a stocking rate of 6 ha/LU during the hot-wet and post-rain seasons. During the cool-dry and hot-dry seasons, cattle are kept on fenced croplands and fed on crop residues. Only lactating cows and suckling calves were kraaled at night. Marketing of cattle in both sweet and sour communal rangelands was informal and was either within or between the local communities. Some farmers depended on hawkers or middlemen who buy cattle for urban markets (Musemwa *et al.,* 2008). In both sites, there were no records available on births, purchases, consumption, sales, theft and mortality.

4.2.2 Sampling of households

Only those households that owned at least one mature cattle and were willing to participate in this study were selected. Using these criteria, a total of 90 households were chosen, comprising of 20 and 25 from Magwiji and Melani, and 20 and 25 from Tiwane and Upper Mnxe, respectively. Households were divided into two categories on the basis of herd size; small (1-20 cattle) and large (more than 20 cattle). Each household had an average of 7 ± 2 cattle.

4.2.3 Data collection

Data on herd dynamics were recorded per household by trained research assistants at the end of every month from August 2007 to July 2008. Months were grouped into four seasons namely; cool-dry (May-August), hot-dry (September-October), hot-wet (November-February) and post-rainy (March-April) (Ellery *et al.,* 1995; Tainton, 1999). The data collected included herd size, herd composition (bulls, oxen, steers, cows, heifers and calves), entries and exits (Appendix 5). Entries recorded were births and purchases, whilst exits were comprised of slaughter, sales, mortalities and thefts. The reasons for entries and exits were also captured.

Off-take was calculated as the number of animals sold and/or slaughtered per month as a percentage of the total herd size. Cattle were categorised into calves, growers and mature cattle for computations of production potential and production efficiency. Growers were described as all cattle from weaning to puberty, while all reproductively active cattle were classified as mature animals. Calves were weaned between six and twelve months of age and were regarded as having reached puberty between 24 and 30 months. Cattle production potential (CPP) for each household was calculated as:

$$CPP = N / H$$

where: CPP= cattle production potential;

N= number of mature cattle + growing cattle; and

H= herd size.

The cattle production efficiency (CPE) was computed for each household as follows:

$$CPE = (M / CPP) x100$$

Where: CPE= cattle production efficiency;

M= number of mature cattle consumed or sold; and

CPP= cattle production potential.

4.2.4 Statistical analyses

Percentages of incidences of calving and mortality, reasons for purchasing, slaughtering and selling cattle, and causes of mortality were determined using the PROC FREQ procedure of SAS (SAS, 2003). The Chi-square test (PROC FREQ procedure) was used to determine the association between rangeland type and the proportion of farmers purchasing, slaughtering and selling cattle, and their theft and mortality experiences (SAS, 2003). The effect of rangeland type, season and their interactions on total cattle numbers and numbers of various cattle classes (calves, heifers, cows, steers, oxen and bulls) were determined using the PROC GLM procedure of SAS (2003). The linear model was:

$Y_{ijkl} = \mu + A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk} + ABC_{ijk} + Ů_{ijkl}$

Where Y_{ijkl}= total cattle numbers and numbers of various cattle classes;

μ = overall mean;

A_i = effect of rangeland type (i= sweet, sour);

B_j = effect of season (j= late cool-dry, hot-dry, hot-wet, post-rainy, early cool-dry);

C_k = effect of herd size (k= small, large);

AB_{ij} = interaction of the i^{th} level of rangeland type and j^{th} level of season;

AC_{ik} = interaction of the i^{th} level of rangeland type and k^{th} level of herd size;

BC_{jk} = interaction of the j^{th} level of season and k^{th} level of herd size;

ABC_{ijk} = interaction of the i^{th} level of rangeland type, j^{th} level of season and k^{th} level of herd size and;

$\mathring{U}_{ijkl}$ = residual error.

A similar model was used to analyse for the effects of rangeland type, season, herd size and their potential interactions on the number of births, purchases, total entries, slaughters, sales, thefts, mortalities, total exits and, off-take and CPP and CPE. Pair-wise comparisons of the least square means were performed using the PDIFF procedure (SAS, 2003).

4.3 Results

4.3.1 Cattle numbers

About 60 % of the farmers in both rangeland types owned between 1-10 cattle small herd sizes. Figure 4.1 shows the effect of rangeland type and season on herd size and composition of cattle on communal rangelands. There were significantly more cattle per household in the hot-dry season in the sour rangeland compared to the sweet rangeland ($P < 0.05$; Figure 4.1A). The herd size in both rangelands was mainly composed of cows. Generally, bull to cow ratio in the sweet and sour rangeland were 1:28 and 1:32, respectively. The respective cow-calf ratios were 5: 2 and 3: 1. The numbers of cows and heifers were highest in the sour rangeland, particularly in the hot-dry season (Figure 4.1B).

The number of steers was highest in the sour rangeland in the hot-dry season whilst oxen numbers were highest in the sour rangeland during the hot-wet season (Figure 4.1C). Generally, the numbers of both steers and oxen were low during the cool-dry season (Figure

4.1C). The number of calves was highest in the sour rangeland in the post-rainy season and lowest in the cool-dry season compared to the sweet rangeland (Figure 4.1D). The number of bulls was highest in the hot-wet season in the sour rangeland (Figure 4.1D).

4.3.2 Cattle herd entries

There were no cattle that were exchanged-in, entrusted-in or received as gifts during the study period. Only 4 % of the farmers purchased cattle during the study period. Farmers (95 %) attributed low cattle purchases to lack of capital. The farmers purchased more heifers (70 %) than bulls (10 %) and cows (8 %), calves (6 %), steers (4 %) and oxen (2 %). The majority of farmers (94 %) perceived that purchase of heifers and bulls improves the reproductive capacity of their herds. Rangeland type and season did not ($P > 0.05$) affect purchases. Farmers with large herd sizes purchased more ($P < 0.05$) cattle (1.2 ± 0.44) compared to those with small (0.1 ± 0.056) herd sizes. The highest number of births and total entries were observed in large herds in the sour rangelands during the hot-wet season (Figure 4.2A and 4.2B). Births (88 %) contributed markedly to the total entries compared to purchases (12 %).

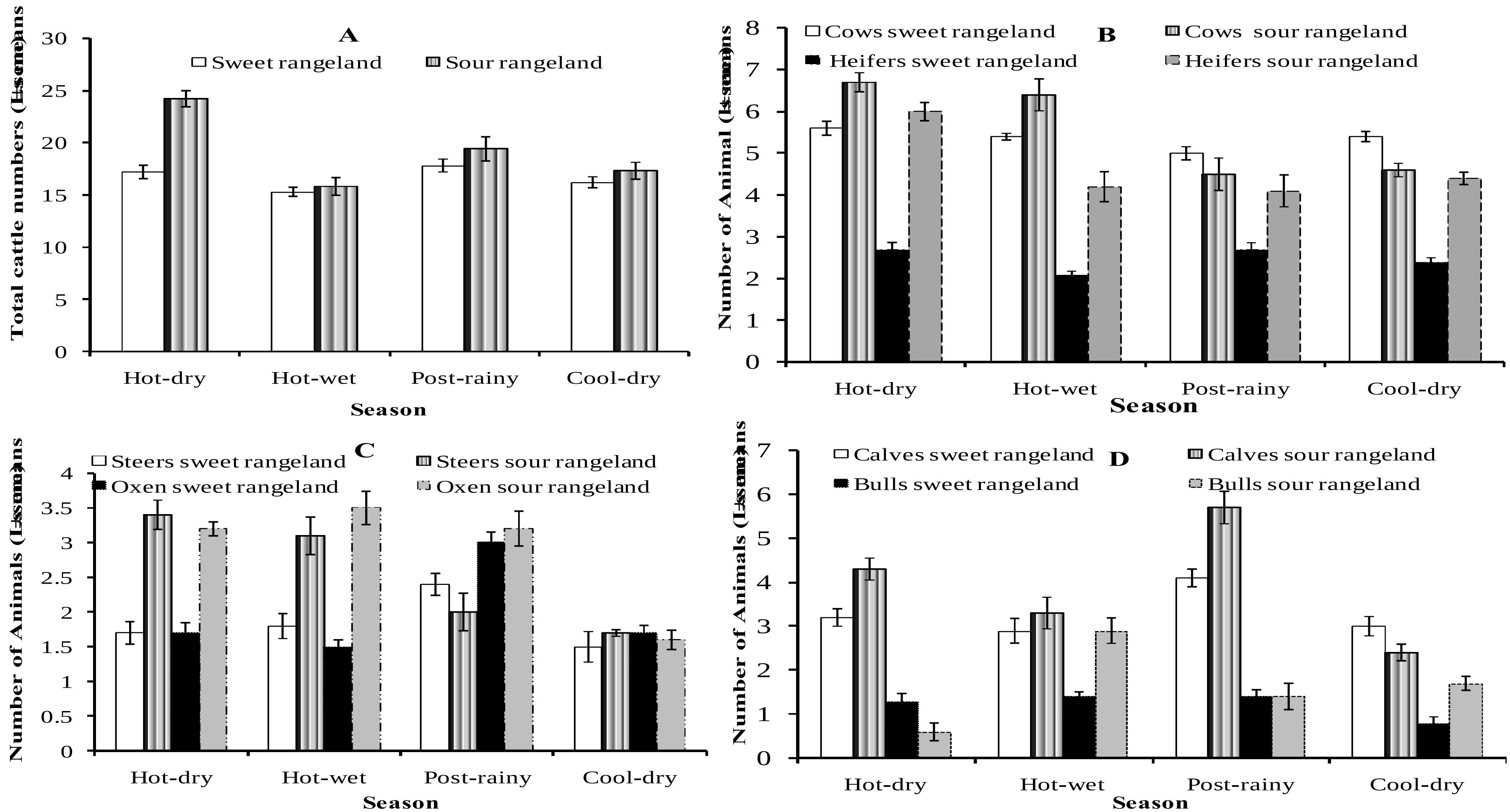

Figure 4.1 A-D: Least square means of total cattle numbers (A), number of cows and heifers (B), steers and oxen (C), and calves and bulls (D) based on rangeland types and seasons

4.3.3 Cattle herd exits

No cattle were exchanged-out, entrusted-out or given as gifts in the current study. The proportion of farmers who sold cattle was not significantly associated with rangeland type. Nearly 8 % of the households sold cattle during the study period. Out of the farmers that sold cattle, 44 and 36 % of the sales were oxen and steers, respectively. All the calves were sold together with their dams. Cash (85 % of the farmers) and culling (15 %) were the main reasons for selling cattle. Cash was used for financing household needs (55 %), school fees (21 %), hospital bills (12 %), village taxes (8 %) and emergencies (4 %). Cattle sales were higher in the large herds in the cool-dry and hot-wet seasons than in the small herds during the same season (Figure 4.3A). Farmers attributed high cattle sales in cool-dry season to shortage of feed and poor body condition of cattle. They reported that due to poor body condition, their cattle fetched low prices at the markets.

The number of stolen cattle was significantly influenced by rangeland type. There were significantly more cattle thefts in the sweet rangeland (1.3 ± 0.05) than in the sour rangeland (0.2 ± 0.01). Season and herd size had no effect on cattle thefts. About 12 and 30 % of the households in the sweet and sour rangelands experienced cattle mortality problems, respectively ($P < 0.05$). As shown in Table 4.1, the major causes of mortality were anaplasmosis and babesiosis diseases. Herd size did not affect mortality. Generally, most cattle died in the hot-wet season in the sour rangeland ($P < 0.05$; Figure 4.3B).

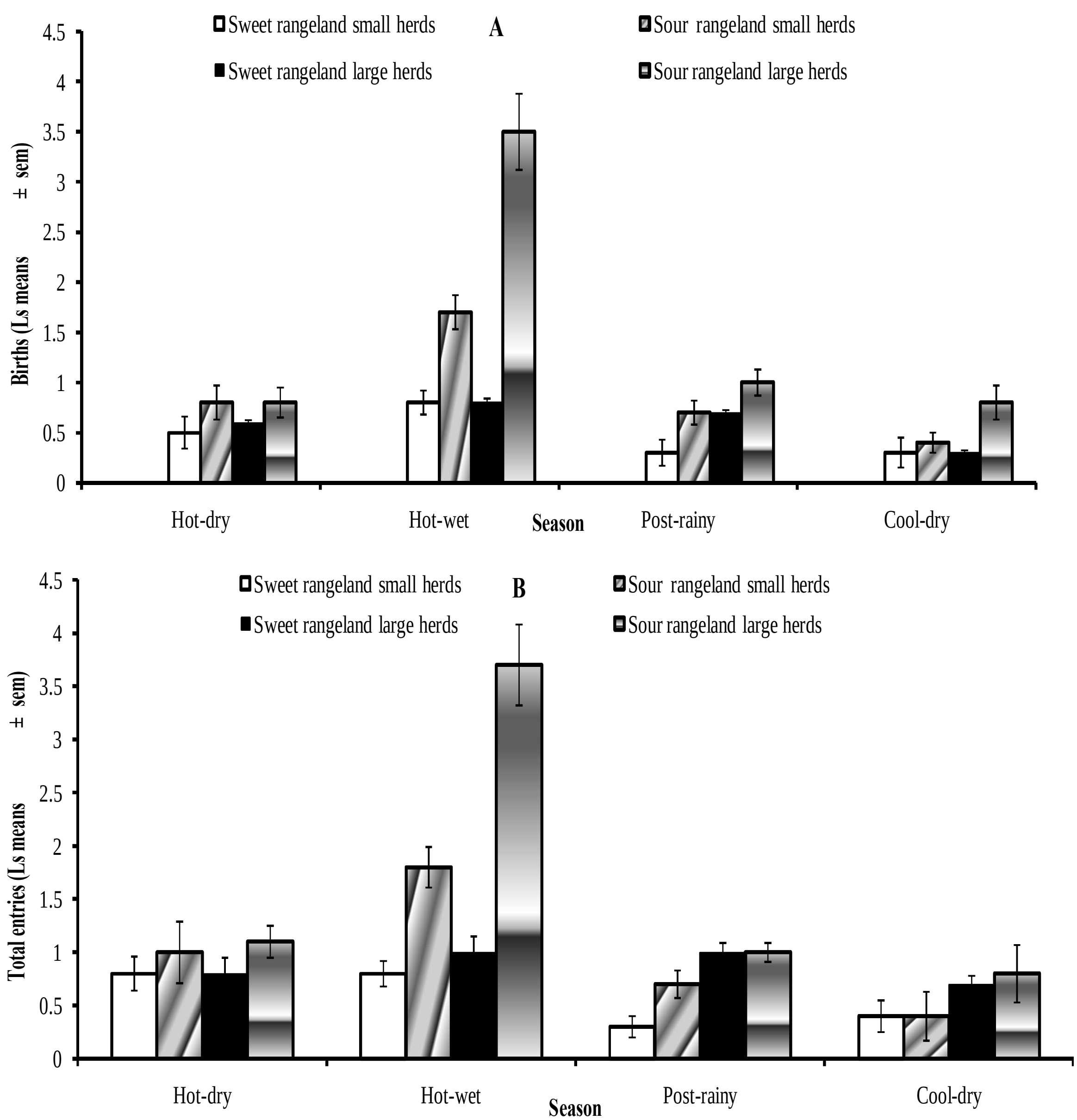

Figure 4.2 A and B: Least square means of births (A) and total cattle entries (B) in the sweet and sour communal rangelands based on herd size, rangeland type and season

Rangeland type was not significantly associated with the proportion of farmers that slaughtered cattle. About 5 % of the households slaughtered cattle during the study period. Oxen (40 %) followed by steers (30 %), cows (25 %), bulls (3 %) and heifers (2 %) constituted the slaughtered animals. Households with large herds slaughtered significantly more cattle (1.2 ± 0.04) compared to households with small (0.13 ± 0.02) herds. Cattle were mainly slaughtered for ceremonies (70 % of the slaughters) such as circumcision, funerals and weddings. The other reasons for slaughter were culling (20 %) and meat consumption (10 %). Highest cattle slaughters were recorded during the hot-wet season in the sour rangeland (Figure 4.3C). Households with large herds had higher ($P < 0.05$) cattle exits (4.9 ± 0.26) compared to households with small (1.6 ± 0.07) herds. The exits were highest during the hot-wet season in the sour rangeland (Figure 4.3D). Sales (45 %) contributed more ($P < 0.05$) to the total exits compared to mortality (30 %), slaughters (15 %) and theft (10 %). Rangeland type, season, herd size and their interactions had no effect on total cattle off-take.

4.3.4 Cattle production potential and cattle production efficiency

There was a significant interaction of herd size, rangeland type and season on CPP. Households owning large herds in the sour rangeland had the highest CPP in the post-rainy season while small herds in the sweet rangeland had the lowest CPP in the cool-dry season (Figure 4.4A). Herd size had no effect on CPE ($P > 0.05$). For CPE, the interaction between rangeland type and season was significant. Cattle production efficiency was highest in the sweet rangeland in the cool-dry season ($P > 0.05$; Figure 4.4A).

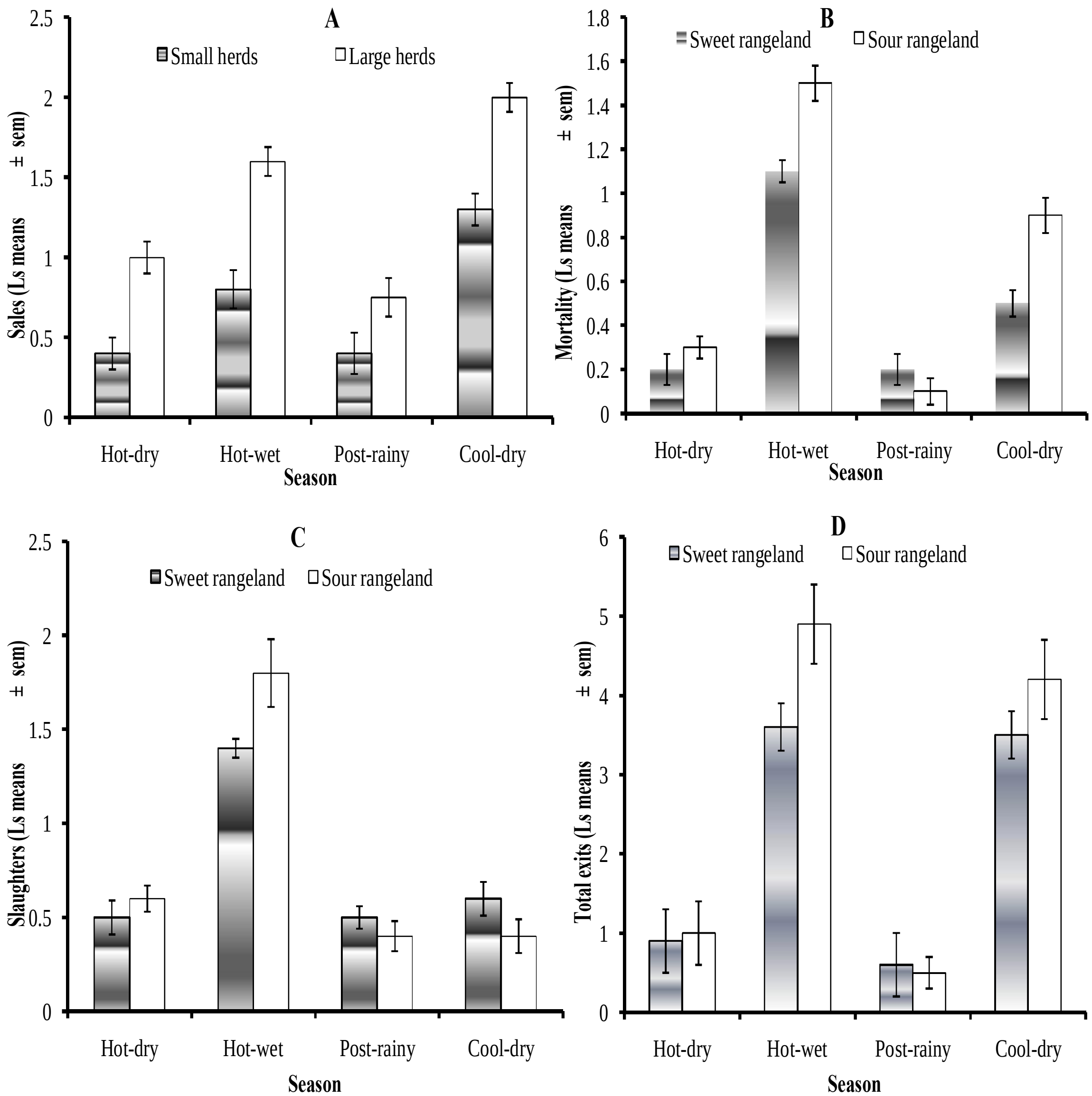

Figure 4.3: Least square means of number of animals sold (A) and effect of season on mortality (B), number of animals slaughtered (C) and total exits (D) based on season and herdsize

Table 4.1: Causes of mortality in the communal herds in the sweet and sour rangelands in the Eastern Cape, South Africa

Causes of mortality	**Frequency (%)**
Anaplasmosis	24
Babesiosis	20
Unknown diseases	14
Black leg	10
Lumpy skin	8
Ehrlichiosis	6
Mastitis	5
Starvation	4
Dystocia	4
Accidents	3
Senility	2

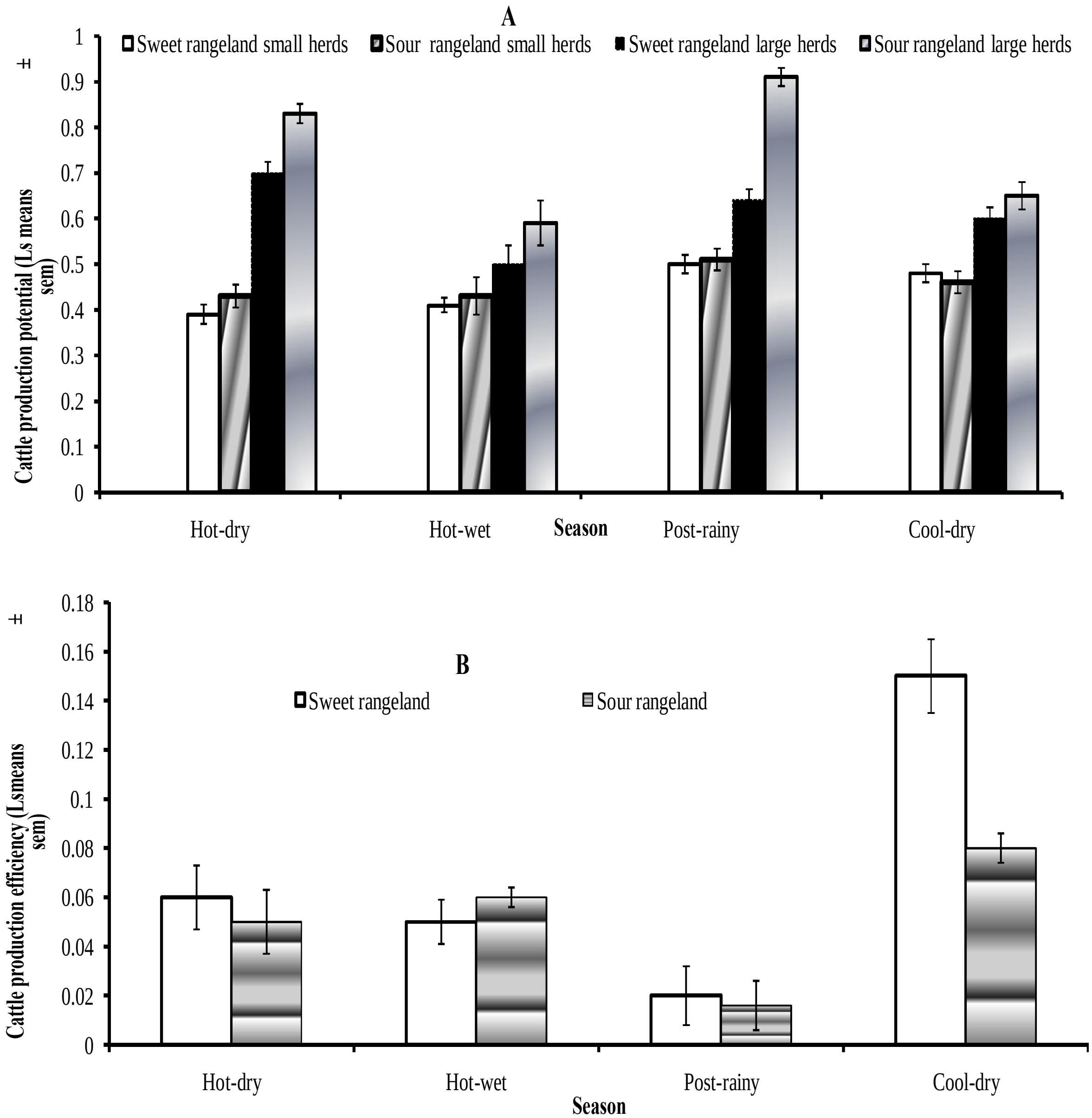

Figure 4.4 A and B: Least square means of CPP (A) and effect of rangeland type and season on CPE (B) based on herd size, rangeland type and season

4.4 Discussion

Decreases or increases in cattle population is a consequence of the interplay of births, deaths, purchases, sales, consumption and exchanges. In general, cattle numbers followed a seasonal trend in rainfall and feed availability. Ellery *et al.* (1995) and Tainton (1999) reported that feed availability declined from post-rainy season onwards as temperatures and rainfall drop, and reach a low-point during the cool-dry season when plant materials are dormant. It then rises with the emergence of new shoots in the hot-dry season, and establishment of plants following rains in the hot-wet season. Similar to current findings, Scoones (1995), Fynn and O'Connor (2000) and Mellink and Martin (2001) reported a curvilinear relationship between rainfall, feed supply and cattle performance in arid and semi-arid areas. The marked decline in cattle numbers in the hot-wet season in the sour rangeland could be ascribed to high levels of mortality, sales and slaughters that occurred in the same period in this study.

High cattle numbers observed in the sour rangeland compared to the sweet rangeland could be attributed to their differences in rainfall. Sour rangelands receive more precipitation at the end of cool-dry season every year compared to the sweet rangeland (Ellery *et al.,* 1995; Tainton, 1999). The high precipitation ensures feed availability in the hot-dry season and, could, in turn, reduce mortality and increase births and, consequently, increase cattle populations. Current findings agree with literature (Bebe *et al.,* 2003; Desta and Coppock, 2002; Boone and Wang, 2007) in which a strong relationship between rainfall, feed availability and cattle populations was reported.

The increased births and calf numbers observed in the rainy seasons could be attributed to feed availability. Nqeno *et al.* (2009) reported that the hot-wet and post-rainy seasons, periods when forage quantity and quality is high, coincide with increased parturitions. The rangeland nutritional base during these periods often meets cattle nutrient requirements for maintenance, growth, reproduction and lactation (Abeygunawardena and Demawatewa, 2004). The observation that cattle entries were predominantly births agrees with earlier studies (Ezanno, 2005; Angassa and Oba, 2007).

The low cattle populations in the cool-dry season in the sweet rangeland can be attributed to mortality and sales triggered by reduced feed and water supply. For example, crude protein content during the cool-dry season is as low as 2 % in the sweet rangelands (Lesoli, 2008). Thus, rainfall modulates livestock populations through the impact of seasonal droughts on rangeland productivity (Kay, 1997; Desta and Coppock, 2002; Begzsuren *et al.,* 2004). As the dry season progresses, livestock are obliged to mobilize body fat reserves to balance for the deficiency of nutrients in the diet (Agenas *et al.,* 2006). Training farmers, especially those in the sweet rangelands on cost-effective methods of conserving and adding-value to indigenous grasses and tree foliage to improve their utilisation by cattle in the cool-dry season could be prioritised.

The low calf to cow ratio could be attributed to low plane of nutrition, poor cow management and productivity levels and low bull fertility. According to Abeygunawardena and Demawatewa (2004), cow productivity on communal rangelands is reflected by delayed age at puberty (24 and 30 months) and at first calving (36-48 months) and long calving intervals (24-48 months). Nqeno *et al.* (2009) reported that cow productivity in the communal areas is limited by feed shortage, reproductive diseases, parasites, low bull to cow ratio, and low bull fertility. The nutritional deficiency observed in the cool-dry season results in loss of body weight and condition, and ovarian activity in cows (Abeygunawardena and Demawatewa, 2004). The bull to cow ratio in this study was within the recommended range of 1 to 25-30

(Ainslie *et al.,* 2002). Bull exposure was not likely to be influential since the bulls and cows were running together throughout the study period. However, the influence of bull fertility, and reproductive diseases were not determined in the current study and therefore, merit investigation.

The farmers rarely purchased breeding stock in the form of heifers to improve the reproductive capacity of their herds. They depended on the reproductive performance of their herds to maintain productivity. In general, cattle sales, consumption and purchases were low. Farmers attributed the low sales and consumption to small herd sizes, and low purchases to lack of capital. The observation that farmers with large herds sold and consumed more cattle than those with small herds agrees with assertions by Coetzee *et al.* (2005) and Montshwe (2005) who reported that the propensity to sell and consume increases with herd size. Besides improving the nutritional status and genetics of the communal herd, financial organizations should provide funds for the establishment of breeding stock multiplication centres to supply farmers with seed for herd building. For example, the University of Fort Hare and the Department of Agriculture have embarked on a programme to distribute two bulls and 10 in-calf heifers to selected communities to allow them to build up Nguni nucleus herds (Musemwa *et al.,* 2008). After five years, the community is expected to give back to the project two bulls and ten in-calf heifers, which are then passed on to another community, such projects can be invaluable in improving Nguni population in the communal areas.

The finding that sales dominated cattle exits contradicts Upton (1989) and Oba (2001) who reported mortality as the dominant factor. The high cattle sales obtained in the hot-wet season in the sour rangeland were expected as communal farmers usually dispose of their cattle to meet high household needs during the festive season and pay school fees. The findings of this study agree with Coetzee *et al.* (2005), Montshwe (2005) and Delali *et al.* (2006), who reported that cattle kept by smallholder farmers are often the main source of income and investment, which is primarily intended for a familyôs education, household needs, health, village taxes and emergencies. The high cattle sales and consumption during the festive season can be partly attributed to ceremonies such as circumcision and weddings which usually occur during the festive season (Ainslie *et al.,* 2002).

The rise in cattle sales in the cool-dry season could have been an attempt to reduce mortality from starvation by reducing herd size. This confirms earlier assertions by Baptist (1990), Amanor (1995) and Oba (2001) that increasing irregularity of rainfall elevates feed insecurity and, consequently cattle mortality. Cattle owners then react to high mortality by selling their animals. The observation that farmers largely sold steers in the cool-dry season agrees with findings by Coetzee *et al.* (2005) and Nqeno *et al.* (2009) who reported that instead of providing supplements to all cattle classes during the dry season, farmers sold young male animals. They preferred retaining and supplementing cows for breeding and milk production purposes, and oxen for draught power. This generates sharp and substantial variations in cattle populations, especially for steers as observed in this study.

Since farmers fetched low prices for their cattle during the cool-dry season due to poor body condition, supplementary feeding could, therefore, be at the core of any strategy aimed at increasing cattle production efficiency in the communal areas. Alternatively, farmers may sell their cattle at the end of post-rainy season before they start losing condition. Before any nutritional improvements are made, it is important to determine the types and levels of limiting nutrients in animals in a given environment (Agenas *et al.,* 2006).

The high cattle theft incidences reported in the sweet rangeland could be accredited to the proximity of one of the communities (Magwiji) to the border zone between South Africa and Lesotho. Kinloch and Ulicki (2001) attributed high stock theft incidences in the South African-Lesotho border zone to the absence of patrols and slow response by police, long distance between rangelands and homesteads, lack of cattle identification and poor conviction and prosecution of the criminals. To minimize cattle thefts, community members may take turns to herd cattle during the day and kraal or guard them at night. Use of mobile police posts and intensification of armed police patrols in the affected areas can be of help. Development of a collaborative community security, with the objective of strengthening social unity among the communities nearer to the borders might be important (Kynoch and Ulicki, 2001). The Department of Agriculture should advise farmers on importance and methods of cattle identification which would assist farmers to trace their animals. Joint initiatives between South Africa and Lesotho law enforcement authorities are of utmost importance in the control of cross-border stock thefts (Kynoch and Ulicki, 2001).

The high mortality observed in the hot-wet season can be attributed to the warm and moist conditions that prevailed during the study period, particularly in the sour rangeland. The hot-wet conditions promote vector survival and multiplication (Marufu *et al.,* 2009). For example, anaplasmosis and babesiosis diseases which were reported as the chief causes of cattle mortality in this study are transmitted by ticks whose rate of proliferation is accelerated when environmental temperatures and humidity are high (Muchenje *et al.,* 2008; Marufu *et al.,* 2009). High cattle mortality observed in the cool-dry season in the sour rangeland might be linked to feed shortage. Poor nutritional status in cattle imparts a decreased immunity and resistance against disease and parasites, resulting in mortality (Coop and Kyriazakis, 2001).

The high mortality rates recorded for cows were related to their greater vulnerability to seasonal droughts and poor pre-drought body conditions compared with the mature males (Oba, 2001). Similarly, Desta and Oba (2004) reported that breeding females are more adversely influenced by the intra-annual feed availability than mature males, probably due to low body fat reserves. Breeding females may be cycling or pregnant and nursing calves, as well as producing milk for the household. Their physiological condition might put them under greater stress and increase their susceptibility to diseases and parasites (Desta and Oba, 2004). Losses due to diseases and their interaction with nutrition are, therefore, a major constraint to communal cattle production. Provision of supplements might modify the reproduction and production efficiency of communal cattle during the dry season.

The finding that herd size, rangeland type and season did not affect cattle off-take might imply that off-take is not a good indicator of cattle productivity on communal rangelands. There is little, if any information on the use of CPP and CPE as measures of herd productivity. The observed CPP values were high and followed the same trend with cattle numbers in both the sweet and sour rangelands, implying that the potential of utilising cattle for consumption or as cash generating assets was high. The highest CPE value recorded in the cool-dry season in the sweet rangeland could be ascribed to high sales that occurred in the same season. The observed higher total exits and CPE in the sweet rangeland compared to the sour rangeland might mean that farmers in the sweet rangeland slaughtered and/or sold more cattle relative to their herd sizes to reduce risk of mortality through starvation.

Generally, the CPE was very low relative to the production potential. The production efficiency was probably lowered by the significant role played by births, mortality and theft in determining CPE. The fact that cows and heifers were the major components of the herd, but were rarely sold or consumed, could, partly, explain the consistently low production efficiency observed in this study. The observed low CPE values could indicate its inadequacy as production efficiency measure of communal cattle productivity. For example, it neglects sale of calves. According to Muchadeyi *et al.* (2005) and Chiduwa *et al.* (2008), under low-input production systems young animals are rarely purchased, sold or consumed, since they are highly susceptible to extreme weather, droughts, diseases and parasites. Calves in this study were, however, purchased or sold together with their dams. Farmers reported that this unique cow-calf unit transaction was done to reduce calf mortality when the dam has been sold-off. Farmers claimed that chances of calf survival after the dam has been sold are low, thereby reducing risk. Given training on appropriate calf rearing practices and feeding management, farmers can retain the calf, sell it when mature and could realise more profit.

On the other hand, the low CPE values might reflect that communal cattle have other important roles, which are not incorporated in the current CPE formulae. For example, production outputs such as draught power, milk, dung for manure, fuel and floor polish, and the socio-cultural importance of cattle reported in Section 3.3.2 are not included in the current CPE computations. Lack of accounting of all cattle uses in a multipurpose livelihood system potentially results in significant underestimation of livelihoods (Delali *et al.,* 2006). Thus, it is vital to modify CPE formulae so that it captures all production outputs and non-monetary contributions of cattle in the communal areas.

4.5 Conclusions

Households owning small herds in the sweet rangeland had the lowest births, purchases and CPP in the cool-dry season whilst those owning large herds in the sour rangeland had the higher sales, slaughters and deaths in the hot-wet and cool dry seasons compared to small herds in the same seasons. Cattle production efficiency was high in the cool-dry season in the sweet rangeland. Supplementary feeding could, therefore, be necessary to increase cattle production efficiency in the cool-dry season, especially in the sweet rangelands. Prior to formulation of supplementary feeding strategies, it is, however, important to determine changes in the nutritional status of cattle with seasons and identify types and levels of nutrients that could be limiting beef production on communal rangelands in the Eastern Cape, South Africa.

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Chapter 5: Seasonal changes in energy-related blood metabolites and mineral profiles of Nguni and crossbred cattle on communal rangelands in the Eastern Cape, South Africa

(Accepted in *Asian-Australian journal of Animal Science*)

Abstract

The objective of this study was to determine seasonal changes in glucose, cholesterol, non-esterified fatty acids (NEFA), serum inorganic phosphorous (SIP), calcium, magnesium and iron concentrations in Nguni and crossbred cattle in the sweet and sour rangelands in the Eastern Cape Province of South Africa. Body weights, body condition scores and serum concentrations of energy-related metabolites and mineral profiles were determined in late cool-dry, hot-dry, hot-wet, post-rainy and early cool-dry seasons in 100 cattle raised on communal rangelands from August 2007 to May 2008. Nguni cattle had lower ($P < 0.05$) and higher ($P < 0.05$) serum concentrations of glucose in the hot-wet season and post-rainy seasons, respectively compared to crossbreds in the same seasons. Serum cholesterol and NEFA concentrations in Nguni were lower ($P < 0.05$) than in the crossbreds. Nguni and crossbred cattle had higher ($P < 0.05$) serum NEFA concentrations in the sweet rangeland during the late cool-dry season than in sour rangeland. Nguni cattle had higher ($P < 0.05$) SIP concentration in the hot-wet season than the crossbreds. Generally, both breeds had lowest SIP concentration during the hot-wet season in the sour rangeland. The lowest magnesium and highest iron concentrations were observed in the hot-wet and post-rainy seasons, respectively, compared to other seasons. Nguni and crossbred cattle in the sour rangeland had lower ($P < 0.05$) iron concentrations than those in the sweet rangeland. It was concluded that Nguni cattle had lower cholesterol and NEFA, and higher SIP concentrations in the hot-wet season than crossbreds and energy deficits mostly occurred during the late cool-dry season in

the sweet rangeland. This could mean Nguni cattle are more adapted to the energy and mineral conditions prevailing on communal rangelands than local crossbreds. Energy and minerals may, therefore, not be the major nutrients limiting Nguni cattle production on communal rangelands.

Key words: Cholesterol, Glucose, Iron, NEFA, Nguni cattle, Phosphorus

5.1 Introduction

Cattle production efficiency on communal rangelands is low, especially in the cool-dry season and is attributed to feed shortage (Chapter 4). Under such conditions, provision of feed supplements could be recommended. Evaluation of the nutritional status of grazing cattle to identify limiting nutrients is a prerequisite to any supplementary feeding programme (Ndlovu *et al.,* 2009). Identification of the types of nutrients that could be limiting cattle production efficiency on communal rangelands is, therefore, important.

Protein, energy and minerals are the most critical nutrients affecting milk and beef production in the semi-arid communal production systems (Devendra and Sevilla, 2002). Some reports have suggested that energy and minerals are not limiting nutrients to communal cattle production, attributing losses in cattle productivity to deficiencies in protein (Tainton, 1999; Chimonyo *et al.,* 2000). Poppi and McLennan (1995) and Devendra and Sevilla (2002), however, reported that during the early to mid hot-wet season, rangelands are not an adequate source of energy and minerals. As a result, low cattle growth rates in the early to mid-wet season are a major constraint to increasing annual body weight gains (Shabi *et al.,* 1998; DelCurto *et al.,* 2000) and consequently beef production in the semi-arid areas. Generally, rangeland energy and mineral supplies in the late wet and dry seasons are arguably deemed to be sufficient to meet production requirements of cattle on rangelands in the semi-arid areas (Poppi and McLennan, 1995; Chimonyo *et al.,* 2000). The impact of seasonal variation in energy and mineral supplies on the condition and performance of cattle on communal rangelands, therefore, warrants investigation. On the same note, the capability of the sweet and sour rangelands to meet energy and mineral requirements of communal cattle is largely unknown.

Due to body size differences, Nguni and crossbred cattle are likely to have different nutrient requirements (Collin-Luswet, 2000) and, subsequently, perform differently on communal rangelands. There is, however, no information on the energy status and mineral profiles of Nguni and crossbred cattle on communal rangelands of South Africa. Determining breed differences in the energy status and mineral profiles across seasons and rangeland types could be useful in understanding nutrient demands and utilisation efficiency of particular breed in a given environment. Such information is also crucial in making recommendations on the adoption of appropriate cattle genotypes under the low-input production systems in the semi-arid areas.

Blood biochemical parameters such as glucose, cholesterol and NEFA are becoming important in determining the energy balance of beef cattle (Agenas *et al.,* 2006; Yokus and Cakir, 2006). On the same note, blood concentrations of macro- and micro-minerals are used to monitor the mineral profiles of beef cattle (Ndlovu *et al.,* 2009). The standard concentrations and the factors that influence the concentrations of these nutritionally-related energy metabolites and mineral profiles in beef cattle on communal rangelands have, however, not been established. Such information is critical in developing appropriate feeding and disease prevention strategies for the on-going Nguni cattle repopulation programmes in the communal areas of South Africa. The objective of the current study was to determine seasonal changes in glucose, cholesterol, non-esterified fatty acids, serum inorganic phosphorous, calcium, magnesium and iron concentrations in Nguni and crossbred cattle in the sweet and sour rangelands in the Eastern Cape Province of South Africa. It was hypothesised that seasonal concentrations of energy-related metabolites and minerals in Nguni and crossbred cattle in the sweet and sour rangelands in the Eastern Cape Province South Africa are similar.

5.2 Materials and Methods

5.2.1 Study sites

The study was conducted in two communities; one from a sour rangeland (Cala) and another from a sweet rangeland (Sterkspruit) in the Eastern Cape Province of South Africa. Figure 5.1 shows mean monthly rainfall data for the sweet and sour rangelands between June 2007 and May 2008. The detailed description of the two study sites are given in Section 4.2.1.

5.2.2 Experimental animals

The selection of cattle was based on the health status of the animals and willingness of cattle owners to participate in the study. For easy identification, all the cattle were ear-tagged at the beginning of the study. Fifty clinically healthy cattle from each rangeland type were targeted for blood sampling in each season. The animals were body condition scored using a 5-point scale (1-very thin and 5-obese). Most of the selected cattle had a BCS between 2 and 3. A total of 520 samples were obtained throughout the study period. Table 5.1 shows the number of Nguni and local crossbred cattle sampled in each season in the sweet and sour rangelands. The number of samples in each season depended on the farmerȯs willingness to bring their tagged animals to the handling facilities.

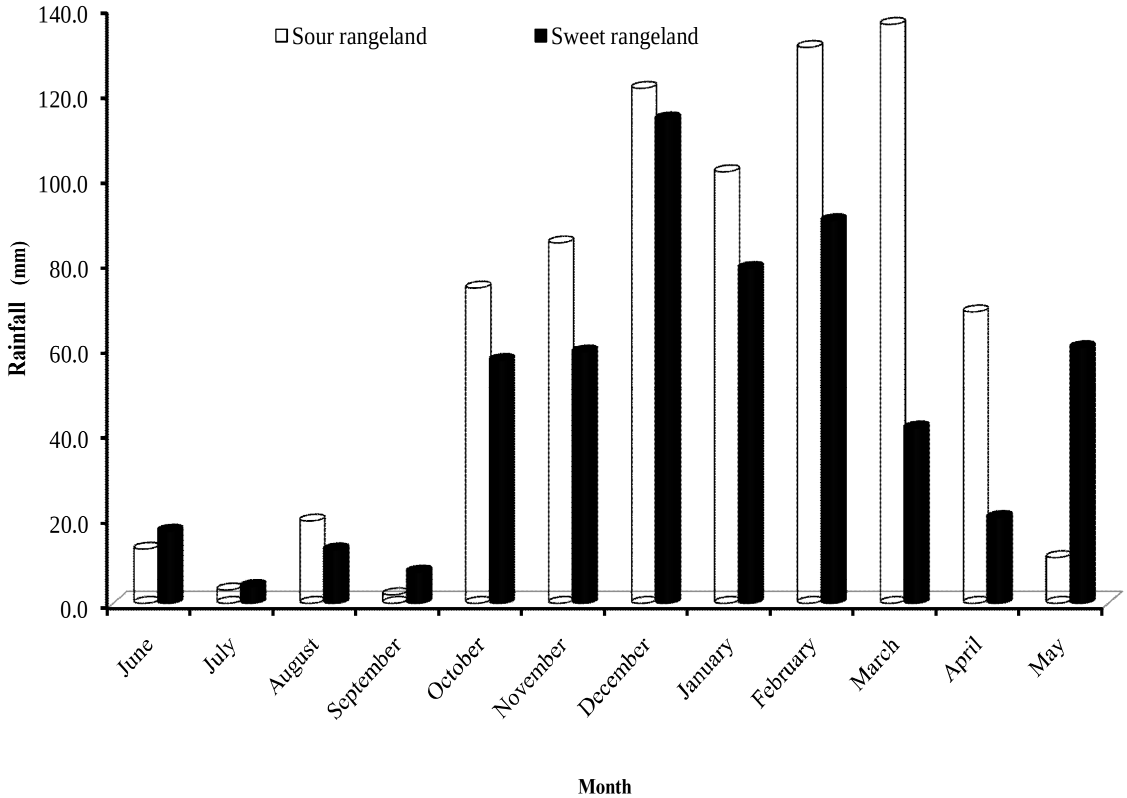

Figure 5.1: Mean monthly rainfall (mm) data for the sweet and sour rangelands between June 2007 and May 2008

Table 5.1: Number of Nguni and crossbred cattle sampled in each season in the sweet and sour rangelands

	Sweet rangeland		**Sour rangeland**	
Season (month)	Nguni	Crossbreds	Nguni	Crossbreds
Late cool-dry (August)	20	35	19	45
Hot-dry (October)	19	26	27	48
Hot-wet (January)	18	22	17	39
Post-rainy (March)	17	31	13	33
Early cool-dry (May)	14	21	19	37

The animals were further categorised into different classes based on age (1-2, >2-3, >3-4, >4-5 and >5 years), physiological status of the cow [pregnant lactating (PL), pregnant non-lactating (PNL), non-pregnant lactating (NPL) and non-pregnant non-lactating (NPNL)] and parity (0, 1, 2, 3, 4, 5 and 6). Pregnancy status of cows was assessed through trans-rectal palpation by a veterinarian.

5.2.3 Body weight and body condition scores

Body weights and BCS were recorded immediately before blood sampling in the late cool-dry (August 2007), hot-dry (October, 2007), hot-wet (January, 2008), post-rainy (March, 2008) and early cool-dry (May, 2008) seasons. Cattle body weights were estimated using a weigh-tape (Cattleway, Johannesburg, South Africa). Cattle were palpated and scored using a 5-point scale (1-very thin and 5-obese) to determine the BCS (Nicholson and Butterworth, 1986).

5.2.4 Blood collection and analyses

Blood was collected between 0700 and 0900 h once every season [late cool-dry (August 2007), hot-dry (October, 2007), hot-wet (January, 2008), post-rainy (March, 2008) and early cool-dry (May, 2008)] from the coccyxgeal vein using an 18-gauge needle. For the determination of glucose, blood was collected into Vacutainer® blood tubes containing sodium fluoride to arrest glycolysis. Vacutainer tubes without anti-coagulant were used for blood collection for analyses of NEFA, cholesterol, Ca, Mg, SIP and Fe concentrations. The blood was allowed to coagulate at room temperature (25^{o}C) and centrifuged for 10 minutes at 1000 x g within 2 hours of collection. The serum was stored in polypropylene tubes that were stored at -20^{o}C, pending analyses.

Serum samples were analysed using a Chexcks machine (Next/Vetex Alfa Wasseman Analyser, Woerden, Netherlands) and commercially purchased kits (Siemens, South Africa). The serum was analysed spectrophotometrically for NEFA (De Villiers *et al.,* 1977), Ca (Cali *et al.,* 1972), Mg (Tietz, 1976), SIP (Young, 1990) and Fe (Tietz, 1976). Enzymatic methods were used for glucose (Gotchman and Schmitc, 1972) and cholesterol (Allain *et al.,* 1974) analyses. Details of energy metabolites and mineral concentrations analyses are described in Appendix 6.

5.2.5 Statistical analyses

To normalise the data, square root transformations were performed on BCS. The data were subjected to analyses of variance using the GLM of SAS (2003). The model fitted the effect of rangeland type, season, breed, sex, age and some interactions on body weight, BCS, and concentrations of minerals and energy-related metabolites. The linear model was:

$Y_{ijklmn} = \mu + A_i + B_j + C_k + D_l + E_m + AB_{ij} + AC_{ik} + BC_{jk} + ABC_{ijk} + \text{Ů}_{ijklmn}$

Where Y_{ijklmn}= Body weight, BCS, concentrations of NEFA, cholesterol, glucose, SIP, Ca, Mg, Fe);

μ = overall mean;

A_i = effect of rangeland type (i= sweet, sour);

B_j = effect of season (j= late cool-dry, hot-dry, hot-wet, post-rainy, early cool-dry);

C_k = effect of breed (k= Nguni, crossbred);

D_l = effect of sex (l= male, female);

E_m = effect of age (m=1-2, >2-3, 3-4, >4-5 and >5 years) and;

AB_{ij} = interaction of the i^{th} level of rangeland type and j^{th} level of season;

AC_{ik} = interaction of the i^{th} level of rangeland type and k^{th} level of breed;

BC_{jk} = interaction of the j^{th} level of season and k^{th} level of breed;

ABC_{ijk} = interaction of the i^{th} level of rangeland type, j^{th} level of season and k^{th} level of breed;

$\mathring{U}_{ijklmn}$ = residual error.

Separate models were used to analyse the effects of parity and physiological status of the cow on concentrations of energy-related metabolites and minerals concentrations. The significant differences between least square group means were compared using the PDIFF procedure of SAS (2003). A chi-square test (PROC FREQ procedure) was used to determine the association between proportions of cattle that had metabolite values within and outside the normal range with season, rangeland type and breed (SAS, 2003). Normal range values were obtained from literature (Doornenbal *et al.,* 1988; Farver 1997, Otto *et al.,* 2000; Ndlovu *et al.,* 2009).

5.3 Results

5.3.1 Body weight and body condition scores

Nguni cattle (420.7 ± 15.35 kg) had lower ($P < 0.05$) body weight than crossbreds (455.8 ± 14.54 kg). Cattle in the sour rangeland (458.4 ± 35.05 kg) were heavier ($P < 0.05$) than those in the sweet rangeland (420.1 ± 35.09 kg). Highest Nguni and crossbred cattle body weights were recorded in the hot-wet and post-rainy seasons compared to other seasons (Figure 5.2A). Cattle BCS in the hot-wet and post-rainy seasons were higher ($P < 0.05$) than in the other seasons (Figure 5.2B). Rangeland type and breed had no effect on BCS.

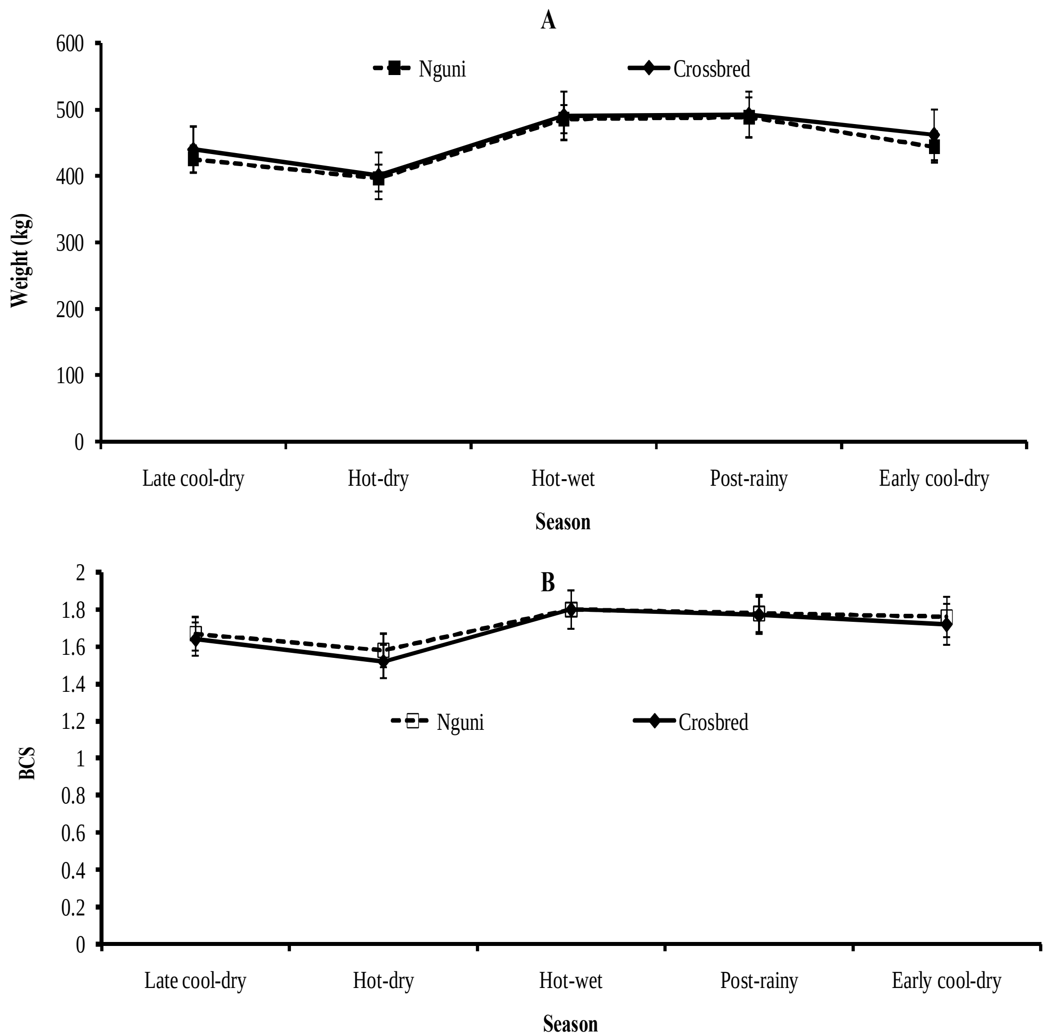

Figure 5.2 A-B: Least square means (± standard error of means) of body weight (A) and body condition (B) of communal Nguni and crossbred cattle based on season

5.3.2 Nutritionally-related energy metabolites

In the hot-wet seasons 78 % of the cattle had glucose concentrations below the normal range ($P < 0.01$; Table 5.2). Season by rangeland type and season by breed interactions for glucose concentrations were significant. Nguni cattle had lower ($P<0.05$) and higher ($P<0.05$) concentrations of glucose in the hot-wet and post-rainy seasons, respectively, compared to crossbreds in the same seasons (Figure 5.3A). Blood glucose concentration was highest in cattle in the sour rangeland during the post-rainy season (Figure 5.3B) compared to other seasons. During late cool-dry season, glucose concentration in cattle in the sour rangeland was lower ($P < 0.05$) than for cattle in the sweet rangeland. The sex, age, parity and cow physiological status had no ($P > 0.05$) effect on glucose concentrations (Table 5.2).

Most of the cattle in the post-rainy (62 %) and early cool-dry season (56 %) had cholesterol concentration above the reference range ($P < 0.01$; Table 5.2). Crossbred cattle had higher ($P < 0.05$) cholesterol concentrations than Nguni cattle (Table 5.3). Highest cholesterol concentrations were recorded in the sweet rangeland during the post-rainy season compared to other seasons (Figure 5.3C). During the late cool-dry season, cholesterol concentrations in the sour rangeland were lower ($P < 0.05$) than in the sweet rangeland. Cholesterol concentrations increased ($P < 0.05$) with age of the animal (Table 5.4). Cholesterol concentrations were not influenced by sex, parity and physiological status of cows.

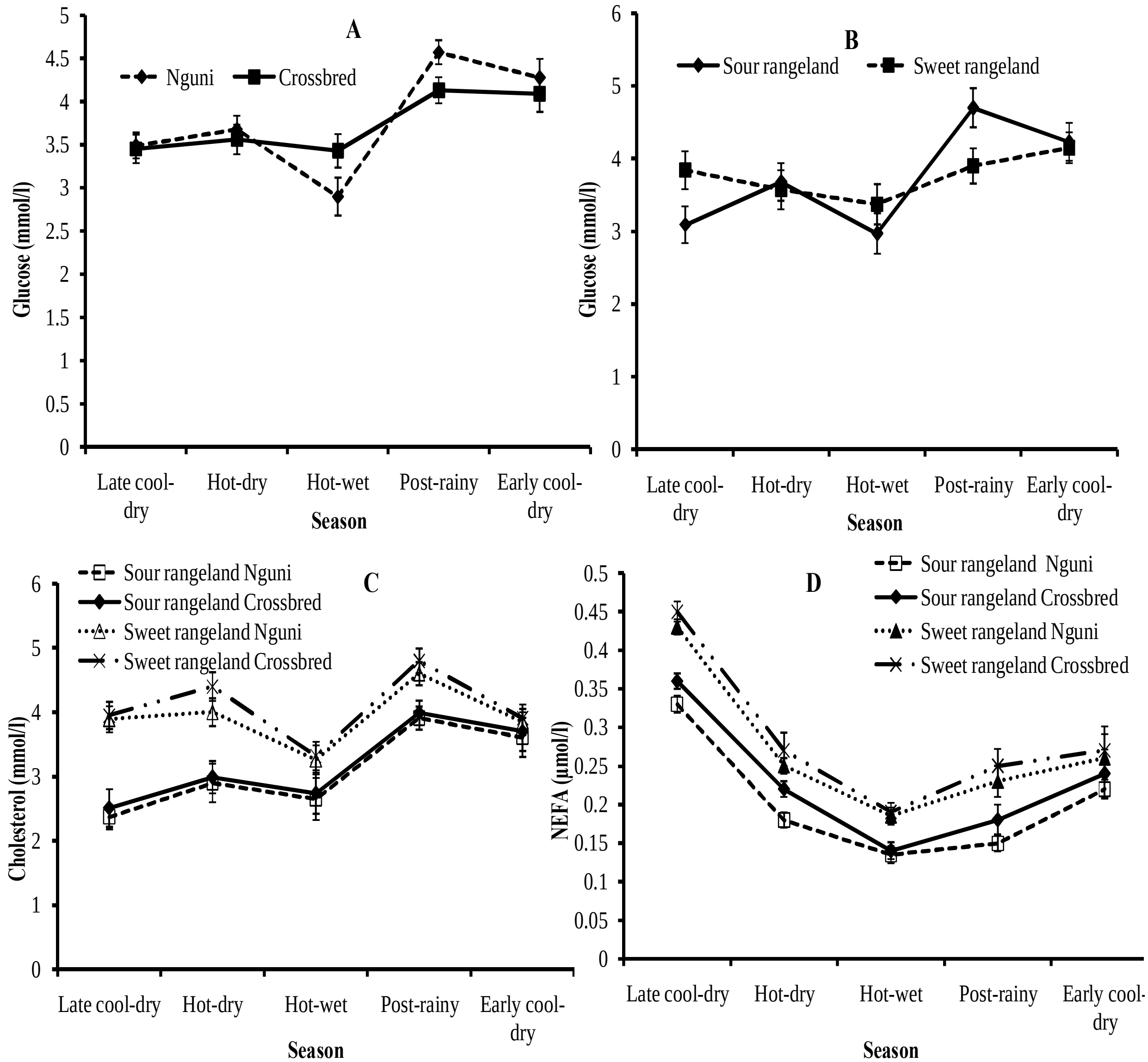

Figure 5.3 A-D: Least square means (± standard error) of glucose based on breed and season (A), glucose based on rangeland type and season (B), cholesterol (C) and non-esterified fatty acids (D) concentrations based on rangeland type, season and breed

Table 5.2: Proportions (%) of cattle that had normal, below and above reference range values for the different blood metabolites

		Energy metabolites			Minerals			
Season	**Category**	Glucose	Cholesterol	[1]NEFA	[2]SIP	[3]Ca	[4]Mg	[5]Fe
	Below	42	0	46	3	1	0	0
Late cool-dry (n=119)	Normal	58	75	33	90	99	100	75
	Above	0	25	21	7	0	0	25
	Below	47	0	85	0	0	0	0
Hot- dry (n= 110)	Normal	53	71	15	92	99	99	96
	Above	0	29	0	9	1	1	4
	Below	78	0	97	25	30	7	3
Hot- wet (n= 89)	Normal	22	83	2	75	70	92	92
	Above	0	17	1	0	0	1	5
	Below	14	0	84	2	0	0	0
Post- (n= 91)	Normal	85	38	12	80	91	97	76
	Above	1	62	4	18	9	3	24
	Below	4	0	87	0	0	0	3
Early cool-dry (n= 81)	Normal	96	44	11	89	100	99	90
	Above	0	56	2	11	0	1	7
Significance		**	**	**	**	**	**	**

** Significance at $P < 0.01$.

[1]NEFA: non-esterifed fatty acids; [2]SIP: serum inorganic supplements; [3]Ca: Calcium; [4]Mg: Magnesium; [5]Fe: Iron

Over 80 % of the cattle in all the seasons, except in the late cool-dry season had NEFA concentrations below the normal range (Table 5.2). Nguni cattle (0.25 ± 0.1 µmol/l) had lower ($P < 0.05$) NEFA concentrations than crossbred (0.31 ± 0.09 µmol/l) cattle (Table 5.3). Non-esterified fatty acid concentrations were highest in the sweet rangeland during the late cool-dry season (Figure 5.3D). Males (0.18 ± 0.03 µmol/l) had significantly lower ($P < 0.05$) NEFA concentrations than females (0.4 ± 0.09 µmol/l). Pregnant cows had higher ($P < 0.05$) NEFA concentrations than the non pregnant ones (Table 5.5). Neither age nor parity affected NEFA concentrations ($P > 0.05$).

5.3.4 Minerals

More than 75 % of the cattle across breeds had phosphorus (SIP) concentrations within the standard range across all the seasons (Table 5.2). Phosphorus concentrations were highest in the sweet rangeland during early cool-dry season and lowest in the sour rangeland during the hot-wet season (Figure 5.4A). Nguni cattle had the higher concentrations of SIP in the post-rainy and early cool-dry seasons compared to crossbreds in the same seasons (Figure 5.4B). Phosphorus concentrations were not affected by sex, age, parity and physiological status of the cows.

Over 90 % of the cattle had Ca concentrations within the reference range across all the seasons (Table 5.2). Calcium concentrations were not influenced by any of the tested factors. More than 90 % of the cattle had Mg concentrations within the normal range across all the seasons (Table 5.2). Magnesium concentration were significantly influenced by season; the hot-wet season had the lowest concentrations of Mg compared to other seasons (Figure 5.4 C). The concentrations of Mg were not influenced by rangeland type, breed, sex, age, parity and cow physiological status.

Table 5.3: Least square means (± standard error of means) of energy-related metabolites and mineral concentration of Nguni and local crossbred cattle on communal rangelands

	Breed		**Reference interval**[1]	
Metabolite	Nguni	Crossbred	Minimum	Maximum
Glucose (mmol/l)	3.76 ± 0.452	3.74 ± 0.441	3.1	4.7
Cholesterol (mmol/l)	3.35 ± 0.578[a]	3.71 ± 0.591[b]	1.3	3.8
Non-esterified fatty acids (µmol/l)	0.25 ± 0.100[a]	0.30 ± 0.090[b]	0.32	0.60
Phosphorus (mmol/l)	1.78 ± 0.263	1.74 ± 0.258	1.2	2.3
Calcium (mmol/l)	2.50 ± 0.852	2.68 ± 0.832	2	2.9
Magnesium (mmol/l)	0.94 ± 0.889	0.95 ± 0.869	0.6	1.2
Iron (mmol/l)	23.71 ± 4.990	23.29 ± 4.872	10.2	29.0

[a,b] Values with different superscripts within a row are different ($P < 0.05$).

[1]Reference values Doornenbal *et al.* (1988), Farver (1997) and Ndlovu *et al.* (2009)

Table 5.4: Least square means (± standard error of means) of cholesterol concentrations of Nguni and crossbred cattle based on age

	Cholesterol (mmol/l)	
Age (years)	Nguni	Crossbred
1-2	3.42 ± 0.605^{a1}	3.46 ± 0.305^{a1}
>2-3	3.96 ± 0.586^{b2}	3.98 ± 0.901^{b2}
>3-4	3.76 ± 0.601^{b2}	3.81 ± 0.521^{b2}
>4-5	3.67 ± 0.604^{b2}	3.69 ± 0.701^{b2}
>5	3.71 ± 0.601^{b2}	3.73 ± 0.521^{b2}

^{a,b} Values with different superscripts withn a row are different ($P < 0.05$).

^{1,2} Values with different superscripts within a column are different ($P < 0.05$).

Table 5.5: Least square means (± standard error of means) of non-esterified fatty acids concentration of cattle on communal rangelands based on cow physiological status

	NEFA (µmol/l)	
Physiological status	Nguni	Crossbred
Non-pregnant lactating	0.21 ± 0.021^{a1}	0.22 ± 0.031^{a1}
Non-pregnant non-lactating	0.21 ± 0.021^{a1}	0.21 ± 0.021^{a1}
Pregnant and lactating	0.30 ± 0.123^{b2}	0.31 ± 0.117^{b2}
Pregnant non-lactating	0.35 ± 0.412^{b2}	0.36 ± 0.361^{b2}

^{a,b} Values with different superscripts withn a row are different (*P < 0.05*).

^{1,2} Values with different superscripts within a column are different (*P < 0.05*).

As shown in Table 5.2, greater than 75 % of the cattle had Fe concentrations within the reference range in all the seasons. Cattle in the sour rangeland had lower ($P < 0.05$) Fe concentrations than those in the sweet rangeland (22.06 ± 2.944 mmol/l versus 24.94 ± 2.951 mmol/l). The highest Fe concentrations were recorded in the post-rainy season compared to other seasons (Figure 5.4D). Breed, sex, age, parity and cow physiological status did not affect Fe concentrations.

5.4 Discussion

The observation that local crossbreds had high body weights and BCS compared to Nguni cattle could be ascribed to their differences in frame sizes. Communal farmers who have capital to purchase commercial supplements and veterinary drugs can be encouraged to keep large-framed crossbreds. The higher body weight and BCS observed in the sour rangeland in the hot-wet and post rainy season compared to the sweet rangeland in the same seasons could be related to rainfall and feed availability. The sour rangeland received higher rainfall in the hot-wet and post-rainy season than the sweet rangeland; this consequently promotes forage and animal growth which reach a peak in the post-rainy season (Tainton, 1999).

The finding that glucose concentration was higher during the post-rainy season in the sour rangeland than in other seasons could be due to increased dietary energy intake. The energy content of forages rises from 250 g/kg DM in the early growing season to 600 g/kg DM in post-rainy season (Tainton, 1999; Lesoli, 2008). The mean values of glucose in cattle were within the normal physiological range for cattle (Otto *et al.,* 2000; Ndlovu *et al.,* 2009). Concentrations of serum glucose are useful indicators of dietary energy intake, stress and muscle damage in cattle (Whitaker *et al.,* 1999).

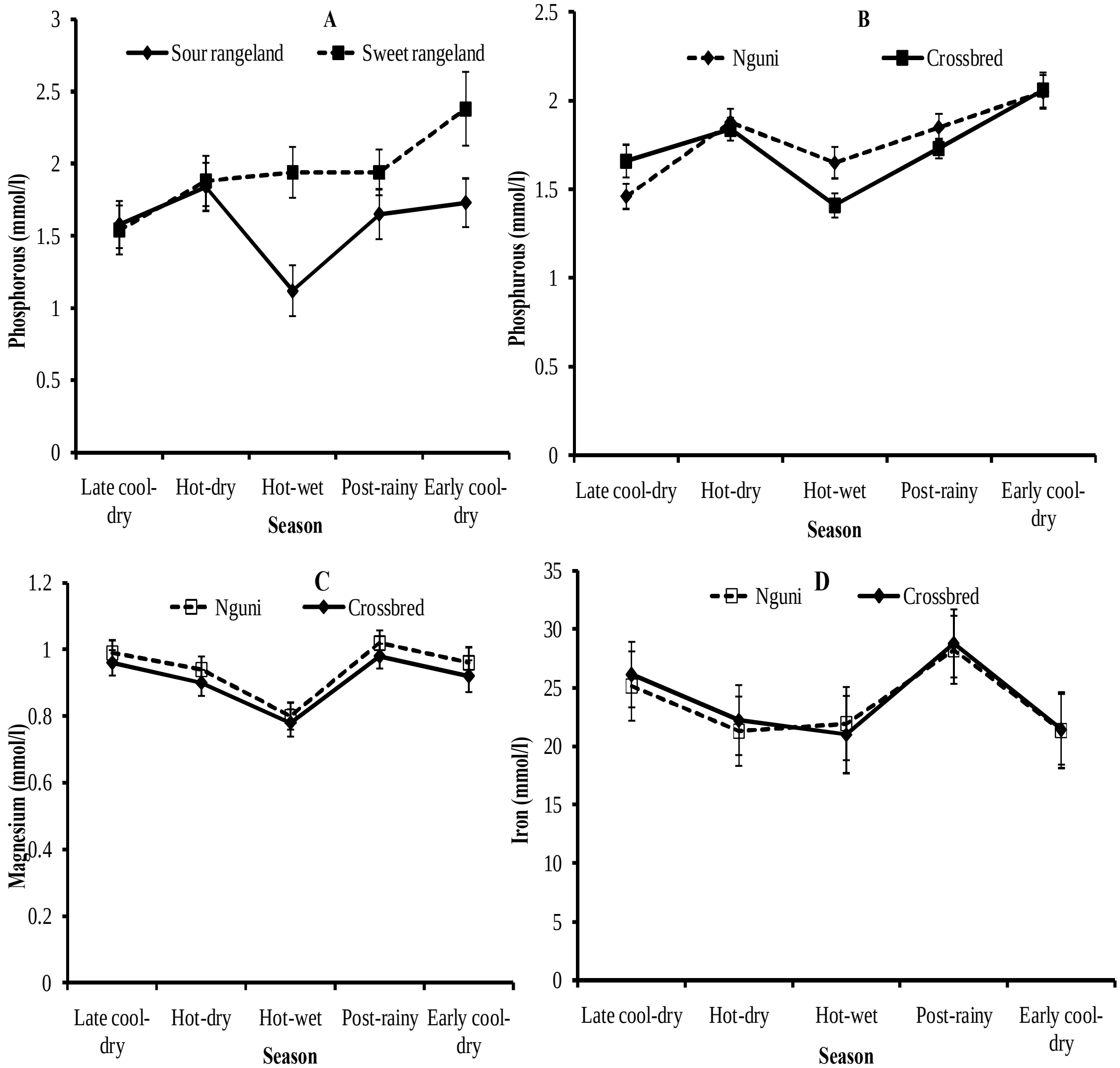

Figure 5.4 A-D: Least square means (± standard error of means) of phosphorus concentration based on rangeland type and season (A), phosphorus concentration based on breed and season (B) and least square means (± standard error of mean) of magnesium (C) and iron (D) concentrations based on season.

The finding that most cattle in the late cool-dry and hot-wet seasons had glucose concentrations below reference range and lower mean glucose concentrations compared to other seasons agrees with reports by Shaffer *et al.* (1981), Nonaka *et al.* (2008) and Ndlovu *et al.* (2009). During the late cool-dry to mid hot-wet season, rangelands have low energy content (Miller *et al.,* 1980; Poppi and McLennan, 1995), therefore, lower serum energy concentration during this period could be attributed to low dietary energy intake. Another possible explanation could be that cattle entering the hot-wet season usually exhibit compensatory growth and are often exposed to high humidity and ambient temperatures, conditions which increase respiratory activity and consequently, the demand for glucose (Grunwaldt *et al.,* 2005; Nonaka *et al.,* 2008). Provision of dietary energy supplements in the early to mid hot-wet season could be essential in improving annual growth rates, carcass weights and meat quality of cattle on communal rangelands.

The lower glucose concentrations observed in Nguni cattle than in crossbreds in the hot-wet season might indicate the former breed has lower respiration rates or lower energy requirements (National Research Council, 2001). The observation that Nguni cattle had lower glucose concentrations may be an adaptation to high temperatures in the hot seasons (Ndlovu *et al.,* 2009). Small-framed cattle have lower energy demands than large-framed cattle (National Research Council, 2001).

The elevated cholesterol concentrations in the sour rangeland during the post-rainy season could be a result of high blood glucose concentration obtained in the same season. Elevated glucose concentrations in blood promote the secretion of insulin (Reynolds *et al.,* 2001), that, in turn, decreases cyclic adenosine monophosphate concentrations, thus stimulating cholesterol synthesis (Grunwaldt *et al.,* 2005; Ndlovu *et al.,* 2009). The mean values of cholesterol in cattle were within the normal reference range for cattle (Para *et al.,* 1999; Ndlovu *et al.,* 2009). High serum cholesterol concentrations in the absence of excess dietary energy intake are considered to reflect the capacity of the animal to mobilise body fat reserves (Ingraham and Kappus, 1988; Ruegg *et al.,* 1992).

The observed low concentrations of cholesterol and NEFA in Nguni cattle compared to crossbreds could reflect low energy demand and, therefore, low amount of adipose tissue breakdown in the former breed. As an adaptation mechanism, Nguni cattle could have low energy requirements (Ndlovu *et al.,* 2009) and therefore, low energy demands (Shaffer et al., 1981). Another possible explanation could be that inherently, Sanga (*Bos Taurus africanus)* cattle tend to deposit more fat intramuscularly compared to *Bos Taurus* and their crosses which tend to deposit fat subcutaneously (Shaffer et al., 1981). These differences in fat deposition have important implications on mobilisation of fatty acids for thermoregulation and energy reserves (Nonaka *et al.,* 2008). For example, during periods of low energy intake, excess subcutaneous fat is the first body tissue used to meet energy requirements (Shaffer *et al.,* 1981; Para et al., 1999). This could mean that Nguni cattle have less subcutaneous fat as energy reserves which could be mobilised to meet energy requirements compared to crossbreds. The increase in cholesterol concentration with age might be expected from stress of gestation and lactation for cows, and stress of work for males (Otto et al., 2000).

The elevated NEFA concentrations reported in the late cool-dry season in the sweet rangeland could be related to poor dietary conditions (Mayes and Bothman, 2003) or increased physical activity in search of feed (Otto *et al.,* 2000). The increase in NEFA concentration during the late cool-dry season is in agreement with previous research, which shows that a physiological response to nutritional stress is expressed as a mobilisation of lipids from body fat to meet energy demands (Ruegg *et al.,* 1992; Mayes and Bothman, 2003). Since ruminal degradation by fibrolytic microbes suffer from nitrogen deficiency, low CP content during the cool-dry season (< 50 g/kg DM) could cause an additional energy deficiency (Hess *et al.,* 2003). The NEFA concentrations reported in the present study were below the range of values reported by Doornenbal *et al.* (1988) and Farver (1997). High NEFA concentrations with normal or low glucose concentrations are a pointer of metabolic energy deficiency (Whitaker *et al.,* 1999; Otto *et al.,* 2000).

The finding that pregnant cows had higher NEFA concentrations could be linked to metabolic changes related to the growth and development of the foetus (Otto *et al.,* 2000). During pregnancy in ruminants, the insulin concentration in the blood and responsiveness of glucose reserves to insulin are decreased (King, 2000; Castillo *et al.,* 2005). A decrease in insulin concentration may cause a decrease in the sensitivity of the pancreas to insulinotrophic agents and surrounding tissues to insulin (Jainudeen and Hafez, 2000; Castillo *et al.,* 2005). In this case, fat mobilisation is enhanced to obtain free fatty acids from adipose tissue as an alternative energy resource. The higher NEFA concentrations observed in female than in males was expected since cows require more energy to meet ovulation, pregnancy and lactation requirements (Otto *et al.,* 2000).

The highest SIP concentrations observed in the sweet rangeland during the early cool-dry season and lowest concentrations in sour rangeland during the hot-wet season could be explained by differences in protein and energy availability. Generally, during the late hot-wet season, energy and protein supplies for grazing cattle are adequate, and cattle gain weight rapidly, and thus require high mineral intake (McDowell, 1992; National Research Council, 2001). On the other hand, during the late cool-dry season, because of a lack of protein and energy, animals normally lose weight, and thus requiring little phosphorus for metabolic activity (McDowell, 1992; National Research Council, 2001). Contrary to results of the current study, Miller *et al.* (1980) and Amin *et al.* (2007) observed a marked increase in SIP concentrations in the wet season and attributed it to availability of rainfall and plants rich in minerals. Generally, SIP content of most plants in semi-arid regions averages 0.30 % during the vegetative stage in the hot-wet season and drops to 0.15 % as grass matures in the post-rainy season (Tainton, 1999). Serum SIP concentrations are, however, influenced by a multitude of factors which include availability of other nutrients, growth, stress, exercise, haemolysis, temperature and breed (McDowell, 1992; National Research Council, 2001). Serum inorganic phosphorous is therefore, not a good indicator of inorganic phosphorus dietary intake (Whitaker *et al.,* 1999).

The differences in SIP concentrations between Nguni and crossbred cattle could be ascribed to their differences in body sizes. Nguni being a small-sized breed might have low demand for phosphorus than large breeds (Ndlovu *et al.,* 2009). Tainton (1999) reported that phosphorus is one of the major minerals limiting livestock production in the False Thorn-veld of the Eastern Cape, South Africa. The higher SIP concentrations observed in Nguni than crossbred cattle could, therefore, imply that the former are adapted to low SIP environments. Generally, SIP concentrations reported in this study were within the range of the previous reports (Doornenbal *et al.,* 1988; Ndlovu *et al.,* 2009).

The finding that season did not affect Ca concentrations is consistent with earlier reports (Grunwaldt *et al.,* 2005; Yokus and Cakir, 2006). Serum Ca concentration is, however, not a good indicator of a dietary calcium deficiency because blood Ca is reflective of both Ca intake and Ca mobilisation from bone (McDowell, 1992; National Research Council, 2001).

The reported mean Ca concentrations concur with earlier findings (Doornenbal *et al.,* 1988; Farver, 1997; Ndlovu *et al.,* 2009). According to National Research Council (2001), a low dietary calcium intake inhibits lipolysis, stimulates de novo lipogenesis, and decreases fat oxidation; through these mechanisms, a low dietary calcium intake leads to weight gain, whereas a high dietary calcium intake exerts the opposite effects.

The observation that Mg was lower in the hot-wet season than in other seasons is likely to be a consequence of low dietary intake. Miller *et al.* (1980) and Poppi and McLennan (1995) reported that grasses in the early vegetative stages in the early to mid hot-wet season usually have low magnesium contents. Reduced Mg utilisation by ruminants during the hot-wet season has also been related to low carbohydrate and high nitrogen intakes (Fontenot *et al.,* 1989; National Research Council, 2001). High rumen ammonia concentrations usually observed during this period also interfere with absorption and/or utilisation of Mg (Martens and Rayssiguier, 1980; Miller *et al.,* 1980). Serum Mg concentrations reflect daily intake rather than reserves, which are not quickly available (Para *et al.,* 1999; Whitaker *et al.,* 1999).

The higher Fe concentrations observed in the post-rainy seasons than in the other seasons could also be ascribed to increased dietary intake. Iron content increases from the early growing season and reach a peak in the post-rainy season (Tainton, 1999). The findings that Fe concentration was low in the sour rangeland and declined markedly in the hot-dry and hot-wet seasons are likely to be a consequence of parasitism (McDowell, 1992). Ticks are highly prevalent in the sour rangeland, especially during the hot-wet seasons (Marufu *et al.,* 2009). The sour rangelands receive high rainfall and have dense and tall vegetation cover (Ellery *et al.,* 1995), and, thus have higher prevalence of ticks compared to the sweet rangeland. The hot-wet season is characterised by high environmental temperatures and humidity, conditions conducive for tick proliferation and survival (Muchenje *et al.,* 2008). High densities of external parasites can cause blood loss and subsequently reduce iron concentration (Marufu *et al.,* 2009).

5.5. Conclusions

Nguni cattle had lower cholesterol and NEFA, and higher SIP concentrations in the hot-wet season than crossbreds and energy deficits occurred in the late cool-dry season in the sweet rangeland. The levels of energy-related metabolites and minerals for both Nguni and crossbreds were generally within the expected range. Energy and minerals were, therefore, not limiting Nguni cattle production on communal rangelands. Thus, Nguni CPE on communal rangelands could be limited by other nutrients, such as protein. Determination of protein levels in Nguni cattle grazing on communal rangelands is, therefore, imperative.

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Chapter 6: Seasonal changes in concentrations of protein-related blood metabolites in Nguni and crossbred cattle in some semi-arid communal rangelands of South Africa

(Accepted in *Asian-Australian Journal of Animal Science,* see Appendix 7)

Abstract

The objective of the current study was to assess the seasonal changes in concentrations of total proteins (TP), albumin, globulin, urea, creatinine, alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma glutamyltransferase (GGT) and creatine kinase (CK) in Nguni and non-descript crossbred cattle raised on sweet and sour rangelands in the Eastern Cape Province of South Africa. The serum concentrations of protein-related metabolites and liver enzymes were determined seasonally in 100 cattle raised on communal rangelands from August 2007 to May 2008. Nguni cattle had lower ($P < 0.05$) albumin, urea and creatinine concentrations but higher ($P < 0.05$) globulin concentration than the local crossbreds across rangeland types. Crossbreds had higher ($P < 0.05$) serum ALT and ALP, but lower ($P < 0.05$) serum AST concentrations in the post-rainy season than Nguni cattle across rangeland types. The creatinine concentrations for both breeds were lowest in the sour rangeland in the hot-wet season. The albumin concentrations in both breeds were higher ($P < 0.05$), whilst packed cell volume (PCV), albumin-globulin ratio and CK concentration were lower ($P < 0.05$) in the sour rangeland than in the sweet rangeland. Generally, TP, albumin, globulin, AST and CK concentrations of Nguni and crossbred cattle were lower ($P < 0.05$) in the hot-wet and late cool-dry seasons across rangeland types. Urea concentrations in both breeds were highest in the sweet rangeland in the hot-dry season compared to other seasons. It was concluded that Nguni cattle had lower concentrations of protein metabolites than crossbreds and protein deficiencies were most prominent in the dry

season in the sweet rangeland. This could possibly imply that Nguni cattle may be better able to utilise protein more efficiently for growth and development under low protein conditions than crossbreds but could require protein supplementation during the dry season, especially in the sweet rangeland.

Key words: Albumin, Alanine aminotransferase, Aspartate aminotransferase, Urea.

6.1 Introduction

Energy and minerals are not limiting nutrients on communal rangelands in the Eastern Cape Province of South Africa (Chapter 5). Cattle production could, therefore, be hampered by shortage of other nutrients. Protein contentin rangeland grasses, for example, is as low as 10 g/kg of DM in the dry season (Tainton, 1999; Lesoli, 2008). Seasonal variations in protein supply leads to changes in cattle condition and populations (Collins-Luswet, 2000; Boone and Wang, 2007), and could subsequently influence cattle production efficiency. The implications of seasonal deficiency in protein supply on CPE on communal rangelands in South Africa deserve investigation.

Protein deficiency on communal rangelands of South Africa could be worsened by predominance of large-framed crossbred cattle, which require large amounts of nutrients (Nqeno *et al.,* 2009). At present, there are on-going efforts to re-introduce Nguni, a small-framed breed, in the communal areas (Chapter 3). No evidence, however, is available on whether the protein status of Nguni and the local crossbreds differ. A comparative study of protein status of Nguni and crossbred cattle on communal rangelands could be influential in deciding which breed to adopt under low-input production systems.

Concentrations of serum total proteins, albumin, globulin, urea, creatinine and liver enzymes are useful indicators of protein and health status of cattle (Agenas *et al.,* 2006; Ndlovu *et al.,* 2009). Generally, high concentrations of these metabolites indicate protein adequacy and good health while low concentrations are an indication of protein deficiency and/or prevalence of a disease (Yokus and Cakir, 2006). Despite their importance, reference values for these protein-related metabolites in cattle breeds raised on communal rangelands in the semi-arid areas are not available, making it difficult to draft suitable supplementary feeding and disease prevention and control strategies. It is also crucial to identify serum proteins that are reliable and sensitive enough to detect changes in protein and health status of Nguni and crossbred cattle on communal rangelands.

Although rangeland type, season, parity, sex and physiological status influence the protein status of animals (Doornenbal *et al.,* 1988; Grunwaldt *et al.,* 2005; Yokus and Cakir, 2006), their effect on Nguni and crossbred cattle reared on communal rangelands has not been adequately quantified. Quantifying the effect of these factors is crucial for the understanding of the production constraints and management of the communal herds. The objective of the current study was to determine the seasonal changes in concentrations of total proteins (TP), albumin, globulin, urea, creatinine, alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma glutamyltransferase (GGT) and creatine kinase (CK) in Nguni and non-descript crossbred cattle raised on sweet and sour rangelands in the Eastern Cape Province of South Africa. The hypothesis tested was that the seasonal concentrations of protein-related blood metabolites in Nguni and crossbred cattle in the sweet and sour rangelands in the Eastern Cape Province, South Africa are not different.

6.2 Materials and Methods

6.2.1 Study sites

The study was conducted in two communities; Cala (sour rangeland) and Sterkspruit (sweet rangeland) in the Eastern Cape Province of South Africa. Details of the study site were described in Section 4.2.1. Rainfall data for the sweet and sour rangelands are shown in Figure 5.1.

6.2.2. Animal management and measurements

Fifty clinically healthy cattle from each community were targeted for sampling throughout the study period. The details on the number and breeds of animals used are given in Section 5.2.2. Body weights and BCS were collected as described in Section 5.2.3.

6.2.3 Blood collection and analyses

Blood was collected from the coccygeal vein using an 18-gauge needle between 0700 and 0900 h once a season from August 2007 to May 2008. For the determination of packed cell volume (PCV), blood was collected into Vacutainer® blood tubes containing ethylene diamine tetra acetic acid (EDTA) anti-coagulant. The blood was transferred into micro-haematocrit tubes and centrifuged in a micro-haematocrit centrifuge (Gemmy Industrial Corp.) for three minutes. Reading of the PCV was performed on the Micro-haematocrit Reader Scale. Blood for biochemical analyses was collected and stored as described in Section 5.2.4.

Serum samples were analysed using a Chexcks machine (Next/Vetex Alfa Wasseman Analyser, Woerden, Netherlands) and commercially purchased kits (Siemens, South Africa). The serum was analysed spectrophotometrically for total proteins (TP) (Wechselbaum, 1946), albumin (Doumas and Biggs, 1972), creatinine (Tietz, 1995) and alkaline phosphatase (ALP) (Tietz *et al.,* 1993) using colorimetric methods. Globulin concentrations were calculated as the difference between TP and albumin whilst albumin-globulin (A/G) ratio was obtained by dividing the albumin concentration by globulin concentration. Enzymatic methods were used for urea (Tietz, 1995) analyses, whilst ultraviolet methods were used for aspartate aminotransferase (AST) (Bergmeyer *et al.,* 1986), alanine aminotransferase (ALT), gamma glutamyltransferase (GGT) and creatine kinase (CK) determinations (Horder *et al.,* 1991). Details of protein metabolites and liver enzymes concentrations determinations are described in Appendix 6.

6.2.4 Statistical analyses

The data were analysed using the generalised linear models procedure of SAS (2003). The model fitted the effect of rangeland type, season, sex, breed, age and some interactions on PCV and concentrations of protein-related blood metabolites and the liver enzymes.

The linear model was:

$Y_{ijklmn} = \mu + A_i + B_j + C_k + D_l + E_m + AB_{ij} + AC_{ik} + BC_{jk} + ABC_{ijk} + \mathring{U}_{ijklmn}$

Where Y_{ijklmn}= PCV, concentrations of protein metabolites and liver enzymes);

μ = overall mean;

A_i = effect of rangeland type (i= sweet, sour);

B_j = effect of season (j= late cool-dry, hot-dry, hot-wet, post-rainy, early cool-dry);

C_k = effect of breed (k= Nguni, crossbred);

D_l = effect of sex (l= male, female);

E_m = effect of age (m=1-2, >2-3, 3-4, >4-5 and >5 years);

AB_{ij} = interaction of the i^{th} level of rangeland type and j^{th} level of season;

AC_{ik} = interaction of the i^{th} level of rangeland type and k^{th} level of breed;

BC_{jk} = interaction of the j[th] level of season and k[th] level of breed;

ABC_{ijk} = interaction of the i[th] level of rangeland type, j[th] level of season and k[th] level of breed;

$\mathring{U}_{ijklmn}$ = residual error.

Separate models were used to analyse the effects of parity and physiological status of the cow. Pair-wise comparisons of the least square means were performed using the PDIFF procedure (SAS, 2003). Chi-square test was computed to determine the association between proportions of cattle that had metabolite values within and outside the normal range with season, rangeland type and breed (SAS, 2003).

6.3 Results

6.3.1 Packed cell volume

Crossbred cattle had higher (*P < 0.05*) PCV values (35.2 ± 0.01) compared to Nguni cattle (33.9 ± 0.08). Cattle raised on the sweet rangelands had higher PCV values (36.6 ± 0.76) compared to those on the sour rangeland (32.5 ± 0.75). Packed cell volume was lowest in the hot-wet season and highest in the cool-dry season (Figure 6.1). Age, sex, parity and physiological status of the cow had no effect on PCV values.

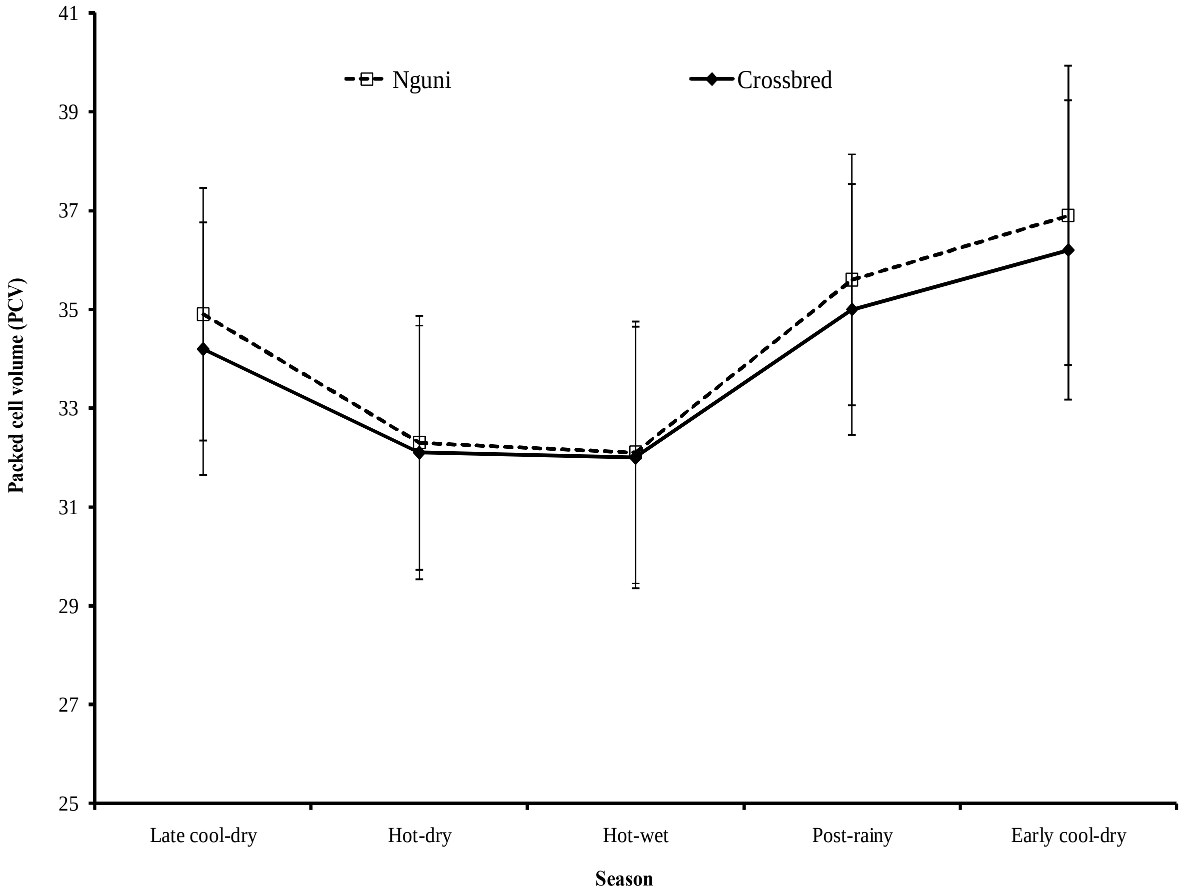


Figure 6.1: Least square means (± standard error of means) of packed cell volume of Nguni and crossbred cattle based on season

6.3.2 Total protein, albumin and globulin concentration

Overall, rangeland type and breed were not associated with proportions of cattle that had protein-related metabolites values within or outside the reference range. In the hot-wet season, about 50 % of the cattle across breeds had TP concentrations below the normal range, while 77 % had concentrations above the normal range ($P < 0.01$; Table 6.1) in the post-rainy season. Total protein concentrations were lowest in the hot-wet season and highest in the post-rainy season in the sweet rangeland (Figure 6.2A). Pregnant non-lactating cows had the highest TP concentrations compared to other cows (Table 6.2). Breed, sex, age and parity had no effect on TP concentrations.

Nearly 70 and 85 % of cattle in the hot-dry and hot-wet seasons, respectively, had albumin concentrations below the normal range ($P < 0.01$; Table 6.1). Nguni cattle had lower ($P < 0.05$) albumin concentrations than local crossbreds (25.4 ± 0.34 vs 27.7 ± 0.24). Cattle raised in the sweet rangeland had higher ($P < 0.05$) albumin concentrations (29.9 ± 0.97 g/l) than those in the sour rangeland (27.4 ± 0.96 g/l). Albumin concentrations in both breeds were lowest in the hot-wet season compared to other seasons. Heifers had the highest albumin concentrations compared to cows (Table 6.3). Albumin concentrations were highest in pregnant non-lactating cows compared to other cows (Table 6.2). Age and sex had no effect on albumin concentrations.

Most of the cattle in the hot-dry (64 %), post-rainy (93 %) and early cool-dry season (76 %) had globulin concentration above the reference range ($P < 0.01$; Table 6.1). Crossbreds on sour rangelands had the higher ($P < 0.05$) globulin concentrations (42.5 ± 2.13 g/l) than Nguni cattle on sour rangeland (38.6 ± 1.24 g/l), local crossbreds on sweet rangeland (36.5 ± 1.31 g/l) and Nguni cattle on sweet rangeland (34.4 ± 1.54 g/l).

Table 6.1: Proportions (%) of Nguni and local crossbred cattle that had normal, below and above reference range values for the different blood metabolites based on season

		Protein-related metabolites					Liver enzymes				
Season	**Level**	[1]TP	[2]ALB	[3]Glob	Urea	[4]Creat	[5]ALT	[6]AST	[7]ALP	[8]CK	[9]GGT
Late	Below	13	26	4	90	0	3	8	0	0	0
cool-dry	Normal	73	73	48	10	39	97	92	99	92	98
(n=119)	Above	14	1	48	0	61	0	0	1	8	2
Hot- dry	Below	6	69	1	69	0	0	0	0	0	0
(n= 110)	Normal	75	30	35	31	83	100	100	100	95	99
	Above	19	1	64	0	17	0	0	0	5	1
Hot- wet	Below	50	85	10	68	0	0	5	0	1	0
(n= 89)	Normal	41	15	47	32	92	100	95	100	98	97
	Above	9	0	43	0	8	0	0	0	1	3
Post-	Below	0	23	0	77	0	0	1	0	0	0
rainy	Normal	23	73	7	23	68	100	99	100	90	94
(n= 91)	Above	77	4	93	0	32	0	0	0	10	6
Early	Below	3	15	0	86	0	0	0	0	0	0
cool-dry	Normal	55	85	24	14	67	100	100	100	91	91
(n= 81)	Above	42	0	76	0	33	0	0	0	9	9
Significance		**	**	**	**	**	**	**	**	**	**
[a]Minimum		65	28	28	3.6	10	36	21	33	12	0
[b]Maximum		78	37	42	10.7	133	91	167	328	146	45

**P<0.01. [a]Minimum and [b]Maximum reference values for cattle. Sources: Doornenbal *et al.* (1988) and Farver (1997).

[1]TP- total protein, [2]ALB: albumin; [3]Glob: globulin; [4]Creat: Creatinine; [5]ALT: alanine aminotransferase; [6]AST: aspartate aminotransferase; [7]ALP: alkaline phosphatise; [8]CK: creatinine kinase; [9]GGT: gamma glutamyltransferase

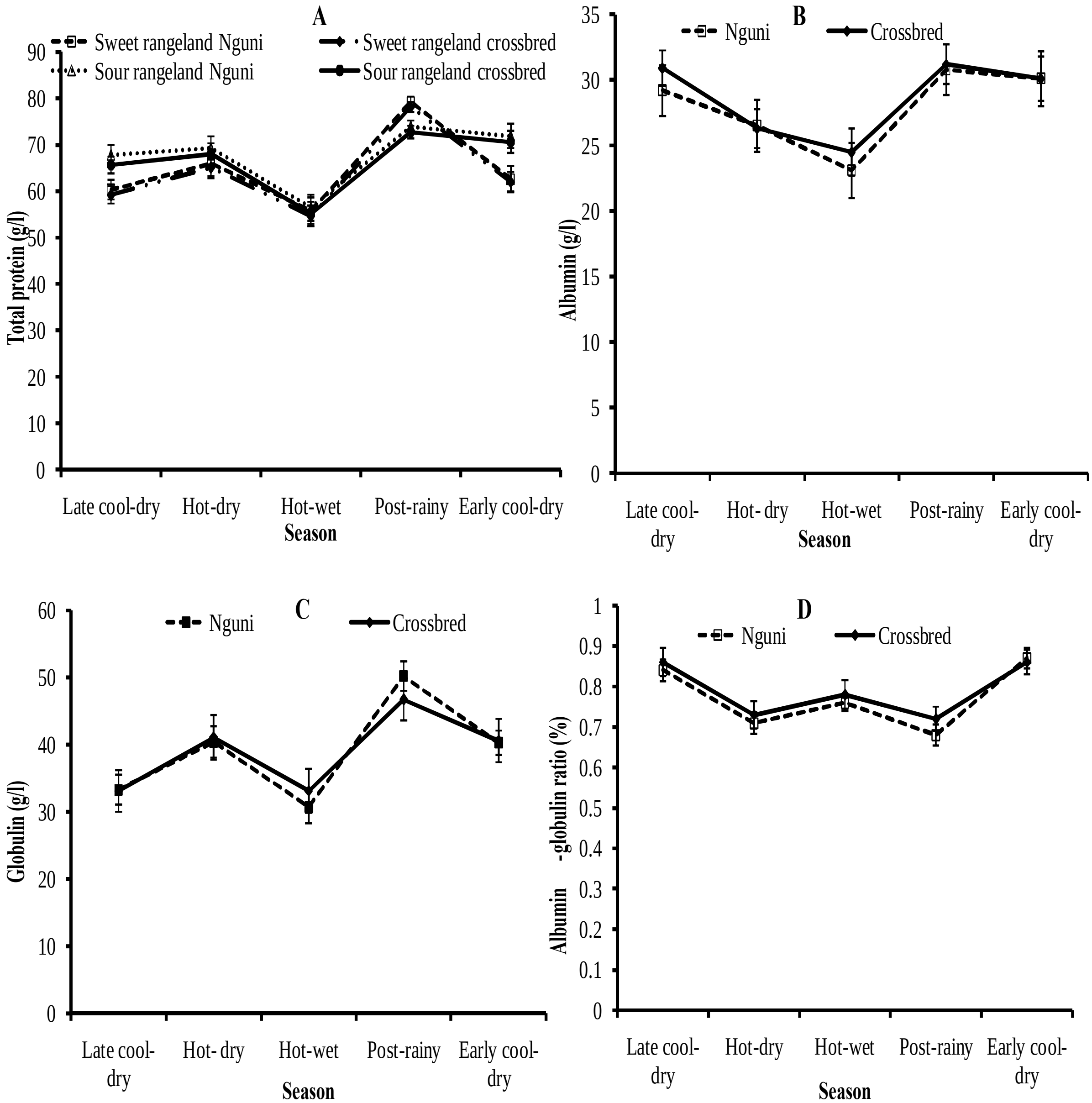


Figure 6.2 A-D: Least square means (± standard error of means) of total protein concentrations of Nguni and crossbred cattle (A) based on rangeland type and season, and least square means (± standard error) of albumin (B), globulin (C) and albumin globulin ratio (D) of Nguni and crossbred cattle based on season

Table 6.2: Least square means (± standard error of means) of total protein (g/l), albumin (g/l), urea (mmol/l), creatinine (µmol/l) and creatine kinase (u/l) concentrations of Nguni and crossbred cattle based on cow physiological status

		Physiological status of the cow			
Metabolite	**Breed**	NPL	NPNL	PL	PNL
[1]TP	Nguni	66.7 ± 4.36^{ab}	63.7 ± 4.28^{a}	64.4 ± 4.37^{a}	73.1 ± 4.29^{b}
	Crossbred	66.2 ± 4.56^{ab}	63.6 ± 4.27^{a}	65.5 ± 4.48^{a}	70.1 ± 4.45^{b}
Albumin	Nguni	27.9 ± 2.33^{a}	28.5 ± 1.33^{a}	28.5 ± 1.95^{a}	32.1 ± 1.34^{b}
	Crossbred	26.5 ± 2.21^{a}	27.4 ± 1.35^{a}	27.6 ± 1.75^{a}	32.0 ± 1.37^{b}
Urea	Nguni	3.09 ± 1.06^{ab}	2.78 ± 1.04^{a}	4.39 ± 1.35^{b}	3.54 ± 1.03^{b}
	Crossbred	3.29 ± 1.16^{ab}	2.88 ± 1.17^{a}	4.51 ± 1.39^{b}	3.80 ± 1.14^{b}
Creatinine	Nguni	114.3 ± 20.00^{b}	118.3 ± 20.09^{b}	85.2 ± 20.42^{a}	138.4 ± 20.21^{c}
	Crossbred	115.3 ± 21.00^{b}	120.3 ± 21.18^{b}	89.3 ± 20.54^{a}	140.4 ± 21.19^{c}
[2]CK	Nguni	20.8 ± 35.67^{a}	38.9 ± 36.32^{a}	66.6 ± 35.95^{b}	61.8 ± 36.09^{b}
	Crossbred	21.8 ± 35.61^{a}	40.1 ± 36.21^{a}	67.5 ± 35.79^{b}	64.4 ± 36.16^{b}

[a,b,c] Values across rows and columns with different superscripts for a particular metabolite are different ($P < 0.05$).

NPL: non-pregnant lactating; NPNL: non-pregnant non-lactating; PL: pregnant lactating; PNL: pregnant non-lactating

[1]TP: Total protein; [2]CK: creatinine kinase

Table 6.3: Least squares mean (± standard error of means) of albumin-globulin (A/G) ratio and albumin (g/l), globulin (g/l), alanine aminotransferase [ALT (u/l)] and aspartate aminotransferase [AST (u/l)] concentrations of Nguni and crossbred cows based on parity

		Metabolite				
Parity	**Breed**	Albumin	Globulin	[1]A/G ratio	[2]ALT	[3]AST
0	Nguni	30.6 ± 2.02^{b}	31.2 ± 2.43^{a}	0.90 ± 0.09^{d}	11.6 ± 9.06^{a}	40.51 ± 17.72^{a}
	Crossbred	31.6 ± 2.12^{b}	32.2 ± 0.43^{a}	0.91 ± 0.09^{d}	11.9 ± 9.16^{a}	42.33 ± 17.72^{a}
1	Nguni	28.98 ± 2.97^{ab}	36.1 ± 2.30^{b}	0.82 ± 0.09^{c}	21.59 ± 8.86^{b}	42.8 ± 17.29^{a}
	Crossbred	28.98 ± 2.97^{ab}	36.3 ± 2.31^{b}	0.82 ± 0.09^{c}	22.56 ± 8.86^{b}	42.7 ± 17.28^{a}
2	Nguni	29.6 ± 2.02^{ab}	36.4 ± 2.44^{b}	0.81 ± 0.08^{c}	31.37 ± 9.11^{c}	51.0 ± 17.78^{a}
	Crossbred	29.4 ± 2.04^{ab}	36.9 ± 2.46^{b}	0.81 ± 0.09^{c}	32.27 ± 9.18^{c}	52.1 ± 17.79^{a}
3	Nguni	29.2 ± 1.91^{ab}	38.3 ± 5.15^{bc}	0.80 ± 0.08^{c}	21.74 ± 8.67^{b}	44.5 ± 16.83^{a}
	Crossbred	29.3 ± 1.71^{ab}	38.5 ± 5.31^{bc}	0.80 ± 0.09^{c}	21.77 ± 8.62^{b}	44.4 ± 16.85^{a}
4	Nguni	28.3 ± 2.08^{ab}	38.9 ± 2.60^{bc}	0.75 ± 0.092^{b}	27.4 ± 9.36^{bc}	69.8 ± 18.20^{b}
	Crossbred	27.3 ± 2.15^{ab}	38.9 ± 3.49^{bc}	0.75 ± 0.09^{b}	27.3 ± 9.37^{bc}	69.7 ± 18.29^{b}
5	Nguni	27.2 ± 1.17^{a}	41.8 ± 3.84^{bc}	0.74 ± 0.09^{b}	21.3 ± 9.73^{ab}	41.2 ± 19.08^{a}
	Crossbred	27.3 ± 1.17^{a}	40.8 ± 2.73^{bc}	0.75 ± 0.09^{b}	21.1 ± 9.77^{ab}	41.9 ± 19.03^{a}
6	Nguni	26.6 ± 0.65^{a}	46.3 ± 7.13^{c}	0.64 ± 0.17^{a}	18.2 ± 11.92^{abc}	45.9 ± 22.27^{ab}
	Crossbred	27.1 ± 0.64^{a}	47.3 ± 6.23^{c}	0.65 ± 0.11^{a}	18.5 ± 11.91^{abc}	45.2 ± 23.29^{ab}

[a,b,c,d] Values with different superscripts within a column and within a particular parity are different (*P < 0.05*).

[1]A/G ratio: albumin-globulin ratio; [2]ALT: alanine aminotransferase; [3]AST: aspartate aminotransferase;

Globulin concentrations were lowest in the hot-wet season and highest in the post-rainy season (Figure 6.2C). Serum globulin concentrations increased ($P < 0.05$) from parity 0 to 6 (Table 6.3). Sex, age and physiological status of a cow had no effect on globulin concentrations. Nguni cattle had lower ($P < 0.05$) A/G ratio than local crossbreds (0.60 ± 0.01 versus 0.71 ± 0.01). The Nguni and crossbred cattle in the sweet rangeland had lower ($P < 0.05$) A/G ratio (0.72 ± 0.087) than those in the sour rangeland (0.84 ± 0.087). Albumin-globulin ratio was higher ($P < 0.05$) in early and late cool-dry seasons compared to other seasons (Figure 6.2D). Males had higher ($P < 0.05$) A/G ratio than females (1.0 ± 0.18 vs 0.56 ± 0.038). Generally, A/G ratio increased ($P < 0.05$) with age of the animal (Table 6.4). The A/G ratio decreased ($P < 0.05$) as the parity increased from 0 to 6 (Table 6.3). Physiological status of the cow had no effect on A/G ratio.

6.3.3 Serum urea and creatinine concentrations

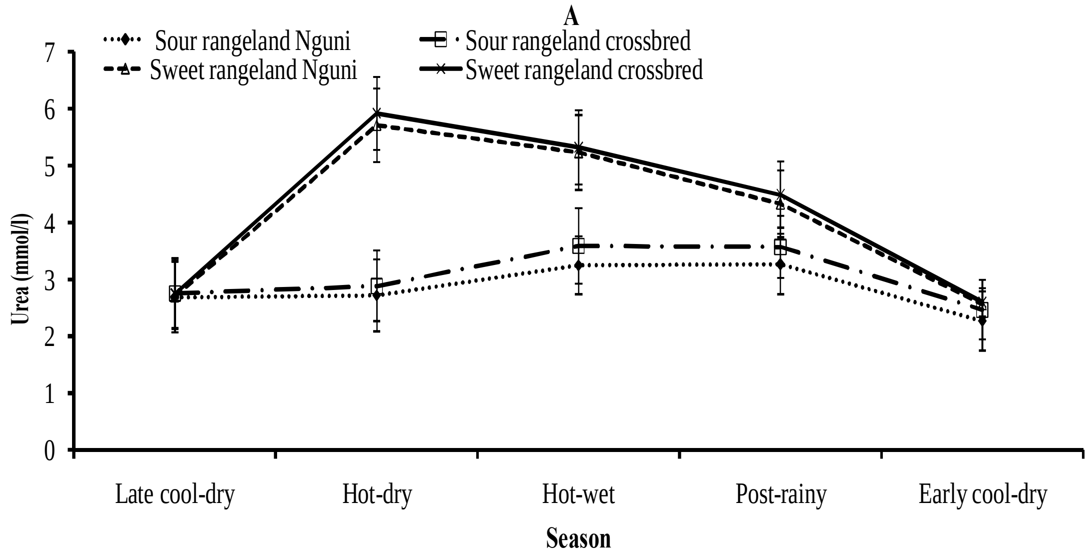
The urea concentrations of about 65 % of the cattle was below the reference range across all the seasons below the reference range across all the seasons ($P < 0.01$; Table 6.1). Nguni cattle had lower ($P < 0.05$) urea concentrations than local crossbred cattle (2.3 ± 0.13 vs 2.8 ± 0.09 mmol/l). Urea concentrations were highest in the hot-dry season in the sweet rangeland compared to other seasons (Figure 6.3A). Pregnant cows had significantly higher ($P < 0.05$) urea concentrations than non-pregnant cows (Table 6.2). Sex, age and parity had no effect on urea concentrations.

About 61 % of the cattle in the late cool-dry season had creatinine concentrations above the normal range whilst more than 65 % of the cattle in the other seasons had creatinine concentrations within the normal range ($P < 0.01$; Table 6.1). Nguni cattle had lower ($P < 0.05$) creatinine concentrations than crossbred cattle (115.8 ± 2.7 vs 123.3 ± 1.82).

Table 6.4: Least square means (± standard error of means) albumin-globulin ratio and alanine aminotransferase concentration of Nguni and crossbred cattle based on age

	Metabolite			
	Albumin-Globulin ratio		Alanine aminotransferase (u/l)	
Age (years)	Nguni	Crossbred	Nguni	Crossbred
1-2	0.72 ± 0.089^{a}	0.73 ± 0.078^{a}	33.20 ± 9.124^{c}	35.21 ± 8.144^{c}
>2-3	0.76 ± 0.089^{ab}	0.77 ± 0.088^{ab}	24.48 ± 8.824^{b}	26.45 ± 8.134^{b}
>3-4	0.81 ± 0.088^{b}	0.82 ± 0.088^{b}	22.36 ± 9.054^{b}	25.23 ± 8.252^{b}
>4-5	0.81 ± 0.089^{b}	0.81 ± 0.089^{b}	15.72 ± 9.104^{a}	19.12 ± 9.314^{a}
>5	0.80 ± 0.089^{b}	0.80 ± 0.089^{b}	13.88 ± 9.054^{a}	14.83 ± 9.224^{a}

^{a,b,c} Values with different superscripts across rows and columns for a particular metabolite are different ($P < 0.05$).



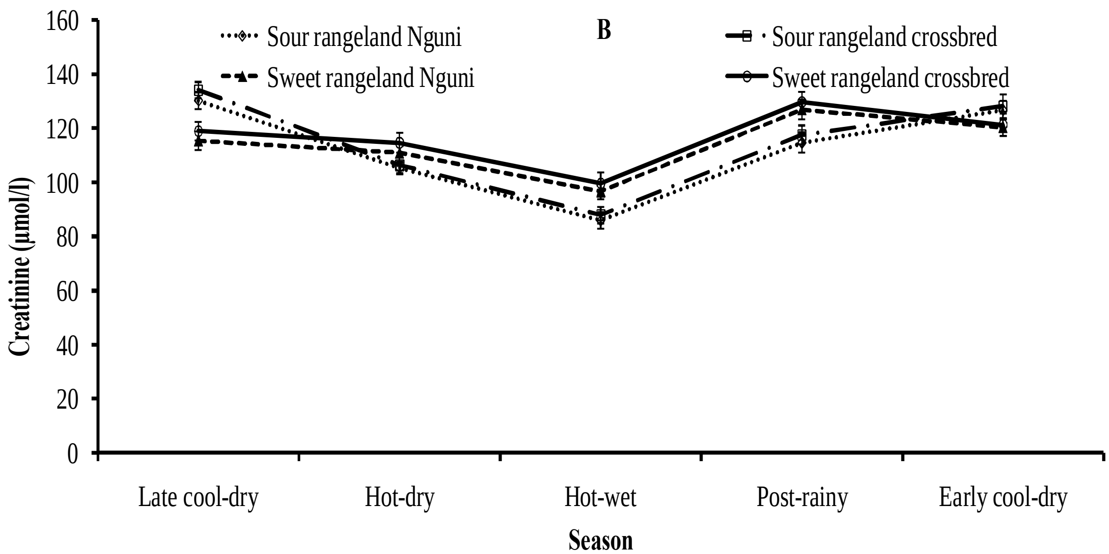


Figure 6.3 A-B: Least square means (± standard error of means) of urea (A) and creatinine (B) concentrations of Nguni and crossbred cattle based on rangeland type and season

Creatinine concentrations of bothe breeds cattle were lowest in the hot-wet season in the sour rangeland compared to other seasons (Figure 6.3B). Pregnant non-lactating cows had higher ($P < 0.05$) concentrations of creatinie as compared to pregnant lactating ones (Table 6.2).

6.3.4 Liver enzyme concentrations

More than 90 % of the cattle had liver enzymes (ALT, ALP, AST, CK and GGT) concentrations within the normal range across all the seasons (Table 6.1). There was no association between rangeland type and breed with the proportions of cattle that had liver enzymes values within and outside the reference range. The concentrations of ALT were highest in local crossbreds during the hot-wet season (Figure 6.4A). ALT concentrations were highest in 1-2 years-old animals compared to other animal ages and decreased ($P < 0.05$) with age (Table 6.4). The concentrations of ALT were lower ($P < 0.05$) in heifers compared to other parities, and it generally increased ($P < 0.05$) with parity (Table 6.3). The ALT concentrations were not influenced by rangeland type, sex and physiological status of the cow ($P > 0.05$). Nguni cattle had the highest concentrations of AST in the post-rainy season compared to other seasons (Figure 6.4B). Generally, AST concentrations increased ($P < 0.05$) up to the fourth parity (Table 6.3). Rangeland type, sex, age and physiological status of the cow had no significant influence on AST concentrations.

Nguni cattle had lower ($P < 0.05$) ALP concentrations in the hot-dry and hot-wet seasons than local crossbreds (Figure 6.4C). Rangeland type, sex, age, parity and cow physiology had no effect on ALP concentrations. The concentrations of CK in Nguni and crossbred cattle were higher ($P < 0.05$) in the sweet rangeland (43.3 ± 30.35 u/l) than in the sour rangeland (69.7 ± 30.39 u/l). The post-rainy and early cool-dry seasons had the highest ($P < 0.05$) CK concentrations (Figure 6.4D).

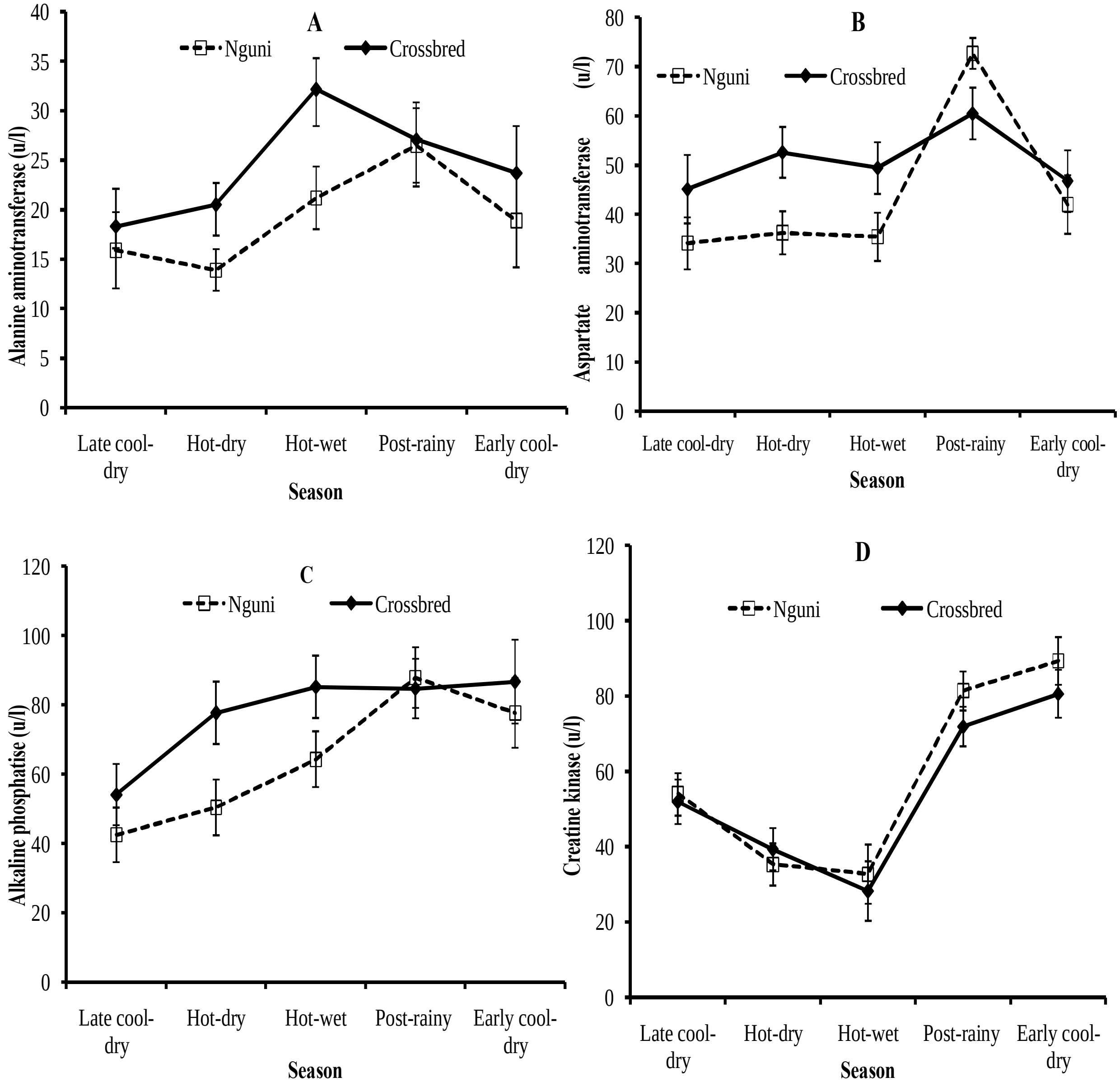


Figure 6.4 A-D: Least square means (± standard error of means) of alanine aminotransferase, (A) aspartate aminotransferase, (B), alkaline phosphatase (C) and creatine kinase (D) concentrations of Nguni and crossbred cattle based on season

Pregnant cows had higher ($P < 0.05$) concentrations of CK compare to non-pregnant cows (Table 6.2). Breed, sex, age and parity had no effect on CK concentrations ($P > 0.05$). All the tested factors did not influence GGT concentrations ($P > 0.05$).

6.4 Discussion

The high albumin concentrations recorded in the sour rangeland can be ascribed to provision of supplementary feeds (Chapter 3). Sour rangelands receive 600-800 mm per annum that supports excess plant growth during the hot-wet season (Ellery *et al.,* 1995), which is subsequently conserved as crop residues or foggage for dry season supplementary feeding (Nqeno *et al.,* 2009). Feed supplies decrease from post-rainy season onwards, as temperatures and rainfall decrease, reaching a low-point during the dry season when plant materials are dormant (Ellery *et al.,* 1995). It subsequently increases as new shoots start appearing on trees and shrubs, during the late dry season, and grass shoots emerge following rains in the hot-wet season. In general, the patterns of serum concentrations of total protein, albumin, globulin and creatinine were consistent with this seasonal trend in rainfall and feed availability, indicating that these blood metabolites are sensitive to seasonal variations in feed availability and protein intake.

The observation that total protein, albumin, urea and creatinine were highest in pregnant non-lactating cows could be a result of the greater efficiency of converting nitrogenous substances to amino acids and proteins for foetus growth and development (Doornenbal *et al.,* 1988; King, 2000). The low albumin and creatinine concentrations in pregnant lactating cows could be a consequence of the damôs increased basal metabolic rate, the maximal nutrient requirements of the placenta and the growing foetus, together with the transfer of serum albumin, and amino acids from the bloodstream to the mammary gland for milk synthesis (Jainudeen and Hafez, 2000; Otto *et al.,* 2000).

The decline in PCV concentrations in the hot-wet season could be an indicator of protein deficiency, and high levels of parasitism. In the Eastern Cape, highest tick loads (Marufu *et al.,* 2009) and nematode (Ndlovu *et al.,* 2008) infections occur in the hot-wet months. The reduction in PCV in the hot-wet season might also be related to the reduction in celluar oxygen requirement in order to reduce metabolic heat load (Carlson, 1990; Johnston and Morris, 1990). The low PCV concentrations observed in sweet rangeland could be due to low plane of nutrition, especially iron (Farver, 1997). The lower PCV values observed in the Nguni breed could suggest a higher innate and/or acquired resistance to parasites than local crossbreds (Muchenje *et al.,* 2008; Ndlovu *et al.,* 2008; Marufu *et al.,* 2009).

The observed mean concentrations of serum TP was within the normal physiological range for cattle (Farver, 1997; Otto *et al.,* 2000). Albumin values were, however, lower than the references and this could be ascribed to protein under-nutrition and parasitism (Slobodianik *et al.,* 1999; Ndlovu *et al.,* 2009). The decrease in albumin, and increases in globulin, ALT and AST concentrations with parity can be attributed to increased calf birth weight and milk production (Doornbos *et al.,* 1984; Browning *et al.,* 1994).

The high percentage of cattle that had TP and albumin concentrations below the normal range and the marked decline in mean TP, albumin, creatinine, AST and CK concentrations in the hot-wet season, especially in the sour rangeland could also be partly attributed to parasitism and heamodilution. In contrast, Akerejola (1980) reported higher values of protein metabolites in the Fulani cattle during the hot-wet season. Ticks and nematodes reduce feed intake and metabolic activity of cattle (Kaufman *et al.,* 2006; Marufu *et al.,* 2009). In addition, gastrointestinal parasitism induces loss of proteins from the blood into the gastrointestinal tract, reducing protein and energy retention in infected animals (Kaufman *et al.,* 2006). Increased blood water concentration and viscosity through consumption of wet forages or as a response to high temperatures during the hot-wet season, lead to haemodilution, which in turn reduces concentrations of blood protein metabolites (Akerejola *et al.,* 1980; Shaffer *et al.,* 1981). The observed low serum protein concentrations during the hot-wet season can be partially attributed to decline in feed consumption and marked increase in respiratory activity with rising temperature (Fox *et al.,* 1988).

The observation that crossbred cattle on sour rangelands had the highest globulin concentrations can be linked to high parasite infections, which are more prevalent in the sour rangeland (Marufu *et al.,* 2009). Parasite infections lead to a chronic stimulation of the immune system and the production of gamma globulin (Otto *et al.,* 2000). Lower globulin concentrations observed for Nguni for each rangeland type could imply that Nguni cattle are resistant or resilient to parasite infections (Marufu *et al.,* 2009; Ndlovu *et al.,* 2009). Following reports by Marufu *et al.* (2009) on sero-prevalence of tick-borne diseases in the same study areas, it is crucial to ascertain the effect of tick infections on blood protein metabolites and cattle performance, especially in the sour rangelands.

The low A/G ratio observed could be due to lower albumin and higher globulin concentrations than normal range values (9-1.4 %) (Doornenbal *et al.,* 1988). Farver (1997) and Ndlovu *et al.* (2009) attributed the low A/G ratio to a marked decrease in albumin concentrations and an increase in globulin concentrations in the infected animals. The low A/G ratio recorded for young animals could mean that they are more susceptible to infections than mature ones. Older animals usually develop age-immunity and, therefore, have low infestation rates, but remain a source of infestation for younger animals (Sikka *et al.,* 1994; Matjila and Penzhorn, 2003).

The observation that most of the cattle had urea concentrations below the reference range was possibly due to lower intakes of CP (Farver, 1997; Ndlovu *et al.,* 2009). The high stocking rates in the communal areas (Nqeno et al., 2009) may affect quantity and quality of grazing, especially protein status and subsequently lead to low protein intake. When protein intake is low, as indicated by low albumin concentrations in this study, resorption of urea nitrogen from blood to the rumen is increased so as to compensate for the decrease in ruminal ammonia nitrogen (Nonaka *et al.,* 2008). Blood urea is, therefore, a good indicator of concentration of rumen ammonia, and this is related closely to intake and solubility of the nitrogen-containing compounds fed (Hayashi *et al.,* 2005).

Blood urea concentration can be inversely related to the efficiency of nitrogen utilisation (Nonaka *et al.,* 2008) and its reduction is generally associated with an increase in the efficiency of nitrogen utilisation (Butler *et al.,* 1996). The low albumin and urea concentrations observed for Nguni cattle compared to local crossbreds might, therefore, imply that Nguni cattle utilised amino acids more efficiently for growth and development, despite the consumption of low protein diets. This could mean that Nguni cattle are more adaptable to low protein diets than local crossbreds. Efficiency of protein utilisation in Nguni cattle, however, deserves further investigation. The higher urea concentrations observed in the sweet rangeland during the hot-dry season compared to other seasons can be attributed to low dietary CP intake (Hayashi *et al.,* 2005).

The observation that local crossbreds had higher creatinine compared to Nguni cattle might suggest that the former have more skeletal muscle compared to Nguni cattle. Creatinine is a break-down product of creatine phosphate in muscle, and its rate of production usually depends on body muscle mass (Gross *et al.,* 2005). The ALT enzymes are a valuable indicator of skeletal muscle mass and tissue damage in response to strenuous physical exercise (Otto *et al.,* 2000). The observation that Nguni cattle had lower ALT than local crossbreds suggests that Nguni cattle had low skeletal muscle mass and experienced less tissue damage. An alternative explanation could be that Nguni cattle are small-framed animals with low feed maintenance requirements compared to large-framed local crossbred cattle (Collins-Luswit, 2000). The small-framed Nguni cattle are, therefore, likely to travel shorter distances in search of feed to meet their low maintenance requirements, thus could be less prone to skeletal tissue damage than large-framed local crossbreeds.

High concentrations of ALT observed in cattle aged less than two years may be a result of the faster growth rate in young animals (Doornenbal *et al.,* 1988). The higher ALT concentrations in young animals are indicative of rapid skeletal growth (Ndlovu *et al.,* 2009), which tend to decline with age (Gross *et al.,* 2005). High metabolic rates of the young result not only from high rates of cellular reactions but also partly from rapid synthesis of cellular materials and growth of the body, which require moderate quantities of energy, and hence ALT (National Research Council, 2001).

The elevated concentrations of AST in Nguni cattle during the post-rainy season could be associated with increased feed availability and, consequently, increased growth rates as indicated by improved body weight and BCS in the same season. Previous research on rangeland showed Nguni cattle have higher growth rates than exotic breeds (Muchenje *et al.,* 2008). Similar to this finding, Otto *et al.* (2000) found higher AST activity in Angoni cattle raised on rangelands. The AST enzyme is an indicator of skeletal muscle growth and liver damage (Otto *et al.,* 2000).

The observed ALP values were within the reference range (Farver, 1997; Ndlovu *et al.,* 2009). Besides possible involvement in membrane phospholipid synthesis, ALP activity is associated with the process of calcification (Farver, 1997) and, therefore, could be correlated with growth (Pattanaik *et al.,* 1999). The observed breed differences in ALP values in the hot-dry and hot-wet seasons reflect differences in growth, body size and weight for the cattle in this study. Small-framed animals, have low feed intake and, consequently, lower skeletal growth (Adachi *et al.,* 1997) than local crossbreds. The high CK concentrations in pregnant cows probably reflect the increase in foetal musculature and muscle damage in the dam (Castillo *et al.,* 2005). It may be partly due to either partitioning of protein towards foetal growth and development or low CP intake over a long period of time (Castillo *et al.,* 2005). In future, blood metabolite profiling should be accompanied by assessment of rangeland condition and nutritional composition of grass species.

6.5 Conclusions

Nguni cattle had lower concentrations of protein metabolites than local crossbreds and protein deficiencies were most prominent in the sweet rangeland during the cool-dry seasons. Since concentrations of protein metabolites were lowest in the cool-dry season compared to other seasons, supplementing Nguni cattle in the cool-dry season with protein-rich indigenous browse trees, such as *A. karroo*, could improve beef production on communal rangelands. It is, therefore, essential to determine the effects of feeding *A. karroo* on the nutritional status, growth performance and carcass traits of Nguni cattle on communal rangelands.

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Chapter 7: Growth performance, blood chemistry and carcass characteristics of Nguni steers supplemented with *Acacia karroo* leaf meal

(Published in *Livestock Science,* see Appendix 8)

Abstract

The objectives of the current study were to determine the effect of supplementing *Acacia karroo* leaf meal on growth performance, blood chemistry and carcass characteristics of Nguni steers. Thirty 19-month old Nguni steers (241.5 ± 14.62 kg) were randomly allotted to three dietary treatments: *A. karroo* leaf meal (AK), sunflower cake (SF) and a control (CN) diet entirely composed of natural pasture. Steers on the AK and SF diets were offered an additional 150 g of protein/steer per day from *A. karroo* and sunflower cake, respectively, for 60 days. Concentrations of nutritionally-related blood metabolites were measured every fortnight. Steers that were given the supplementary feeds had higher ($P < 0.05$) total protein, albumin, creatinine, non-esterified fatty acids, calcium, phosphorus, magnesium and iron concentrations, and larger eye muscle area than those that received the CN diet. Steers supplemented with the AK and SF diets had lower ($P < 0.05$) glucose and cholesterol, but higher ($P < 0.05$) NEFA concentrations than those that received the CN diet. Steers that were given the SF diet had the highest average daily gain, body condition score, slaughter weight, warm carcass weight, and cold carcass weight followed by those on the AK diet. Steers supplemented with AK and SF diets had higher ($P < 0.05$) gross margins than those that received the CN diet. It was concluded that *A. karroo* could be a low-cost alternative to improve the nutritional status, growth performance, and carcass traits of Nguni steers reared on natural pasture.

Key words: Average daily gain, carcass weight, total protein, non-esterified fatty acids.

7.1 Introduction

Cattle production efficiency on communal rangelands is mainly constrained by low protein availability, especially in the dry season (Chapter 6). In the communal areas of South Africa, productivity of cattle is further curtailed by the predominance of large-framed indigenous x exotic crossbred cattle that have high feed maintenance requirements (Marufu *et al.,* 2009). On the other hand, Nguni cattle are resistant to nematodes (Ndlovu *et al.,* 2008; Xhomfulana *et al.,* 2009), ticks (Muchenje *et al.,* 2008a) and tick-borne diseases (Marufu *et al.,* 2009). Results from Chapters 5and 6 have shown that Nguni cattle lose weight and condition and have low blood protein levels in the dry season. The reduced performance could, consequently, lower CPE on semi-arid communal rangelands. Supplementary feeding is, therefore, essential for viable and sustainable cattle production in semi-arid communal areas.

Most resource-poor cattle producers in the semi-aid areas use legume crop residues and their by-products as protein supplements (Devendra and Sevilla, 2002). Although these crop residues have relatively high CP, they are highly fibrous, have low vitamin and mineral contents and require expensive production inputs such as seed, fertilisers, herbicides and pesticides (Ngongoni *et al.,* 2007). Moreover, misuse of biocides in crop production increases consumersô worries about risk of chemical residues in beef products (Paull, 2006). Supplementation with exotic herbaceous and browse legumes such as *A. angustissima*, *C. calothyrsus* and *Leucaena spp.* has been evaluated (Maarsdop *et al.,* 1999; Rubanza *et al.,* 2005), but the potential of these browse legumes in the subtropics was limited by scarcity and high cost of inputs such as seed and fertilisers, and poor establishment (Devendra and Sevilla, 2002). Evaluation of locally available protein supplements grown without use of chemicals is, therefore, essential.

Indigenous legume trees in Southern Africa which include *C. mopane*, *Brachystegia spiciformis*, and the genera of *Acacia* and *Guibourtia* are used as livestock protein supplements (Aganga *et al.,* 1998). As such, *A. karroo* is gaining importance as a protein supplement for grazing ruminants because it is widespread and moderately available in the early dry season (Mokoboki *et al.,* 2005). More importantly, *A. karroo* contains high concentrations of crude protein (100-250 g/kg DM) and minerals (Aganga *et al.,* 1998; Mokoboki *et al.,* 2005), and has antihelmintic properties (Xhomfulana *et al.,* 2009). Although the existence of thorns and tannins restricts its utilisation, these factors can be effectively reduced by use of protective clothing during harvesting and simple detannification processes based on drying treatments, respectively (Makkar, 2003).

Although *A. karroo* has potential as protein supplement, itös value in improving nutritional status, growth and carcass characteristics of indigenous cattle raised on communal rangelands is largely unknown. Given that body weights and condition respond slowly to short-term changes in nutrition and are influenced by the physiological status of the animal, concentrations of nutritionally-related blood metabolites could be more useful indicators of the rate at which animals respond to short-term nutritional changes (Agenas *et al.,* 2006). In addition, blood metabolites are quick indicators of animal health (Ndlovu *et al.,* 2009). The objective of the current study was therefore, to determine the effect of supplementing *A. karroo* leaf meal on growth performance, blood chemistry and carcass characteristics of Nguni steers. The hypothesis tested was that Nguni steers supplemented with *A. karroo* leaf meal and those that entirely rely on rangelands have similar growth performance, blood chemistry and carcass traits.

7.2 Material and Methods

7.2.1 Study site

The study was conducted at the University of Fort Hare farm, Alice, South Africa. It lies along longitude 32° 78' E and latitude 26° 85' S at an altitude of 450-500 m above the sea-level. It is located in the False Thornveld of the Eastern Cape Province characterised by mean annual rainfall of 480 mm and mean annual temperature of 18.7°C, respectively. Most rain falls in summer. Cattle graze on natural pastures mainly composed of the following grass species; *A. congesta*, *C. plurinodis*, *C. dactylon*, *D. eriantha*, *S. africanus*, *S. fimbriatus*, *T. triandra* and *Eragrostis* species. *Acacia karroo*, *Scutia myrtina* and *Maytenus polyacantha* are the dominant tree species. *Acacia karroo* is a small to medium sized leguminous tree with population densities of 500-1500 tree/ha in the False Thornveld of the Eastern Cape Province (van Wyk *et al.,* 2000). It has long (5 to 10 cm) and straight-paired thorns, and its leaves are bipinnately compound, finely textured and dark green (van Wyk *et al.,* 2000).

7.2.2 Acacia karroo leaf meal preparation

The *A. karroo* leaf meal was prepared at the University of Fort Hare farm between February and March 2008 by lopping small branches with a diesel-powered saw-mill. The cut branches were stacked (1-1.5 m high) on plastic sheets of 5 x 3 m dimension. The leaves were sun-dried for four days. The dried leaves were collected from the plastic sheet by shaking them off the branches. Thereafter, the leaves were passed through a 2-cm sieve to separate them from thorns, twigs and exploded pods. The leaf meal was bagged and stored in a well-ventilated dry shade.

7.2.3 Treatments and feeding management

Thirty 19-month old Nguni steers which had a mean weight of 241.5 ± 14.62 kg were randomly assigned to three dietary treatments: *A. karroo* leaf meal (AK), sunflower cake (SF) and the control diet with no supplement (CN), from April 2008 to June 2008. All the steers were ear-tagged for easy identification. Each treatment was composed of 10 steers. In addition to natural pasture, steers on the AK and SF diets were offered 1 500 g and 650 g of feed, respectively, to supply 150 g of protein per day. Natural pasture hay (300 g) was mixed with 1500 g of *A. karroo* foliage to improve palatability. The natural pasture hay was harvested in March 2008 in the same paddocks where the steers were grazing. The feed supplements were offered daily at 0830 h. The steers on the control diet (CN) relied entirely on the natural pasture.

7.2.4 Management of steers

Steers on the same treatment were kept in one paddock. The steers on the supplementary diets were allowed 21 days to adapt to their respective diets prior to the 60-day supplementary feeding trial. Each steer on the supplementary diet was fed individually. These steers were trained for 14 days during the adaptation period to feed from individual troughs. Residues for each steer on the supplementary diet were weighed at 1015 h using a digital scale (Teraoka Seiko Co. Ltd, Japan). Supplement intake for each steer was calculated as the difference between feed offered and refusals. All the steers were released daily for grazing at 1000 h and penned at 1730 h throughout the trial period. The three treatment groups were continuously rotated on three paddocks (2 ha each) every seven days. This was done to avoid variations in quality and quantity of forage consumed that is attributable to differences in plant growth or micro-environmental condition of the paddocks. Clean tap water was freely accessible to the experimental animals. All steers were neither de-wormed nor dipped throughout the trial.

7.2.5 Evaluation of the nutritive value of feed ingredients

During the trial, biomass of forage in the paddocks was estimated every month by random sampling of natural pasture using a disc meter (Figure 7.1A). Three 100 m long transects were randomly positioned in each paddock and five 0.25 m^2 quadrats were placed 20 m apart along each transect for evaluation of grass nutritional composition. Sunflower cake, *A. karroo*, natural pasture hay and fresh herbage were assessed for dry matter (DM), crude protein (CP), crude fat (Table 7.1), calcium, magnesium, potassium, zinc, copper, iron, manganese, phosphorus and sodium (Table 7.2) using the Association of Official Analytical Chemists (AOAC, 2003) procedures. Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), acid detergent cellulose (ADC) and hemi-cellulose were determined according to Van Soest *et al.* (1991) (Table 7.1).

The 24 and 48 h *in vitro* DM and NDF disappearances of *A. karroo* (Table 7.1) were determined in accordance with the Daisy ANKOM system based on Goering and Van Soest (1970) and Van Soest and Robertson (1985). The medium for incubation consisted of micro minerals, tryptose, rezasurin and distilled water. The medium was kept in a water bath at 39.5°C at a pH of 7.6. The reducing solution was composed of cysteine hydrochloride ($C_3H_7NO_2$.HCL), potassium hydroxide (KOH) pellets, sodium sulphide non-hydrate ($Na_2S.H_2O$) and distilled water. Rumen fluid was collected from two ruminally cannulated Dohne Merino sheep. The sheep were confined and fed a diet consisting of oat hay, lucerne hay, wheat straw and crushed maize concentrate. Rumen fluid was squeezed through layers of cheese cloth into pre-warmed flasks and a small amount of coarse material was added. The rumen fluid was then blended in a pre-warmed blender at a low speed for 10 seconds. The rumen fluid was then filtered through four layers of cheese cloth into pre-warmed flasks while flashing with carbon dioxide (CO_2). The temperature of the rumen fluid averaged 38°C and the pH averaged 6.5.

The *in vitro* incubation procedure required four glass vessels (2 L). The glass vessels were flushed with CO_2 while adding 1076 ml of incubation medium and 54 ml of the reducing solution to each vessel. The vessels were closed and placed in an incubator at 39°C until the medium was clear. The vessels were opened and flushed with CO_2 while adding 270 ml of rumen fluid and nylon bags to the vessels. Incubation periods were 24 and 48 hours. At each of the time intervals one vessel was removed and the residue bags washed with water, air-dried and then placed in a conventional oven at 100°C for 24 hours. The NDF of the residues in the bags was determined using the method of Van Soest *et al.* (1991). Sodium sulphite (20 g) was added to 1.9 L of NDF solution during digestion and heat stable amylase (4 ml x 2 rinse) was added during rinsing. Bags were further rinsed in acetone for three to five minutes and then air-dried before being placed in a conventional oven at 100°C for 24 hours.

Condensed tannins (CT) assays were performed colorimetrically with butanol-HCl method (Bate-Smith, 1981) using purified CT from *Desmodium intortum* as a reference standard. This method is based on oxidative cleavage of the interflavan bonds in the presence of mineral acids in alcoholic solutions at about 95°C to yield pink coloured anthocyanidins, which are measured at 550 nm (Bate-Smith, 1981). Total phenolics were assayed colorimetrically according to Price and Butler (1977). In this method 6 ml of aqueous solution of phenolics and 50 ml of distilled water were mixed and 0.1 ml ferric chloride was added immediately followed by timed addition of 3 ml of 0.008 M of ferricyanide solution. The absorbance at 720 nm was read after 10 min standing at room temperature. Distilled water was used as a blank.

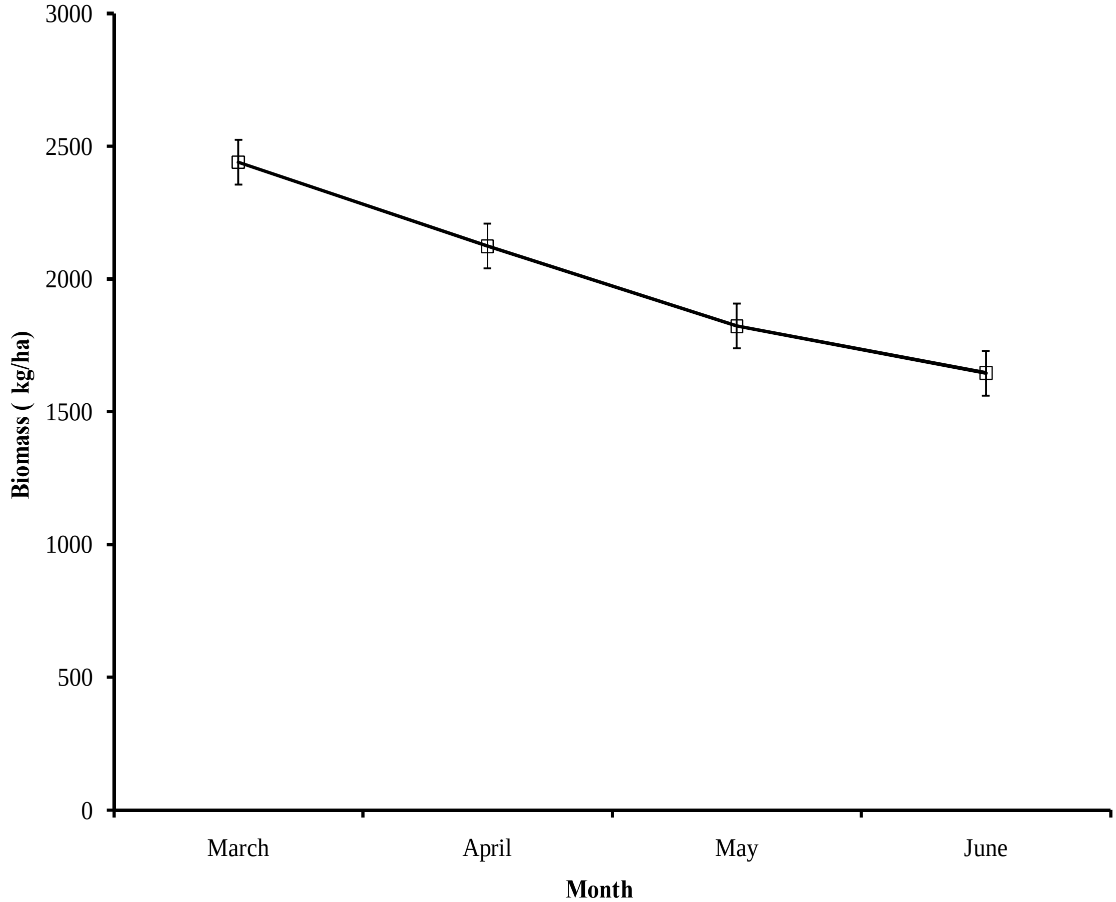

Figure 7.1: Average rangeland biomass per month per hectare

Table 7.1: Nutritive value of the dietary components

Nutritive value (g/kg DM)	**Supplement**		**Natural pasture**				
	A. karroo	Sunflower	Hay	March	April	May	June
DM	897	911	925	924	925	921	927
Crude protein	148.9	358.8	36.3	39.6	31.9	33.5	32.7
Fat	20.0	25.0	22.2	22.2	22.1	22.1	22.0
Neutral detergent fibre	502	516	656.1	648.6	636.9	625.7	648.3
Acid detergent fibre	289.9	180	404.1	383.9	407.7	395.9	417.2
24 h DM disappearance	580	440	570	560	555	540	560
48 h DM disappearance	580	430	550	540	530	510	540
24 h NDF disappearance	460	410	520	540	530	540	530
48 h NDF disappearance	440	410	510	500	500	500	510
Condensed tannins	73.9	0.06	0.04	1.7	1.4	1.8	1.5
Total polyphenols	305.4	123.4	39	75	55.8	61.4	38.1

Table 7.2: Mineral composition of dietary components

	Supplement			Natural pasture			
Mineral	*A. karroo*	Sunflower	Hay	March	April	May	June
Calcium (g/kg DM)	3.77	0.87	1.03	0.86	0.88	0.82	0.86
Magnesium (g/kg DM)	0.39	0.50	0.22	0.16	0.14	0.15	0.13
Potassium (g/kg DM)	1.87	2.34	1.98	1.96	1.60	1.59	1.29
Sodium (g/kg DM)	0.17	0.06	0.10	0.12	0.08	0.09	0.07
Phosphorus (g/kg DM)	0.08	0.82	0.09	0.05	0.06	0.05	0.05
Zinc (ppm)	22.30	114.10	29.20	21.67	23.07	20.63	19.53
Copper (ppm)	14.00	48.00	10.00	9.00	8.33	9.67	7.33
Iron (ppm)	336.80	240.30	421.60	432.60	370.10	310.67	326.83
Manganese (ppm)	32.00	37.00	43.00	49.67	53.67	41.67	47.67

The method exploits an oxidation-reduction reaction in which the phenolate ion is oxidized (Price and Butler, 1977). The ferric ions are reduced to the ferrous state and detected by the formation of the Prussian Blue complex ($Fe_4[Fe(CN)_6)]_3$) with a potassium ferricyanide-containing reagent.

Fatty acids in feed (AK, SF and CN) were extracted according to AOAC (2003) procedures. Approximately 10 mg of extracted lipid was transferred into a Teflon-lined screw-top test tube by means of a disposable glass Pasteur pipette. Fatty acid methyl esters (FAME) were prepared for gas chromatography by methylation of the extracted fat, using methanolï BF3 (Christie *et al.,* 2001). Fatty acid methyl esters were quantified using a Varian GX 3400 flame ionization GC, with a fused silica capillary column, Chrompack CPSIL 88 (100 m length, 0.25 mm ID, 0.2 εm film thickness). Column temperature was 40 to 230°C (hold 2 minutes; 4°C/minute; hold 10 minutes). Analysis was performed using an initial isothermic period (40°C for 2 minutes). Thereafter, temperature was increased at a rate of 4°C/minute to 230°C. Finally an isothermic period of 230°C for 10 minutes followed. Fatty acid methyl esters in n-hexane (1εl) were injected into the column using a Varian 8200 CX Autosampler with a split ratio of 100:1. The injection port and detector were both maintained at 250°C. Hydrogen, at 45 psi, functioned as the carrier gas, while nitrogen was employed as the makeup gas. Varian Star Chromatography Software recorded the chromatograms.

Fatty acid methyl ester samples were identified by comparing the retention times of FAME peaks from samples with those of standards obtained from Supelco (Supelco 37 Component Fame Mix 47885-U, Sigma-Aldrich Aston Manor, Pretoria, South Africa). Conjugated linoleic acid (CLA) standards were obtained from Matreya Inc. (Pleasant Gap, Unites States). These standards included: *cis*-9, *trans*-11; *cis*-9, *cis*-11, *trans*-9, *trans*-11 and *trans*-10, *cis*-12 isomers. All other reagents and solvents were of analytical grade and obtained from Merck Chemicals (Pty) Ltd Halfway House, Johannesburg, South Africa. All other reagents and solvents were of analytical grade and obtained from Merck Chemicals (Pty) Ltd Halfway House, Johannesburg, South Africa. Fatty acids were expressed as the proportion of each individual fatty acid to the total of all fatty acids present in the sample. The following fatty acid combinations and ratios were calculated: omega-3 (*n*-3) fatty acids, omega-6 (*n*-6), total saturated fatty acids (SFA), total mono-unsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), PUFA/SFA ratio (P/S) and *n*-6/*n*-3 ratio. Fatty acids composition of A. AK, SF and CN are shown in Table 7.3.

7.2.6 Growth rate and body condition scores

Individual steer weights were recorded using a heavy duty scale (Cattleway, Johannesburg, South Africa) every fortnight. Average daily gain (ADG) (g/day) between the initial weight and slaughter weight was computed for each steer. Cattle were palpated and scored using a 5-point scale (1-very thin and 5-obese) to estimate the BCS every fortnight (Nicholson and Butterworth, 1986).

7.2.8 Blood collection and analyses

Blood was collected from the jugular vein using an 18-gauge needle at 0800 h every fortnight from March to June 2008. Blood for biochemical analyses was collected and stored as described in Section 5.2.4. Nutritionally-related energy metabolites and minerals were analysed as described in Section 5.2.4 whilst protein-related metabolites and liver enzymes were analysed as described in Section 6.2.3. Details of nutritionally-related metabolites and, and minerals concentration analysis are described in Appendix 6.

7.2.7 Slaughter procedures and carcass measurements

Steers were slaughtered in June 2008 at 21 months of age. Twenty-four hours prior to slaughter, the steers were weighed and trucked to the slaughtering plant at the East London Abattoir (120 km from the University of Fort Hare). At the abattoir, the steers were deprived of feed overnight, but water was always available. Cattle slaughter and dressing were done humanely, following the usual commercial procedures at the East London Abattoir. The captive bolt method was used to stun the steers. The dressed carcasses were comprised of the body after removing the skin, the head at the occipito-atlantal joint, the fore-feet at the carpal-metacarpal joint, the hind feet at the tarsal-metatarsal joint and the viscera.

Carcasses were split, weighed and then chilled at $3^{o}C$ 1 h after evisceration. The warm carcass weight was recorded 1 h after slaughtering, while the cold carcass weight was obtained 24 h later. The carcass fatness was graded on a scale of 0-6 (0 = no visual fat cover, 1 = very lean, 2 = lean, 3 = medium, 4 = fat, 5 = over-fat, and 6 = excessively over-fat). The South African meat industry (SAMIC, 2006) uses a conformation scale of 1-5 (with 1 = a very flat carcass, 2= a flat carcass, 3 = medium carcass, 4 = a round carcass, and 5 = very round carcass). Dressing percentage was calculated as warm carcass weight expressed as a proportion of slaughter weight. The eye muscle area was measured a day after slaughter by tracing the *longissimus dorsi* eye muscle area between the 10^{th} and 11^{th} thoracic vertebrae. The surface area of the eye muscle was then determined by video image analysis (VIA, Kontron, Germany).

Table 7.3: Fatty acids composition (% total fatty acids) of *A. karroo*, sunflower cake and the natural pasture

	Diet		
Fatty acid	Control	*A. karroo*	Sunflower cake
C14:0	2.57	3.09	0.11
C15:0	0.20	0.17	0.04
C16:0	16.69	23.28	9.57
C16:1c9	0.08	0.04	0.14
C17:0	0.22	0.21	0.14
C18:0	4.14	4.71	4.4
C18:1c9	6.18	4.7	30.4
C18:1c7	0.7	0.49	1.1
C18:2c9,12 (n-6)	15.2	13.7	51.2
C18:3c9,12,15 (n-3)	13.51	27.8	0.9
C20:0	21.84	5.43	0.53
C20:1c11	0.076	0.33	0.22
C20:2c11,14 (n-6)	0.02	0.04	0.0
C20:3c11,14,17 (n-3)	0.02	0.01	0.003
C21:0	2.1	0.9	0.03
C22:0	3.4	6.4	0.71
C22:5c7,10,13,16,19 (n-3)	0.06	0.03	0.0
C22:6c4,7,10,13,16,19 (n-3)	0.06	0.12	0.01
C22:1c13	0.02	0.04	0.0
C24:0	2.82	3.8	0.36
Total Saturated Fatty Acids (SFA)	63.33	52.39	15.65
Total Mono Unsaturated Fatty Acids MUFA)	7.13	5.48	32.11
Total Poly Unsaturated Fatty Acids (PUFA)	29.55	42.14	52.24
Total Omega- 6 Fatty Acids (*n*-6)	15.9	14.15	51.31
Total Omega- 3 Fatty Acids (*n*-3)	13.64	27.99	0.93
PUFA/SFA	0.47	0.80	3.34
n-6/*n*-3	1.16	0.51	55.32

7.2.8 Economic analysis

The gross margin analysis was employed to determine the economics of supplementing *A. karroo*. The gross margin was obtained by subtracting the total variable costs from gross income. Total variable costs for each treatment were calculated as costs directly related to production of steers, these included items such as labour, fuel, transport and feed. Gross income for each treatment was calculated as the total estimated income earned from selling the carcasses.

7.2.9 Statistical analyses

The effect of week of sampling on supplementary feed intake were analysed using the GLM procedures of SAS (2003). To normalise the data, square root transformation was performed on BCS. The linear model used for BCS, ADG and concentrations of nutritionally-related blood metabolites was:

$Y_{ijk} = \mu + D_i + W_j + DW_{ij} + \mathring{U}_{ijk}$

Where

Y_{ijk}= BCS, ADG and concentrations of TP, albumin, urea, creatinine, glucose, cholesterol, NEFA, SIP, Ca, Mg and Fe;

μ = overall mean;

D_i = effect of diet (i= AK, SF, CN);

W_j = effect of week of sampling (j= 0, 2, 4, 6, 8);

DW_{ij} = interaction of the i^{th} level of diet and j^{th} week of sampling and;

$\mathring{U}_{ijk}$ = residual error.

To determine the effect of diet on slaughter weight, warm carcass weight, cold carcass weight, dressing percentage and eye muscle area, the initial weight for each steer was incorporated in the linear model as a covariate. The effect of diet on total variable costs, gross income and gross margin was also analysed using GLM procedure of SAS (2003). Pair-wise comparisons of the least square means were performed using the PDIFF procedure of SAS (2003). Chi-square test was used to determine the association between diet and fatness and, diet and conformation classes.

7.3 Results

7.3.1 Supplementary feed intake, average daily gains and body condition scores

Steers supplemented with SF diet consumed all their daily feed allocation. Generally, consumption of the AK diet increased ($P < 0.05$) from week 1 to 4 and remained constant until week 8 (Figure 7.2). Steers that were given SF diet had the highest ADG (380.0 ± 33.09 g/day) followed by those that received the AK diet (305.4 ± 33.09) while those on CN diet (270.3 ± 33.09) had the lowest ADG. Week of sampling had no effect on ADG. Body condition scores increased ($P < 0.05$) from week 0 to 8 in steers that were given supplementary diets (Figure 7.3) but not in the control group.

7.3.2 Nutritionally-related blood metabolites

Steers that were given AK and SF diets had higher ($P < 0.05$) serum TP concentrations than those that those on the control group (Table 7.4). Total protein concentrations were not significantly influenced by time of sampling. Albumin concentrations were higher in steers that were supplemented with AK and SF diets and increased ($P < 0.05$) from week 0 to 4 and then declined to week 6 after which it remained constant (Figure 7.4A). Steers that received SF diet had the highest urea concentration (Table 7.4) and it increased ($P < 0.05$) from week 0 to 2, remained constant to week 4 after which it increased to week 8 (Figure 7.4B). Creatinine concentrations were highest ($P < 0.05$) in steers that received CN control diet and it rose ($P < 0.05$) from week 0 to 8 (Figure 3C).

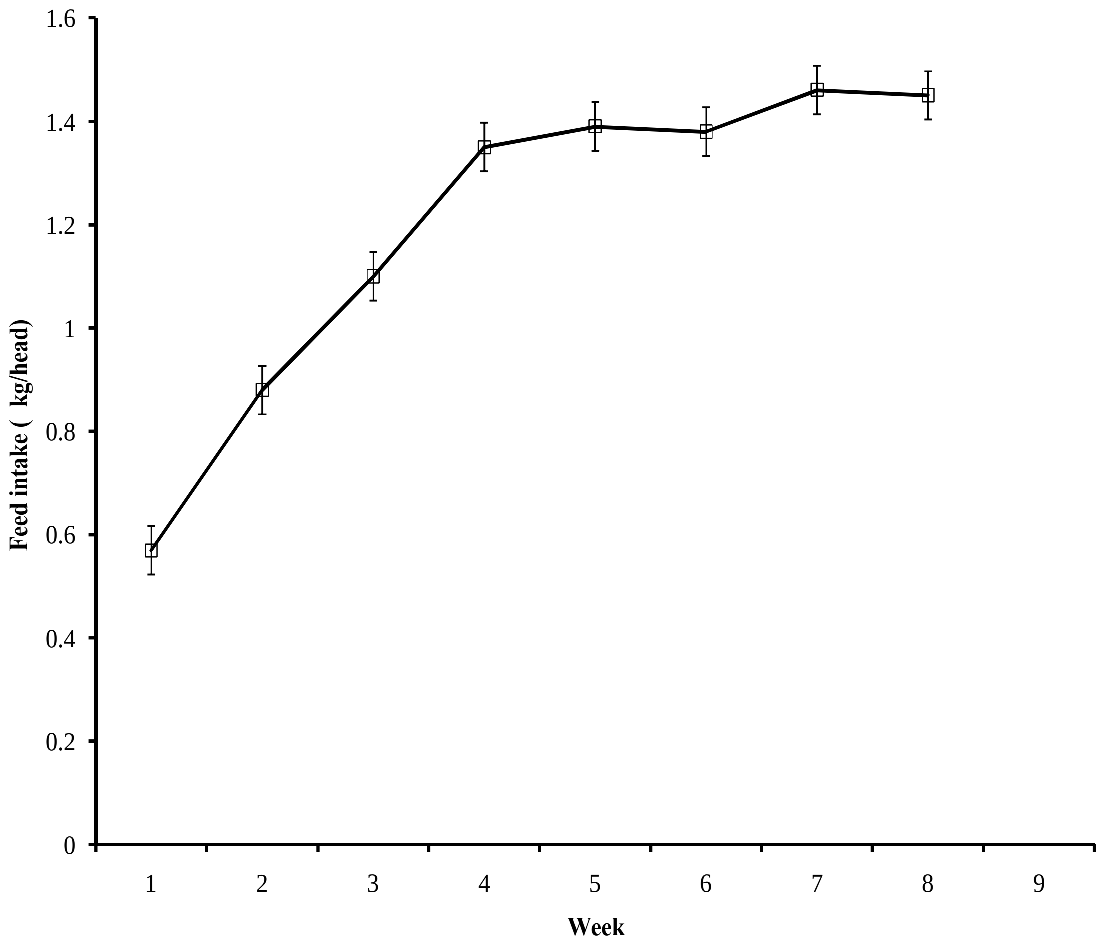

Figure 7.2: Average daily intake of steers fed *A. karroo* leaf meal per week

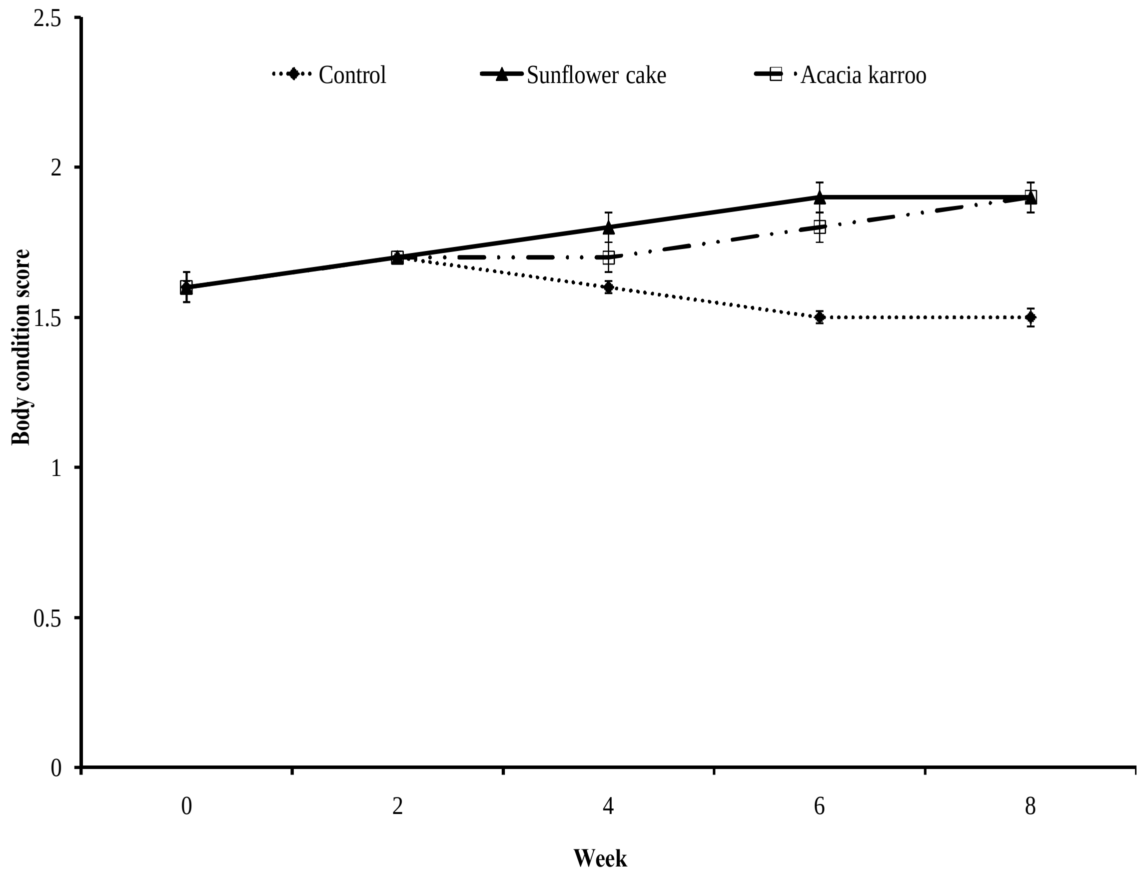

Figure 7.3: Least square means ± (standard error) of body condition scores of Nguni steers based on diet and week of sampling

Steers that were given the CN diet had the highest glucose and cholesterol concentrations compared to those on AK and SF diets (Table 7.4). The NEFA concentrations were higher ($P < 0.05$) in steers that received supplements than those that received CN diet (Table 7.4). Week of sampling had no effect on the concentrations of glucose, cholesterol and NEFA. Steers that were given the AK diet had higher ($P < 0.05$) calcium concentrations than those that received SF and CN diets (Table 7.4). Serum inorganic phosphorus concentration was higher in steers that were given supplementary diets than those that received the CN diet (Figure 7.4C). Serum magnesium and iron concentrations were higher ($P < 0.05$) in steers that received supplementary diets than those that received the CN diet (Table 7.4). Week of sampling did not influence calcium, magnesium and iron concentrations.

7.3.3 Carcass characteristics

Highest slaughter weights, warm and cold carcass weights were recorded in steers supplemented with sunflower cake followed by those supplemented with *A. karroo* leaf meal (Table 7.5). There were no diet effects on dressing percentage. Steers that were given the AK and SF diets had larger ($P < 0.05$) eye muscle areas than those on the CN diet (Table 7.5). Nearly, 75 % of carcasses from steers supplemented with AK, 70 % of those from steers supplemented with SF and 60 % of those from CN steers were classified as 2, 3 and 1, respectively, based on fatness. On a conformation scale of 1 to 5, all the carcasses were classified as 3 (medium).

Table 7.4: Least square means ± (standard error) of nutritionally-related blood metabolites in Nguni steers given three different diets

	Diet		
Metabolite	**Control**	***A. karroo***	**Sunflower cake**
Total protein (g/l)	77.0 ± 0.97^{a}	82.4 ± 1.02^{b}	83.5 ± 1.00^{b}
Albumin (g/l)	29.1 ± 0.31^{a}	32.9 ± 0.29^{b}	33.2 ± 0.29^{b}
Urea (mmol/l)	1.7 ± 0.14^{a}	2.0 ± 0.13^{b}	2.8 ± 0.14^{c}
Glucose (mmol)	4.2 ± 0.11^{b}	3.7 ± 0.11^{a}	3.8 ± 0.11^{a}
Cholesterol (mmol)	2.8 ± 0.07^{c}	2.6 ± 0.06^{b}	2.5 ± 0.06^{a}
NEFA (mmol)	0.25 ± 0.021^{a}	0.31 ± 0.019^{b}	0.32 ± 0.021^{b}
Calcium (mmol)	2.2 ± 0.04^{a}	2.4 ± 0.04^{b}	2.2 ± 0.04^{a}
Phosphorus (mmol)	2.1 ± 0.04^{a}	2.3 ± 0.03^{b}	2.3 ± 0.03^{b}
Magnesium (mmol)	0.81 ± 0.011^{a}	0.87 ± 0.011^{b}	0.88 ± 0.011^{b}
Iron (mmol)	17.9 ± 0.43^{a}	18.9 ± 0.40^{b}	19.3 ± 0.41^{b}

[a,b,c] Values with similar superscripts within a row are not significantly different *(P < 0.05)*.

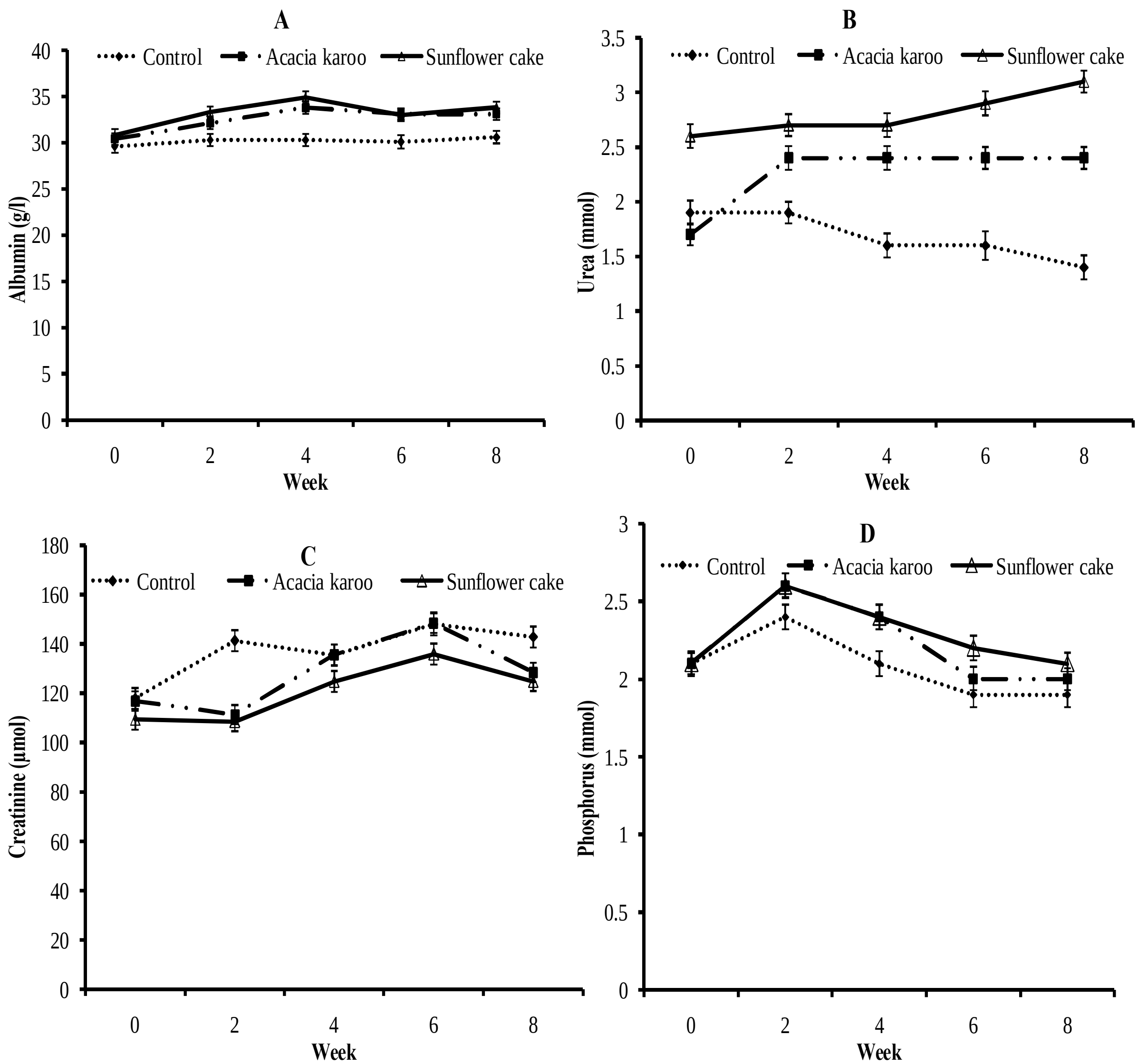

Figure 7.4: Least square means ± (standard error) of albumin (A), urea (B), creatinine (C) and phosphorus (D) concentrations in Nguni steers based on diet and time of sampling

Table 7.5: Least square means ± (standard error) of slaughter weight and carcass characteristics of Nguni steers given three different diets

Parameter	Diet			
	Control	*A. karroo*	Sunflower cake	s.e.m[1]
Slaughter weight (kg)	259.4[a]	280.1[b]	294.5[c]	3.65
Warm carcass weight (kg)	131.4[a]	153.2[b]	170.1[c]	3.94
Dressing (%)	51	52	53	11
Cold carcass weight (kg)	129.5[a]	149.3 [b]	165.8[c]	4.02
Eye muscle area (cm^2)	60.8[a]	67.4[b]	67.8[b]	2.82

[a,b,c] Values with similar superscripts in a row are not different *(P< 0.05)*.

7.3.4 Economic analyses

Steers supplemented with AK diet had lower (*$P < 0.05$*) total variable costs than those that received the SF diet (Table 7.6). Gross income of steers supplemented with SF diet was the highest followed by those on the AK diet (*$P < 0.05$*). There was no difference (*$P > 0.05$*) in gross margin between the steers supplemented with AK and SF diets (Table 7.6).

7.4 Discussion

The low intake observed for the AK diet in the first three weeks of the trial, despite the 21-day adaptation period and addition of natural pasture hay concurs with Kaitho *et al.* (1997), who reported that the palatability of *Acacia* species leaf meal is relatively low. The low intake of *Acacia* species could be ascribed to the presence of condensed tannins. The condensed tannin concentration observed for *A. karroo* (74 g/kg DM) was above 60 g/kg DM, which confer bitterness and astringency resulting in low palatability and depression of voluntary feed intake (Makkar, 2003; Rubanza *et al.,* 2005). Similar to findings of the present study, Kaitho *et al.* (1997) and Maasdorp *et al.* (1999) reported that intake of *Acacia* species improves over-time as the animals adapt to the diet. When feeding *A. karroo* leaf meal, it is, therefore, important to prolong the adaptation phase to about 30-35 days or mix the leaf meal with more palatable feeds.

Table 7.6: Least square means ± (standard error) of variable costs, gross income and gross margin/steer by dietary treatments

	Diet			
Parameter	Control	*Acacia karroo*	Sunflower cake	
Labour cost (*$)	0.00	4.95[A]	0.00	
Transport cost ($)	0.00	0.00	7.20	
Fuel cost ($)	0.00	0.57	0.00	
Feed costs ($)	0.00	0.00	11.72	
				s.e.
Total variable costs ($)	0.00[c]	5.52[b]	18.92[a]	2.55
Gross income ($)	44.60[c]	54.90[b]	68.40[a]	1.25
Gross margin ($)	44.60[b]	49.38[a]	49.48[a]	0.95

[*]$: US dollar.

[A]Labour for harvesting *A. karroo* was calculated as follows: 1.5 kg leaf meal/steer/day × 60 days × $0.55/kg of leaf meal. N.B. the cost of harvesting a kilogram of *A. karroo* leaf meal was $0.55.

[a,b,c] Values with similar superscripts in a row are not different ($P < 0.05$).

High BCS and ADG observed in supplemented steers could also be due to high dietary protein and energy intake. It has been reported that increment in the concentration of protein increases feed intake, digestibility and, consequently, growth rate (Rubanza *et al.,* 2005; Juniper *et al.,* 2007). Although the ADG values (270.3 ± 33.09 g/day) of Nguni steers on supplementary diets were lower than those reported by Thénard *et al.* (2006), du Plessis and Hoffman (2007) and Muchenje *et al.* (2008a) on natural pasture. This could be attributed to differences in feed quality and age of animals.

The higher ADG and BSC of steers on SF diet than those given AK diet could be partly explained by high fat content in sunflower diets, which boosts protein nutrition by coating proteins, thus preventing microbial degradation, thereby increasing post-ruminal protein supplies (Ngongoni *et al.,* 2007). In addition, the fat component of the SF diet, while not digested in the rumen, might provide increased energy for animal growth (Ngongoni *et al.,* 2007).

The finding that steers on AK diet had higher slaughter weights and BCS than those on CN diet may be partially attributed to higher concentration of CP in AK as well as higher *in vitro* digestibility of AK. Previous studies have shown that preference and digestibility of tanniniferous plants by cattle (Rubanza *et al.,* 2005) is regulated by the potential digestible fraction of plants (CP and NDF) rather than by their content of polyphenolic compounds. The higher ADG observed for steers supplemented with *A. karroo* than those that relied entirely on natural pasture could also be partly ascribed to high tannin concentrations which could have increased live-weight gain by improving nutrient utilisation efficiency (Makkar, 2003; Rubanza *et al.,* 2005). Condensed tannins form complex with proteins and protect them from ruminal degradation, hence may increase their availability in the lower intestines

(Bhatta *et al.,* 2005). The effects of tannins on feed digestibility and utilisation depend on tannin structure and chemical nature and the nature of tannin anti-nutritive activity (Makkar, 2003). The observed concentrations of tannins (74 g/kg DM) could, therefore, be beneficial by promoting flow of protected but digestible protein to the lower intestines (Rubanza *et al.,* 2005), thereby increasing body weight and condition gains (Gleghorn *et al.,* 2004). The tannin structure, chemical nature and the nature of anti-nutritive activity of *Acacia karroo* has not been established, therefore merits investigation.

The result that TP and albumin concentrations in steers given supplementary diets were higher than those on CN diet could be attributed to higher dietary CP concentrations (Ndlovu *et al.,* 2009). Total protein and albumin concentrations for steers on the CN diet were within the normal interval (Farver, 1997) which might signify that Nguni cattle are adapted to low protein diets (Ndlovu *et al.,* 2009).

The higher urea concentrations observed in steers that received supplementary diets than those that did not could be a consequence of high dietary CP intake (Grunwaldt *et al.,* 2005). Urea concentrations for all the treatment diets were, however, below the upper limit for beef cattle (Farver, 1997). Blood urea concentration can be inversely related to the efficiency of nitrogen utilisation and its reduction is generally associated with an increase in the efficiency of nitrogen utilisation (Otto *et al.,* 2000).

Creatinine concentrations in steers that received the CN diet were above the standard concentrations (Ndlovu *et al.,* 2009). Since the steers on the CN diet were not given additional feed between 0800 h and 1000 h, the elevated concentrations of creatinine could be ascribed to the increased muscle mass activity resulting from walking long distances in search of food (Otto *et al.,* 2000).

The higher glucose and cholesterol, but lower NEFA concentrations in steers on the AK and SF diets compared to those on the CN diet could be attributed to differences in growth rates. Steers on the supplementary diets had higher ADG, suggesting that they were likely to have higher energy demands for growth. The increased growth rate would, therefore, lead to a reduction in blood glucose and cholesterol and, consequently, increased NEFA concentrations (Grunwaldt *et al.,* 2005). The low NEFA concentration observed in steers on the CN diet could imply that these animals were not straving and could, therefore, not mobilise body fat reserves to meet their energy demands. The high cholesterol concentrations reported for steers on the CN diet could possibly be explained by high glucose concentrations relative to reference values. High glucose levels promote the secretion of insulin which, in turn, decreases cyclic adenosine monophosphate (cAMP) concentrations, thus stimulating cholesterol synthesis (Farver, 1997).

Overall, high mineral concentrations recorded for steers on supplementary diets could be attributed to high dietary intake of minerals (Grunwaldt *et al.,* 2005). The observation that the minerals investigated were consistent with standard values (Farver, 1997; Grunwaldt *et al.,* 2005) could indicate little, if any, negative effects of condensed tannin in *A. karroo* on mineral absorption. Anti-nutritional effects of tannins are exerted through a reduction of feed protein digestion, a decline in mineral absorption and a depression of proteolytic enzyme activities (Bhatta *et al.,* 2005).

The observation that week of sampling had no effect on ADG and the fact that differences in BCS of steers on supplementary diets were observed after 4 weeks yet concentration differences for most blood metabolites were noticed earlier (after 2 weeks) confirms earlier assertions by Agenas *et al.* (2006) and Ndlovu *et al.* (2009). Body weight and condition quantifiable changes on a subjective five-point scale are observed too slowly to be used as an index for assessing short-term changes in diets or feeding management of the herd (Agenas *et al.,* 2006). On the other hand, blood metabolites concentrations give an immediate indication of nutritional and health status of cattle at that point in time (Agenas *et al.,* 2006; Ndlovu *et al.,* 2009). Utilisation of blood metabolites is, therefore recommended when assessing the effects of a given diet on cattle performance in the short to medium-term.

The finding that dietary protein supplementation increased slaughter and carcass weights of steers agree with literature (Juniper *et al.,* 2007; Jerez-Timaure and Huerta-Leidenz, 2009). Since steers that were given supplementary diets had high ADGs they were expected to have greater muscle deposition and, consequently high slaughter weights and heavy carcasses (Gleghorn *et al.,* 2004; Rubanza *et al.,* 2005; Jerez-Timaure and Huerta-Leidenz, 2009). Moreover, Apple *et al.* (1999) reported that BCS and body weight of cattle at the time of slaughter influence carcass quality yields. The observed slaughter and carcass weights for Nguni steers that entirely relied on rangeland were similar to those reported earlier (du Plessis and Hoffman, 2007; Muchenje *et al.,* 2008a).

The observed dressing percentages fall within intervals for Nguni cattle on rangelands (du Plessis and Hoffman, 2007; Muchenje *et al.,* 2008a). The lack of differences across treatments could be attributed to lack of gut fill effect (du Plessis and Hoffman, 2007). Since treatment groups had equal access to natural pasture they were likely to have the similar dry matter intake and consequently, similar guts fill. The large muscle area values observed in steers on supplementary diets further confirms earlier assertions that muscle development depends on protein availability and utilisation (Choi *et al.,* 2006). The eye muscle values for steers that depended entirely on natural pastures were higher than those obtained by Muchenje *et al.* (2008a). This could be due to differences in age at slaughter and the quantity and quality of the available feeds. Increased age at slaughter (maturity) is associated with increased eye muscle area (du Plessis and Hoffman, 2007).

The observation that steers supplemented with tannin-rich browse trees had leaner carcasses than those that received SF diet agrees with Choi *et al.* (2006). Information on the effect of feeding tanniniferous browse trees on meat quality is very scarce. Meat quality such as nutritional, composition, flavour, tenderness and colour determines consumer acceptance and purchasing decisions (Muchenje *et al.,* 2008b). The finding that most carcasses were medium-sized was consistent with Muchenje *et al.* (2008b) for Nguni cattle on natural pasture. Albeit being an indicator of potential meat yield, carcass conformation is not considered in carcass classification in South Africa (Muchenje *et al.,* 2008b).

The observation that gross margin for steers that on the AK diet was higher than those that received CN diet but similar to steers given the SF diet could mean that *A. karroo* is a relatively cheaper protein supplement. This could be attributed to its lower total variable costs compared to SF diet. In support of the current findings, Devendra and Sevilla (2002) and Ngongoni *et al.* (2007) reported that the cost of feed governs the choice of feeds and the quantity of concentrates that can be fed to livestock in a given environment. Utilisation of *A. karroo* leaf meal as a protein supplement could, therefore, be a profitable option for communal cattle producers who usually have insufficient capital to purchase supplements.

7.5 Conclusions

Acacia karroo improves the nutritional status, growth performance and carcass traits of Nguni steers reared on natural pasture. *Acacia karroo* could, therefore, be an economically viable alternative to commercial protein supplements for resource-poor beef producers in the semi-arid areas of Southern Africa. Although feeding *A. karroo* leaf meal improves carcass yield, consumer meat acceptance and purchasing decisions, depend on its quality attributes. Further studies should, therefore, evaluate the quality attributes of beef from Nguni steers supplemented with *A. karroo*.

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Chapter 8: Meat quality attributes of Nguni steers supplemented with *Acacia karroo* leaf meal

(Published in *Meat Science,* see Appendix 9)

Abstract

The objective of the study was to determine the meat quality of Nguni steers supplemented with *A. karroo* leaf meal. Thirty 19-month old steers were randomly assigned to *A. karroo* leaf meal (AK), sunflower cake (SF) and a control (CN) diet that consisted of natural pasture grazing. Steers on the AK and SF diets were each given an additional 150 g of protein per day for 60 days. The steers were slaughtered at 21 months and the *m. longissimus thoracis et lumborum* was sampled for meat quality measurements. Steers that received SF diet had lighter-coloured ($P < 0.05$) meat than those on AK and CN diets. The highest redness (17.3 ± 0.29) and colour saturation (18.8 ± 0.04) values were recorded in steers supplemented with AK compared to those that received SF and CN diets. Diet had no effect on meat yellowness, pH, drip loss, water holding capacity, sarcomere length, muscle bundle areas, myofibrillar fragment length, Warnerï Bratzler shear force and cholesterol values. Steers supplemented with AK (22.4 ± 0.08 %) and SF (22.5 ± 0.08 %) had higher ($P < 0.05$) meat protein content than those on the CN (20.2 ± 0.08 %) diet. Highest muscle fibre area (3472.6 ± 119.51 μm^2), fat content (1.2 ± 0.11 %) and cooking loss (25.2 ± 0.73 %) of meat aged for two days were recorded in steers given the SF diet compared to those on the AK and CN diets. It was concluded that supplementing Nguni cattle on natural pasture with *A. karroo* leaf meal could produce beef of comparable quality to natural pasture alone but with a fresher appearance and higher protein content.

Keywords: Colour, fat, muscle fibre area, natural pasture, protein, tenderness.

8.1 Introduction

Meat is an important source of nutrients but most people consume it because they enjoy the flavour and texture that it provides (Muchenje *et al.,* 2009a). Utilisation of appropriate cattle genotypes with proper dietary regime could produce superior meat quality that meets both producers and customersô expectations (FAO, 2007). In South Africa, for example, the Nguni breed has a small frame (200-400 kg) but it is hardy and adapted to subtropical conditions (Ndlovu *et al.,* 2008; Strydom, 2008; Marufu *et al.,* 2009). Although the growth performance and carcass yield of Nguni cattle is low under both rangeland (Muchenje *et al.,* 2008a) and feedlot conditions (Strydom *et al.,* 2000a), there are small or no differences in meat quality when compared to exotic breeds (Strydom *et al.,* 2000b; Muchenje *et al.,* 2008b). Random tests for tenderness-related gene markers confirm the presence of a high frequency of favourable genes in the Nguni breed that support its meat quality potential (Strydom *et al.,* 2008). The opportunity for producing nutritious and highly acceptable beef products from Nguni cattle is high due to their rangeland-based production systems (Muchenje *et al.,* 2009b).

Currently, most rural development initiatives in South Africa are focused on the improvement of Nguni cattle production and the introduction of communal producers into the mainstream commercial beef supply chain (Strydom, 2008). To improve viability and sustainability, beef production systems based on Nguni cattle should improve beef quality, particularly tenderness (Muchenje *et al.,* 2008b). One major constraint of rangeland-based finishing systems is the limited protein content of rangelands (less than 50 g/kg DM) in the dry season, which results in low growth rates (du Plessis and Hoffman, 2004; Muchenje *et al.,* 2008a). The decline in growth rates during the dry season delays attainment of slaughter body weight and could reduce the supply of good quality beef (du Plessis and Hoffman, 2004).

Supplementing Nguni cattle on natural pasture with locally available protein sources could be a low-cost way of increasing supply of superior quality beef to consumers located in marginalised agro-ecological regions. In Southern Africa, one such potential protein supplementary feed is leaf meal from the indigenous *Acacia* tree species, particularly *A. karroo*, which is rich in protein and minerals, widespread and found in relatively large quantities throughout the year (Mokoboki *et al.,* 2005).

Even though some browse legumes including the *Acacia* species contain spines which inhibit feed consumption and phenolic compounds which reduce intake, degradability and nutrient availability (Mokoboki *et al.,* 2005), they have been reported to improve meat quality in small ruminants (Priolo and Ben Salem, 2004; Choi *et al.,* 2006). The effects of spines and phenolic compounds can be easily alleviated by use of protective clothing during harvesting and sun-drying, respectively (Mokoboki *et al.,* 2005). In Chapter 7, it was established that *Acacia karroo* improves nutritional status, growth performance, and carcass traits of Nguni steers reared on natural pasture. The effect of *A. karroo* on meat quality, which influences its purchase and acceptance by consumers has, however, not been determined. The objective of the current study was, therefore, to determine the meat quality of Nguni steers supplemented with *A. karroo* leaf meal. It was hypothesised that beef from Nguni cattle supplemented with *A. karroo* leaf meal and those that entirely rely on natural pasture have similar meat quality characteristics.

8.2 Materials and Methods

8.2.1 Animal and feeding management

The study was conducted at Fort Hare farm in Alice in the Eastern Cape province of South Africa. The detailed description of the study site was given in section 7.2.2. Details of treatments and feeding and animal management were described in Sections 7.2.3 and 7.2.4, respectively. Rangeland biomass and nutritional analyses of the feed constituents (rangeland, hay, *A. karroo*, and sunflower cake) were described in Sections 7.2.5 and 7.2.6, respectively. Feed intake was calculated as stated in Section 7.2.4. Data on ADG and BCS were collected as described in Section 7.2.7. Slaughter procedures and carcass measurements were described in Section 7.2.9.

8.2.2 Meat sampling

Carcasses were electrically stimulated, using a voltage of 300 V, a frequency of 50 Hz, a current of 5A in 4045 s at a pulse rate of 12/s, to control the effect of rapid chilling on cold shortening of muscles. Carcasses were split, weighed and then chilled at 3 ± 3°C before being processed a day after slaughter. The *m. longissimus thoracis et lumborum* (LTL) of the left side was sampled a day after slaughter from the 10^{th} rib in the direction of the rump. The amounts for meat quality analyses were sampled in the following order:

a) 100 mm thick for 2 day-aged Warner-Bratzler test,

b) 100 mm thick for 21 days-aged Warner-Bratzler test,

c) a 20 mm steak for myofibrillar length and muscle fibre areas on 2 days-aged samples,

d) a 20 mm steak for myofibrillar length and muscle fibre areas on 21 days-aged samples,

e) a 10 mm steak for sarcomere length,

f) a 15 mm steak for drip loss in duplicate,

g) a 20 mm steak for Commission International De Iô Eclairage (CIE) Lab colour measurement.

8.2.5 Meat quality measurements

8.2.5.1 pH, drip loss and water holding capacity measurement

The pH-value of the LTL was measured using a meat pH meter at 24 hours after slaughter. For drip loss measurement, two blocks of meat measuring 15 x 15 x 30 mm were sliced from the LTL steak so that the fibres ran across the longer axis of the sample. The samples were suspended on metal hooks in plastic sample bottles so that the sample did not touch the side of the bottle. The suspended samples were stored in a cold room at 2^{o}C for 72 h. Drip loss was calculated as the difference between the initial and final weight of the sample, expressed as a percentage.

Water holding capacity (WHC) of the meat was measured as the amount of water expressed from a minced meat sample (1 g) held under pressure (60 kg pressure) using the filter-paper press method developed by Grau and Hamm (1957). Water holding capacity was calculated using the equation: WHC = 100% - [(outer circle area ï inner circle area)/outer circle area] x 100 %.

8.2.5.2 Sarcomere length determination

To determine sarcomere length, meat portions of about 20 g were cut from the core of the frozen samples and prepared according to the method of Hegarty and Naude (1970) as modified by Dreyer *et al.* (1979). The frozen samples were homogenised using distilled water (Dreyer *et al.,* 1979). A few droplets of the homogenate were mounted on a slide, covered with a cover slip and immediately viewed under a microscope attached to a video image analyser (VIA; Kontron Germany) at a magnification of 100x. One hundred randomly selected fibres were selected. The length of five consecutive sarcomeres was recorded per selected fibre, to improve the accuracy of the measurement. The recorded value was then divided by five and the final sarcomere length was the average length of 100 measurements.

8.2.5.3 Determination of myofibrillar fragment length and fibre cross-sectional areas

Two samples (50 g each) of the LTL were taken for myofibril fragment length (MFL) measurement as an indication of fragmentation due to proteolysis. The samples were vacuum-packed and aged for 2 and 21 days at 3 ± 3°C, respectively, for determination of myofibrillar length (MFL) according to the method of Culler *et al.* (1978) modified by Heinze and Bruggemann (1994). Myofibrillar length was determined by means of Video Image Analysis (Kontron, Germany). The methods involved the extraction of the myofibres in buffer solution at around 4^{o}C to arrest any further proteolysis. Droplets of the extracted MFL solution were mounted on a slide, covered and viewed at a magnification of 40x under a microscope attached to the VIA. The MFL was determined as the average length of the first 50 myofibrils that were longer than five sarcomeres. Fibre cross-sectional areas [muscle fibre areas (MFA) and muscle bundle areas (MBA)] of meat aged for 2 and 21 days were also determined by Video Image Analysis (Kontron, Germany).

8.2.5.4 Determination of meat colour

Muscle colour was measured with a Minoltameter (Model CR200, Minolta, Japan) on fresh unaged samples (2 days *post-mortem*). The Minoltameter was standardised against a white calibration tile that was wrapped in the same polythene cling film used for the meat samples. A 30 g portion of the LTL was cut and left to bloom for at least 30 minutes at chiller temperatures (3°C) before recording. The following CIE (1976) colour coordinates were measured: lightness (L*), redness (a*) and yellowness (b*) from three locations on the cut surface of individual steaks. Three replicate measurements, which avoided areas of connective tissue and intramuscular fat, were taken per sample. Colour saturation were calculated as the square root of the sum of a^{*2} and b^{*2}.

8.2.5.5 Determination of chemical composition and cholesterol levels

A 50 g sample of the LTL was ground and freeze-dried for the determination of protein, fat, moisture and ash contents (AOAC, 2003). The extraction and quantification of cholesterol were carried out by the method of Al-Hasani *et al.* (1993), with modifications (Rowe *et al.,* 1999). Meat samples weighing 5 to 10 g were placed in a 250 ml flat-bottom flask and dispersed in an ethanol-methanol-isopropanol (90:5:5 v/v/v) solution in an amount equivalent to 4 ml/g of sample. A 1 ml aliquot of 60 % potassium hydroxide in water was then added. The flask containing this mixture was connected to a water-cooled condenser and refluxed for 1 hour. After cooling to room temperature, 100 ml of n-hexane was added and the mixture was stirred for 10 min and finally 25 ml of deionised water was added and the mixture was stirred for a further 15 min. Layers were separated and the n-hexane layer was collected in a flask. An aliquot of 25 ml of the n-hexane layer was evaporated to dryness under nitrogen. The residue was dissolved in 2 ml of n-hexane containing 0.2 mg of 5 Ŭ-cholestane internal standard/ml and transferred to a vial. Approximately 3 εl were injected into a gas chromatograph. A Shimadzu 14A instrument GC (Japan) fitted with a flame ionization detector (FID, 300°C) and a split/splitless injector (260°C, split 1: 150) was used for the analysis of cholesterol. Separation was carried out in a fused silica capillary column at 300°C (25 mm x 0.25 mm), coated with SE-30 (0.25 εm phase thickness) (Quadrex, USA). The carrier gas used was hydrogen (1.5 ml/min) and the make-up gas was nitrogen (25 ml/min). Cholesterol identification was made by comparing the relative retention time of peaks from samples with standards from SIGMA (USA). The internal standard used was 5Ŭ-cholestane. For peak integration a CG 300 computing integrator (GC Instruments, Brazil) was used.

8.2.5.6 Determination of Warner-Bratzler shear force

The sampled LTL to be used for Warner-Bratzler shear force (WBSF) resistance were vacuum packed and either frozen directly (for those aged for 2 days) or aged at 2°C for 21 days and frozen. Two days before preparation, three steaks measuring 30 mm thick were cut with a band saw, vacuum packed and thawed over 24 hours at 0 to 4°C. The steaks were prepared according to an oven-broiling method using direct radiant heat [American Meat Science Association (ASMA), 1995]. An electric oven was set on ñbroilò 10 min prior to preparation at 260°C. Steaks were placed on an oven pan on a rack to allow meat juices to drain during cooking and placed in the pre-heated oven 90 mm below the heat source. The steaks were cooked to an internal temperature of 35°C recorded by direct probe, then turned and finished to 70°C. Raw and cooked weights were recorded.

Following cooking, the steaks were cooled down at room temperature for five hours before shear force determination. Eight sub-samples measuring 2.5 mm core diameter were cored parallel to the grain of the meat, and sheared perpendicular to the fibre direction using a Warner-Bratzler shear device mounted on an Universal Instron apparatus (cross head speed = 400 mm/minute, one shear in the centre of each core). The mean maximum load recorded for the eight cores represented the average of the peak force in kilograms (kg) of each sample.

8.2.5.7 Determination of cooking loss

Percentage cooking loss was calculated as [(weight of steak after thawing ï weight of cooked steak)/weight of raw steak after thawing] x 100. It was made up of evaporation and dripping loss during cooking.

8.2.6. Statistical analyses

The effect of diet on meat quality attributes were analysed using GLM procedure of SAS (2003). The linear model was:

$Y_{ij} = \mu + D_i +$ Ů$_{ij}$

Where Y_{ijk} = meat pH, drip loss, WHC, colour, sarcomere length, MFA, MBA, MFL, WBSF, cooking loss and moisture, protein, fat, ash and cholesterol contents;

μ = Overall mean;

D_i = effect of diet (i= AK, SF, CN) and;

Ů$_{ij}$ = residual error

Pair-wise comparisons of the least square means were performed using the PDIFF procedure of SAS (2003).

8.3. Results

8.3.1 Meat pH, drip loss, water holding capacity and colour

Meat pH, drip loss and WHC of meat aged for 21 days were not ($P > 0.05$) influenced by diet (Table 8.1). Steers that received the SF diet had lighter-coloured (L*) ($P < 0.05$) meat than those on the AK and CN diets (Table 8.1). The highest redness and colour saturation values were recorded in steers that were given the AK diet compared to those that received SF and CN diets. Diet had no effect on meat yellowness (b*) (Table 8.1).

8.3.2 Meat tenderness attributes

Muscle fibre area (MFA) was higher ($P < 0.05$) in steers that were supplemented with SF diet than those that were supplemented with the AK and CN diets (Table 8.1). Diet had no effect on sarcomere length, MBA, MFL of meat aged for 2 and 21 days and WBSF of meat aged for 2 and 21 days (Table 8.1).

Table 8.1: Meat pH, drip loss, water holding capacity, colour and tenderness attributes of Nguni steers given three supplementary diets

	Diet			
Parameter	Control	*Acacia karroo*	Sunflower cake	Standard error
pH	5.6	5.6	5.5	0.04
Drip loss (%)	1.7	1.7	1.9	0.17
Water holding capacity (%)	0.37	0.37	0.39	0.14
Lightness (L^*)	36.6^a	36.4^a	38.2^b	0.52
Redness (a^*)	15.7^a	17.3^b	15.8^a	0.29
Yellowness (b^*)	7.3	7.5	7.4	0.28
Colour saturation	17.3^a	18.8^b	17.4^a	0.04
Sarcomere length (µm)	1.78	1.78	1.77	0.044
MBA (mm^2)	0.68	0.75	0.79	0.067
MFA (μm^2)	2981.1^a	2835.8^a	3472.6^b	119.51
MFL2 (µm)	33.4	31.5	31.2	1.27
MFL21 (µm)	21.2	19.9	21.5	1.17
WBSF2 (kg)	5.8	6.2	6.3	0.46
WBSF21 (kg)	3.8	4.4	4.2	0.30

^{a,b,c} Least square means in the same row with different superscripts are different at $P < 0.05$.

MFL2: Myofibrillar fragment length for meat aged for 2 days;

MFL21: Myofibrillar fragment length for meat aged for 21 days;

WBSF2: Warner Bratzler value for meat aged for 2 days;

WBSF21: Warner Bratzler value for meat aged for 21 days

MBA: Muscle bundle area

MFA: Muscle fibre area

8.3.3 Meat chemical composition and cooking properties

Steers supplemented with the AK and SF diets had higher ($P < 0.05$) meat protein content than those on the CN diet (Table 8.2). Diet had no effect on moisture and ash contents. The highest fat content was recorded in steers that received SF diet (Table 8.2) compared to those on the AK and CN diets. Cholesterol levels were not affected ($P > 0.05$) by diet. Cooking loss of meat aged for 21 days was not influenced by diet. Highest cooking losses of meat aged for 2 days were obtained in steers supplemented with SF diet compared to those on AK and CN diets (Table 8.1).

8.4 Discussion

Few, if any, studies have investigated the effects of feeding protein-rich tanniniferous indigenous browse legumes on meat quality of cattle raised on natural pasture. The high redness (a*) and colour saturation values reported for steers supplemented with the AK diet could be attributed to high dietary iron consumed by steers on the AK diet in addition to what they obtained from the natural pasture. High iron levels could increase haemoglobin and myoglobin concentrations in meat of grazing animals (Priolo *et al.,* 2001). Another possible explanation could that since the AK diet was rich in phenolics that are antioxidant nature, they may have slowed down colour deterioration. Changes in a* (redness) values over a period of time describe meat colour deterioration from red to brown, and reflect the myoglobin concentration and its redox state in meat (Mancini and Hunt, 2005). Meat iron content was, however, not assessed in the current study and warrants investigation. Consumers associate a red colour with fresh meat and brown colour with stale or spoiled meat (Priolo *et al.,* 2001). Feeding *A. karroo* could, therefore, improve meat freshness and, subsequently consumer acceptance.

Table 8.1: Chemical composition and cooking properties of beef from Nguni steers given three supplementary diets

	Diet			
Parameter	Control	*Acacia karroo*	Sunflower cake	Standard error
Cooking loss 2 (%)	22.5^{a}	22.7^{a}	25.2^{b}	0.73
Cooking loss 21 (%)	22.9	23.7	22.7	0.69
Moisture (%)	76.4	76.1	76.2	0.32
Ash (%)	1.05	1.06	1.06	0.013
Protein (%)	20.2^{a}	22.4^{b}	22.5^{b}	0.08
Fat (%)	0.87^{a}	0.88^{a}	1.2^{b}	0.11
Cholesterol (mg/100g)	35.0	36.3	34.5	1.35

^{a,b,c} Least square means in the same row with different superscripts are different at $P < 0.05$.

The low L* values in the steers supplemented with CN and AK diets compared to those fed on SF diet could probably be due to the observed differences in meat fat content between these treatments (Priolo *et al.,* 2001; Baublits *et al.,* 2004). Similarly, Bennett *et al.* (1995) and Muir *et al.* (1998) reported that animals fed on concentrates had lighter muscle colour and related it to an increase in intramuscular fat and marbling. Baublits *et al.* (2004) reported that higher levels of intramuscular fat increases meat brightness. In most beef markets, excessive darkness is undesirable and may incite consumer purchase resistance (Priolo *et al.,* 2001). Generally, it is important to sensitise consumers on meat quality attributes, such as colour, to assist them in making informed purchasing decisions.

Since all the steers had access to grass, the observed lack of dietary effect on b* values was expected. Yellowness depends on the degree of carotenoid pigmentation prior to the initiation of finishing, the complement of ingredients in the diet offered, the duration of concentrate feeding and carotenoid content of the forage fed (Muir *et al.,* 1998). Yellowness is positively associated with traditional, grass-based beef and is perceived to be a positive quality criterion which is more ñecologically favourableò and can have a positive influence on consumer purchase decisions (Muir *et al.,* 1998).

The similarity in the sarcomere length across the three treatment diets agrees with literature (Vestergaard *et al.,* 2000). This was expected since all carcasses were effectively stimulated. Sarcomere length is used to determine the effectiveness of electrical stimulation as a way of preventing cold-shortening (Strydom *et al.,* 2005). Cold shortens sarcomere length and consequently, the meat becomes tough (Stolowsk *et al.,* 2006). Electrical stimulation, therefore improves meat tenderness by reducing the likelihood of myofibrillar contraction and cold shortening (Strydom *et al.,* 2005). Meat tenderness improves as the sarcomere length increases, thus it is used as an indicator of meat tenderness (Stolowsk *et al.,* 2006).

The higher MFA observed for steers on the SF diet than those on AK diets could be attributed to differences in growth rates. Cattle which grow more rapidly before slaughter have increased rates of protein turnover, resulting in higher concentrations of proteolytic enzymes in the carcass tissues at slaughter which, in turn, increase MFA and myofibril fragmentation (Strydom *et al.,* 2000b). The differences in ADG across diets have, however, not been high enough to elicit significant changes in MFL of meat aged for 2 and 21 days. The differences in MFA could be partly due to the observed differences protein and fat content across the dietary treatments. The effects of fibre size on meat quality may be, in part, due to indirect effects of muscle fibre type on meat quality through differences in associated muscle components, such as sarcoplasmic proteins, intramuscular fat, muscle enzymes and connective tissue (Mills *et al.,* 1992; Monsón *et al.,* 2005).

The observed lack of protein supplementation effect on muscle bundle area agrees with earlier assertions by Dannenberger *et al.* (2006), but contradicts previous reports (Vestergaard *et al.,* 2000). Different numbers of muscle fibres are surrounded by connective tissue to form bundles (Dannenberger *et al.,* 2006). Muscle fibre bundles are macroscopically visible as meat fibres or meat grain. Consumers prefer fine-grained meat, suggesting that a large fibre bundle is related to less tender meat (Vestergaard *et al.,* 2000) and, therefore, deemed undesirable.

The observation that protein supplementation had no effect on MFL contradicts findings by Dannenberger *et al.* (2006). The MFL values of meat aged for 2 and 21 days were within the range reported by Muchenje *et al.* (2008b) and Strydom *et al.* (2008). Measurement of myofibril fragmentation is used to determine *post-mortem* proteolysis in beef (Vestergaard *et al.,* 2000). The differences in rates of fragmentation of myofibrillar proteins may, therefore, account for differences in the rate of *post-mortem* tenderization of meat. The increase in myofibrillar fragmentation, therefore, reflects an increase in meat tenderness (Strydom *et al.,* 2008).

The lack of dietary influence on WBSF of meat aged for 2 and 21 days concurs with previous reports (Bidner *et al.,* 1986; French *et al.,* 2001). On the contrary, Bennett *et al.* (1995) and Razminowicz *et al.* (2006) reported significantly higher WBSF values for pasture-finished than for concentrate supplemented or feedlot steers. The WBSF values of meat aged for 2 and 21 days, respectively reported for this study were higher than those reported for Nguni cattle on natural pasture (du Plessis and Hoffman, 2004; Muchenje *et al.,* 2008b). Warnerï Bratzler shear force values reported for beef vary considerably, depending on factors such as handling prior and at slaughter, age and weight at slaughter, feed regime, pH and fatness (French *et al.,* 2001). Tenderness, which can be measured as WBSF, is, arguably, the most important factor in determining beef quality and consumersô taste preferences (Strydom, 2008; Muchenje *et al.,* 2009a).

The observation that there were no differences in ultimate muscle pH across protein supplementary diets is consistent with previous reports (Morris *et al.,* 1997). Stress, prior to slaughter, is arguably one of the most important influences on pH and ultimate meat tenderness and taste (Muchenje *et al.,* 2009b; Orellana *et al.,* 2009). It may result from transportation, rough handling, high temperatures, or other factors that cause the animal to draw on its glycogen reserves before slaughter (Muchenje *et al.,* 2009a, b). In this study, penning, handling and transport facilities, breed, and pre-slaughter environmental conditions were uniform across the three dietary treatments.

The finding that WHC and drip loss were unaffected by the dietary treatments was expected since these traits are almost exclusively determined by genotype, handling of the animals at slaughter and post-slaughter treatment (Huff-Lonergan and Lonergan, 2005; Mushi *et al.,* 2009), factors which were kept constant in the present study. Water holding capacity and drip loss affect meat appearance and saleable weight, and subsequently, the purchase intent (Mushi *et al.,* 2009).

The higher fat content in meat of steers supplemented with the SF than those fed AK and CN could partly explain the higher cooking loss values of meat aged for 2 days. Correspondingly, Hedrick *et al.* (1983) reported higher cooking losses on concentrate supplemented beef when compared with forage-fed cattle. The alterations in meat size as a consequence of cooking negatively affect purchases (Muchenje *et al.,* 2009a).

The observations that protein supplementation had no effect on ash and moisture levels are similar to findings by French *et al.* (2001). In future, determining the effect of diet on the concentration of individual minerals in meat could be important. The observation that meat from steers fed on supplementary diets had higher protein content than those on CN diet can be ascribed to high dietary CP intake (Schor *et al.,* 2008). The steers on supplementary diets consumed about 150 g of protein (CP) more than those on CN diet. The higher fat content observed in meat of steers supplemented with the SF could be due to higher dietary fat intake. Similarly, Santos-Silva *et al.* (2002) evaluated the effects of dietary energy on nutritional quality of beef and found that concentrate supplemented and feedlot animals had higher fat content than pasture-fed ones.

The finding that diet had no substantial effect on meat cholesterol contradicts with Garcẽa and Casal (1992), who observed that beef coming from steers finished on pasture has lower fat and cholesterol concentrations than that from concentrate fed ones. The observed cholesterol values were consistent with earlier reports by Muchenje *et al.* (2008c) and Muchenje *et al.* (2009a) under natural pastures and were less than 300 mg, the recommended maximum daily intake (Jiménez-Colmenero *et al.,* 2001). Levels of cholesterol in foods have become important health issues for consumers since they are directly associated with obesity, hypercholesterolaemia and increased risk of cancer and heart diseases (Schor *et al.,* 2008; Muchenje *et al.,* 2008c; 2009a; Orellana *et al.,* 2009). Since long chain fatty acids have similar adverse effects on human health and modern consumers have increased demand for health foods (Muchenje *et al.,* 2009a), it is essential to determine fatty acids composition of beef from Nguni cattle supplemented with *A. karroo.*

8.5 Conclusions

The SF diet did not have any clear advantage over AK and CN diets as it had desired (high lightness, protein and fat values) and less favourable (high MFA and cooking loss values) effects. Supplementing Nguni cattle on natural pasture with *A. karroo* produced beef of comparable quality to natural pasture alone but with a fresher appearance and higher protein content. Since modern consumers are demanding palatable, safe and healthier meat, research on fatty acid profiles and sensory quality attributes of beef produced from Nguni cattle supplemented with *A. karroo* could be valuable.

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Chapter 9: Fatty acid composition and sensory attributes of beef from Nguni steers supplemented with *Acacia karroo* leaf meal

(Submitted to *Journal of Food Composition and Analysis*)

Abstract

The objective of the trial was to determine fatty acid composition and sensory attributes of beef from Nguni cattle supplemented with *A. karroo* leaf meal. Thirty 19-month old steers were randomly assigned to *A. karroo* leaf meal (AK), sunflower cake (SF) and the control with no supplement (CN) diets. The *m. longissimus thoracis et lumborum* muscle was sampled for fatty acid composition and sensory quality analyses. Highest Ǚ-linolenic acid, eicosopentaenoic acid, docosapentaenoic acid and polyunsaturated fatty acids to saturated fatty acids (PUFA/SFA) ratio, and lowest omega 6 (*n*-6) to omega 3 (*n*-3) ratio were recorded in beef from steers that received AK diet compared to those that received SF followed by those on the CN diet. Myristic acid and palmitic acid proportions were lower whilst *n*-3 PUFA proportions were higher ($P < 0.05$) in beef from steers that were given AK and CN diets than those on the SF diet. Diet had no effect on sensory attributes. The AK diet reduced *n*-6/*n*-3 ratio and increased PUFA/SFA ratio in Nguni beef without influencing its sensory quality.

Keywords: Eicosapentaenoic acid; Flavour; Juiciness; Ǚ-linolenic acid, Nguni beef.

9.1 Introduction

Recently, consumers have increased preference for naturally/organically produced animal products, which do not adversely affect their health (Alfaia *et al.,* 2009; Muchenje *et al.,* 2009). In response to that demand, nutritionists now recommend a reduction in total fat intake, particularly of saturated fatty acids (SFA) (Simopoulos, 2004), which are associated with an increased risk of cardio-vascular diseases and some cancers (Griffin, 2008; Alfaia *et al.,* 2009). Besides reducing fat intake, human nutritionists urge consumers to increase intake of polyunsaturated fatty acids (PUFA), particularly the *n*-3 PUFA at the expense of *n*-6 PUFA (Alfaia *et al.,* 2009). In addition, Wood *et al.* (2008) recommended an increase in Ŭ-linolenic acid (18:3*n*-3) consumption and a decrease in linoleic acid (18:2*n*-6) intake, to promote the endogenous synthesis of long chain (> C18) *n*-3 fatty acids. Long chain *n*-3 PUFA, such as eicosapentaenoic acid and docosahexaenoic acid, are linked to the development and functionality of nervous, vision and immune systems and have cardio-protective and anticarcinogenic functions (Enser *et al.,* 1998; Griffin, 2008). The PUFA/SFA and *n*-6/*n*-3 PUFA ratios have, therefore, become some of the most important parameters in assessing the nutritional value and healthiness of foods (Simopoulos, 2004; Orellana *et al.,* 2009).

The fatty acid composition of beef is mainly influenced by diet, genotype, feeding regime, age and sex of the animal (Warren *et al.,* 2008; Zapletal *et al.,* 2008). Appropriating certain biological types of cattle to proper dietary regimens has great potential to improve fatty acid profiles and, consequently beef sensory attributes and healthiness (Baublits *et al.,* 2006; Muchenje *et al.,* 2008a; Orellana *et al.,* 2009). In Southern Africa, for example, research has shown that under rangeland conditions, the Nguni breed has favourable carcass and meat quality characteristics (du Plessis and Hoffman, 2007; Muchenje *et al.,* 2008b, c), fatty acid profiles (Muchenje *et al.,* 2008d; Strydom, 2008) and sensory attributes (Muchenje *et al.,* 2008a). On the other hand, dietary condensed tannins have been reported to protect dietary lipids from biohydrogenation in the rumen (Schreurs *et al.,* 2008) and have a strong negative effect on the microorganisms that are responsible for ruminal biohydrogenation (Molan *et al.,* 2001; Vasta *et al.,* 2009). Condensed tannins, thus, influence meat fatty acids composition and sensory quality (Vasta *et al.,* 2007; 2008).

In Southern Africa, leaves from *A. karroo*, a condensed tannin-rich (80-110 g/kg DM), densely populated and widely distributed indigenous leguminous tree, are used as protein supplements by smallholder cattle producers (Aganga *et al.,* 1998; Mokoboki *et al.,* 2005). *Acacia karroo* leaves are also rich in minerals (Aganga *et al.,* 1998) and have antihelmintic effects (Kahiya *et al.,* 2003; Xhomfulana *et al.,* 2009). In addition, *A. karroo* leaf meal improves nutritional status, growth performance, carcass traits, (Chapter 7), meat appearance and protein content (Chapter 8) of Nguni steers reared on natural pasture. No reported work has, however, evaluated the fatty acid composition and sensory characteristics to estimate the safety, healthiness and palatability of beef from local cattle genotypes supplemented with an organic substance such as *A. karroo* under rangeland conditions. The objective of the current study was, therefore, to determine fatty acid composition and sensory attributes of meat from Nguni cattle supplemented with *A. karroo* leaf meal. The hypothesis tested was that beef from Nguni cattle supplemented with *A. karroo* leaf meal and those that entirely rely on natural pasture have similar fatty acid profiles and sensory quality attributes.

9.2. Material and Methods

9.2.1 Treatments, feeding management and experimental animals

Thirty Nguni steers raised at Fort Hare farm in Alice in the Eastern Cape Province of South Africa were allocated to three dietary treatments; *A. karroo* leaf meal (AK), sunflower cake (SF) and the control diet with no supplement (CN), from April 2008 to June 2008. The details of site where the study was conducted, how the supplementary diets were supplemented and how the experimental animals were managed were described in Sections 7.2.1, 7.2.3 and

7.2.4, respectively. Evaluations of the nutritive value of feed ingredients were described in Sections 7.2.5. Feed intake and ADG were computed as described in Section 7.2.5 and 7.2.6, respectively. The BCS were appraised as described in Section 7.2.6.

9.2.2 Slaughter procedures, carcass and meat quality measurements

Slaughter procedures and carcass measurements were described in Section 7.2.7. Meat quality measurements were described in Section 8.2.5. The *m. longissimus thoracis et lumborum* (LTL) of the right side was sampled, a day after slaughter, from the 10^{th} rib in the direction of the rump and a 100 mm thick piece of the posterior side of the right LTL was taken and vacuum-packaged at 3°C, pending fatty acid analysis.

9.2.3 Determination of fatty acid profiles of meat samples

Total lipid from muscle samples were quantitatively extracted, according to the method of Folch *et al.* (1957), using chloroform and methanol in a ratio of 2:1. An antioxidant, butylated hydroxytoluene, was added at a concentration of 0.001 % to the chloroform: methanol mixture. A rotary evaporator was used to dry the fat extracts under vacuum and the extracts were dried overnight in a vacuum oven at 50°C, using phosphorus pentoxide as a moisture adsorbent. Total extractable intramuscular fat was determined gravimetrically from the extracted fat and expressed as percent fat (w/w) per 100 g tissue. The extracted fat from feed and muscle was stored in a polytop (glass vial, with push-in top) under a blanket of nitrogen and frozen at ï20°C pending analyses. Fatty acid methyl esters (FAME) were prepared for gas chromatography by methylation of the extracted fat, using methanolïBF3 (Christie *et al.,* 2001) and identified as described in Section 7.2.6. Fatty acids were expressed as the proportion of each individual fatty acid to the total of all fatty acids present in the sample. The following fatty acid combinations and ratios were calculated: *n*-3 fatty acids, *n*-

6, total SFA, total mono-unsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), PUFA/SFA ratio (P/S) and *n*-6/*n*-3 ratio.

9.2.4 Sensory evaluation

The sampled LTL used for sensory evaluation were vacuum packed and either frozen directly (for those aged for 2 days) or aged at 2°C for 21 days and frozen. Two days before preparation, three steaks (one of each treatment) measuring 30 mm thick were cut with a band saw, vacuum packed and thawed over 24 hours at 0 to 4°C. The steaks were prepared according to an oven-broiling method using direct radiant heat (ASMA, 1995). An electric oven was set on ñbroilò 10 min prior to preparation at 260°C. Steaks were placed on an oven pan on a rack to allow meat juices to drain during cooking and placed in the pre-heated oven 90 mm below the heat source. The steaks were cooked to an internal temperature of 35°C recorded by direct probe, then turned and finished to 70°C. Raw and cooked weights were recorded.

Every steak was then trimmed of any external connective tissue, cut into approximately 2× 2×2 cm samples, wrapped in coded aluminium foil and stored in warm pans at 60°C until tasting. Samples were put in plates and randomly allocated in individual booths under red lighting to mask the differences in meat colour. Each of the 10 panellists had wide experience in meat sensory evaluation. The panel performed training tests using the methods outlined by ASMA (1995). Tasting was done in two sessions per day with one each of the three treatments and one ageing period (2 days or 21 days) within a session. Samples were presented in a different order to each panellist.

On an eight-point rating scale, assessments were made on beef aroma intensity, initial impression of juiciness (defined as the amount of fluid exuded on the cut surface when pressed between the thumb and the forefinger), first bite (the impression that is formed on the first bite) and sustained impression of juiciness (the impression of juiciness formed as chewing starts). The assessment criteria also included tenderness (the opposite of the force required to bite through the sample with the molars), amount of connective tissue (the chewiness of the meat), overall flavour intensity (the combination of taste while chewing and swallowing – referring to the typical beef flavour) and atypical flavour intensity (this refers to a flavour that is present over and above typical beef flavour, such as livery, bloody, metallic, grassy and vegetables. A score of 1 represented for extremely low aroma and flavour intensities, tough, dry, abundant connective tissue and no atypical flavour and 8 represented for extremely intense aroma and flavour intensities, very tender, very juicy, no connective tissue and extremely intense atypical flavour (ASMA, 1995). Details of the meat evaluation form are shown in Appendix 10.

9.2.5 Statistical analyses

The effects of diet on meat fatty acid composition and meat sensory attributes were analysed using GLM procedure of SAS (2003). The linear model was:

$Y_{ij} = \mu + D_i + \varepsilon_{ij}$

Where Y_{ij} = meat fatty acid profiles and sensory attributes;

μ = Overall mean;

D_i = effect of diet (i= AK, SF, CN) and;

ε_{ij} = residual error

The significant differences between least square group means were compared using the PDIFF procedure of SAS (2003), at a significance level of $P < 0.05$. Pearson's correlation coefficients between fatty acid profiles and sensory characteristics were determined using the PROC CORR procedure (SAS, 2003).

9.3 Results

9.3.1 Meat fatty acid composition and sensory quality

Least square means of fatty acid proportions in beef from Nguni steers given three supplementary diets are shown in Table 9.1. The predominant fatty acids in intramuscular fat of Nguni steers were palmitic acid (C16: 0), stearic acid (C18: 0) and oleic acid (C18: 1c9). Meat from Nguni steers supplemented with sunflower cake had higher ($P < 0.05$) myristic acid (C14:0) and palmitic acid (C16: 0), and lower ($P < 0.05$) pentadecenoic acid (C15: 1c10) proportions than those that received AK and CN diets. Nguni steers that received AK diet had lower ($P < 0.05$) elaidic acid (C18: 1t9) and higher ($P < 0.05$) Ŭ-linolenic acid [C18: 3c9,12,15 (*n*-3)] than those that received SF and CN diets. Highest eicosatrienoic acid [C20: 3c11,14,17 (*n*-3)], arachidonic acid [C20: 4c5,8,11,14 (*n*-6)], eicosopentaenoic acid [C20: 5c5,8,11,14,17 (*n*-3)], docosadienoic acid [C22:2c13,16 (*n*-6)] and docosapentaenoic acid [C22: 5c7,10,13,16,19 (*n*-3)] proportions were recorded in meat from steers on the AK diet followed by those that were on the control diet.

Polyunsaturated fatty acids and total *n*-3 fatty acids proportions were significantly higher in meat from steers on the AK and CN diets than those that received SF diet. Meat from steers given the AK diet had the highest PUFA/MUFA and PUFA/SFA ratios followed by those that received the CN diet. The lowest *n*-6/*n*-3 ratio was recorded in meat from steers that received the AK diet compared to those on TSF and CN diets. All the tested sensory quality attributes were not influenced by diet.

Table 9.1: Least square means and standard errors of fatty acid composition in percentage by weight of total identified fatty acids in beef from Nguni steers given three different diets

	Diet			
Fatty acid (% total fatty acid)	Control	*A. karroo*	Sunflower	s.e.
C14:0	1.99[a]	1.88[a]	2.39[b]	0.147
C14:1c9	0.25	0.31	0.37	0.054
C15:0	0.46	0.36	0.45	0.036
C15:1c10	0.12[b]	0.15[b]	0.05[a]	0.024
C16:0	24.31[a]	24.22[a]	25.71[b]	0.096
C16:1c9	2.78	2.95	3.38	0.264
C17:0	1.06	0.94	1.00	0.059
C17:1c10	0.07	0.11	0.06	0.022
C18:0	18.22	16.28	17.29	0.955
C18:1t9	2.29[b]	1.87[a]	2.34[b]	0.149
C18:1c9	30.05	30.69	31.84	0.895
C18:1c7	1.37	1.46	1.39	0.054
C18:2c9t11(*n*-6)	0.29	0.32	0.39	0.034
C18:2c9,12 (*n*-6)	6.14	6.32	5.44	0.598
C18:3c9,12,15 (*n*-3)	1.94[a]	2.59[b]	1.53[a]	0.212
C20:0	0.21	0.16	0.16	0.027
C20:1c11	0.06	0.05	0.03	0.031
C20:3c11,14,17 (*n*-3)	0.58[b]	0.63[c]	0.48[a]	0.045
C20:4c5,8,11,14 (*n*-6)	3.38[ab]	3.74[b]	2.54[a]	0.364
C20:5c5,8,11,14,17 (*n*-3)	1.56[ab]	1.81[b]	1.09[a]	0.173
C22:0	0.31	0.31	0.21	0.143
C22:2c13,16 (*n*-6)	0.25[b]	0.33[c]	0.14[a]	0.041
C22:5c7,10,13,16,19 (*n*-3)	2.20[b]	2.43[c]	1.60[a]	0.213
C22:6c4,7,10,13,16,19 (*n*-3)	0.11	0.11	0.10	0.040
SFA	46.56	44.15	47.22	1.266
MUFA	36.97	37.58	39.47	1.129
PUFA	16.47[b]	18.27[b]	13.31[a]	1.574
PUFA/MUFA	0.44[ab]	0.51[b]	0.35[a]	0.537
Omega- 6 fatty acids (*n*-6)	10.07	10.71	8.51	0.947
Omega- 3 fatty acids (*n*-3)	6.40[b]	7.56[b]	4.80[a]	0.644
PUFA/SFA	0.36[ab]	0.42[b]	0.28[a]	0.043
n-6/*n*-3	1.58[b]	1.44[a]	1.78[c]	0.448

[a,b,c]Values in the same row with different superscripts are different at $P < 0.05$.

9.3.2 Correlations between sensory scores and fatty acid profiles

Table 9.2 shows correlation coefficients between sensory scores and fatty acid profiles of Nguni cattle given three different diets. Initial impression of juiciness was positively correlated ($P < 0.05$) to intramuscular fat, pentadecylic acid and conjugated linoleic acid but negatively correlated to palmitic acid and oleic acid. The correlation between intramuscular fat and tenderness was positive ($P < 0.05$). There was a positive correlation ($P < 0.05$) between atypical flavour intensity with palmitoleic acid.

9.4. Discussion

The individual fatty acids proportions except C18:2c9,12 (*n*-6) and C15:1c10 were within the normal range of values for beef cattle (Aldai *et al.,* 2006; Alfaia *et al.,* 2009; Muchenje *et al.,* 2008d; 2009). The finding that stearic acid (C18: 0) and palmitic acid (C16: 0) were amongst the most abundant fatty acids in intramuscular fat of beef cattle is consistent with previous reports (Partida *et al.,* 2007; Muchenje *et al.,* 2008d; Orellana *et al.,* 2009). The meat from Nguni steers on the SF diet contained more individual saturated fatty acids (C14: 0 and C16: 0) compared to the meat from steers on the AK and CN diets, respectively. Comparable to these findings, French *et al.* (2000) and Baublits *et al.* (2006) reported that beef from cattle receiving concentrate supplements have more C 16:0 than beef from forage-fed cattle.

Table 9.2: Correlations between sensory scores and fatty acid composition (% total fatty acids) of beef from Nguni cattle given three different diets

	IMF[1]	Pentadecylic acid	Palmitic acid	Palmitoleic acid	Oleic acid	Conjugated linoleic acid	Veccenic acid
Aroma intensity	-0.05	0.01	0.29	0.1	0.05	0.11	-0.11
Initial impression of juiciness	0.36*	0.43*	-0.47*	-0.1	-0.44*	0.54*	0.25
First bite	-0.31	0.045	0.21	0.01	-0.03	0.03	-0.02
Juiciness	-0.10	0.12	0.19	-0.21	-0.04	-0.3	0.12
Tenderness	0.39*	0.02	-0.20	0.06	0.02	0.04	0.16
Overall flavour intensity	0.34	0.19	0.23	0.13	0.07	0.16	0.08
A-typical flavour intensity	0.32	-0.01	0.30	0.46*	-0.22	0.18	0.01

Significantly correlated at *$P < 0.05$. [1]Intramascular fat.

Animal growth performance, through its effect on fat formation, can strongly influence muscle fatty acid composition (Gerson *et al.,* 1985; Aurousseaua *et al.,* 2004). Aurousseaua *et al.* (2004), for example, reported higher C18:0 and total even chain saturated fatty acids contents in lambs with high growth rate than in those with low growth rate. The observed higher growth rates in the Nguni steers on the SF diet than those on the AK and CN diets could, therefore, partly explain the observed differences in individual saturated fatty acid in meat across the three diets. According to Wood *et al.* (2003), C14:0 and C16:0 fatty acids raise low-density (LDL) serum cholesterol, which is positively related to the occurrence of various cancers and heart diseases. Since all the experimental animals had access to grasses and forages which are rich in PUFA precursors, the effect of SFA could have been masked by the PUFA proportions.

The observation that beef from steers that were given the AK diet had the highest proportions of individual PUFA and total PUFA could be related to dietary fatty acid composition. Part of dietary 18:3*n*-3 fatty acids such as Ŭ-linolenic acid (ALA) and docosapentaenoic acid (DPA), which was found in higher proportions in AK diet, could have escaped ruminal biohydrogenation and got deposited in tissues (Scollan *et al.,* 2006). These fatty acids (ALA and DPA) are precursors of the *n*-3 series of PUFA (Wood *et al.,* 2008). Alpha-linolenic acid is converted by desaturase and elongase enzymes into the desirable long-chain (C20ï 22) *n*-3 PUFA such as eicosapentaenoic acid (EPA, 20:5*n*-3) and docosahexaenoic acid (DHA, 22:6*n*-3) (Nürnberg *et al.,* 2005; Scollan *et al.,* 2006). Docosapentaenoic acid can be converted to DHA or back to EPA (Simopoulos, 2004). The higher proportions of individual PUFA in the AK diet could also be ascribed to the presence of condensed tannins, which protect dietary lipids from biohydrogenation in the rumen (Schreurs *et al.,* 2008; Wood *et al.,* 2008), and inhibit growth and metabolism of ruminal bacteria responsible for ruminal biohydrogenation (Molan *et al.,* 2001; Vasta *et al.* 2007; 2009).

The lower proportion of individual *n*-3 fatty acids in meat from steers supplemented with SF diet than those that received AK and CN diets might have influenced the total *n*-3 fatty acids proportions. Nürnberg *et al.* (2005) and Warren *et al.* (2008) obtained low amounts of total *n*-3 PUFA in beef cattle fed concentrate-based diets and attributed it to lower levels of C18:3 and C20:5 *n*-3 in meat. The observed long chain *n*-3 PUFA like EPA and DHA play an important role in the development of cerebral and retinal tissues and in the prevention of heart diseases and some cancers (Simopoulos, 2004; Alfaia *et al.,* 2009). As a result, nutritionists now recommend not only limiting fat intake but also consumption of large amounts of PUFA, especially those of the *n*-3 rather than the *n*-6 PUFA (Simopoulos, 2004).

Raes *et al.* (2004) noted that as fatness increases, the levels of SFA and MUFA increase faster than the PUFA levels, leading to an increase in the relative proportions of SFA and MUFA and decrease in PUFA and PUFA/SFA ratio. The observed higher intramuscular fat content in steers that received SF diet could, therefore, partly explain their low PUFA proportions and, PUFA/MUFA and PUFA/SFA ratios compared to AK and CN diets. The observation that *n*-6/*n*-3 ratio was lowest in steers that were given the AK diet was probably due to the higher proportions of *n*-3 PUFA in the meat. French *et al.* (2000) also reported that muscle from cattle fed concentrates had a lower PUFA/SFA ratio and a higher *n*-6/*n*-3 PUFA ratio than muscle from grass-fed cattle. A proper balance of these essential fatty acids helps to maintain and improve human health (Simopoulos, 2004; Alfaia *et al.,* 2009).

The PUFA/SFA and *n*-6/*n*-3 PUFA ratios are commonly used to assess the nutritional value and consumer health of beef (Simopoulos, 2004; Orellana *et al.,* 2009). In general, a ratio of PUFA/SFA above 0.4 (Wood *et al.,* 2008) and a ratio of *n*-6/*n*-3 below 4.0 (Raes *et al.,* 2004) are recommended in the diet to combat some cancers and cardiovascular diseases (Partida *et al.,* 2007; Griffin, 2008). The low ratios of *n*-6/*n*-3 (1.44-1.78 %) observed in this study are a characteristic of fat from ruminants that are fed forage-based diets, which contains high levels of C18:3*n*-3 (Aldai *et al.,* 2006). Contrary to current findings, Muchenje *et al.* (2008d) found slightly higher PUFA/SFA ratio for Nguni cattle under rangeland conditions. The variation could be attributed to age differences. Nguni steers in this study were older than those used by Muchenje *et al.* (2008d). Further studies to determine the possible interaction between diet and age on fatty acid composition are warranted. The observation that beef from steers given AK diet had PUFA/SFA ratio above 0.4 and the lowest *n*-6/*n*-3 ratio implies that supplementing Nguni steers with *A. karroo* could be beneficial to human health.

The finding that diet did not influence any of the tested sensory attributes was probably because the steers in the three treatments had similar characteristics; i.e., the same breed, sex, and age and they all grazed on natural pasture. These results were consistent with lack of significant dietary differences for most of the sensory-related physical beef characteristics (sarcomere length, myofibrillar fragment length, Warnerï Bratzler shear force) (French *et al.,* 2001).

The observation that initial impression of juiciness was positively correlated to marbling fat, pentadecylic acid and conjugated linoleic acid and negatively correlated to palmitic acid and oleic acid was expected (Wood *et al.,* 2003). Intramuscular fat deposited between fasiculi, disrupts the honeycomb structure of the endomysium; separates and thins perimysial fibres, thereby increasing tenderness (Wood *et al.,* 2008). The finding that palmitoleic acid was positively correlated to atypical flavour intensity confirms earlier reports that PUFA proportions can influence meat sensory quality (Nute *et al.,* 2007). If the level of PUFA is too high, odd and off-favours can dominate the meat aroma profile (Nute *et al.,* 2007) thereby masking the typical species aromas. Since some minerals and vitamins, such as selenium and vitamin E, can reduce production of meat off-flavours (Vasta *et al.,* 2008), evaluation of mineral and vitamin profiles of beef from Nguni steers supplemented with *A. karroo* is crucial.

9.5 Conclusions

The AK diet reduced *n*-6/*n*-3 ratio and increased PUFA/SFA ratio in Nguni beef without influencing its sensory quality. Beef from cattle supplemented with *A. karroo* could, therefore, be a palatable, safe and healthy food for the human population. Additional research on mineral and vitamin profiles of beef from Nguni cattle supplemented with *A. karroo* could be of importance.

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Chapter 10: General discussion, conclusions and recommendations

10.1 General discussion

The broad objective of the current study was to evaluate cattle production on communal rangelands and the potential of *A. karroo* in improving Nguni beef production in the Eastern Cape province of South Africa. The main hypothesis tested was that the provision of locally available organic protein supplements, such as *A. karroo,* can increase beef yield and quality of Nguni cattle on communal rangelands. Prior to improving beef production under low-input production systems, it is, however, important to understand constraints faced by cattle farmers as well the nutritional status and performance of existing cattle genotypes under such production systems.

The hypothesis tested in Chapter 3 was that constraints faced by smallholder Nguni cattle farmers in the sweet and sour rangelands are similar. Although constraints varied with production systems and rangeland types, smallholder farmersô ranked shortage of feed as the most important constraint, particularly during the dry season in communal areas in the sweet rangeland. Feed availability varied with production system and ecological zones. The factors that influence feed shortage and their effects on herd dynamics, CPP and CPE on communal rangelands should be established to improve cattle production under low-input production systems.

A monitoring study (Chapter 4) was conducted to test the hypothesis that season, rangeland type and herd size do not affect births, deaths, sales, purchases, off-take, CPP and CPE on communal rangelands in the Eastern Cape. Households owning small herds in the sweet rangeland had the lowest births, purchases and CPP in the cool-dry season whilst those households owning large herds in the sour rangeland had higher sales, slaughters and deaths in the hot-wet and cool-dry seasons. Cattle production efficiency was high in the cool-dry season in the sweet rangeland and this was attributed to high cattle sales that occurred in the same season. These cattle sales were mainly done to reduce cattle mortality through starvation as most farmers did not have capital to purchase feed supplements. Given that cattle fetched low prices in the cool-dry season due to poor body condition, supplementary feeding during this period could, therefore, increase CPE on communal rangelands. Prior to execution of supplementary feeding programmes, it is important to assess the nutritional status of cattle grazing on communal rangelands and determine the types and levels of limiting nutrients.

In Chapter 5, it was hypothesised that the seasonal concentrations of energy-related metabolites and minerals in Nguni and crossbred cattle in the sweet and sour rangelands in the Eastern Cape Province South Africa are the same. Cattle body weights and BCS were lower in the dry seasons compared to rainy and post-rainy seasons. NEFA concentrations were highest in the late cool-dry season in the sweet rangeland compared to other seasons. Nguni cattle had lower cholesterol and NEFA but higher SIP concentrations in the hot-wet season than crossbreds. These results could suggest that Nguni cattle might have low energy requirements than crossbreds. It might also imply that Nguni cattle are more adapted to the prevailing energy and mineral conditions found on communal rangelands than crossbreds. Given that the levels of serum energy-related metabolites and minerals for both Nguni and crossbreds were generally within the expected range, energy and minerals could, therefore, not be the major nutrients limiting Nguni cattle production on communal rangelands in the Eastern Cape, South Africa. It was observed that herbage, though not quantified, was abundant throughout the year. It was, therefore, essential to assess the concentrations of protein metabolites in communal cattle and confirm whether protein is limiting or not.

The hypothesis tested in Chapter 6 was that the seasonal concentrations of protein-related blood metabolites in Nguni and crossbred cattle in the sweet and sour rangelands in the Eastern Cape are not different. Nguni cattle had lower albumin, urea and creatinine than the local crossbreds. Total protein and albumin concentrations of both breeds Nguni and crossbred cattle were lower in the hot-wet and dry seasons. Urea concentrations of both breeds were highest during the hot-dry season in the sweet rangeland. Generally, Nguni cattle had lower concentrations of protein metabolites than crossbreds and protein deficiencies were most prominent during the dry season in the sweet rangeland. These findings suggest that Nguni cattle are able to utilise protein more efficiently for growth and development under low protein conditions than local crossbreds. Communal farmers could, therefore, be encouraged to adopt Nguni cattle as they could be capable of utilising protein efficiently and are resistant to nematodes (Ndlovu *et al.,* 2008) ticks (Muchenje *et al.,* 2008) and tick-borne diseases (Marufu *et al.,* 2009), which are more prevalent in the hot-wet season on communal rangelands. Provision of protein supplements to Nguni cattle could, however, be crucial especially, in the cool-dry season where body weights, BCS and blood protein levels are low.

The hypothesis tested in Chapter 7 was that Nguni steers supplemented with *A. karroo* leaf meal and those that entirely rely on rangelands have similar growth performance, blood chemistry and carcass traits. Nguni steers that were supplemented with AK and SF diets had higher TP, albumin, urea, Ca, SIP, Mg and Fe concentrations than those that received CN diet. Steers that were given AK and SF diets had lower glucose and cholesterol but higher NEFA concentrations than those that received the CN diet. Although steers supplemented with the AK diet had higher ADG, BCS, slaughter weight, warm carcass weight and cold carcass weight, and a larger eye muscle area than those that received the CN diet, they were out performed by those that were given the SF diet. Since steers that were given supplementary diets had higher concentration of protein metabolites and ADG, they were expected to have greater muscle deposition and, consequently higher slaughter weights and heavier carcasses (Rubanza *et al.,* 2005). The gross margin for steers on the AK diet was higher than for those on the CN diet, but was not significantly different from that for the SF diet. *Acacia karroo* leaf meal could, therefore, be a viable supplementary feeding strategy to improve protein status, growth performance and carcass characteristics of Nguni cattle in the communal areas, where in most cases, producers do not have adequate financial resources to buy commercial supplementary feeds. Despite that feeding *A. karroo* leaf meal reduces nematode burdens (Xhomfulana *et al.,* 2009), improves growth performance and carcass traits of Nguni cattle, consumer meat acceptance and purchasing decisions depend on meat quality attributes.

The hypothesis that beef from Nguni cattle supplemented with *A. karroo* leaf meal and those that entirely rely on natural pasture have similar meat quality characteristics was tested in Chapter 8. Steers that received the SF diet had lighter-coloured meat than those on AK and CN diets. The highest redness (freshness) and colour saturation values were recorded in steers that were supplemented with the AK diet. This was attributed to high dietary iron consumed by steers on the AK diet, which could increase haemoglobin and myoglobin concentrations in meat of grazing animals (Priolo *et al.,* 2001). The observation that meat from steers fed on supplementary diets had higher protein content than those on CN diet was ascribed to high dietary CP intake. It was concluded that supplements containing *A. karroo* could produce beef of comparable quality to natural pasture but with a fresher appearance and higher protein content. Feeding *A. karroo* leaf meal could, therefore, improve meat nutritive value and freshness and, subsequently consumer acceptance. Increase in fat intake, particularly of SFA from meat is associated with an increased risk of cardio-vascular diseases and some cancers (Simopoulos, 2004). As a result, modern consumers are demanding palatable, safe and healthier meat (Partida *et al.,* 2007). To estimate meat safety, healthiness and palatability of beef from Nguni cattle supplemented with *A. karroo* foliage, it is essential to evaluate its fatty acid composition and sensory quality.

In Chapter 9, the hypothesis tested was that beef from Nguni cattle supplemented with *A. karroo* leaf meal and those that entirely rely on natural pasture have similar fatty acid profiles and sensory quality attributes. Highest Ǖ-linolenic acid, eicosopentaenoic acid, docosapentaenoic acid and PUFA/SFA ratio, and lowest *n*-6/*n*-3 ratio were recorded in beef from steers that received AK diet and this was related to its dietary fatty acid composition. The quantity and composition of fatty acids in meat are related to the presence of some of their precursors in the diet, since part of dietary fatty acids escape from the process of ruminal biohydrogenation and is absorbed unchanged (Wood *et al.,* 2003). Myristic acid and palmitic acid proportions were lower while *n*-3 PUFA proportions were higher in beef from steers that were fed on AK and CN diets than those on the SF diet. Diet had, however, no effect on sensory quality attributes. The AK diet, thus, reduced *n*-6/*n*-3 ratio and increased PUFA/SFA ratio in Nguni beef without influencing its sensory quality. Besides being palatable, beef from cattle supplemented with *A. karroo* diet may be useful in combating cardiovascular diseases and some cancers in humans.

10.2 Conclusions

Farmers ranked feed shortage as the major cattle production constraint, particularly during the dry season in communal areas in the sweet rangeland. Although the CPP was low in the sweet rangelands, households in these areas had higher CPE, especially in the cool-dry season compared to those in the sour rangelands. Nguni cattle had lower cholesterol and NEFA, and higher SIP concentrations in the hot-wet season than crossbreds. Non-esterified fatty acids concentrations were highest in the late cool-dry season in the sweet rangeland compared to other seasons. Nguni cattle had lower concentrations of protein metabolites than crossbreds, especially in the sweet rangeland during the cool-dry seasons. *Acacia karroo* leaf meal supplementation, however, improved the protein status, growth performance, carcass characteristics and gross margin of Nguni steers. It also produced beef of comparable quality to natural pasture but with a fresher appearance and higher protein content. More importantly, *A. karroo* reduced *n*-6/*n*-3 fatty acid ratio and increased PUFA/SFA ratio in Nguni beef without influencing its sensory quality. It was concluded that low feed quality in the dry season, particularly low protein content was the major factor limiting the production efficiency of Nguni cattle on communal rangelands. Protein deficiency in the dry season could, however, be rectified by feeding *A. karroo* leaf meal, which can cheaply improve growth performance, carcass traits, beef quality and fatty acid profiles of Nguni cattle.

10.3 Recommendations and further research

It can be advised that Nguni cattle producers in the communal areas should sell their animals at the end of post-rainy season before they start losing condition. Alternatively, resource-poor farmers can supplement their Nguni cattle on communal rangelands with *A. karroo* leaf meal in the cool-dry season before selling them. Roughly, one *A. karroo* tree (3 m tall) in the semi-arid areas can produce 1.0-1.5 kg of leaf meal per annum, which can feed one steer per day.

Beef from Nguni cattle supplemented with *A. karroo* can be a palatable, safe and health-promoting food for human consumption. Developing producer cooperatives or producer contracts in the communal areas and, subsequently create local and international niche markets for such palatable, safe and health-promoting beef could be of paramount importance. These efforts can be complemented by educating farmers through extension, on cost effective ways of harvesting, conserving and value-addition of indigenous legume tree foliages to improve their nutritive value, palatability, digestibility and utilisation. Provision of a framework for capacity building for farmers and documentation of information on cattle production, product processing, value addition, marketing and entrepreneurship could also be essential.

Aspects that require further research include the following:

1. Determination of *A. karroo* tannin structure and chemical nature, and their effects on palatability, degradability, fatty acids hydrogenation, digestibility, absorption and meat quality is critical. The effects of tannins on feed degradability, digestibility, utilisation and meat quality could depend on tannin structure and chemical nature.
2. Evaluation of mineral and vitamin composition of beef from Nguni cattle supplemented with *A. karroo* leaf meal could be valuable. The concentration of these nutrients in meat could affect meat quality and development of off-flavours in stored meat.
3. Screening and evaluation of other indigenous *Acacia* species for beef production in areas where *A. karroo* is less dominant could also be important.
4. Factors affecting utilisation of developmental technologies based on indigenous animal genetic resources and locally available feed resources could be worth researching. To get widespread and sustainable utilisation of developmental

technologies, it is important to establish constraints faced by farmers in implementing and utilising such technologies.

5. Research on appropriate ways of processing and adding value to Nguni beef and related products such as hides and horns in the communal areas could be invaluable. Information from such studies could assist farmers to diversify, spread beef marketing risks and promote utilisation of some marginal cattle products in rural areas.

10.4 References

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11: Appendices

Appendix 1: Potential for value-addition of Nguni cattle products in the communal areas of South Africa: a review (Manuscript published in *African Journal of Agriculture Research*)

Appendix 2: Opportunities for improving Nguni cattle production in the smallholder farming systems of South Africa (Manuscript published in *Livestock Science*).

Appendix 3: Baseline survey questionnaire on factors affecting Nguni cattle production in the Eastern Cape Province, South Africa

Questionnaire numberé é é é é é é é
Municipality Nameé é é é é é é é ..
Name of respondenté é é é é é é é ..
Enumerator nameé é é é é é ...é
Community nameé é é é é é é ...
Date...é é é é é é é é é é é é é é ..

A. HOUSEHOLD DEMOGRAPHIC INFORMATION

1. Head of household
a. Sex M☐ F☐ **b. Marital status** Married☐ Single ☐ Divorced☐ Widowed☐
c. Age < 30☐ 31-45☐ 30-50☐ 46-60☐ >60☐
d. Highest level of education No formal education ☐ Grade 7☐ Grade 12☐ Tertiary☐
2. What is your principal occupation? ....
3. What is your religion? Christianity ☐ Traditional☐ Moslem☐ other (specify)é é é é
4. What is the size of your household? Adults: Mé é . Fé é é .. Children: Mé é Fé é
5. How much land do you own (ha)? é é é é **6. How much land is arable (ha)?** é é é é é é
7. How much land is used for grazing (ha)? .... **8. Is grazing communal? Yes**☐ No☐
9. What crops did you grow last season? (Rank 1 as the most commonly grown used crop)

Crop	Rank	Area (ha)	Purpose of production	
			Consumption	Sale

10. What type of livestock species do you keep? (Rank 1 as the most important specie)

Class	Cattle	Goats	Sheep	Chickens	Other (specify)
Number					
Rank					

11. What are your sources of income? (Tick first column as appropriate and rank 1 as the most important source of income)

Source	Amount raised	Rank
Crops		
Livestock		
Salary/wages		
Pension		
Other (specify)		

B. CATTLE HERD COMPOSITION AND GENDER ROLES

1. What is the composition of your cattle herd?
Calves (less than 7 months)☐ ..é . Heifers☐ é ... Steers☐ é ... Cows☐ ..é . Oxen☐é é . Bulls☐é
2. If you have lactating cows, how many are they? ....
3. How did you acquire your cattle? Inherited☐ Given☐ Bought☐ Others (Specify)é é é é é é
4. Who is the owner of the cattle? Community☐ Father☐ Mother☐ Children☐ Other (specify).é é

5. Why do you keep cattle? (Tick one or more) (Rank 1 as the most common use)

Use	Rank	Use	Rank
Meat		Sales	
Milk		Status	
Draught power		Dowry	
Manure		Ceremonies	
Skin		Other (specify)	

6. What role(s) does each family member play in cattle production? (Tick one or more)

Role	Adults		Children		Hired labour
	Male	Female	Boy	Girl	
Feeding/supplementation					
Herding					
Fencing					
Kraal construction & maintenance					
Breeding					
Health management					
Milking					
Purchasing					
Slaughtering					
Marketing/Selling					
Other (specify)					

C. CATTLE FEEDING MANAGEMENT

1. What type of feeding system do you use?
Herding☐ Paddock☐ Stalling☐ Yard☐ Free grazing☐ Other (specify)é é é é
2. What are the sources of feed for your cattle? (Tick 1 or more)
Veld☐ Pasture☐ Conserved feed☐ Crop residues☐ Bought-in feed☐ Other (specify)é é é é
3. How do you evaluate the condition of your veld? ....
é é
4. How do you describe the condition of your grazing lands?

Condition	Tick	Condition	Tick
Extremely deteriorating- Very Poor Condition Little Grass		Good - Plenty Grass	
Deteriorating -Poor Condition, but Some Grass		Very Good-Improving	
Fair - Reasonable Amount of Grass		I donα't know	

5. What are the reasons that have led to the current state of rangelands? (Tick one or more)
Poor grazing management ☐ Fire☐ Poor soils☐ Low rainfall☐ Bush encroachment☐ otheré é ..é
6. What problems do you face in the management of grazing areas? ....
é é
7. What are the possible solutions to the problems you have mentioned above? é é é é é é é é é
é ....
8. What is the general body condition of your animals? Very poor☐ Poor☐ Good☐ Excellent☐
9. How has the condition changed over the past 12 months? Deteriorated☐ Improved☐ No change☐
10. If the condition has deteriorated, what are the causes? Poor grazing☐ Diseases☐ Other é é é é
11. Comment on the availability of grazing in the different seasons of a year:
***Rainy season*:** Too much☐ Adequate ☐ Moderate☐ Too little☐
***Winter*:** Too much☐ Adequate ☐ Moderate☐ Too little☐
12. Do you provide supplementary feeding to your cattle? Yes ☐ No☐
13. If yes, when do you provide supplements to your cattle?
Rainy season ☐ Winter ☐ Dry season☐ All year round☐ In times of emergence ☐ Otheré é é é é .
14. How often do you provide supplementary feeding?
More than twice/day ☐ Once/day☐ every 2-4 days☐ Weekly☐ Forty -nightly☐ otheré é é é
15. What type of supplements do you provide to your cattle? (Tick one or more)
Energy/Roughage☐ Protein☐ Minerals/vitamins☐ None ☐ Other (specify)é é é é é é
16. Which class of cattle do you give supplements and why?

Class	Rank	Reason
Calves		
Heifers		
Steers		
Cows		
Oxen		
Bulls		

D. BREEDING MANAGEMENT

1. What breeds do you have?

Breed	Nguni	Bonsmara	Mixed Breed	Otheré é é é .é é é
Number				

2. What are your reasons for using the breed you named above? (Tick one or more) (Rank 1 as the most important)

Reason	**Rank**
High growth rate	
High milk yield	
Adapted	
Meat quality	
Temperament	
Horns	
Colour	
Affordability	
Availability	
Other (specify)	

3. How do you mate your cattle?
Uncontrolled☐ Group mating☐ Artificial insemination☐ (Others Specify) é é é é é

4. What are the sources of cattle used for breeding? (Rank 1 as the most common source)

Source	**Bulls**		**Cows**	
	Tick	Rank	Tick	Rank
Locally bred				
Bought				
Donated				
Community				
Borrowed				
Other				

5. What factors do you consider when selecting breeding stock? (Rank 1 as the most important reason)

Reason	**Bulls**		**Cows**	
	Tick	Rank	Tick	Rank
Performance				
Conformation				
Body condition				
Health				
Old age				
Temperament				
Others (specify)				

6. Do you have problems of bull fertility? Yes☐ No ☐
7. If yes, what are they? ....
é é
8. How do you identify your cattle? Give names☐ tag☐ brand☐ Other (specify) é é é é .
9. If you castrate your male cattle, what are your reasons? (Tick one or more) Do not castrate☐
To control breeding ☐ To improve meat quality ☐ For better temperament ☐ Others (specify). é é
10. Which method of castration do you use? Rubber ring ☐ Burdizzor ☐ Open method ☐ Other é é .
11. What is the reason for your choice? ....
12. At what age do you normally castrate male cattle? < 1 wk ☐ Fortnightly☐ Monthly ☐ > 3mo☐
13. Do you have problems of low bull numbers? Yes ☐ No ☐
14. If you have access to Nguni project bulls, after how long do you have access?
< 1yr☐ 1-2yrs ☐ 3-4yrs ☐ > 4yrs ☐
15. When did you start using bulls from the Nguni project? é é é é é é é é é é é é é é é é é
16. What other support do you get from the Nguni cattle project? ....
é é é é é é é ....
17. When did you decide to participate in the Nguni Project? é é é é é é é é é é é é é é é é é
18. Are all the community members willing to participate in the Nguni project? Yes ☐ No ☐
19. If you need more support from the Nguni project, what type support do you require? ....

E. HEALTH MANAGEMENT

1. If your animals get sick, what do you do? Nothing☐ Treat☐ Other (specify)é é é é é é é ...

2. If your animals get sick, whose advices do you seek? (Tick on or more)

No one☐ Neighbours☐ Veterinary☐ Extension ☐ Drug suppliers☐

3. If you treat your animals, what type of medicine do you use?

Conventional ☐ Traditional ☐ Other (specify)é é ..

4. Which traditional medicine do you use to treat your animals? ....
é ....

5. What are the major causes of mortality of your cattle? (Tick one or more) Extreme climate Predators☐
Diseases☐ Old age☐ Poor diet☐ Others (specify)é é é ..

6. Do you dip your animals? Yes ☐ No ☐

7. If no, why? ....

8. If yes, how often do your dip animals? Weekly ☐ Fortnightly ☐ Monthly ☐ Other (Specify)é é

9. How do you dip your animals? Plunge ☐ Spray ☐ Pour on ☐ Other (specify)é é é é é é é

10. What type of dip do you use? Conventional ☐ Organic ☐ Other (specify) é é é é é é é é é .

12. What are your reasons for using the above mentioned dip? ....

13. How do you control internal parasites? ....

14. Do you conduct post-mortems on your dead animals? Yes ☐ No ☐

15. If yes, how do you do it? ....

16. How do you dispose off dead animals? é é é é ....

17. What are the most prevalent diseases and parasites in your area? (Rank 1 as the most common) **State season of high prevalence and control measures for the named diseases and parasites.**

Diseases	**Rank**	**Season of high prevalence**	**Control**
Parasites			

16. If you vaccinate your cattle, which diseases do you vaccinate againsté é é é é é é é é é é é
é ....

17. What are the most common cattle predators in your area? é é é é é é é é é é é .é é é é é

End.
Thank you!

Appendix 4: Seasonal dynamics, production potential and efficiency of cattle in the sweet and sour communal rangelands in South Africa. (Manuscript published in *Journal of Arid Environments*)

Appendix 5: Recording sheet for herd dynamics

Name of community………………………………………………………………………… .
Name of Household………………………………………………………………………… ..
Month…………………………………………………………………………………………
Year ……………………………………………… ……………………………………… ..

	Total	**Comments**
Herd composition		
Calves (Amathole)		
Young bulls (Inkunzana)		
Heifers (Amathokazi)		
Steers (Amadyongo / inkatyana)		
Growers *(heifers + growing bulls)*		
Oxen (Iinkabi)		
Cows (Iimazi)		
Mature bulls (Iinkunzi)		
Mature cattle *(reproductive cows + mature bulls)*		
Total number for all the cattle		
	Class	**Reasons**
Entries		
Births (Ezizelweyo)		
Purchases (Ezithengiweyo)		
Gifts-in (Izipho)		
Exchange-in (Ukutshintshisa)		
Entrusted-in (Ukunqoma /Ukusisa)		
Exits		
Sold (Ezithengisiweyo)		
Slaughtered (Ezixheliweyo)		
Died (Ezifileyo)		
Predated upon/stolen/lost (Ezibelixhoba/Ezebiweyo/Ezilahlekileyo)		
Gifts-out (Ekuphiswe ngazo)		
Exchange-out (Ekutshintshiswe ngazo)		
Entrusted-out (Ukunqonywa/ Ukusiselwa)		

Appendix 6: Methods for determining serum concentrations of nutritionally-related metabolites, liver enzymes and minerals

1. Determination of non-esterified fatty acids concentration

Non-esterified fatty acids assays were performed colorimetrically according to De Villiers *et al.* (1977) using an extraction solution, phosphate buffer, cobalt and colour (stock) as reagents. The extraction solution was made up of chloroform and heptanes in 1:1 (v/v) ratio and 2 % methyl alcohol was used. Phosphate buffer (pH 6.4) was comprised of M/30 potassium dihydrogen phosphate and M/30 disodium-hydron mixture in a 2:1 (v/v) ratio. Cobalt reagent was a mixture of two solutions. Solution A consisted of cobalt nitrate (6 g) and glacial acetic acid (0.8 ml) added to a saturated and filtrated solution of potassium sulphate to give a final volume of 100 ml at 37°C. The solution was then maintained at 37°C. Solution B was a saturated solution of sodium sulphate, also maintained at 37°C. Triethanolamine (1.35 volumes) was made up to 10 volumes with solution A, following which 7 volumes of solution B were added and the mixture shaken well. This reagent being unstable was prepared just before use. The stock (colour) reagent consisted of a 0.4 % (m/v) 1-nitroso-2-napthol solution in 96 % ethyl alcohol. Just before the use, the colour reagent was diluted by a factor of 12.5 with ethyl alcohol.

The procedure involved addition of 250 µl of serum to glass-stoppered centrifuge tubes followed by 1.0 ml phosphate buffer and 6.0 ml of extraction solution. The mixture was shaken for 15 min on a reciprocating shaking machine at a rate of 100 cycles/min and centrifuged for 15 min at 826 x g. The buffer was removed by suction and 3 ml of the organic phase was added to 2.5 ml of cobalt reagent, mixed for 10 min and then centrifuged for 5 min at 826 x g. Finally a 2 ml aliquot of the organic phase was added to 2.5 ml of colour reagent and shaken. After 30 min the absorbance was read in a spectrophotometer at 500 nm. A blank and three standards were also run through the complete procedure. These standard solutions were prepared by dissolving the appropriate amounts of palmitic acid in the- chloroform-heptane-methanol extraction solution (De Villiers *et al.,* 1977).

2. Determination of glucose concentration

Glucose was determined using the enzyme method described by Gochman and Schmitz (1972). The method is based on the oxidation reaction in which the formed hydrogen peroxide reacts with phenol and 4-aminophenazone under catalysis of peroxidase to form a red-violet quinoneime dye as indicator. The absorbance of the reaction was bichromatically measured at 505 nm/692 nm. The change in absorbance is directly proportional to the amount of glucose present in the sample.

3. Determination of cholesterol concentration

An enzymatic method described by Allain *et al.* (1974) was used for cholesterol determination. The method involves complete hydrolysis of cholesterol esters in the serum to free cholesterol and free fatty acids by pancreatic cholesterol esterase. Thereafter, cholesterol liberated by the esterase, plus any free cholesterol originally present in the serum, are both oxidized by cholesterol oxidase. The liberated peroxide reacts with phenol and 4-aminoantipyrine in a peroxide catalysed reaction to form a quinoneimine dye, which absorbs at 500 nm. The change in absorbance is measured bichromatically at 505 nm/692 nm and is directly proportional to the amount of cholesterol present in the sample.

4. Determination of total protein concentration

Serum total protein was estimated by the Biuret method of Weichselbaum (1946). In this method, biuret reagent was allowed to complex with the peptide bonds of protein from the sample under alkaline condition to form a violet-coloured compound. Sodium potassium titrate was used as an alkaline stabilizer, and potassium iodide was used to prevent auto-reduction of the copper sulfate. The amount of the violet complex formed was proportional to the increase in absorbance when measured bichromatically at 544 nm/692 nm.

5. Determination of albumin concentration, globulin and albumin-globulin ratio

Albumin concentration was determined colorimetrically according to Doumas (1972). This method is based on the reaction between bromocresol green and albumin to form bromocresol green albumin complex. The increase in absorbance, as albumin complexes with the dye, is measured bichromatically at 629 nm/692 nm. This increase is proportional to the amount of albumin present in the sample. Globulin concentrations were computed as a difference between TP and albumin, whilst albumin/globulin (A/G) ratio was obtained by dividing the albumin value by the globulin value.

6. Determination of urea concentration

Urea estimation was by urease enzymatic kinetic ultraviolet method of Tietz (1995). The procedure involves hydrolysis of urea in the presence of water and urease to produce ammonia and carbon dioxide. The ammonia produced in the first reaction combines with Ŭ-oxoglutarate and Nicotinamide adenine dinucleotide (NADH) in the presence of glutamate-dehydrogenase to yield glutamate and NAD^+. The conversion of NADH chromophore to NAD^+ product, measured at 340 nm/647 nm, is proportional to the level of urease in the sample.

7. Determination of creatinine concentration

Creatinine concentrations were determined spectrophotometrically using colorimetric methods (Tietz, 1995). The method is based on the reaction between picrate and creatinine to form a red-orange complex. The change in absorbance is measured at 505 nm. The coloured complex formed is proportional to the creatinine concentration in the sample.

8. Determination of enzyme concentrations

Aspartate and alanine amino transaminases were determined by spectrophotometric method of Bergmeyer *et al.* (1986). The alanine transaminase (ALT) enzymatic assay kit uses a coupled enzymatic reaction scheme: alanine and Ŭ-oxoglutarate are first converted by ALT to L-glutamate and pyruvate, which is converted by lactate dehydrogenase to lactate and NAD^+. For aspartate transaminase (AST) determination, L-aspartate reacts with Ŭ-oxoglutarate in the presence of AST to yield L-glutamate and oxaloacetate. Oxaloacatate is then converted by malate dehydrogenase to L-malate and NAD^+. The conversion of NADH chromophore to NAD^+ product, measured at 340 nm, is proportional to the level of enzyme (ALT or AST) in the sample.

Alkaline phosphatase (ALP) was determined by the spectrophometric nitrophenol method of Tietz *et al.* (1993). In this method, ALP in serum catalyzes the hydrolysis of colourless p-nitorphenyl phosphate to p-nitrophenol and inorganic phosphate. In an alkaline solution (pH 10.5), p-nitrophenol is in the phenoxide form and has a strong absorbance at 408 nm. Zinc and magnesium ions act as activators for this reaction while the 2-amino-2-methyl-1-propanol buffer acts as an acceptor for the phosphate ions, which would inhibit the enzyme. The rate of increase in absorbance, monitored bichromatically at 408 nm/486 nm, is directly proportional to the ALP activity in the sample.

Creatine kinase (CK) and gamma-glutamyltransferase (GGT) were determined by enzymatic assay kits as described by Horder *et al.* (1991). The CK enzymatic assay kit measures the concentration of CK using the CK enzyme that converts ADP to ATP. The ATP produced by the CK is then detected by a coupled enzymatic reaction in which the ATP is first used to produce 6-glucose phosphate that is then used by a third enzyme to produce NADH from NAD^+, which is monitored by the absorbance change at 340 nm.

Gamma-glutamyltransferase determination procedure involves transfer of the gamma-glutamyl group of gamma-glutamyl-3-carboxy-4-nitroanilide by GGT to glycyl-glycine with the production of p-nitroaniline. The amount of 5-amino-2-nitrobenzoate results in the elevated absorbance at 408 nm, which is directly proportional to the activity of GGT in the sample.

9. Determination of the concentration of minerals

A dye binding method was used for calcium (Ca) determination (Cali *et al.,* 1972). In this method, Arsenazo reacts with calcium in an acid solution to form a bluish-purple coloured complex. The amount of coloured complex formed is quantified by determining the absorbance of the reaction mixture bichromatically at 647 nm/692 nm. At this wavelength, there is a linear relationship between absorbance, corrected for the reagent blank, and the amount of calcium-arsenazo complex.

Serum inorganic phosphorus (SIP) was determined colorimetrically according to the method of Young (1990). The method is based on the reaction between ammonium molybdate and phosphorus in the sample under acidic conditions to form phosphomolybdate complex. At completion of the reaction, the absorbance of the sample reagent mixture is read bichromatically at 340 nm/378 nm. The difference between these two absorbance values is proportional to the amount of SIP present in the sample.

Magnesium (Mg) concentration was determined colorimetrically (Tietz, 1976). In this method, magnesium ions react with xylidyl blue in an alkaline medium to form a water soluble purple-red chelate. The intensity of colour produced is directly proportional to the Mg concentration in the sample at 525 nm.

Iron (Fe) concentration was determined by a colorimetric method (Tietz, 1976) that uses ferrozine as the chromogen. In the measurement of serum Fe, ferric Fe is disassociated from its carrier protein (transferrin) by action of guanidine in an acid medium and simultaneously reduced to the ferrous form by hydroxylamine. The ferrous iron is then complexed with the chromogen to produce a blue chromophore. Iron concentration in the sample is directly proportional to the chromophore colour intensity measured at 560 nm.

Appendix 7: Protein status of indigenous Nguni and crossbred cattle in the semi-arid communal rangelands in South Africa. (Accepted in *Asian-Australian Journal of Animal Science*.

Appendix 8: Nutritional status, growth performance and carcass characteristics of Nguni steers supplemented with Acacia karroo leaf meal. (Published in *Livestock Science*)

Appendix 9: Meat quality of Nguni steers supplemented with Acacia karroo leaf-meal

Appendix 10: Meat sensory evaluation form

Sensory analysis of beef
Name: ………………………………… .. **Date: ………………**
Panellist No…………………………………… ..
Please evaluate the following samples of beef for the designated characteristics.

	Characteristics	Rating scale	1	2	3
1	**Aroma intensity** Take a few short sniffs as soon as you remove the foil. Typical chicken aroma	1= Extremely bland 2= Very bland 3= Fairly bland 4= Slightly bland 5=Slightly intense 6= Fairly intense 7= Very intense 8=Extremely intense			
2	**Initial impression of juiciness** The amount of fluid exuded on the cut surface when pressed between the thumb and forefinger	1= Extremely dry 2= Very dry 3= Fairly dry 4= Slightly dry 5=Slightly juicy 6= Fairly juicy 7= Very juicy 8=Extremely juicy			
3	**First bite** The impression that you form on the first bite	1= Extremely tough 2= Very tough 3= Fairly tough 4= Slightly tough 5=Slightly tender 6= Fairly tender 7= Very tender 8=Extremely tender			
4	**Sustained impression of juiciness** The impression of juiciness that you form as you start chewing	1= Extremely dry 2= Very dry 3= Fairly dry 4= Slightly dry 5=Slightly juicy 6= Fairly juicy 7= Very juicy 8=Extremely juicy			
5	**Muscle fibre & overall tenderness** Chew sample with a light chewing action	1= Extremely tough 2= Very tough 3= Fairly tough 4= Slightly tough 5=Slightly tender 6= Fairly tender 7= Very tender 8=Extremely tender			

6	**Amount of connective tissue (Residue)** The chewiness of the meat	1=Extremely abundant 2= Very abundant 3= Excessive amount 4= Moderate 5= Slight 6= Traces 7= Practically none 8= None			
7	**Overall flavour intensity** This is the combination of taste while chewing and swallowing referring to the typical chicken flavour	1= Extremely bland 2= Very bland 3= Fairly bland 4= Slightly bland 5=Slightly intense 6= Fairly intense 7= Very intense 8=Extremely intense			
8	**A- Typical flavour intensity**	**1**= None 2= Practically none 3= Traces 4= Moderate 5= Slightly intense 6= Fairly intense 7= Very intense 8= Extremely intense			

TICK RELEVANT A-TYPICAL FLAVOR/S						
1	Livery/bloody			**5**	Metallic	
2	Cooked vegetable			**6**	Sour	
3	Pasture /grassy			**7**	Unpleasant	
4	Animal like/kraal (manure			**8**	Other	