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Seasonal Changes in Energy-related Blood Metabolites and Mineral Profiles of Nguni and Crossbred Cattle on Communal Rangelands in the Eastern Cape, South Africa

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ABSTRACT : The objective of the current 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 on the sweet and sour rangelands of the Eastern Cape Province of South Africa. Body weights, body condition scores (BCS) 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 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 on the sweet rangeland during the late cool-dry season than on 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 on 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. Cattle on the sour rangeland had lower ($p<0.05$) iron concentrations than those on 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 on the sweet rangeland. (**Key Words :** Cholesterol, Glucose, Iron, Non-esterified Fatty Acids, Nguni Cattle, Phosphorus)

INTRODUCTION

Cattle production efficiency on communal rangelands is low, especially in the cool-dry season (Mapiye et al., 2009). For example, age at first calving and calving interval for cows exceed two years (Nqeno et al., 2009), steers reach slaughter weight between 24 and 30 months of age (du Plessis and Hoffman, 2004) and off-take rates vary between 2 and 10% per annum (Mapiye et al., 2009). This is mainly attributed to low feed quantity and quality on communal rangelands, particularly in the dry season (Angassa and Oba, 2007; Nqeno et al., 2009). Under such conditions, provision of feed supplements could be recommended to improve cattle production on communal rangelands. Before any nutritional improvements are recommended, it is, however, important to identify the types of nutrients limiting cattle production on a given rangeland (Ndlovu et al., 2009a).

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 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

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variation in energy and mineral supplies on the condition and performance of cattle on communal rangelands in South Africa has not been established.

Cattle production efficiency on communal rangelands in the semi-arid areas is often determined by nutrient availability, which, in turn, is mainly influenced by temperature and seasonal distribution of rainfall (Angassa and Oba, 2007). In South Africa, communal rangelands are principally divided into sweet and sour according to amount of precipitation received per annum and vegetation type. Sour rangelands receive between 600 and 800 mm of precipitation per annum and are mainly composed of annual grass species, which lose nutritive value and palatability during the dry season (Ellery et al., 1995). In contrast, precipitation on the sweet rangeland is less than 500 mm per annum and vegetation consists of perennial grasses that remain nutritious and palatable throughout the year (Ellery et al., 1995). The capability of these two rangeland types to meet energy and mineral requirements of communal cattle is largely unknown and therefore, warrants investigation.

The dominant beef breeds in the communal areas are non-descript crossbreds and the indigenous Nguni cattle. The non-descript crossbred cattle, characterised by a large frame size, are a product of indiscriminate crossbreeding between imported and indigenous breeds and institutional policies that promote use of imported beef breeds in communal areas (Mapiye et al., 2009). On the other hand, the Nguni breed is a sub-type of the African Sanga cattle (*Bos taurus africanus*) characterised by a small mature size (200-400 kg), hardiness and adaptability to subtropical conditions such as frequent occurrence of droughts (Mapiye at al., 2009) and high prevalence of nematodes (Ndlovu et al., 2009b), ticks (Muchenje et al., 2008) and tick-borne diseases (Marufu et al., 2009). Due to body size differences, Nguni and crossbred cattle raised under low-input production systems in South Africa are likely to have different nutrient requirements (Collin-Luswet, 2000) and, subsequently, perform differently on communal rangelands. Moreover, Sanga cattle have inherent capacity 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 for mobilisation of fatty acids for thermoregulation and energy reserves (Nonaka et al., 2008). There is, however, no information on the energy status and mineral profiles of Nguni and crossbred cattle on communal rangelands in 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 a 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 semi-arid areas.

Blood biochemical parameters such as glucose, cholesterol and non-esterified fatty acids (NEFA) are becoming important in determining the energy status 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., 2009a). 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, NEFA, inorganic phosphorous, calcium, magnesium and iron concentrations in Nguni and crossbred cattle on the sweet and sour rangelands of the Eastern Cape Province of South Africa. It was hypothesised that seasonal concentrations of energy-related metabolites and minerals in Nguni and crossbred cattle on these sweet and sour rangelands are similar.

MATERIALS AND METHODS

Study sites

The selection of research sites was based on rangeland type and the willingness of the communities to participate. 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. Cala area is positioned 31° 33′ S and 27° 36′ E at an altitude of 1,440 m above sea level. Mean monthly rainfall (mm) data for Cala between June 2007 and May 2008 is shown in Figure 1. Mean monthly minimum and maximum ambient temperatures in day time are recorded in July (11°C) and January (20°C), respectively. The most common grass species are *Themeda triandra*, *Heteropogon contortus*, *Sporobolus africanus* and *Microchloa ciliate*. *Acacia karroo*, *Acacia mearnsii*, *Chrysocoma ciliate* and *Dyspyrose scrabrida* are the common bush species (Lesoli, 2008). In the sour rangelands, cattle are grazed on communal rangelands during the hot-wet and post-rainy season and on croplands during the cool-dry and hot-dry seasons.

Sterkspruit area is situated 30° 37′ S and 27° 22′ E at an altitude of 1,507 m above sea level. It has a semi-arid climate with most of the rain falling between November and April (Figure 1). Ambient temperatures fluctuate between 10°C and 20°C, with minimum and maximum temperatures being recorded in July (9°C) and January (22°C), respectively. The most common grass species are *Elionurus muticus*, *H. contortus*, *Microchloa caffra*, *Setaria*

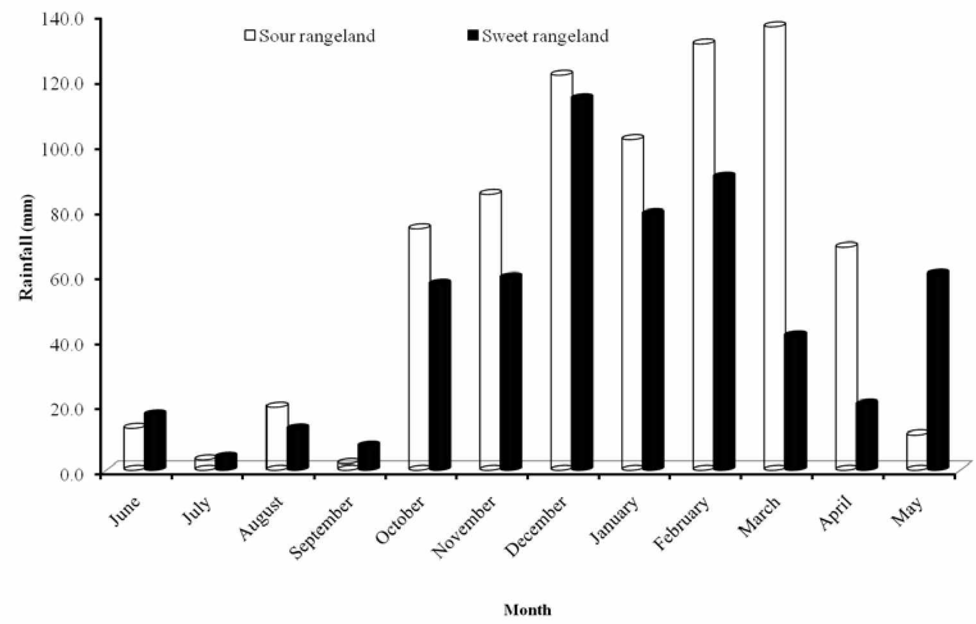

Figure 1. Mean monthly rainfall (mm) data for the sweet and sour rangelands between June 2007 and May 2008.

sphacelata and *T. triandra*. The rangelands are dominated by *Euryops pyroides* and *A. karroo* invader woody species (Lesoli, 2008). Cattle are grazed on communal rangelands throughout the year.

Animals

Cattle used for this research were selected based on the health status of the animals and willingness of cattle owners to participate. All cattle were ear-tagged at the beginning of the study for easy identification. Fifty clinically healthy cattle from each rangeland type were targeted for blood sampling in each season. The animals were scored for body condition using a 5-point scale (1-very thin and 5-obese). Most of the selected cattle had a BCS between 2 and 3. Table 1 shows the number of Nguni and local crossbred cattle sampled in each rangeland type by sex across seasons. Bulls were not included in this study. The number of cattle sampled in each season depended on the farmer's willingness to bring their tagged animals to the handling facilities. The animals were also classified by 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.

Body weight and body condition scores

Cattle body weights and BCS were measured 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). To determine the BCS, cattle were palpated and scored using a 5-point scale (1-very thin and 5-obese) (Nicholson and Butterworth, 1986).

Blood collection and analyses

Blood was collected from the coccyxgeal vein using an 18-gauge needle between 0700 and 0900 h once every season. For the determination of glucose, blood was collected into Vacutainer® blood tubes containing sodium

Table 1. Number of Nguni and crossbred cattle sampled on each rangeland type by sex across seasons

Season	Nguni				Crossbreds			
	Sweet rangeland		Sour rangeland		Sweet rangeland		Sour rangeland	
	M[1]	F[2]	M	F	M	F	M	F
Late cool-dry	8	12	8	11	15	20	20	25
Hot-dry	8	11	10	17	11	15	20	28
Hot-wet	8	10	7	10	10	12	17	22
Post-rainy	7	10	6	7	14	17	13	20
Early cool-dry	6	8	8	11	9	12	14	23

[1] M = Male. [2] F = Female.

Table 2. Least square means (±standard error of means) of body weight and body condition score of communal Nguni and crossbred cattle based on season

Season	Weight (kg)		BCS	
	Nguni	Crossbred	Nguni	Crossbred
Late cool-dry	425.3±20.10[ab]	439.3±35.10[ab]	1.67±0.09[ab]	1.64±0.09[ab]
Hot-dry	396.4±20.27[b]	400.4±35.27[b]	1.58±0.09[b]	1.52±0.09[b]
Hot-wet	485.4±21.32[a]	490.4±36.32[a]	1.8±0.103[a]	1.8±0.103[a]
Post-rainy	488.1±29.80[a]	492.1±34.8[a]	1.78±0.100[a]	1.77±0.100[a]
Early cool-dry	443.7±23.53[ab]	461.7±38.53[ab]	1.76±0.109[a]	1.72±0.109[a]

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°C) and centrifuged for 10 minutes at 1,000×g within 2 hours of collection. The serum was transferred into polypropylene tubes that were stored at -20°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.

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 and sex and some interactions on body weight, BCS, and concentrations of minerals and energy-related metabolites. The linear model was:

$$Y_{ijklm} = \mu+A_i+B_j+C_k+D_l+AB_{ij}+AC_{ik}+BC_{jk}+ABC_{ijk}+\varepsilon_{ijklm}$$

Where Y_{ijklm}= 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);

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;

ε_{ijklm} = 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. 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 the literature (Doornenball et al., 1988; Farver, 1997; Otto et al., 2000; Ndlovu et al., 2009a).

RESULTS

Body weight and body condition scores

Crossbreds (455.8±14.54 kg) had higher ($p<0.05$) body weights than Nguni cattle (420.7±15.35 kg). Sweet rangeland (420.1±35.09 kg) had lower ($p<0.05$) cattle weights than the sour rangeland (458.4±35.05 kg). Body weights for both breeds were higher on the sweet rangeland (420.1±35.09 kg) in the hot-wet and post-rainy seasons compared to other seasons (Table 2). Body condition scores for Nguni and crossbred cattle were higher ($p<0.05$) in the hot-wet and post-rainy seasons than in the other seasons (Table 2). Rangeland type and breed did not affect BCS.

Nutritionally-related energy metabolites

In the hot-wet seasons 78% of the cattle had glucose concentrations below the normal range ($p<0.01$; Table 3). 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 2A). Blood glucose concentrations were highest in cattle on the sour rangeland during the post-rainy season (Figure 2B) compared to other seasons. During the late cool-dry season, glucose concentrations in cattle on the sour rangeland were

Table 3. Proportions (%) of cattle that had normal, below and above reference range values for the different blood metabolites

Season	Category	Energy metabolites			Minerals			
		Glucose	Cholesterol	NEFA[1]	SIP[2]	Ca[3]	Mg[4]	Fe[5]
Late cool-dry	Below	42	0	46	3	1	0	0
(n = 119)	Normal	58	75	33	90	99	100	75
	Above	0	25	21	7	0	0	25
Hot-dry	Below	47	0	85	0	0	0	0
(n = 110)	Normal	53	71	15	92	99	99	96
	Above	0	29	0	9	1	1	4
Hot-wet	Below	78	0	97	25	30	7	3
(n = 89)	Normal	22	83	2	75	70	92	92
	Above	0	17	1	0	0	1	5
Post-rainy	Below	14	0	84	2	0	0	0
(n = 91)	Normal	85	38	12	80	91	97	76
	Above	1	62	4	18	9	3	24
Early cool-dry	Below	4	0	87	0	0	0	3
(n = 81)	Normal	96	44	11	89	100	99	90
	Above	0	56	2	11	0	1	7
Significance		**	**	**	**	**	**	**
Reference Interval [a]	Minimum	3.1	1.3	0.32	1.2	2.0	0.6	10.2
	Maximum	4.7	3.8	0.60	2.3	2.9	1.2	29.0

** Significance at $p<0.01$. [1] NEFA: Non-esterifed fatty acids; [2] SIP: Serum inorganic phosphorus; [3] Ca: Calcium; [4] Mg: Magnesium; [5] Fe: Iron.
[a] Reference values: Doornenball et al. (1988), Farver (1997) and Ndlovu et al. (2009a).

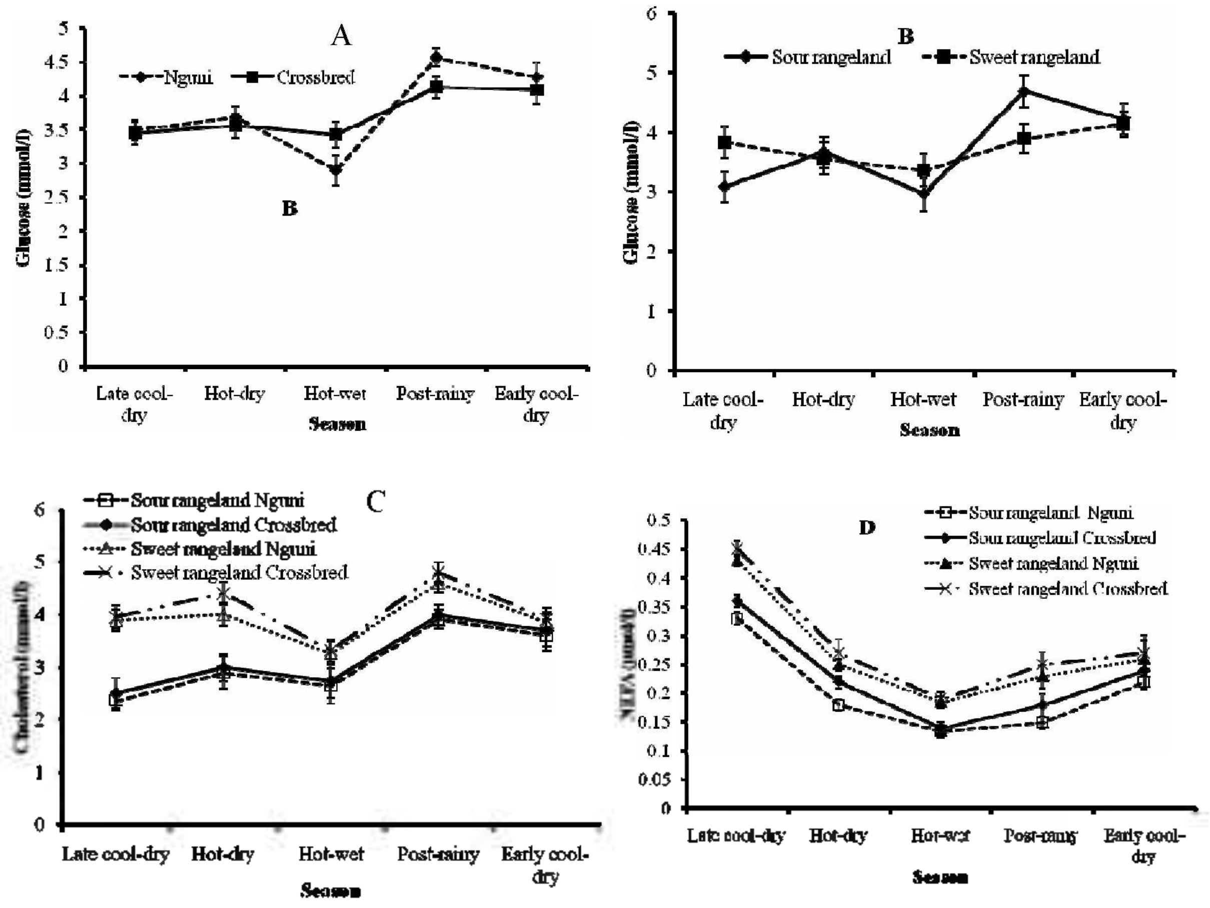

Figure 2. Least square means (±standard error) of glucose based on breed and season (A), glucose based on rangeland type and season (B), cholesterol (C) and non-esterified fatty acids (D) concentrations based on rangeland type, season and breed.

lower ($p<0.05$) than for cattle on the sweet rangeland. The sex, parity and cow physiological status had no effect on glucose concentrations (Table 3).

Most of the cattle in the post-rainy (62%) and early cool-dry season (56%) had cholesterol concentrations above the reference range ($p<0.01$; Table 3). Crossbred cattle had higher ($p<0.05$) cholesterol concentrations than Nguni cattle (Table 4). Highest cholesterol concentrations were recorded on the sweet rangeland during the post-rainy season compared to other seasons (Figure 2C). During the late cool-dry season, cholesterol concentration on the sour rangeland was lower ($p<0.05$) than on the sweet rangeland. Cholesterol concentrations were not influenced by sex, parity and physiological status of cows.

Over 80% of the cattle in all seasons, except in the late cool-dry season, had NEFA concentrations below the normal range (Table 3). 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 4). NEFA concentrations were highest on the sweet rangeland during the late cool-dry season (Figure 2D). Males (0.18±0.03 μmol/L) had 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). Parity did not affect NEFA concentrations.

Minerals

More than 75% of the cattle across breeds had phosphorus (SIP) concentrations within the standard range across all seasons (Table 3). Phosphorus concentrations were highest on the sweet rangeland during early cool-dry season and lowest on the sour rangeland during the hot-wet season (Figure 3A). Nguni cattle had higher concentrations of SIP in the post-rainy and early cool-dry seasons compared to crossbreds in the same seasons (Figure 3B). Phosphorus concentrations were not affected by sex, parity and physiological status of the cows.

Over 90% of the cattle had Ca concentrations within the reference range across all seasons (Table 3). 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 seasons (Table 3). Magnesium concentrations were significantly influenced by season; the hot-wet season had the lowest concentrations of Mg compared to other seasons (Figure 3C). The concentrations of Mg were not influenced by rangeland type, breed, sex, parity and cow physiological status.

As shown in Table 3, greater than 75% of the cattle had Fe concentrations within the reference range in all seasons. Cattle on the sour rangeland had lower ($p<0.05$) Fe concentrations than those on 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 3D). Breed, sex, parity and cow physiological status did not affect Fe concentrations.

Table 5. Least square means (±standard error of means) of non-esterified fatty acid concentration of cattle on communal rangelands based on cow physiological status

Physiological status	NEFA (μmol/L)	
	Nguni	Crossbred
Non-pregnant lactating	0.21±0.021[a]	0.22±0.031[a]
Non-pregnant non-lactating	0.21±0.021[a]	0.21±0.021[a]
Pregnant and lactating	0.30±0.123[b]	0.31±0.117[b]
Pregnant non-lactating	0.35±0.042[b]	0.36±0.036[b]

[a, b] Values with different superscripts across rows and columns are different ($p<0.05$).

DISCUSSION

The observation that glucose concentration was higher during the post-rainy season on the sour rangeland than in other 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;

Table 4. Least square means (±standard error of means) of energy-related metabolites and mineral concentrations of Nguni and local crossbred cattle on communal rangelands

Metabolite	Breed		Reference interval[1]	
	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	2.0	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 Doornenball et al. (1988), Farver (1997) and Ndlovu et al. (2009a)

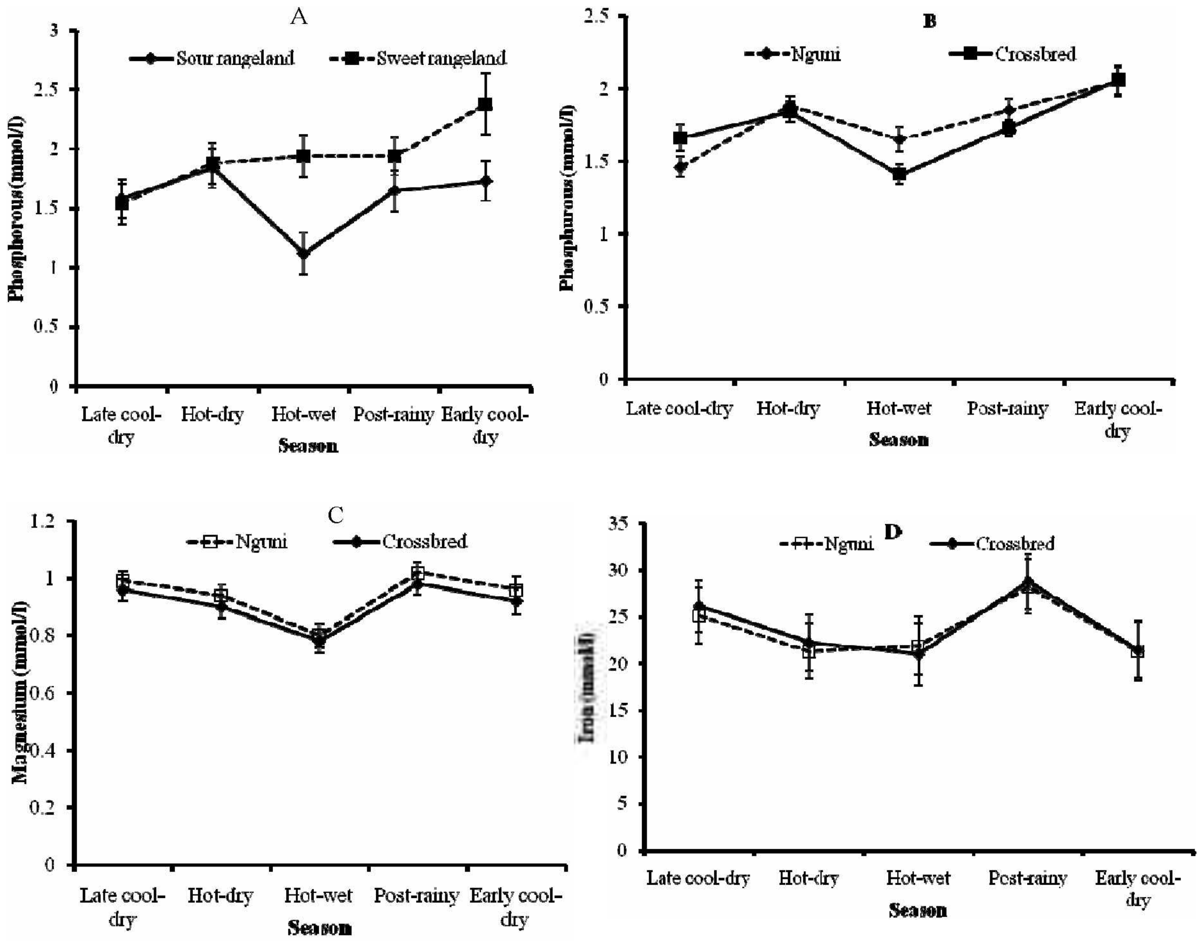

Figure 3. Least square means (±standard error of means) of phosphorus concentration based on rangeland type and season (A), phosphorus concentration based on breed and season (B) and least square means (±standard error of mean) of magnesium (C) and iron (D) concentrations based on season.

this consequently promotes forage and animal growth which reach a peak in the post-rainy season (Lesoli, 2008). According to Tainton (1999), the energy content of forages rises from 250 g/kg DM in the early growing season to 600 g/kg DM in the post-rainy season. The mean values of glucose in cattle were within the normal physiological range for cattle (Otto et al., 2000; Ndlovu et al., 2009a). Concentrations of serum glucose are useful indicators of dietary energy intake, stress and muscle damage in cattle (Whitaker et al., 1999).

The finding that most cattle in the late cool-dry and hot-wet seasons had glucose concentrations below the reference range and lower mean glucose concentrations compared to other seasons agrees with reports by Shaffer et al. (1981) and Ndlovu et al. (2009a). 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, therefore, 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. According to National Research Council (2001) small-framed cattle have lower energy demands than large-framed cattle. The observation that Nguni cattle had lower glucose concentrations may be an adaptation to high temperatures in the hot seasons (Ndlovu et al., 2009a). Use of small-framed and adapted cattle genotypes under low-input production systems where energy supply is limiting is, therefore, advisable.

The elevated cholesterol concentrations on 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). The mean values of cholesterol in cattle were within the normal reference range for cattle (Para et al., 1999; Ndlovu et al., 2009a). 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., 2009a) and therefore, low energy demands (Shaffer et al., 1981). Another possible explanation could be that the Nguni breed, being a Sanga type of cattle, tends to deposit fat intramuscularly and could, therefore, have less subcutaneous fat as energy reserves that could be mobilised to meet energy requirements compared to crossbreds.

The elevated NEFA concentrations reported in the late cool-dry season on the sweet rangeland could also be related to low rainfall and feed quality (Mayes and Bothman, 2003) and 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 suffers from nitrogen deficiency, low CP content reported during the cool-dry season (<50 g/kg DM) (Lesoli, 2008) could cause an additional energy deficiency (Hess et al., 2003). It could, therefore, be important to supplement cattle with both energy- and protein-rich feeds in the cool-dry season. 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, 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 females than in males was expected since cows require more energy to meet ovulation, pregnancy and lactation requirements (Otto et al., 2000).

Serum SIP concentrations are influenced by a multitude of factors which include availability of other nutrients, stress, growth, exercise, haemolysis, temperature and breed (McDowell, 1992; National Research Council, 2001). Serum inorganic phosphorous could therefore, be not a good indicator of inorganic phosphorus dietary intake (Whitaker et al., 1999). The highest SIP concentrations observed on the sweet rangeland during the early cool-dry season and lowest concentrations on sour rangeland during the hot-wet season could be, however, explained by differences in protein and energy availability (Lesoli, 2008). 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, 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).

The differences in SIP concentrations between Nguni and crossbred cattle could be ascribed to their difference in body size. Nguni, being a small-sized breed, might have lower demand for phosphorus than large breeds (Ndlovu et al., 2009a). 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 in crossbred cattle could, therefore, imply that the former are adapted to low SIP environments and could be recommended under such conditions. Generally, SIP concentrations reported in this study were within the range of the previous reports (Doornenbal et al., 1988; Ndlovu et al., 2009a).

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., 2009a). 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 effect.

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 content. 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). According to Martens and Rayssiguier (1980) and Miller et al. (1980), high rumen ammonia concentrations usually observed during the hot-wet season also interfere with absorption and/or utilisation of Mg. 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 season than in the other seasons could also be ascribed to increased availability (Lesoli, 2008). Iron content increases from the early growing season and reaches a peak in the post-rainy season (Tainton, 1999). The findings that Fe concentration was low on the sour rangeland and declined markedly in the hot-dry and hot-wet seasons are likely to be a consequence of parasitism (McDowell, 1992). The sour rangeland, especially in the hot-wet season, is characterised by high environmental temperatures and humidity, conditions conducive for tick proliferation and survival (Muchenje et al., 2008; Marufu et al., 2009). High densities of external parasites can cause blood loss and subsequently reduce iron concentration (Marufu et al., 2009).

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. These results could suggest that Nguni cattle are more adapted than crossbreds to the prevailing energy and mineral conditions found on communal rangelands. Cattle producers experiencing energy and SIP deficits during certain periods of the year are advised to use adapted breeds such as Nguni cattle or locally available energy and mineral supplements. However, 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.

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