Effect of season and age on blood minerals, liver enzyme levels, and faecal egg counts in Nguni goats of South Africa

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ABSTRACT: The objective of the study was to determine the relationships between age of the goat and faecal egg counts, liver enzymes, and minerals in the wet and dry seasons in male and female Nguni goats of South Africa. Fifty-six female and forty male Nguni goats were used for the study. Faecal and blood samples were collected once in the dry (August) and wet (January) season. Faecal egg counts (FEC) were determined by the modified McMaster technique while trematodes were determined by the sedimentation method. Blood was analyzed for phosphorus, calcium, magnesium, alkaline phosphatase (ALP), alanine transaminase (ALT), creatine kinase (CK), aspartate aminotransferase (AST), and gamma-glutamyltransferase (GGT) levels. Faecal egg counts were significantly higher in the wet compared with the dry season. Most ($P < 0.05$) of the goats were within the reference values for calcium, phosphorus, and magnesium in both seasons. Phosphorus concentrations were significantly affected by age with higher levels in the young (2.1 ± 0.06) compared to the adult (2.0 ± 0.03) goats. Alkaline phosphate was significantly affected by age with higher levels in young than in mature goats. Higher AST, CK, and GGT concentrations were recorded in the wet compared to the dry season ($P < 0.05$). Higher CK and AST were recorded in male than in female goats while for ALP, the values were higher in female than in male goats. Linear negative relationships ($P < 0.05$) existed between age and ALP, phosphorus, and FEC, while quadratic relationships existed between age and strongyles and *Strongyloides* egg counts. Calcium was linearly related ($P < 0.05$) to FEC, while CK was related to FEC in a quadratic fashion. Age of the Nguni goats can be used to predict faecal egg counts, phosphorus, and ALP levels.

Keywords: alkaline phosphatase; aspartate aminotransferase; calcium; phosphorus; nematodes

The health status of goats is a major determinant of the efficiency of goat production. Monitoring of goat health is, therefore, fundamental prior to addressing anomalies that might adversely affect performance of goats. Changes in live-weight and body conditioning (Ndlovu et al., 2007) have been used in the determination of the health status of livestock. These methods, however, fail to precisely indicate the health status of the animal (Schroder and Staufenbiel, 2006). Estimating the number and species of eggs, larvae or oocysts produced by endoparasites infecting the liver, digestive system, and respiratory tract of goats is a practical aid to diagnosis of gastrointestinal parasitism (Aitken, 2007). In addition, determination of levels of blood parameters is useful in predicting health problems that reduce animal performance and might result in mortalities (Kida et al., 2007). Blood profiling is capable of detecting subclinical metabolic disorders (Bertoni et al., 2000) and, therefore, reflects the actual status of the animal (Caldeira et al., 2007).

This fact, therefore, induces the need to determine levels of blood analytes such as serum minerals and quantities of liver enzymes in blood.

Minerals play a fundamental role in forage digestion, reproductive performance, and the development of bones, muscles, and teeth (Smith and Sherman, 1994). Below or above normal calcium, magnesium, and/or phosphorus levels indicate problems with health status of goats (Invartsen and Andersen, 2000). In addition, aspartate aminotransferases (AST), glutamyltransferase (GGT), alkaline phosphatase (ALP), and alanine aminotransferase (ALT), which are enzymes that are mostly produced by the liver (Smith and Sherman, 1994), are also predictive of the health status of goats (Otto et al., 2000; Ikhimioya and Imasuen, 2007; Pierce et al., 2007; Mahgoub et al., 2008). The information obtained from liver enzymes, blood minerals, and faecal egg counts substantiates the physical examination and, coupled with medical history, provides an excellent basis for estimation of severity of cases (Piccione et al., 2010) and treatment of goats (Tibbo et al., 2008). Although several studies have been conducted on blood parameter levels in goats (Pambu-Gollah et al., 2000; Kannan et al., 2003; Stella et al., 2007) and several others on the use of faecal egg counts (Hoste et al., 2005; Stella et al., 2007; Rumosa Gwaze et al., 2009a) in monitoring the health status of goats, none have been focused on the relationship between these parameters.

In determining such relationships, it is also of paramount importance to investigate the effect of sex on blood analytes and faecal egg counts. Mbassa and Poulsen (1991) reported a higher level of creatine in male than in female goats and attributed the higher levels in the male goats to their more active muscle mass compared to females. Some researchers (Qamar et al., 2009; Rumosa Gwaze et al., 2010b) have indicated a negative relationship between age and faecal egg counts which they attributed to the delay in development of immunity in younger animals thereby increasing their susceptibility to infection by faecal eggs compared to the adult goats. Others have reported an inverse relationship between age and some liver enzymes (Toba et al., 1992; Antunovic et al., 2004). Qamar et al. (2009) reported higher faecal egg counts in the wet compared to the dry season. These authors attributed the rise in FEC in the wet season to the presence of suitable climatic conditions for the development of free-living stages of the nematodes during the rainy season. A few reports have focused on assessing the relationships between age and blood profile analytes. If a relationship exists between any two parameters, the value of either can be used to predict the value of the other. In addition, several researchers have indicated that breed (Azab and Abdel-Maksoud, 1999; Daramola et al., 2005; Tibbo et al., 2008) modulates blood profiling values. However, a universal metabolic profile for goats cannot be established. Moreover, the values that are in use have been generated from goats raised outside the local conditions and, might therefore be inappropriate to indigenous breeds. The Nguni goats are endowed with good mothering ability, adaptability, hardiness, and resistance to diseases and parasites (Barry and Godke, 2001). They exhibit low mortality rate (less than 10%) compared to breeds such as the Boer goats that can exhibit mortality of up to 30% (Lehloenya et al., 2005). Conception rates of 52%, litter sizes of 2.0, and a gestation period of 149.1 ± 0.8 days, with some goats giving birth to quadruplets, have been observed in this genotype (Lehloenya et al., 2005). In addition, the Nguni doe's milk has been shown to have high milk fat yield of 8%, lactose content of 8%, and protein content of 5% (Lehloenya et al., 2005). Due to such attributes, farmers in the Eastern Cape Province of South Africa place a high value on this goat genotype (Rumosa Gwaze et al., 2009b, 2010a). The objective of the study was, therefore, to determine the relationships between age of the goat and faecal egg counts and, liver enzymes and blood minerals in the wet and dry seasons in male and female Nguni goats of South Africa.

MATERIAL AND METHODS

Description of the study site

The study was conducted at the University of Fort Hare farm, which is situated in the False Thornveld of the Eastern Cape Province. The average annual rainfall is 480 mm with most of it falling in summer. The mean annual temperature on the farm is 18.7°C. The vegetation is composed of several trees, shrubs, and grass species. *Acacia karroo, Themeda triandra,* and *Panicum maximum* dominate in this area. The soil types in this area are loam, sand, and clay soils.

Experimental goats and their management

Fifty-six female and forty male Nguni goats were randomly selected for the study. The goats were clinically healthy throughout the study period. The animals were vaccinated against cowdriosis and

dosed once every fortnight in the rainy season and once a month in the dry season. The goats were allowed to graze and browse on natural pastures from 9 a.m. till 5 p.m. when they were penned. No supplementary feeding was provided. The goats were classified into young (less than one year old) and mature (whose age exceeded one year).

Faecal sample collection

Faecal samples were collected per rectum for each goat using a glycerine lubricated latex glove once in the dry (August, 2007) and wet (January, 2008) season. Faecal samples were stored in a cooler box at 4°C before being transported to the laboratory for analysis. Faecal egg counts (FEC) were determined by the modified McMaster technique with saturated solution of sodium chloride as the floating medium. 4 g of faeces were mixed in 56 ml of saturated solution of sodium chloride. The number of nematode eggs per g of faeces was obtained by multiplying the total number of eggs counted in the two squares of the McMaster slide by the dilution factor of 50 (Whitlock, 1948). The McMaster technique detects 50 or more eggs per g of faeces. Samples were screened for flukes by means of the sedimentation method described by Soulsby (1982). This technique is the most widely employed method for this purpose. It is quick and the eggs are floated free of debris before counting. In addition, the method is robust and accurate (Levecke et al., 2011). The method was used without any modification. Nematode egg types were identified using keys developed by Soulsby (1982), Uhlinger (1991), and Foreyt (2001). The prevalence for each species of gastrointestinal parasite was calculated as

$$P = \frac{d}{n}$$

where:

P = prevalence

d = number of goats infested with the gastrointestinal parasite at a given time

n = number of animals in the population at risk at that particular time

Blood collection and analyses

The experiment was approved by the Animal Ethics Committee of the University of Fort Hare. Blood samples from each goat were collected in January and August (i.e. in the wet and dry season, respectively), via the jugular vein into a plain test tube. The plain test tubes containing blood were centrifuged at 1000 *g* for 10 min to obtain serum, which was stored at −20°C prior to analysis. Serum was analyzed using commercially available kits (Siemens, Midrand, South Africa) and a Chexcks machine (Next/Vetex Alfa Wasseman Analyser, Woerden, the Netherlands). Inorganic phosphorus (Young, 1990), calcium (Cali et al., 1972), and magnesium (Tietz, 1976) were determined by the use of colorimetric methods. Alkaline phosphatase activity, alanine transaminase, and gamma-glutamyltransferase levels in the blood serum were analyzed spectrophotometrically according to the method by Bürger et al. (2005). Ultraviolet methods were used for determinations of creatine kinase (CK) (Horder et al., 1991) and aspartate aminotransferase (AST) (Bergmeyer et al., 1986). The values for blood analytes were categorized into below, within, and above normal values considering the reference values, as presented in Table 1.

Table 1. Reference values[1] of selected blood chemistry measurements in clinically healthy goats

Blood parameter	Reference values
AST (U/l)	167.00–513.00
ALP (U/l)	93.00–387.00
ALT (U/l)	6.00–19.00
CK (U/l)	0.80–8.90
Calcium (mmol/l)	2.23–2.93
Magnesium (mmol/l)	0.31–1.48

ALP = alkaline phosphatase, ALT = alanine transaminase, CK = creatine kinase, AST = aspartate aminotransferase, GGT = gamma-glutamyltransferase

[1]Kaneko (1997)

Statistical analyses

Data were analyzed using the general linear models procedure of SAS (Statistical Analysis System, Version 9.0, 2003) to determine the effect of season and age of goat on faecal egg counts (FEC) and levels of blood minerals and liver enzymes. The FEC were transformed using $\log_{10}$ (FEC + 1) to normalize the data. Comparison of means was done using the PDIFF procedure of SAS. The chi-square test was used to compare frequencies among animals that were below, within, and above the

reference range for the liver enzymes and minerals. The effect of season on prevalence of each parasite species was determined by the chi-square test of SAS. The relationships between the liver enzymes and mineral levels with age of the goat and faecal egg counts were determined using the quadratic response surface model PROC RSREG procedure of SAS.

RESULTS

Faecal egg counts

The total egg counts were significantly affected by main effects of season and age of the goats. There were higher ($P < 0.05$) total egg counts in the wet season (3.0 ± 0.07) than in the dry season (1.6 ± 0.18). Significantly higher counts were observed in young (3.1 ± 0.18) than in mature (2.4 ± 1.12) goats.

Season had an effect ($P < 0.05$) on counts of the *Trichlostrongylus* egg type with higher egg counts in the wet than in the dry season as shown in Figure 1. Age of the goat had no effect ($P > 0.05$) on counts of this egg type. Strongyle egg counts were affected ($P < 0.05$) by main effects of season and age of the goat. Significantly higher strongyle egg type counts were recorded in the wet than in the dry season as shown in Figure 1. Young goats had significantly higher (2.5 ± 0.71) strongyle egg counts compared to counts in mature (2.0 ± 0.17) goats.

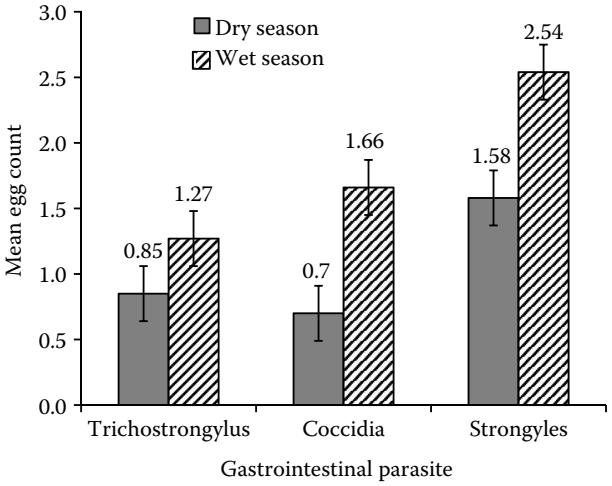

Figure 1. Variation of faecal egg counts for different parasites with season

Paramphistomum egg type counts were significantly affected by age with higher counts in the young (1.6 ± 0.17) than in mature (0.7 ± 0.11) goats, with the high standard error resulting from the unselected goats. Season did not affect ($P > 0.05$) *Paramphistomum* egg type counts. *Fasciola* egg type counts were not affected ($P > 0.05$) by the fixed factors tested. Coccidial egg counts were affected ($P < 0.05$) by main effects of season and age of the goat. Higher ($P < 0.05$) egg counts were observed in the wet than in the dry season (Figure 1). Coccidial egg counts were higher ($P < 0.05$) in young (1.7 ± 0.73) than in mature (1.1 ± 0.11) goats.

Table 2. Percentages of goats that were below, within, and above the reference range of values for different blood metabolites

Parameter	Wet season				Dry season			
	below	within	above	SL	below	within	above	SL
Calcium	19.5 (8)	80.5 (33)	0	**	9.1 (5)	90.9 (50)	0	**
Magnesium	0	100 (41)	0	**	1.8 (1)	98.2 (54)	0	**
ALT	0	78.0 (32)	22.0 (9)	**	0	90.9 (50)	9.1 (5)	**
ALP	82.9 (34)	14.6 (6)	2.4 (1)	**	58.2 (32)	38.2 (21)	3.64 (2)	*
AST	97.6 (40)	2.4 (1)	0	**	98.2 (54)	1.82 91)	0	**
CK	0	0	100 (41)	**	1.8 (1)	98.2 (54)	0	**
GGT	0	92.7 (38)	7.3 (3)	**	7.3 (4)	90.9 (50)	1.8 (1)	**

SL = significance level, ALP = **al**kaline phosphatase, ALT = alanine transaminase, CK = creatine kinase, AST = aspartate aminotransferase, GGT = gamma-glutamyltransferase

figures in parentheses indicate the number of goats in that particular category

*significance at $P < 0.05$

**significance at $P < 0.001$

Blood mineral and liver enzyme levels

Serum calcium, magnesium, and phosphorus. Most ($P < 0.05$) of the goats were within the reference values for calcium in both seasons (Table 2). Season and age had no ($P > 0.05$) effect on calcium levels. Serum levels of magnesium were within the reference range for most ($P < 0.05$) of the goats (Table 2). Significantly higher phosphorus levels were observed in the young compared to the adult goats (Table 3). Season had no effect ($P > 0.05$) on blood phosphorus concentrations.

Liver enzymes. Alanine transaminase values for most ($P < 0.05$) of the goats were within the reference range. Season had no effect ($P > 0.05$) on ALP while main effects of age affected ($P < 0.05$) the ALP concentrations. Alkaline phosphatase levels were significantly higher in young than in mature goats (Table 3).

Aspartate aminotransferase values were below the normal values in both seasons (Table 2). Higher ($P < 0.05$) AST concentrations were recorded in the wet than in the dry season (Table 4) and in male than in female goats (Table 5). For most ($P < 0.05$) of the goats, CK levels were above the normal values in the wet season and within the reference values in the dry season as depicted in Table 2. Creatine kinase was significantly affected by season

Table 3. Least square means (± standard errors) of blood chemistry measurements of young and mature experimental goats

Characteristics	Age	
	young (<1 year old)	mature (>1 year old)
Calcium (mmol/l)	2.40 ± 0.050	2.4 ± 0.030
Magnesium (mmol/l)	1.00 ± 0.035	0.99 ± 0.020
Phosphorus (mmol/l)	2.13 ± 0.060[a]	1.96 ± 0.030[b]
ALT (U/l)	15.43 ± 2.590	16.54 ± 1.550
ALP (U/l)	109.25 ± 14.001[a]	79.32 ± 3.003[b]
AST (U/l)	78.55 ± 4.900	76.32 ± 3.022
CK (U/l)	208.20 ± 28.801	196.75 ± 17.513
GGT (U/l)	42.17 ± 2.260	39.14 ± 1.360

ALP = **a**lkaline phosphatase, ALT = alanine transaminase, CK = creatine kinase, AST = aspartate aminotransferase, GGT = gamma-glutamyltransferase

[a,b]values in the same row with different superscripts are different ($P < 0.05$)

Table 4. Least square means (± standard errors) of blood chemistry measurements of experimental goats in dry and wet seasons

Characteristics	Season	
	dry	wet
Calcium (mmol/l)	2.45 ± 0.032	2.37 ± 0.046
Magnesium (mmol/l)	1.03 ± 0.022	0.96 ± 0.031
Phosphorus (mmol/l)	2.02 ± 0.040	2.08 ± 0.058
ALT (U/l)	15.07 ± 1.633	16.91 ± 2.297
ALP (U/l)	83.49 ± 8.870	84.88 ± 12.540
AST (U/l)	69.60 ± 3.139[b]	85.26 ± 4.438[a]
CK (U/l)	148.47 ± 18.126[b]	256.69 ± 25.630[a]
GGT (U/l)	35.44 ± 1.422[b]	45.86 ± 2.010[a]

ALP = **a**lkaline phosphatase, ALT = alanine transaminase, CK = creatine kinase, AST = aspartate aminotransferase, GGT = gamma-glutamyltransferase

[a,b]values in the same row with different superscripts are different ($P < 0.05$)

Table 5. Least square means (± standard errors) of blood chemistry measurements of different sexes of experimental goats

Characteristics	Sex	
	male	female
Calcium (mmol/l)	2.34 ± 0.030[b]	2.48 ± 0.050[a]
Magnesium (mmol/l)	1.00 ± 0.023	0.99 ± 0.030
Phosphorus (mmol/l)	2.04 ± 0.040	2.06 ± 0.060
ALT (U/l)	16.43 ± 1.687	15.54 ± 2.508
ALP (U/l)	74.31 ± 8.070[b]	114.06 ± 6.851[a]
AST (U/l)	80.86 ± 3.191[a]	74.00 ± 2.109[b]
CK (U/l)	206.01 ± 18.100[a]	199.09 ± 18.126[b]
GGT (U/l)	41.20 ± 1.460	40.01 ± 1.402

ALP = **a**lkaline phosphatase, ALT = alanine transaminase, CK = creatine kinase, AST = aspartate aminotransferase, GGT = gamma-glutamyltransferase

[a,b]values in the same row with different superscripts are different ($P < 0.05$)

Table 6. Effect of age of goat and faecal egg counts on blood analytes

Parameter	Polynomial	Equation	R^2
Age			
ALP	linear	197.0 (49.84)* – 59.4 (27.67)x	0.04
Phosphorus	linear	2.4 (0.12) – 0.2(0.07)x	0.08
Strongyloides egg counts	quadratic	14.4(3.89) – 5.9 (2.11)x – 0.1(0.3) x^2	0.09
Strongyles egg counts	quadratic	48.3 (8.70) – 19.1 (4.72)x – 0.2(1.0) x^2	0.17
Total FEC	linear	84.5 (12.47) – 33.9(6.77)x	0.23
Total FEC			
Calcium	linear	2.5 (0.03) – 0.1 (0.02)x	0.07
Phosphorus	linear	1.9 (0.07) + 0.1 (0.03)x	0.05
CK	quadratic	10.3 (31.10) + 4.2 (1.47)x – 0.2 (0.01) x^2	0.06

FEC = faecal egg counts, ALP = alkaline phosphatase, CK = creatine kinase

*values in parentheses are standard errors

with a higher ($P < 0.05$) concentration in the wet compared to the dry season (Table 4). Age had no effect ($P > 0.05$) on serum CK levels. Significantly higher GGT values were recorded in the wet than in the dry season (Table 4). Age of the goat did not ($P > 0.05$) affect the GGT values.

Relationship between age, faecal egg counts, and blood mineral and liver enzyme levels in the wet and dry seasons

Table 6 shows the relationships between age and the faecal egg counts and blood parameters, and between faecal egg counts and the different blood parameters. There were significant quadratic relationships between age and strongyles egg counts and *Strongyloides* egg counts as indicated in Table 6. A negative linear relationship existed between age and total faecal egg counts. There was a significant quadratic relationship between CK and faecal egg counts while the relationship between faecal egg counts and calcium was in a negative linear fashion, as shown in Table 6. A negative relationship ($P < 0.05$) between FEC and phosphorus also existed.

There was a negative relationship ($P < 0.05$) between age and ALP. There was no relationship

($P > 0.05$) between age and AST, ALT, CK, and GGT. There was a negative linear relationship ($P < 0.05$) between age and phosphorus levels. Calcium and magnesium were not significantly related to age.

DISCUSSION

The finding that helminth egg counts were higher in the wet than in the dry season concurs with observations by several researchers (Regassa et al., 2006; Mbuh et al., 2008; Chenyambuga et al., 2009; Rumosa Gwaze et al., 2009a). Wet environmental conditions are favourable for the development, survival, and translocation of pre-parasitic stages of gastrointestinal nematodes and trematodes during the wet season implying a steady build up of adult worms in grazing goats that results in peak worm loads being recorded in the wet season (Mbuh et al., 2008). Thereafter, worm populations decline with the lowest numbers being encountered in the dry season (Nwosu et al., 2007; Rumosa Gwaze et al., 2009a). The higher levels of egg counts in the younger goats were ascribed to the poor immunity status of the young (Matjila and Penzhorn, 2003) goats which increases their susceptibility to gastrointestinal parasites.

The observation that there were no significant differences in blood calcium and phosphorus levels in goats between the seasons might indicate that *A. karroo,* which the goats browsed, catered for the period when deficiency of this mineral would have been experienced. *Acacia karroo* has calcium and phosphorus contents of around 1.73 and 0.13%, respectively (Mapiye et al., 2009), which augment the lower values in grass in the dry season. Our finding might also indicate that these minerals are regulated homeostatically and are, therefore, maintained within narrow limits (Honhold et al., 1991). The finding that phosphorus was higher in younger goats compared to mature goats concurs with Mbassa and Poulsen (1991) who reported a decrease in phosphorus level of goats with an increase in age. The lower serum phosphorus concentration in mature goats could be attributed to a reduced capacity to assimilate phosphorus from diet as the animal grows (Blood and Radostits, 1989). In addition, serum phosphate may be higher in younger animals because the growth hormone increases renal phosphate resorption (Kaneko et al., 1997).

The finding that magnesium levels were within the reference range might be attributed to the regulation of this mineral in the body of the animal. With excessive magnesium intake, the main route of excretion is through urine while with low intake or absorption, serum magnesium levels may be stabilized by magnesium mobilization from the bone (Neathery et al., 1990). This regulation might explain why there was no seasonal variation in the magnesium level. The finding that most goats had mineral values within the physiological ranges might indicate that the goat flock studied did not require supplementation of the minerals investigated in this study. It might also suggest that the goats are adapted to the levels prevailing on the pastures available to them.

Liver enzymes have an extracellular function and, thus, occur in low quantities with increases signifying damage in the tissues in which they are lodged. The concentration of serum enzymes reflects enzymes that are either in transit from the site of synthesis to the site of action or which have been released from the damaged cells (Grünwaldt et al., 2005). The observed lower values of ALP in mature goats correspond with the lower values of phosphorus recorded for the mature animals compared to the young goats. The finding that ALP levels were higher in young goats compared to mature goats concurs with Antunovic et al. (2004) who reported a decrease in ALP level with an increase in age of goats. Tibbo et al. (2008) and Piccione et al. (2010) had similar findings with Arsi-Bale goats of Ethiopia and Girgentana goats of Italy, respectively. In young growing animals, osseus ALP is the predominant form of serum ALP which diminishes as maturation progresses until the epishysis closes (Toba et al., 1992; Farver, 1997). In addition, ALP activity is associated with the process of calcification (Toba et al., 1992), which accompanies growth, thereby resulting in higher values in younger animals. The finding that ALP levels were below the reference range might indicate that the reference range used is inappropriate for the goat breed studied.

The elevated concentrations of AST in the wet season might be ascribed to the increased feed availability compared to the feed available during the dry season. In addition, the finding that AST levels were below normal in both seasons might indicate that either the goats did not reach their peak in terms of muscle growth, probably due to lack of feed in the dry season and due to helminthes

in the wet season, or that the reference values used were inappropriate for the breed studied.

The higher CK concentrations in the wet season compared to the dry one could be partly attributed to gastrointestinal parasites which were significantly higher in the wet season compared to the dry one. This was further evidenced by the fact that all the goats were above the reference range in the wet season and within the range during the dry season, when the faecal egg load was low. Creatine kinase, an enzyme lodged in skeletal muscles, is released into the plasma in response to stress and/or muscle damage (Kannan et al., 2000). The finding that GGT values were higher in the wet season than in the dry season might also signify the stress caused by gastrointestinal parasites.

The observed negative relationship between age and strongyles, *Strongyloides*, and total FEC highlights the negative impact of gastrointestinal parasites in the Nguni goats. The finding that higher CK concentrations were obtained in the wet season compared to the dry was further evidenced by a quadratic relationship between FEC and the levels of CK. Moreover, the negative linear relationship between calcium levels and faecal egg counts also signifies how helminthes can interfere with the nutrition of the host animal. Similar findings were also established by Mbuh and Mbwaye (2005) and Tu et al. (2009) who attributed the low calcium levels in infected goats to the distribution of some of the calcium as an inflammatory response induced by helminthes infection. It might, therefore, be assumed that these negative effects of helminthes were responsible for lack of weight gain in goats in the wet season, as there were higher faecal egg counts in the wet season compared to the dry one, regardless of the abundance of lush pastures during that particular season.

The observed lower values of ALP in mature goats were further evidenced by a negative linear relationship between this enzyme and age. In addition, the low levels of the enzyme obtained corresponded with the lower values of phosphorus recorded for the mature animals compared to the young goats, a finding also confirmed by a negative linear relationship between age and phosphorus.

The fact that ALP was the only enzyme that was affected by age might indicate that this enzyme did not originate from the liver. High values of ALP in the young goats are due to their fast growth rate that results in leakage of the enzyme from the growing bones and intestines into the blood (Kaneko et al., 1997). If the helminthes in goats had elicited enough hepatic insults, then other enzymes would have been elevated as well, which was not the case in this study. Our findings indicate that the goats used in this study are resilient to helminth infection or the reference values used were inappropriate for the breed studied.

CONCLUSION

Blood mineral levels of the goats studied were within the reference range indicating that the flock does not require mineral supplementation. Liver enzymes such as AST, CK, and GGT were elevated in the wet season when faecal egg counts were higher compared to the dry season. Linear negative relationships existed between age and ALP, phosphorus and FEC while quadratic relationships existed between age and strongyles and *Strongyloides* egg counts. Calcium was linearly related to FEC while CK was related to FEC in a quadratic manner. Results from this study signify that there is a potential in using these liver enzymes and calcium levels in the determination of stress in the Nguni goats. Age of the Nguni goats, however, can only be used to predict faecal egg counts, phosphorus, and ALP levels.

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Received: 2011–11–09
Accepted after corrections: 2012–05–16

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