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Relationship between Nutritionally-related Blood Metabolites and Gastrointestinal Parasites in Nguni Goats of South Africa

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ABSTRACT : The objective of the study was to determine the relationship between faecal egg counts and nutritionally-related blood metabolites in Nguni goats of South Africa. Body weights, body condition scores (BCS), FAMACHA scores, faecal and blood samples were collected from 96 Nguni castrates. Faecal samples were analysed using the modified McMaster technique for nematodes and the sedimentation method for trematodes. Blood was analysed for packed cell volume (PCV), glucose, cholesterol, total protein, albumin, urea and creatinine. Season had an effect on glucose, globulin, total protein, creatinine, PCV and faecal egg counts (FEC). Globulin, PCV, creatinine and FEC were significantly higher in the wet season compared to the dry season. A quadratic relationship existed between faecal egg count loads and BCS whilst negative linear relationships were observed between faecal egg counts and creatinine, albumin and cholesterol levels of Nguni goats. (**Key Words :** Alkaline Phosphatase, Creatinine, FAMACHA Scores, Total Protein)

INTRODUCTION

The South African goat population is estimated at seven million (FAOSTAT, 2008) with 50% being owned by smallholder farmers (Shabalala and Mosima, 2002). One of the major indigenous goat breeds in South Africa is the Nguni breed (Lehloenya et al., 2005). 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 other breeds such as the Boer goats that can exhibit a mortality of up to 30% (Lehloenya et al., 2005). Although the milk yield of these goats is low, the quality of the milk has been shown to have high milk fat yield of 8%, lactose content of 8% and protein content of 5%. Conception rates as high as 52%, litter sizes of 2.0±0.2 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).

With the desirable characteristics exhibited by the indigenous Nguni goat, coupled with a notion of breeding them commercially, it is imperative to accurately assess and monitor their nutritional status. Under such situations, it is important to accurately assess the nutritional status of this breed as such information is fundamental in the formulation of their diets. The conventional methods of using changes in live-weight, body condition scores (Ndlovu et al., 2007) and worm identification (Kusiluka and Kambarage, 1996) to determine the nutritional status of livestock lack accuracy (Schroder and Staufenbiel, 2006). Knowledge of the metabolic profiles could be useful in predicting and avoiding metabolic problems before a serious or even irreparable condition is presented (Caldeira et al., 2007; Kida et al., 2007). Analysis of biochemical properties of goats, coupled with other methods, such as packed cell volume and the FAMACHA technique, is essential in diagnosing the various nutritional, pathological and metabolic disorders (Daramola et al., 2005) in goats.

Nutritionally-related blood metabolites, routinely used in the dairy industry, include glucose, non-esterified fatty acids, cholesterol, blood urea nitrogen, creatinine and total proteins. Studies have been conducted to determine metabolites that indicate energy status in goats and the effect of variation in nutrient supply on blood metabolites (Pambu-Golla et al., 2000). These studies did not, however, determine if there were relationships between the metabolites and the health status of the goats. It is important

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to note that there is an interaction between nutrition and nematode parasitism (Sasaki et al., 2002; Hoste et al., 2005). It is, therefore, important to determine the relationships, if any, between blood metabolite levels and parameters that indicate the health status of the animal. Little, if any, information is available on relationships of concentrations of nutritionally-related blood metabolites with faecal egg counts, FAMACHA scores, body condition scores and body weights in Nguni goats. The objectives of the study were, therefore, to determine the relationship between faecal egg counts and nutritionally-related blood metabolites in Nguni goats of the Eastern Cape Province of South Africa. The hypothesis tested was that there is no relationship between faecal egg counts and nutritionally-related blood metabolites in Nguni goats raised in the Eastern Cape Province of South Africa.

MATERIALS AND METHODS

Description of the study site

The study was conducted at the University of Fort Hare farm. The farm is situated in the False Thornveld of the Eastern Cape Province. The average annual rainfall is 480 mm with most of it falling in the hot-wet season. 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*, *Sporobolus africanus*, *Sporobolus fimbriatus*, *Panicum maximum*, *Aristida congesta*, *Digitaria eriantha*, *Eragrostis* species and *Cynodon dactylon* are the main browse species found in the area. The soil types in this area are loam, sand and clay soils. The topography of the area is generally flat with a few steep slopes (Mucina and Rutherford, 2006). Most grasses had about 160 and 70 g/kg crude protein in the wet and dry seasons, respectively.

Experimental goats and their management

Ninety-six Nguni castrates were randomly selected for the study. The goats were clinically healthy throughout the study period. Animals were subjected to a routine sanitary control programme i.e. vaccination against cowdriosis and dosing once every fortnight in the rainy season and once a month in the dry season. The goats grazed and browsed on natural pastures from 09:00 h and were penned at 17:00 h. No supplementary feeding was provided. The goats were classified into young (≤one year) and mature (>one year) goats.

Body weights, body condition scores and FAMACHA scores

The goats were weighed using a digital scale and body condition scored in the dry (August, 2007) and wet (January, 2008) seasons. Body condition scores were assigned on a scale of 1 to 5, according to Friedricks (1993), with a score of 1 indicating a thin and emaciated goat whilst a condition of 5 indicated an obese goat. The FAMACHA scores were determined by opening the lower eyelid of the goat and comparing the colour of the conjunctivae with five different scores on a chart, with 1 indicating a non-anaemic goat whilst a 5 indicated a severely anaemic goat following guidelines by Kaplan et al. (2004). Two veterinarians were responsible for body condition and eye scoring and the average scores were considered.

Faecal sample collection and laboratory analyses

Faecal samples were collected in the dry (August, 2007) and wet (January, 2008) seasons. Faecal egg counts were determined by the modified McMaster technique with a saturated solution of sodium chloride as the flotation medium (Whitlock, 1948). Four grams of faeces were mixed in 56 ml of saturated solution of sodium chloride. The number of nematode eggs per gram 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 gram of faeces. Samples were screened for flukes by means of the sedimentation technique and identified using keys developed by Soulsby (1982), Uhlinger (1991) and Foreyt (2001).

Blood collection and laboratory analyses

Blood samples were collected in January and August (i.e. in the wet and dry season, respectively). For each goat, blood samples were taken via the jugular vein into a plain test tube (for biochemical assays) and one containing ethylene diamine tetra acetic acid (EDTA) to obtain un-coagulated blood for PCV determination. Within two hours after collection, blood from EDTA-containing tubes was mixed gently for two minutes before drawing it up a 75× 1.5 mm capillary tube for three-quarters of its length. One end of the capillary tube was sealed before the capillary tubes were then placed in a micro-haematocrit centrifuge before centrifuging at 2,000×g for 10 minutes at room temperature. The tubes were then put in the haematocrit reader to note the reading. The reading was expressed as a percentage of packed red cells in the total volume of whole blood.

Plain test tubes containing blood for biochemical assays were centrifuged at 1,000×g for 10 minutes to obtain serum, which was stored at -20°C until analysis. Serum was analysed at the University of Pretoria in South Africa, using commercially available kits (Siemens, South Africa) and a Chexcks machine (Next/Vetex Alfa Wasseman Analyser, Woerden, Netherlands). Serum samples were analysed by

the enzymatic method for glucose and, spectrophotometrically for total protein (TP) (Wechselbaum, 1946), albumin (Doumas, 1972) and creatinine (Tietz, 1995) by use of colorimetric methods. 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 concentration.

Glucose was analysed using the method described by Gochman and Schmitz (1972), where reagent NAE2-27 was used after enzymatic oxidation in the presence of glucose oxidase. For the determination of the cholesterol content of the sample, cholesterol esters in the serum were completely hydrolysed to free cholesterol and free fatty acids by pancreatic cholesterol esterase as described by Calame et al. (1975). Total protein content of the samples was determined by the method described by Lowry et al. (1951) whilst the albumin content of each sample was determined by the method of Pinnell and Northam (1978). Blood urea nitrogen (BUN) analysis (Tietz, 1995) was quantified using an enzymatic kinetic UV method. The blood values were categorized into below, within and above normal values based on the reference values presented in Table 1.

Statistical analyses

Data were analyzed using the generalized linear models procedures of SAS (2003) to determine the effect of season and age on body condition score (BCS), FAMACHA scores, faecal egg counts (FEC), PCV and levels of blood parameters. Faecal egg counts (FEC) were logarithmically transformed using $\log_{10}$ (FEC+1), whilst body condition and FAMACHA scores were square root-transformed to normalize the data. Comparison of means was done using the PDIFF procedure (SAS, 2003). The chi-square test was also used to compare frequencies of goats that had normal, below and above the reference value for each metabolite. The relationships between each blood metabolite and FAMACHA score, body condition score and body weight were determined using the quadratic response surface model PROC RSREG procedure of SAS (SAS, 2003).

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

Blood parameter	Reference values
Glucose (mmol/L)	2.78-4.16
Cholesterol (mmol/L)	-
Creatinine (μmol/L)	88.4 0-159.00
Total protein (g/L)	64.00-70.00
Albumin (g/L)	27.00-39.00
Globulin (g/L)	27.00-41.00
A/G (albumin:globulin ratio)	6.30-12.60
Urea (mmol/L)	3.57-7.14

Source: Kaneko (1997).

RESULTS

Body condition, FAMACHA scores and packed cell volume

Body weights of the goats were affected by age with young goats weighing less ($p<0.05$) than mature goats (19.1±1.76 versus 52.3±1.03). Season did not affect body weights and BCS. FAMACHA scores were influenced by season with significantly higher scores in the wet (2.0± 0.07) season than in the dry season (1.3±0.05). Age did not ($p>0.05$) affect FAMACHA scores. Packed cell volume values were affected by season, with significantly higher levels in the dry season (31.3±0.64) compared to the wet season (24.3±0.93), and age, with higher values in mature goats (30.5±0.63) compared to young goats (25.2±1.01).

Faecal egg counts

The total faecal egg counts were affected by season and age of the goats. There were higher ($p<0.05$) egg counts in the wet season (3.0±0.07) than in the dry season (1.6±0.18). Significantly higher egg counts were observed in young (3.1±0.18) than in mature (2.4±1.11) goats. Season affected ($p<0.05$) *Trichlostrongylus* egg type counts, with higher counts in the wet than in the dry season (Figure 1). Age had no effect ($p>0.05$) on counts of *Trichlostrongylus* egg type. Strongyle egg counts were affected ($p<0.05$) by season with higher counts in the wet than in the dry season (Figure 1). Young goats had significantly higher (2.5±0.71) strongyle egg counts compared to mature (2.0±0.17) goats.

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. Season did not affect

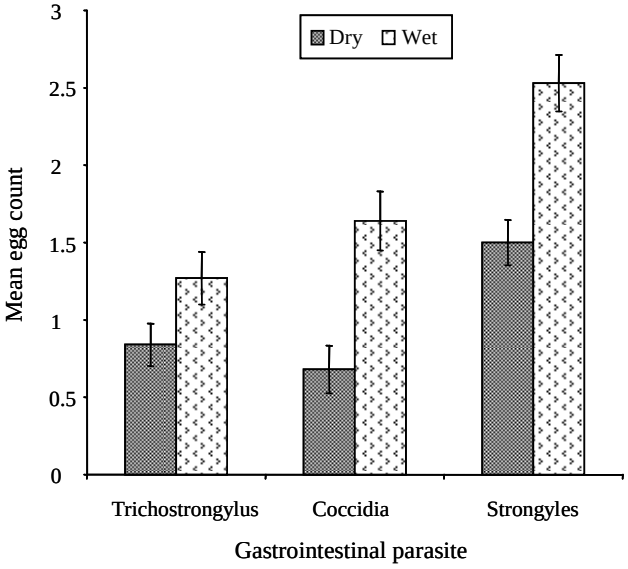

Figure 1. Variation of levels of faecal egg counts for different parasites with season.

Table 2. Proportions (%) of goats that had normal, below and above reference values for the different blood metabolites

Parameter	Wet				Dry			
	Below	Normal	Above	SL	Below	Normal	Above	SL
Glucose	65.9 (27)	34.2 (14)	0	**	47.3 (26)	46.6 (24)	9.1 (5)	NS
TP	0	2.4 (1)	97.6 (40)	**	0	12.7 (7)	87.3 (48)	**
Albumin	85.4 (35)	14.63 (6)	0	**	36.4 (20)	63.6 (35)	0	*
Globulin	0	0	100 (41)	**	0	3.6 (2)	86.4 (53)	**
Creatinine	87.8 (36)	12.2 (5)	0	**	68.5 (37)	31.5 (17)	0	**
Urea	0	73.2 (30)	26.8 (11)	*	9.1 (5)	52.7 (29)	38.2 (21)	*
A/G ratio	100	0	0	**	100 (55)	0	0	**

Values in parentheses indicate the number of goats in that particular category.
* Iindicates significance at p<0.05; ** Indicates significance at p<0.01.
SL = Significance level; NS = Not significant; TP = Total protein; A/G = Albumin:globulin.

(p>0.05) *Paramphistomum* egg type counts. *Fasciola* egg counts were not (p>0.05) affected by the fixed factors tested. Coccidia egg counts were affected (p<0.05) by both season and age. Higher (p<0.05) coccidia egg counts were observed in the wet season than in the dry season (Figure 1). Coccidia egg counts were higher (p<0.05) in young (1.7± 0.73) than in mature goats (1.1±0.11).

Blood metabolites

Glucose and cholesterol : Most (66%, p<0.05) of the goats had blood glucose levels below the normal values in the wet season (Table 2). Blood glucose levels were significantly affected by season with higher levels (p<0.05) in the dry compared to the wet season (Table 3).

Total protein, albumin, globulin, creatinine, urea and albumin/globulin ratio : About 98% of the goats had TP values above the reference values in both seasons (Table 2). Season affected TP levels with higher (p<0.05) values in the wet than in the dry season (Table 3). Age had no effect on the level of TP. The majority (about 85%, p<0.05) of the goats had albumin levels below the normal values during the wet season (Table 2). Season had an effect on the albumin levels with significantly higher levels in the dry compared to the wet season (Table 3). All the goats had globulin levels above the reference values in the wet season (Table 2). The A/G ratios for all the goats were below the normal values. Season did not affect A/G ratio.

Most (p<0.05) of the goats had creatinine levels below the normal values in both seasons (Table 2). Blood creatinine concentrations were significantly affected by season with higher (p<0.05) levels in the dry than in the wet season (Table 3) and in the mature than in young goats (Table 4).

Relationships between blood metabolites, faecal egg counts and BCS

There was a negative relationship (p<0.05) between age and the different gastrointestinal faecal egg counts (Table 5). There was a linear relationship between age and coccidial oocyst counts whilst quadratic relationships existed between age and *Paramphistomum*, strongyles, *Trichuris* and *Strongyloides* egg counts (Table 5). There was a quadratic relationship between BCS with *Fasciola* and total nematodes whilst a linear relationship existed between BCS

Table 3. Least square means (±standard errors) of blood chemistry measurements of Nguni goats in the dry and wet seasons

Parameter	Season	
	Dry	Wet
Glucose (mmol/L)	2.99±0.076[a]	2.65±0.109[b]
Cholesterol (mmol/L)	2.01±0.088	1.99±0.125
Total protein (g/L)	75.28±1.046[b]	87.87±1.471[a]
Albumin (g/L)	27.48±0.378[a]	24.06±0.535[b]
Globulin (g/L)	48.21±1.046[b]	63.86±1.479[a]
Albumin/globulin ratio	0.64±.119	0.34±0.169
Creatinine (μmol/L)	77.31±1.950[a]	69.27±2.750[b]
Urea (mmol/L)	7.22±0.690	6.17±0.976

[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 young and mature experimental goats

Characteristic	Age	
	Young	Mature
Glucose (mmol/L)	2.80±0.122	2.84±0.070
Cholesterol (mmol/L)	1.95±0.140	2.04±.081
Total protein (g/L)	80.34±1.662	82.82±0.994
Albumin (g/L)	25.43±0.600	26.11±0.360
Globulin (g/L)	55.30± 0.990	55.76±1.000
Albumin/globulin ratio	0.45±0.190	0.53±0.110
Urea (mmol/L)	6.88±1.090	6.51±.660
Creatinine (μmol/L)	67.9±3.100[b]	78.7±1.870[a]

[a,b] Values in the same row with different superscripts are different (p<0.05).

Table 5. Relationships among age, blood metabolites and gastrointestinal parasites

Parameters	Polynomials	p-value	R^2
Age*globulin	Quadratic	0.63	0.00
	Linear	0.04	0.05
Age*NEFA	Quadratic	0.91	0.02
	Linear	0.05	0.00
Age*TP	Quadratic	0.26	0.01
	Linear	0.04	0.05
Age*albumin	Quadratic	0.05	0.00
	Linear	0.69	0.04
Age*albumin-globulin ratio	Quadratic	0.51	0.00
	Linear	0.10	0.03
Age*glucose	Quadratic	0.88	0.00
	Linear	0.56	0.00
Age*cholesterol	Quadratic	0.11	0.03
	Linear	0.54	0.03
Age*urea	Quadratic	0.04	0.05
	Linear	0.56	0.00
Age*creatinine	Quadratic	0.05	0.00
	Linear	0.69	0.04
Age**Paramphistomum*	Quadratic	0.05	0.25
	Linear	0.05	0.11
Age**Fasciola*	Quadratic	0.88	0.00
	Linear	0.56	0.00
Age*Total trematodes	Quadratic	0.05	0.25
	Linear	0.05	0.18
Age*coccidian	Quadratic	0.08	0.04
	Linear	0.05	0.05
Age*strongyles	Quadratic	0.03	0.06
	Linear	0.06	0.04
Age**Trichuris*	Quadratic	0.04	0.05
	Linear	0.05	0.08
Age**Strongyloides*	Quadratic	0.05	0.12
	Linear	0.05	0.04
Age*total nematodes	Quadratic	0.05	0.11
	Linear	0.05	0.07

NEFA = Non-esterified fatty acids. TP = Total protein.

Table 6. Relationships among BCS, blood metabolites and gastrointestinal parasites

Parameters	Polynomials	p-value	R^2
BCS*globulin	Quadratic	0.53	0.00
	Linear	0.92	0.00
BCS*NEFA	Quadratic	0.61	0.00
	Linear	0.45	0.00
BCS*TP	Quadratic	0.45	0.00
	Linear	0.50	0.00
BCS*albumin	Quadratic	0.78	0.00
	Linear	0.05	0.08
BCS*glucose	Quadratic	0.05	0.22
	Linear	0.05	0.09
BCS*cholesterol	Quadratic	0.27	0.02
	Linear	0.21	0.02
BCS*urea	Quadratic	0.06	0.05
	Linear	0.76	0.00
BCS*creatinine	Quadratic	0.20	0.02
	Linear	0.05	0.17
BCS**Paramphistomum*	Quadratic	0.08	0.04
	Linear	0.05	0.15
BCS**Fasciola*	Quadratic	0.05	0.18
	Linear	0.05	0.17
BCS*total trematodes	Quadratic	0.05	0.25
	Linear	0.05	0.18
BCS*coccidia	Quadratic	0.08	0.00
	Linear	0.67	0.05
BCS*strongyles	Quadratic	0.61	0.00
	Linear	0.07	0.05
BCS**Trichuris*	Quadratic	0.09	0.05
	Linear	0.87	0.00
BCS**Strongyloides*	Quadratic	0.66	0.00
	Linear	0.25	0.02
BCS*total nematodes	Quadratic	0.58	0.00
	Linear	0.04	0.08

BCS = Body condition score. NEFA = Non-esterified fatty acids. TP = Total protein.

with *Paramphistomum* and total trematode counts (Table 6). As shown in Table 7, there was a linear decrease in albumin, cholesterol and creatinine with an increase in total faecal egg count. A negative quadratic relationship existed between *Paramphistomum* egg type counts and age of the goat (Table 5).

There was a quadratic relationship between glucose level and BCS (Table 6). There was a linear increase in albumin with an increase in BCS (Table 6), whilst a linear increase in creatinine level with an increase in BCS was also observed (Table 6). There also existed a negative quadratic relationship between age and creatinine (Table 5). None of the fixed effects tested affected ($p>0.05$) urea levels.

DISCUSSION

The finding that body weights did not improve in the wet season, regardless of the availability of lush pasture, might indicate that goats were adversely affected by the higher infestation of gastrointestinal parasites in the wet season compared to the dry season. The higher faecal egg loads in the wet season compared to the dry season were accompanied by higher FAMACHA scores. The FAMACHA technique estimates the level of infection by *H. contortus* through assessing the anaemic level of the mucous membranes of the goat (Kaplan et al., 2004). Higher levels of strongyle egg loads in the wet season, obtained in the current study, associated with higher FAMACHA scores and lower PCV values, than in the dry season, might indicate that *H. contortus* was a health

Table 7. Relationships between FEC and blood metabolites

Parameters	Polynomials	p-value	R^2
FEC*globulin	Quadratic	0.66	0.00
	Linear	0.92	0.00
FEC*NEFA	Quadratic	0.36	0.02
	Linear	0.51	0.00
FEC*TP	Quadratic	0.42	0.01
	Linear	0.23	0.03
FEC*albumin	Quadratic	0.96	0.00
	Linear	0.04	0.17
FEC*albumin-globulin ratio	Quadratic	0.70	0.04
	Linear	0.18	0.00
FEC*glucose	Quadratic	0.18	0.04
	Linear	0.20	0.03
FEC*cholesterol	Quadratic	0.06	0.06
	Linear	0.04	0.08
FEC*urea	Quadratic	0.32	0.02
	Linear	0.82	0.00
FEC*creatinine	Quadratic	0.10	0.03
	Linear	0.01	0.07

FEC = Faecal egg counts. NEFA = Non-esterified fatty acids.
TP = Total protein.

challenge for the flock during the wet season. These findings agree with Kaplan et al. (2004) and Dawo and Tibbo (2005) who reported positive correlations between FAMACHA eye scores and worm burden of *H. contortus* and a negative correlation between eye scores and PCV. A high *H. contortus* level of infestation entails a reduction in the volume of red blood cells due to the blood-sucking nature of this helminth (Honhold et al., 1989; Kaplan et al., 2004). The positive linear relationship between albumin levels and BCS conforms to the negative linear relationship that existed between the albumin levels and FEC. These relationships might be ascribed to the fact that goats with high loads of gastrointestinal parasites exhibited a poor condition and low levels of albumin, since amino acids that are supposed to be used in the formation of albumin are used by the gastrointestinal parasites. Matanovic et al. (2007) found higher levels of albumin in uninfected goats compared to the infected group. According to this author, there is a strong relationship between nutrition and gastro intestinal parasites in goats, where animal with higher protein, of which albumin is a component, are able to control establishment of new parasites and reduce fecundity of existing parasites, both of which could result in reduced FEC (Coop and Kyriazakis, 2001).

The finding that egg loads of different gastrointestinal parasites were significantly higher in the wet than in the dry season agrees with several reports (Abo-Shehada, 2003; Regassa et al., 2006; Mbuh et al., 2008). Wet environmental conditions are favourable for the development, survival and translocation of pre-parasitic stages of gastrointestinal nematodes and trematodes during the wet season. There is, therefore, a steady build up of adult worms in grazing goats resulting 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). The higher levels of egg counts of the different gastrointestinal parasites and coccidia in the younger goats is ascribed to the poor immunity status of the young (Matjila and Penzhorn, 2003) goats which increases their susceptibility to gastrointestinal parasites. The quadratic relationship between BCS and *Fasciola* egg type counts and the linear relationship between BCS and *Paramphistomum* egg loads also highlights the negative impact of gastrointestinal parasites in the Nguni goats.

The finding that blood glucose concentrations in goats were lower in the wet than in the dry season could be attributed to the increase in body temperatures and respiration rate of the animals as a physiological response to thermal stress that is characteristic of the wet season in the study area (Grunwaldt et al., 2005). The observed increase in cholesterol with a decrease in faecal egg counts could be ascribed to elevated glucose concentrations in blood, during the dry season, that promote the secretion of insulin (Reynolds et al., 2003). Elevated insulin levels decrease cyclic adenosine monophosphate concentrations, thereby triggering cholesterol synthesis (Grunwaldt et al., 2005).

The seasonal variation in TP could partly be explained by fluctuations of grass quality with season. It, however, is important to note that globulin levels were above the normal values in both seasons, thereby contributing to the high values of TP. The even higher globulin levels in the wet season, probably due to helminth infestation, contributed to the higher TP values in the wet season compared to values in the dry season. The higher globulin values obtained in the wet compared to the dry season might be attributed to inflammation due to gastrointestinal parasites whose load was higher in the wet season. The globulin concentrations become elevated to counterbalance the lower concentrations of albumin to support osmotic pressure (Payne and Payne, 1987). The high globulin values in the current study, regardless of season, warrant investigation to determine what chronic health challenge is affecting this goat flock. The observed negative linear relationship between globulin and age indicates that young goats had higher strongyle egg loads leading to more globulin production compared to mature goats. The low A/G ratio can be ascribed to an increase in globulin concentration caused by chronic parasitism or compensation for the albumin loss, signifying protein malnutrition which might be characteristic of helminthosis (Honhold et al., 1989).

In addition to the higher levels of globulin in the wet season, higher creatinine levels were obtained in the dry

season compared to the wet season. The elevated levels of creatinine in the dry season could be attributed to recycling of urea which is a response to limited dietary protein intake as indicated by the lower TP in the dry compared to the wet season. Higher creatinine values are indicative of disorders of renal origin (Wisloff et al., 2003). Blood creatinine concentrations are related to reduced filtration in the kidneys and increased production due to muscle catabolism. Higher urea levels can be attributed to increased production of ammonia in the rumen due to a high feed intake (Caldeira et al., 2007). Under restricted feeding, however, breakdown of muscle can result in elevated levels of urea. This, therefore, implies that inferences about dietary intake of protein based solely on blood urea might be inappropriate (Mellado et al., 2004). Blood urea concentration may be a useful indicator of protein status within a group of animals, and could, therefore aid in altering diets or identifying problems associated with a feeding programme (Kohn et al., 2005). The finding that mature goats had more creatinine than young goats might be attributed to more muscles in the former. The positive relationship between creatinine and BCS might also be due to the fact that goats in a better condition have more muscles and, therefore, more creatinine. The negative relationship between faecal egg counts and creatinine might be attributed to a deficiency of protein as high faecal egg counts, which signify high gastrointestinal parasite loads, cause protein loss resulting in muscle loss (Matanovic et al., 2007).

The observed relationships between BCS and albumin levels and creatinine indicate that BCS is a useful tool in estimating the energy and protein status of goats (Cabiddu et al., 1999). This improvement of body condition score with most of the blood metabolites indicates that goats in good condition had a better nutritional status compared to goats in poor condition.

CONCUSION

A quadratic relationship existed between faecal egg count loads and BCS whilst a negative linear relationship was observed between creatinine, cholesterol and albumin with faecal egg counts. These metabolites could be useful in studies of subclinical effects of parasites in Nguni goats. It, therefore, means that determination of these metabolites, coupled with physical examination of Nguni goats are crucial in maintenance of the health of these genotypes.

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