Gastrointestinal nematode infestation, goat performance and nutritionally-related blood metabolites of Xhosa lop-eared does foraging in grasslands and forestland vegetation types

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Declaration

I declare that this dissertation has not been submitted to any University and that it is my original work conducted under the great supervision of Professor Michael Chimonyo at University of KwaZulu-Natal and Dr Munyaradzi C. Marufu at the University of Pretoria. All the assistance towards the production of this work and all the references contained herein have been duly credited.

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Abstract

Gastrointestinal nematode infestation, goat performance and nutritionally-related blood metabolites of Xhosa-lop-eared does foraging in grasslands and forestland vegetation types

By

Luxolo Qokweni

The broad objective of the current study was to determine gastrointestinal nematode infestation (GIN), goat performance and nutritional status of Xhosa lop-eared does foraging in grassland relative to those browsing in forestland vegetation types. A cross-section survey was conducted to 282 goat farmers from Mbizana Local Municipality in Alfred Nzo district, South Africa to investigate perceptions on the control of GIN infestation. Data collected included household demography, goat health and parasites, goat feeding and management. Variation in the prevalence of gastrointestinal parasites and their effect on growth performance in 309 Xhosa lop-eared goats with an average age of 7 months raised in grassland and forestland vegetation types were determined. In this experiment, 165 indigenous Xhosa lop-eared does were conducted to assess the effect of vegetation type, season and parity on the burden of GIN in Xhosa lop-eared does that were foraging in grassland and forestland vegetation types. Morever, 24 indigenous Xhosa lop-eared does were used to determine the interaction between vegetation type and season on nutritionally-related blood metabolites, liver enzymes and minerals.

Farmers in the grassland vegetation type ranked gastrointestinal parasites as the major constraint to goat productivity than those in the forestland. Farmers in the grassland were more likely to experience gastrointestinal nematode infestation than those in forestland vegetation types ($P < 0.05$). Farmers in the grassland vegetation types were more likely to control gastrointestinal nematode infestation than to those in forestland vegetation type ($P < 0.05$). Xhosa lop-eared goats in the forestland vegetation type had higher ($P < 0.05$) body condition score (BCS), body weight (BW) and lower faecal egg count (FEC) compared to those in grassland. Goats with higher ($P < 0.05$) BCS and BW had lower FEC in both vegetation types. The higher higher ($P < 0.05$) BCS was observed in Xhosa lop-eared does foraging in the forestland vegetation type compared to those in the grassland vegetation type. Xhosa lop-eared does from grassland had higher FEC ($P < 0.05$) compared to those in forestland vegetation type. In the forestland vegetation type body condition scores and FAMACHA scores were significantly higher during the hot-wet season than cool-dry and post-rainy seasons, while FEC were observed higher in the grassland than forestland vegetation type. Strongyles and *Strongyloides* eggs were higher in does grazing in the grassland than those in the forestland vegetation type during the hot-wet season. It was concluded that goats are constrained by infestation of gastrointestinal parasites, particularly in the hot-wet season. Poor quality and quantity of forage experienced in the grassland vegetation type can be rectified by feeding goats in forestlands, which can cheaply improve growth performance of goat and health and production in does.

Xhosa lop-eared does in the forestland vegetation types had higher ($P < 0.05$) serum concentration of total protein (TP), globulin, albumin/globulin (A/G) ratio and total bilirubin (TB) during the hot-wet than cool-dry seasons. Total bilirubin concentrations werehigher ($P < 0.05$) in does in the forestland vegetation type during hot-wet season. The serum concentration of calcium was lower ($P < 0.05$) during the cool-dry season in both vegetation types. Phosphorus concentrations were higher ($P < 0.05$) in the grassland vegetation type during the cool-dry season than hot-wet season. Albumin/globulin ratio was lower ($P < 0.05$) in the forestland vegetation type during hot-wet season than cool-dry season. It was concluded that Xhosa lop-eared does are constrained by high prevalence and loads of gastrointestinal nematode infestation, particularly in the grassland vegetation type during hot-wet season. Kids were more susceptible to gastrointestinal nematodes than older goats. The interaction of vegetation type and season should be considered in developing control strategies for gastrointestinal nematodes in Xhosa lop-eared goats.

Key words: Faecal egg count, Parasites, Indigenous goats, Body condition scores, Body weights. FAMACHA score. Packed cell volume

List of Acronyms and Abbreviations

Abbreviation	Description	Units
BCS	Body condition score	
BW	Body weight	
GLM	General linear model	
DRDAR	Department of Rural Development and Agrarian Reform	
FEC	Faecal egg count	
FS	FAMACHA score	
EPG	Eggs per gram	
Kg	Kilogram	
LSM	Least square means	
SAS	Statistical Analysis System	
GIN	Gastrointestinal nematodes	
° C	Degrees Celsius	
Log_{10}	Logarithm to base 10	
SE	Standard Error	
TP	Total protein	mg/dl
Alb	Albumin	g/dl
A/G	Albumin/globulin ratio	U/I
ALT	Alanine aminotransaminase	U/I
GGT	Gamma-glutamyltransferase	U/l
LDH	Lactate dehydrogenase	U/I

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Dedication

I dedicate this thesis to my family and those who supported me through thick and thin on my journey. May this thesis be an instrument and tool to encourage more PhD’s in my entire family, as I am the first person to obtain PhD.

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Chapter 1: General Introduction

1.1 Background

The South African indigenous goat population is estimated at over six million (Chokoe *et al.*, 2020). Eastern Cape Province is a leading producer of goats in South Africa with a total flock of 2.12 million goats (Chokoe *et al.*, 2020), with more than 60 % of indigenous goats being kept under communal production systems (du Toit *et al*., 2014; Mdladla *et al*., 2017). These goats contribute greatly on livelihoods of resource-limited farmers on food and nutrition security, as they serve as an important source of meat (Simela, 2005), milk, manure, hides and cash (Thornton *et al*., 2002). They are also used in traditional ceremonies (Mdladla *et al*., 2017). Moreover, indigenous goats possess good mothering ability, adaptability, hardiness and resistance to diseases and parasites (Barry and Godke, 2001). These features make it easier to keep and manage indigenous goats in resource-limited communities.

Despite the positive attributes, goat farming system in communal production systems is faced with various challenges which include, high prevalence of gastrointestinal nematodes (Zvinorova *et al*, 2016), frequent droughts, fluctuations in feed availability and quality, poor husbandry practices and low and unreliable market prices (Thornton *et al*., 2007; Musemwa *et al*., 2008). Gastrointestinal nematode infestation is considered as one of the main health challenges that limit goat production worldwide, especially in communal areas of developing countries (Roeber *et al*., 2013; Zvinorova *et al.*, 2016). Globally, *Haemonchus contortus* is the most common and major health challenge in goats (Vatta and Lindberg, 2006; Sanhokwe *et al*., 2016). It is associated with great economic losses, lowered goat productivity and cause high mortality, especially of kids (Jiménez-Colmenero *et al*., 2001; Marume *et al*., 2012). Both Marume *et al.* (2012) and Jansen *et* *al.* (2020 highlighted that *Haemonchus contortus* reduce the immunity status of goats and its ability to fight infections.

Natural vegetation plays an important role in goat farming. Rangelands in Southern Africa are dominated by grasslands, fodder trees and shrubs that are important sources of feed for goats (Aganga *et al*., 2000; Belachew *et al*., 2013). There are many tree species such as *Vachellia* species that are abundant in rangelands of Southern Africa and are able to grow in severe and dry conditions (Abdulrazak *et al.*, 2001; Mapiye *et al*., 2011, Gxasheka *et al*., 2015) that goats prefer (Ngambu *et al.*, 2012). Optimising the use of the available natural feed resources can markedly enhance goat productivity in resource-limted communities. Few studies, if any, have focused on gastrointestinal nematode infestation, nutritionally-related blood metabolites in Xhosa lop-eared does and goat performance foraging on grassland relative to those browsing on forestland vegetation types. Therefore, it is important to consider ideas and views that resource-limited farmers have on gastrointestinal nematode infestation in goats reared in different vegetation types. Such information assists in the formulation of strategies that enhance goat productivity in resource-limited communities. It is also necessary to determine the interactions among vegetation type, season and parity on the prevalence and loads of gastrointestinal nematodes and nutritionally-related blood metabolites.

1.2 Justification

Indigenous goat production systems play an important role in the agricultural industry of many developing countries. These goats contribute greatly to improve the local economy and food and nutrition security of resource-limited farmers. Indigenous goats adapt well under stressful environmental conditions and are natural resistance to wide-range of diseases and parasites. Gastrointestinal nematodes, particularly *Haemonchus contortus* are the most common and dangerous internal parasites in goats among resource-limited farmers (Vatta and Lindberg, 2006). These farmers lack veterinary services and they cannot afford anthelmintics (Vatta and Lindberg, 2006). On other hand, grassland and forestland vegetation types are most dominant in semi-arid environments (Dixon *et al*., 2014), however, their impact on kid performance, gastrointestinal nematodes and nutritionally-related blood metabolites, liver enzymes and minerals in Xhosa lop-eared does is poorly understood. Xhosa-lop eared goats are one of the indigenous goat ecotypes that are resilient to endemic diseases and parasites and are large-framed relative to other indigenous goat ecotypes (Marume *et al*., 2011). They are thought to perform well where browse predominates. They have a huge potential to improve livelihoods of resource-poor farmers. Forestland vegetation type consists of various forage tree and shrub species in Southern Africa (Gxasheka *et al*., 2015). These forage trees and shrubs are better and cheaper supplementary feed for goats in most communal areas, especially during the dry seasons when natural grasses are dormant. Information of the nutritionally-related metabolites status of indigenous Determining concentrations of nutritionally-related blood metabolites could be useful in establishing their adaptation to different vegetation types. Moreover, understanding the effect of vegetation types and season on the prevalence of gastrointestinal nematodes, goat performance and variations on nutritionally-related blood metabolites, liver enzymes and minerals is essential in improving productivity of Xhosa lop-eared goats.

Since gastrointestinal nematodes are the limiting factor on small ruminants globally, an accurate measure of prevalence is required. It is essential to determine seasonal trends of gastrointestinal nematodes infestation in goats that forage on grassland and those browsing in forestlands. A clear understanding of seasonal dynamics of prevalence of gastrointestinal nematodes is helpful in maintaining health status of Xhosa lop-eared goats. Understanding the interaction of vegetation type and seasons in these goats assists policy makers and non-governmental institutions to design appropriate and sustainable interventions for effective goat management plan. Information on the effect of these vegetation types on the prevalence of gastrointestinal nematodes also benefit resource-limited farmers who cannot afford anthelmintics to control gastrointestinal nematodes. Therefore, it is vital to investigate these constraints before establishing programs that are aimed at improving indigenous goat productivity.

1.3 Objectives

The broad objective of the study was to determine gastrointestinal nematode infestation, goat performance and nutritional status of Xhosa lop-eared does foraging in grasslands relative to those browsing in forestlands. The specific objectives were to:

1. Investigate the perceptions of resource-limited goat farmers on the infestation and control of gastrointestinal nematodes.
2. Determine monthly changes in body condition scores, body weights and on the prevalence of gastrointestinal parasites in Xhosa lop-eared goats raised in grassland relative to those in forestlands.
3. Assess the effect of vegetation type, season and parity on the burden of gastrointestinal nematodes in does that were foraging in grassland and forestland vegetation types.
4. Determine interaction between vegetation type and season on serum concentrations of nutritional related blood metabolites, liver enzymes and minerals in Xhosa lop-eared does.

1.4 Hypotheses

The hypotheses tested were that:

1. Perceptions on the infestation rate and control of gastrointestinal nematodes across vegetation types are similar.
2. Vegetation type influences body weight, body condition score ad faecal egg counts.
3. Seasonal gastrointestinal nematode burden in Xhosa lop-eared does is influenced by vegetation type.
4. Serum concentration of blood metabolites, some liver enzymes and minerals in Xhosa lop-eared does are influenced by the interaction of vegetation type and season.

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Chapter 2: Literature Review

2.0 Introduction

Globally, the goat population is estimated to be 218 million (Ceccobelli *et al*., 2020), and 30 % is located in Africa. In South Africa, more than 60 % of goat population is owned by resource-limited farmers (Devendra, 2013). Indigenous goat production contributes significantly to improve livelihoods of resource-limited farmers under communal production systems, as they provide milk, meat, skin and hides and to generate income (Idamokoro *et al*., 2017). Despite the contributions of indigenous goat farming to resource-limited farmers, their productivity is hampered by the high prevalence gastrointestinal nematodes (GIN) and diseases, poor quality and quantity of forage (Mpofu *et al*., 2020). Therefore, to improve indigenous goat productivity, it is essential to determine loads and control methods of GIN in goats foraging in grassland and those in forestland vegetation types. This review discusses the prevalence of GIN, effect of vegetation types on the prevalence of GIN, effect of feeding systems on prevalence of GIN and impact of GIN infestation in Xhosa lop-eared goat production, factors influencing GIN in goats, impact of GIN in goats and control measures of GIN in goats.

2.1 Prevalence of gastrointestinal nematode infestation

Gastrointestinal nematode infestation is a main limiting factor of goat farming globally, more specifically in tropical and sub-tropical regions (Mpofu *et al*., 2020). The epidemiology of GIN infestation in small ruminants have been investigated in several countries, which contributed greatly to their control, for example in study conducted in Ghana by Blackie, (2014) reported that about 95 % of small ruminants are infested with GIN. Sissay, (2007) in Ethiopia highlighted that higher helminth parasite infestation in ruminants were abundant in all agro-climatic zones.

Matsepe *et al.* (2021) highlighted nematode infestation is a serious veterinary health concern in Lesotho. Poor livestock management, quality and quantity of forage exacerbate the GIN challenge in goats of resource-limited farmers. Moreover, goat kids are more susceptible to GIN than older goats due to low immunity (Zvinorava *et al*., 2016) and there is a tendency of decreasing of worm burdens with the increase in goat age. Amran *et al*. (2018), however, indicated higher prevalence of GIN in older goats than younger goats. Infestation with GIN is highly associated with great economic losses in goat farming through lowered productivity and the cost of treatment and mortality (Jiménez-Colmenero *et al.,* 2001; Marume *et al*., 2012). The most common GIN infecting goats include *Haemonchus contortus, Teladorsagia circumcincta, Trichostrongylus spp., nematodirus spp., Strongyloides papilosus, Oesophagostomum spp., Trichuris spp., Cooperia spp.*, and *Dictyocaulus filarial* (Mpofu *et al*., 2020).

2.2 Effect of vegetation type on prevalence of gastrointestinal nematodes

Natural vegetation is considered as the important source of feed for livestock in most developing countries, which merely depends on natural pastures. Both Shabalala and Mosima (2002) and Kusina and Kusina (2002) accentuated that most of goats in Southern Africa highly dependent on natural veld. Grazing lands in most communal areas are characterized by being poorly managed, which contribute greatly on the prevalence and loads of GIN infestation. An increase in the spread of parasitic diseases and worm burden in goats can be associated with grassland vegetation types, since goats are able to re-infection on contaminated pastures. Lower infestation rate in the forestland vegetation could be that goats had access to various trees and shrubs such *as Vachellia karroo* which ability to reduce worm burden in livestock. Infestation may be lower in goats foraging in the forestland vegetation type due to their browsing behavior, which minimizes chances of ingesting the larve which is found on plants closer to group. Study conducted by Marume *et al*. (2012) further indicated that goats fed on V*achellia* leaves had a markedly low faecal larva and worm counts at necropsy. Lower infestation in the forestland vegetation types can be also explained by the presence of tannin-rich plants found in forestlands that are capable of reducing worm burden and improving goat performance.

Spread of parasitic diseases in extensive farming is aggravated by uncontrolled and free grazing systems practiced in many developing countries (Sanhokwe *et al*., 2016). Moreover, goats kept under poorly managed vegetation are characterized by poor performance, high GIN infestation and mortality and lower reproductive rate (Scholtz and Bester, 2010; Nower *et al*., 2013). Hoste *et al*. (2011) reported that goats fed on areas composed of various trees and shrubs carry less GIN relative to those grazing in the grassland vegetation types. Therefore, for effective control of GIN in goats require an integrated control strategy that should be based on vegetation type on each environment.

2.3 Effect of feeding system on prevalence of gastrointestinal nematodes

Farmers use various feeding systems for managing their livestock that include free grazing, tethering and herding based on different seasons. Goat tethering is the most widely used feeding management system in most communal areas of developing countries and is associated with low growth performance and higher loads of GIN infestation (Nsereko *et al.*, 2015). The goats pick more nematode larvae from infested pasture compared to those goats that are browsing (Nsereko *et al.*, 2015). Moreover, Nsereko *et al*. (2015) indicated that tethered goat have higher faecal egg counts (FEC) compared to those free grazing goats. Free-grazing goats have access on browse varies plants, some containing substantial amounts of crude protein and condensed tannins, which effectively enhance nutrition and ability of the goats to resist infection. Marume *et al*. (2012) provided evidence of the benefits of protein supplementation as one of the ways to control parasites. Kumar *et al*. (2013) also indicated that goats fed on low protein forage are more susceptible to infestation since they release less immunoglobin IgA. For effective control of gastrointestinal nematodes infestation and management of veld is, therefore, essential.

Rotational grazing and resting as a means of GIN control limits the host-parasite contact, thus reducing pasture contamination and increasing productivity of vegetation type. Uncontrolled grazing systems refers to goats that graze and browse the entire grazing/browsing land without any restriction throughout the year while rotational grazing system alternates goats from one camp to the next with a specific goal of allowing the rested camps to regrow pastures (Hawkins, 2017). Rotational grazing with effective management plan sustains good vegetation condition while maximizing livestock production and reduction on infestation rate of GIN. In many developing countries, community members manage rangelands communally and everyone has the equally right and access to keep animals on the grazing land (Mapekula, 2009). These farmers do not consider grazing management practices that include vegetation condition, grazing capacity, stocking rate, rest and rotation of livestock as ways minimize GIN infestation. Continuous grazing or browsing lead to vegetation deterioration, increase undesirable grasses species in grassland and bush encroachment in forestland vegetation type. Communal grazing make it difficult to make decisions on which management practice to be used on the grazing areas. That makes it difficult to control GIN and goat diseases.

2.4 Health management of goats

High prevalence of GIN is considered as the main challenge on goat production system, more precisely in humid areas (Zvinorova *et al.,* 2016; Mpofu *et al*., 2020). It has been reported that parasitic diseases have significant impact in most communal areas of developing countries (Mdladla *et al*. (2017). Infestation of gastrointestinal nematodes (GINs) is highlighted as the most limiting factor in goat production system (Zvinorova *et al.*, 2016), affecting economic effectiveness and even lead to high mortality when goats are not treated on time. A livestock calendar which guide farmers on flock health management and preventive medicine programs should be designed to minimize potential effects goat's health problems. This strategy can be helpful, since most communal farmers only apply medication when they start to notice signs of disease in the animal. Provision of training on livestock management could assist communal farmers to improve goat productivity. Mwacharo and Drucker (2005) and Devendra *et al.* (2000), also highlighted parasitic diseases as the main limiting factor to the improvement of livestock industry, particularly in communal areas of developing countries. Some common health problems impacting goat production include foot rot, internal and external parasites and *Caseaous Lymphadenitis* (abscesses). For successful goat enterprises, there is a need of strategies to overcome challenges that limit goat production.

2.5 Factors influencing gastrointestinal nematode infestation in goats

2.5.1 Climate

Gastrointestinal nematodes and other diseases are significantly influenced by temperature, rainfall and humidity. These climatic variables influence the parasite reproduction, development, survival and population dynamics in varies stages of their life cycle. Temperature is one of the most important climatic variables that influence survival and development of larvae. Once the eggs pass out of the host, they hatch into first-stage larvae (L1) and moult into second-stage larvae (L2) and they require appropriate conditions of temperature and humidity. For eggs to undergo these development processes, they require warm temperatures greater than 25 ºC and moist conditions (Kim *et al*., 2012). The infective L3 larve can survive for months on pasture depending on the environmental conditions. Moisture and relative humidity maintain parasite pressure until they are ready for the next stage in their life cycle. However, parasite activities are arrested in temperatures below 10 ºC. During the rainy season, rainfall and temperature accelerate rate of development of GIN (Menkir *et al*., 2006). Pfukenyi and Mukaratirwa. (2013) revealed that GIN and parasitic diseases reach their peak prevalence in warm and rainy seasons and become less-abundant during dry seasons. Gastrointestinal parasites are more predominant during hot-wet season than cool-dry season (Zvinorova *et al*., 2016; Mpofu *et al*., 2020).

2.5.2 Host factor and environment

Host-parasite dynamics can be highly influenced by seasonality and age-related host immune response (Turner and Getz, 2011). Baker *et al.* (1998) reported breed differences in their susceptibility to GIN. Gopalraj *et al*. (2013) showed that Nguni goats had higher levels of acquired immunity than Saanen goats. Onzima *et al*. (2017) showed that Kigezi goats had higher FEC than Small East Africa and Mubende genotypes. Mpofu *et al*. (2020), however, revealed no difference in FEC and GIN loads. Similarly, Zvinorova *et al*. (2016a) observed no interaction of age and sex on parasitic infection. Terefe *et al*. (2012) showed an association of sex with prevalence of strongyle-type parasites. Amran *et al*. (2018) observed that females were more susceptible to GIN infection than the males. This can be explained by the challenging period of physiological, metabolic and endocrine changes experienced by does exacerbated by temporal loss of immunity. Dagnachew *et al*. (2011) reported that lowlands had higher GIN than highland agro-ecological zones. Mpofu *et al.* (2020) and Matsepe *et al*. (2021), however recorded a high prevalence of *Strongyloides* in goats kept under the highland zones. This can be attributed by the conducive environmental conditions for parasite breeding, survival and development.

2.6 Impact of gastrointestinal nematode infestation in goat production

Gastrointestinal nematode infestations are the main prevalent parasitic diseases affecting goats. The most common nematode species that affect goats are *Haemonchus contortus*, *trichostrongylus colubriformis* and *Teladorsagia circumcincta* (Bishop and Morris, 2007; Zvinorova *et al*., 2016). Infestation with GIN is associated with great economic losses and huge impact in livestock productivity through affecting body weight loss of between 6 and 12 kg per animal per year (Hassan *et al.,* 2019), fertility, meat quality and milk production and lead to mortality (Zvinorova *et al*., 2016). Table 2.1 shows the estimated loss caused by gastrointestinal parasites in goats in different countries. Mortality rates caused by GIN may exceed 40 % in goat flocks (Hassan *et al.,* 2019). Goats highly infested with GIN are characterized by having weakness, diarrhoea, signs of hypo-proteinaemia, submandibular oedema (bottle jaw), loss of appetite and weight. These parasites lead to anaemia since they have the ability to remove erythrocytes as well as protein (Zvinorova *et al*., 2016; Mpofu *et al*., 2020). Conventional drugs to control parasites are expensive for many resource-limited farmers.

Table 2.1: Estimated costs of gastrointestinal nematodes to goat production

Country	Costs (US $)	Reference
Globally	10 Billion	Roeber *et al*., 2013
Sub Saharan Africa	1 Billion	Shakya *et al*., 2017
South Africa	46 Million	Mcleod, 2004
Kenya	26 Million	Mcleod, 2004
Ethiopia	400 Million	Kumsa, 2006; Worku *et al*., 2017
Nigeria	40 Million	Ma'azu *et al.,* 2008

2.7 Control measures of gastrointestinal nematodes

2.7.1 Conventional medicines

Anthelminthic are a group of drugs used to treat infections with parasitic worms (Vatta and Lindberg, 2006). These drugs are the most common way of controlling GIN in small ruminants (Pfukenyi and Mukaratirwa, 2013). Frequent and continuous use of a single drug leads to the development of resistance on the drugs. These drugs are expensive for resource-limited farmers. In the absence of vaccines, GIN control is reliant on chemotherapy to ease symptoms and reduce transmission. The intensive use of drugs in the livestock industry has led to widespread resistance to anthelmintics. Understanding drug resistance in parasitic helminths is crucial to prolonging the efficacy of current anthelmintics and developing markers for monitoring drug resistance. Vaccination is being considered as the most feasible alternative for anthelmintic drugs to control GIN. Livestock industry has no current vaccine available to control GIN (Pfukenyi and Mukaratirwa, 2013).

2.7.2 Ethno-veterinary control

Medical plants play an imperative role in the health and productivity of livestock in developing countries. For example, in Kenya, smallholder livestock farmers are mainly dependent on the use of ethno-veterinary medicine to control of GIN (Njoroge and Bussmann, 2006). Masika *et al*. (2000) reported that about 75 % of communal farmers in the Eastern Cape Province of South Africa highly depends on the use of ethno-veterinary medicines to control GIN in their livestock. Ndlela *et al*. (2021) reported that indigenous knowledge as the most common method used by livestock farmers to control GIN in goats. Maphosa and Masika (2010) indicated that conventional medicines are expensive and unaffordable for resource-limited farmers. Moreover, traditional medicines are more accessible for resource-limited farmers. Natural vegetation such as forestlands have great variety of medicinal plants that are likely to possess anthelmintic. Some medicinal plants in the forestlands composed of tannin-rich plants that are capable of reducing worm burden and improve goat performance.

2.7.3 Biological control

Biological control is the use of living organisms introduced into an environment to control target microorganisms and thereby reduce the population growth of the targeted to a threshold below it no longer causes clinical problems and economic losses experienced (Larsen, 2006). Biological control has been considered as the effective alternative of chemical anthelmintic due to an alarming increase on the development of anthelmintic resistance and the increase concern of chemical residues in livestock products and the environment. Biological control involves the use of natural enemies of nematodes to reduce the number of nematodes developing in pastures to a level which is clinical and sub-clinical. A number of microorganisms have been found to feed on nematodes, reducing the number of free-living larvae in the soil ecosystem in a process called biological control. *Duddingtonia flagrans, Drechmaria coniospora, Harposporium anguillulae, Verticillium chlamysporium, Anthrobotrys oligosopa*, and *Paecilomyces lilacimus* have potential to kill and digest GIN (Campos *et al*., 2008). Biological control is becoming an important non-chemical option since biocontrol agents have low mammalian toxicity, high efficacy and are naturally occurring (Moore *et al*., 2000). Moreover, it is essential to formulate integrated strategies to control GIN infestations which involve biological control and pasture management as the best way of improving goat productivity.

2.7.4 Control of gastrointestinal nematodes through grazing management

Grazing animals are always exposed to GIN, so good grazing management is the most effective way to control GIN (Stuedemann *et al*., 2004). Rotational grazing/browsing breaks the parasite lifecycle in its free-living stages through moving goats to new camps before eggs could develop to L3 and has a higher larval death rate. Therefore, implementation of grazing and browsing management strategies can result in a significant reduction of GIN infestations, anthelmintic usage, and delays the development of anthelmintic resistance. Rotational grazing and resting, veld burning and co-grazing with other livestock species on same veld should be considered. Rotational grazing with correct stocking rate allows maintaining adequate stubble height and carbohydrate reserves that maximizes forage regrowth, since overstocking increases GIN concentration (Kumar *et al*, 2013). Good pasture management also involves close monitoring the condition of the veld to ensure that overgrazing does not occur and to maintain a productive pasture. Singh *et al.* (1997) showed that sheep grazed under rotational grazing had low FEC compared to those on continuously grazed contaminated pasture. The longer a pasture rests, the less chances of worm larvae contamination, highlighting that rotational grazing with optimum rest period is an important component to minimize GIN re-infection. Moreover, regular burning of old grazed pasture after three years should always be conducted to reduce GIN (Kumar *et al*, 2013).

2.8 Summary

Vegetation type and management practices contribute significantly on the prevalence and control of GIN in goats. Anthelmintic resistance has been reported globally on both commercial and communal farming system in small ruminant production. Improvements in the livestock management systems and husbandry practices together with considering vegetation type to control

GIN infestations could be the most sustainable way of improving goat production in resource-limited communities. Moreover, epidemiological knowledge is the most crucial to the development of a comprehensive and sustainable strategy for controlling of GIN in goats kept in different vegetation types

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Chapter 3: Attitudes and practices of resource-limited farmers on the control of gastrointestinal nematodes in goats foraging in grassland and forestlands

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Abstract

Gastrointestinal nematode infestations remain one of the main constraints to goat productivity. A cross-sectional survey was conducted to investigate the perceptions of goat farmers on the infestation and control of gastrointestinal nematodes infestation. A total of 282 goat farmers from two villages of Mbizana local municipality in Alfred Nzo district were interviewed. Higher prevalence of diseases, parasites and feed availability were among the major constraints to goat productivity. Gastrointestinal parasites were ranked as the major constraint by farmers in grassland than those in forestland. Ordinal logistic regression analyses revealed that farmers in grassland were 3.2 times more likely to experience gastrointestinal nematodes infestation than those in forestland ($P < 0.05$). On both vegetation types tethered goats were perceived to have higher ($P < 0.05$) GIN infestation compared to free browsing goats. Poor farmers were 3.1 times more ($P< 0.05$) likely to experiencing high GIN infestation compared to less poor farmers. Farmers in grassland were 2.1 times more likely to control GI nematodes infestation than to those in forestland ($P < 0.05$). Intervention strategies to control gastrointestinal nematodes should mainly target farmers from the grassland vegetation, since they experience higher infestation rates of gastrointestinal nematodes.

Key words: Farmers, Perceptions, Goats, Parasites, Diseases.

3.1 Introduction

Goat production in developing countries contributes significantly to the economic development and alleviation of hunger and poverty of resource-limited households. More than 60 % of the total goat population are owned by resource-limited households (Devendra, 2013). Goats are important in providing food security and income of between 49 to 86 % is resource-limited households (Kumar *et al*., 2006; Manzi *et al*., 2013). Despite providing these benefits, goat production is highly impacted by parasitic diseases, feed availability and quality and low reproduction efficiency (Thornton *et al.,* 2007; Scholtz *et al.*, 2013a).

Gastrointestinal nematode (GIN) infestations are among the important limiting factors to goat production (Calvete *et al.*, 2014; Zvinorova *et al*., 2016; Mpofu *et al*., 2020). *Haemonchus contortus* is the major goat health challenges in developing countries (Vatta and Linderg, 2006; Spickett *et al*., 2012) and linked with great economic impact (Marume *et al*., 2011; Roeber *et al.*, 2013). Infestation with GIN is highly associated with low productivity, reduced performance, weight gain, retarded growth, costs relative to treatment and mortality (Vatta *et al*., 2006; Marume *et al*., 2011). Molento (2009) reported that GIN prevalence is higher where the level of management is low. Moreover, resource-limited farmers treat sick animals than adopting preventive measures (Idamokoro *et al.,* 2016).

Vegetation type plays a significant role on goat production. Variations in the quality and quantity of vegetation vary with climate and soil characteristics, water availability, soil nutrients and grazing management. The most common types of vegetation in Southern Africa are grassland, desert, shrublands, savanna, woodlands, forestland and tundra (Dixon *et al*., 2014). Vegetation type affects nutrition, immunity of goats, worm cycle and stocking density (Kumar *et al.*, 2013; Giday *et al*., 2018).

Grassland is a vegetation type that is dominated by grasses and lack of trees whilst forestland is characterised by dominance of various species of trees. Zvinorova *et al*. (2016) and Mpofu *et al*. (2020) indicated that GIN infestation is considered as the main challenge in goat production. To enhance goat productivity, it is essential to investigate perceptions on goat-keepers on the infestation and control of GIN to assist policy-makers and local municipalities to develop effective deworming programmes based on the type of vegetation in each environment. Understanding perceptions and attitudes of goat-keepers on GIN assist in the formulation of sustainable and effective control strategies.

The forestlands have a great variety of medicinal plants that are likely to possess anthelmintic properties, so information on the list of medical plants used by resource-limited farmers to control GIN is essential. Moreover, comparison of the perceptions of goat-keepers in the grassland and forestlands on the likelihood and burden of infestation, as well as control of gastrointestinal nematodes provides a platform to assess whether goat health programmes could be vegetation-specific. The hypothesis tested was that perceptions on the infestation rate and control of gastrointestinal nematodes across vegetation types are similar.

3.2 Materials and Methods

3.2.1 Description of study site and ethical clearance

This study was conducted in two communities (Khanyayo and Mpetsheni) in Mbizana local municipality under Alfred Nzo district in the Eastern Cape Province, South Africa. Alfred Nzo district is located at 30º 50’83’ S and 28º 58’97’ E and lies at an altitude of 342 m above sea level. Climate ranges from pleasant warm summers to cold winters with snow in high lying areas. The study sites also experience climatic extremes in the form of storms, tornadoes and floods which normally occur once or twice in a year and resulted in soil erosion in some areas. Study sites receive an annual rainfall range between 650 and 1100 mm per annum; the rainy season is between October and March. The warmest month is February with an average temperature of 24ºC and lowest average temperature of 8ºC in July. Vegetation types are owned by community members and farmers have an equal opportunity to choose the types of vegetation to feed their goats. The district has a fragmented topography and consists of a wide-ranging ecotone between the grassland and forestland with *Vachellia* species. In the grassland, the dominant grass species are *Richardia humistrata, Eragrostis plana, E. chloromelas, Sporobolus africanus, Aristida congesta, Aristida juniformi, Cynodon dactylon, Themeda triandra, Eragrostis curvula* and *Cybopogon plurinodis*. The dominant tree species in the forestland are *Sclerocarya birrea, Caddra rudis, Hereto rigida, Cussonia spicuto* and *Vachellia karroo* (Acocks, 1988*).* The study complied with the standards required by the Animal Research Ethics Committee of the University of KwaZulu-Natal (Reference Number: 1434/018D).

3.2.2 Sampling and data collection

These study sites were selected based on vegetation type, livestock production system and willingness of the communities to participate in the survey. Khanyayo village represented forestland as goats are freely browsing on natural forestland whilst Mpetsheni village represented the grassland vegetation, as goat farmers practise goat herding and tethering on grassland. Goat farmers were selected using snowball sampling, based on willingness to participate in the study and on the number of goats owned per household. Preference was given to those farmers with four or more goats. A total of 282 goat farmers were interviewed in this study, 119 from Khanyayo village and 163 from Mpetsheni village. Informal interviews were conducted with the animal health technicians, extension officers, herbalists and community leaders to obtain more quality data and information for the study. Farmer's perceptions on gastrointestinal nematode infestation in goats foraging on natural grasslands and those browsing on forestlands were gathered using a structured questionnaire. Trained enumerators conducted the interviews using the local Xhosa vernacular to obtain the accurate information. Each farmer was interviewed individually in his/her homestead. Aspects covered in the questionnaires included household demography, goat health and parasites, goat feeding and management.

3.2.3 Statistical analyses

All the data were analysed using Statistical Analysis System (2012). Chi-squared test was used to determine associations between demographic information and vegetation types. The general linear model procedure was used to determine effect of vegetation type on livestock herd composition and size. Chi-square test was also used to determine the associations between household perceptions and vegetation types. Pairwise comparisons of the least square means were performed using the PDIFF option. An ordinal logistic regression model (PROC LOGISTIC) was used to predict the odds of a household's perceived infestation of GIN in goats between the vegetation types. The variables that fitted in the logit model included vegetation type gender, marital status, age, level of education, religious and social status.

The model used was: $\text{Ln}\,[p/1-p] = \beta 0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_t x_t + \varepsilon$

Where: P is the probability of a farmers perceived infestation of gastrointestinal nematode infestation;

[p/1-p]: is the odds ratio of a households perceived infestation GIN infestation; $\beta 0$ is the intercept; $\beta 1 \ldots \beta t$: are the regression coefficients of predictors; $X_1 \ldots X_t$: are the predictor variables; ε is the random residual error. When computing each predictor ($\beta_1 \ldots \beta_t$), the odds ratio for GIN infestation was interpreted as the proportion of households that experience GIN infestation versus those households that experience no GIN infestation. A similar model was performed to determine farmer perceptions on the control of GIN infestation, with P being the probability of a farmer perceiving to control GIN infestation.

3.3 Results

3.3.1 Social demographic information and constraints to goat productivity

Vegetation type was significantly associated with level of education ($P < 0.05$) and socio-economic status ($P < 0.05$) as shown in Table 3.1. Most of the farmers in grassland (41 %) and forestland (40 %) had gone through primary education. Most of farmers ($P < 0.05$) in forestland (53 %) were considered poor compared to 21 % in grassland. High prevalence of diseases ($P < 0.05$) was the main limiting factor on goat production in both areas (Table 3.2). High prevalence of parasites was reported as the major constraint in grassland ($P < 0.05$) compared to forestland.

Table 3.1: Socio-economic status of farmers participated in the study

Parameters	Grassland (%) (n=163)	Forestland (%) (n=119)	X^2 value	Significance
Gender				
Male	52	55	0.30	NS
Female	48	45		
Age				
21-30	7	10	3.56	NS
30-45	27	27		
45-60	41	43		
> 60	25	20		
Marital				
Married	68	70	6.61	NS
Single	22	22		
Widow	8	6		
Level of education				
Never attend school	37	20	15.34	*
Primary	41	40		
Secondary	21	33		
Tertiary	1	7		
Source of income				
Formal-employed	4	13	14.00	NS
Self-employed	14	13		
Social grant	59	41		
Pension	7	11		
Part-time	6	9		
Unemployed	10	13		
Religious				
Christian	64	67	0.36	NS
Traditional	36	33		
Socio-economic status				
Very poor	27	13	12.70	*
Poor	38	58		
Less poor	35	29		
Who own goats				
Male	53	60	1.10	NS
Female	47	40		

*Significant association at $P < 0.05$; NS: not significant ($P > 0.05$).

Table 3.2: Constraints to goat production

Variables	Grassland (n=163)	Forestland (n=119)	Significance
Low feed availability	4 (3.16)	3 (3.11)	NS
High prevalence of diseases	1 (2.35)	1 (1.92)	*
High prevalence of parasites	2 (2.47)	4 (3.21)	*
Goat thefts and predation	3 (2.70)	2 (2.53)	NS
Poor marketing channels	5 (4.85)	5 (4.68)	NS

*The lower the rank (mean rank score), the greater its importance values in parenthesis indicates means for ranks * P < 0.05; NS: not significant (P > 0.05).*

3.3.2 Burden of gastrointestinal nematode infestation

There was an association ($P < 0.05$) between feeding systems and the vegetation type. Tethered goats were reported to have higher ($P < 0.05$) infestation of GIN than free grazing goats from both vegetation types. Farmers across the vegetation types practiced communal grazing for their goats. Unlimited browsing was the major goat feeding system practiced (61 %) in the forestland type while tethering was feeding system practiced (57 %) in the grassland type. Most of the farmers in the grassland (78 %) and forestland (91 %) reported that goat tethering lead to higher gastrointestinal nematodes infestation. Farmer perceptions on the prevalence of gastrointestinal nematodes infestation were significantly associated ($P < 0.05$) with vegetation types. Gastrointestinal nematode prevalence was higher in the grassland (82 %) than in forestland (57 %).

The odds ratio estimates of farmers who perceived to experience effect of gastrointestinal nematode infestations in goats foraging in the grassland and those in the forestland were higher on vegetation type, age and social economic status (Table 3.3). Farmers in grassland were perceived 3.2 times more likely to experience effect of gastrointestinal nematodes infestation than those in grassland ($P < 0.05$). The probability of experiencing GIN infestation by younger farmers between the vegetation types ($P < 0.05$) were perceived to be four times more likely compared to older farmers. Poor farmers perceived to be 3.1 times more ($P < 0.05$) likely to experience effect of GIN infestation compared to less poor farmers.

Table 3.3: Odds ratio estimates lower (L) and upper (U) confidence interval (CI) of household perceived infestation of gastrointestinal nematodes in goats fed kept in grassland and forestland vegetation types

Predictor	Odds ratio	L CI	U CI	Significance
Vegetation type (grassland vs forestland)	3.2	1.436	7.452	*
Gender (male vs female)	1.0	0.354	2.171	NS
Marital status (single vs married)	1.9	0.768	4.532	NS
Age (youth vs adult)	4.3	1.802	10.369	*
Education (educated vs uneducated)	1.0	0.329	1.543	NS
Source of income (Employed vs unemployed)	1.0	0.422	2.105	NS
Religious (Christian vs traditional)	1.8	0.567	5.730	NS
Social economic status (Poor vs less poor)	3.1	1.425	6.714	*

*The higher the odds ratio the stronger the household perceive infestation of GIN infestation between vegetation types. CI-confidence interval. NS: $P > 0.05$ * $P <0.05$, GIN= gastrointestinal nematodes.*

3.3.3 Control of gastrointestinal nematodes

Vegetation type, age, level of education and socio-economic status highly influence ($P < 0.05$) the household's likelihood to control GIN (Table 3.4). Farmers in grassland were 2.1times more likely to control GIN infestation than those in forestland ($P < 0.05$). The youth were more likely to control GIN infestation than older farmers ($P < 0.05$). Educated farmers were more likely to be aware of the practices to control GIN infestation compared to uneducated farmers ($P < 0.05$). Poor farmers were 3.1 times less likely to apply clearly attitudes and practices to control GIN infestation in goats ($P<0.05$).

Farmer views on the goat management to control gastrointestinal nematodes were significant associated ($P < 0.05$) as shown in Table 3.5. Most farmers in the grassland (98 %) and forestland (74 %) reported that they treat and vaccinate their goat flocks to control gastrointestinal nematodes infestation. About 68 % and 36 % farmers in the grassland and forestland, respectively use anthelmintics in newly introduced goat in the flock. A higher proportion of the farmers in the grassland (76 %) reported to rotate the anthelmintics ($P < 0.05$) to control gastrointestinal nematodes in contrast to only 22 % in the forestland type. Most ($P < 0.05$) of the farmers in the grassland (84 %) and forestland (62 %) highlighted that goats that are frequently prone to gastrointestinal infestation were culled from the flock. Moreover 58 % and 60 % farmers in the grassland and forestland type, respectively perceived to practicing treating sick goat separately to avoid spread of disease to other goats. All the interviewed farmers from both vegetation types never weighed their goats before dosing.

Table 3.4: Odds ratio estimates for control of gastrointestinal nematode infestation

Predictor	Odds ratio	L CI	U CI	Significance
Vegetation type (grassland vs forestland)	2.1	0.991	4.612	*
Gender (male vs female)	1.4	0.363	5.675	NS
Marital status (single vs married)	1.5	0.632	3.394	NS
Age (youth vs adult)	0.5	0.211	1.141	*
Education (educated vs uneducated	0.2	0.083	0.388	*
Source of income (employed vs unemployed)	1.2	0.590	2.587	NS
Religious (Christian vs traditional)	1.0	0.472	2.237	NS
Social economic status (Poor vs less poor)	3.1	1.411	6.811	*

*The higher the odds ratio the stronger predictions to control GIN infestation between vegetation types. CI-confidence interval. NS: P > 0.05 * P < 0.05, GIN= gastrointestinal nematodes.*

Table 3.5: Measures to control gastrointestinal nematodes

Activities	Grassland %	Forestland %	Significance
Use any anthelmintics in new animals	68	36	*
Rotational use of anthelmintics	76	22	*
Deworming new goats before introduction to the flock	48	58	*
Separation sick animals when showing signs of GIN infestation?	40	60	*
Culling of goats which frequently prone to GIN infestation?	84	62	*
Is it important to you deworm does and kids during lactation?	91	91	NS
Vaccination of goats against GIN?	2	5	NS
Evaluation of goat faecal pats on pasture/in kraals for visible GIN regularly?	60	67	NS

**Indicate significant association at $P \leq 0.05$) not significant ($P > 0.05$)*

3.3.4 Perceptions on gastrointestinal nematode control methods

There was a significant difference on round worms between the vegetation types as shown in Table 3.6. Farmers from forestland type reported roundworms as the most common gastrointestinal parasites affecting goat flock. Farmer perceptions on seasons with high prevalence of gastrointestinal nematodes infestation were different ($P < 0.05$) on cool-dry and hot-wet season. Most of the farmers in the grassland 60 % and forestland 82 % reported that goats and weaners are more susceptible to gastrointestinal nematodes infestation. Most of the respondents in both grassland and forestland reported that they use conventional medicines to control gastrointestinal nematodes infection. About 35 and 29 % of the farmers in grassland and forestland received advice from drug suppliers concerning sick goats, respectively.

Table 3.6: Ranks of common types of internal parasites and their seasons of prevalence

Internal Parasites	Grassland	Forestland	Significance
Round worms	2 (1.68)	1 (1.41)	*
Tape worms	1 (1.59)	2 (1.56)	NS
Fluke	3 (1.95)	3 (2.11)	NS
Seasons			
Hot-wet	1 (1.02)	1 (1.12)	NS
Post-rainy	2 (2.13)	3 (1.97)	NS
Cool-dry	4 (2.84)	4 (2.45)	*
Hot-dry	3 (2.26)	2 (1.76)	*

*The lower the rank (mean rank score) of common types of GIP and seasons of prevalence, the greater its importance values in parenthesis indicates means for ranks, * $p < 0.05$; NS: not significant ($P > 0.05$)*

3.3.5 Medicinal plants used to control gastrointestinal nematodes

There are several medical plants used to control gastrointestinal nematodes infestation (Table 3.7). *Aloe ferox, Vachellia karroo, Asteraceae, Melia azedarach* and *Trema Orientaisl (L) Blume* were dominant medical plant species used to control gastrointestinal nematodes infestation in goats reared under forestland type as illustrated in Figure 3.1. *Psidium guajava* and *Ziziphus mucronata* medical plant species were only reported in the grassland type to treat internal parasites. Plant parts used for preparation of traditional remedies include fruit, leaves, barks, stem and roots. Leaves were highlighted as the frequently used plant parts for preparation of medicine. Decoction and infusion preparation methods were highlighted as the common methods used for preparation of traditional medicine for goats. Few farmers 8 % and 9 % in the grassland and forestland highlighted that there is no difference on gastrointestinal nematodes infestation on goats browsing in forestland relative to those grazing on grassland type. More farmers in the grassland type (1.3 ± 0.07) indicated to use conventional medicine against gastrointestinal nematodes infestation compared to forestland (1.0 ± 0.08). Moreover, 5 % and 34 % ($P < 0.05$) of the farmers in grassland and forestland highlighted, respectively to use both conventional and traditional medicine to control gastrointestinal nematodes infestation as shown in Figure 3.2.

Table 3.7: Medicinal plants used to control gastrointestinal nematode infestation

Family	**Scientific name**	**Local name**	**Part of plant used**	**Preparation method**	**Significance**
Asphodelaceae	*Aloe ferox*	Ikhala elikhulu	Leaves	Decoction	*
Fabaceae	*Elephantorrhiza elephantina*	Intolwane	Roots	Decoction	NS
Fabaceae	*Vachellia Karroo*	Umnga	Bark, leaves	Decoction	*
Cannabaceae	*Trema Orientaisl (L) Blume*	Umbhangabhanga	Leaves, bark	Infusion	*
Fabaceae	*Asteraceae*	Udywabasini	Leaves	Decoction	*
Myrtaceae	*Psidium guajava*	Umgwava	Leaves	Infusion	NS
Rhamnaceae	*Ziziphus mucronate*	Umphafa	Leaves	Infusion	NS
Meliaceae	*Melia azedarach*	Umsilinga	Leaves	decoction	*
Artermisa	*Asteraceae*	Umhlonyane	Leaves	decoction	*
Moraceae	*Ficus craterostoma*	Intendekwane	Leaves, roots	infusion	NS

Decoction=Heating in water to boiling point; Infusion= Soaking in ambient water temperature overnight.

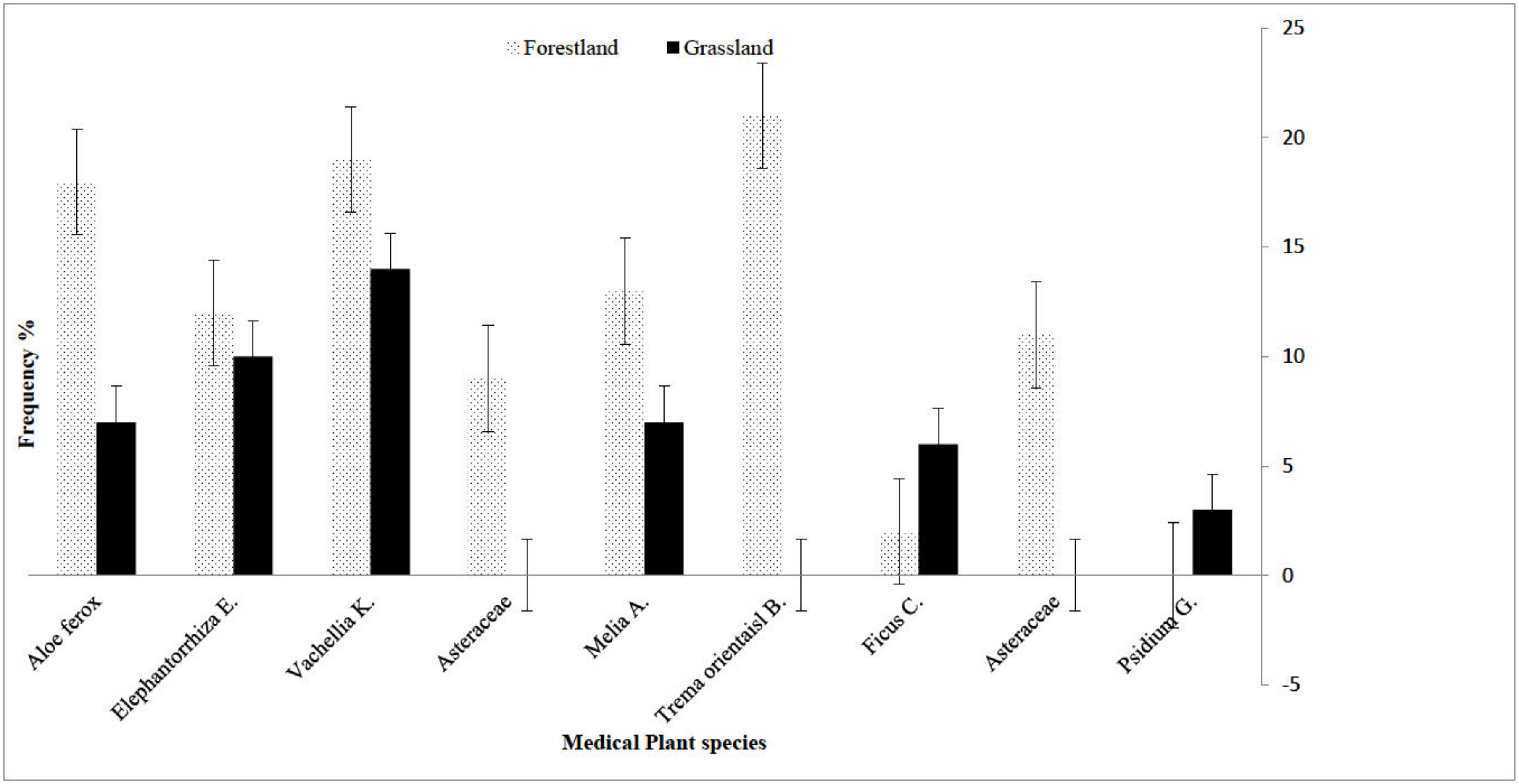

Figure 3.1: Perceived medical plants to control gastrointestinal nematodes in goats

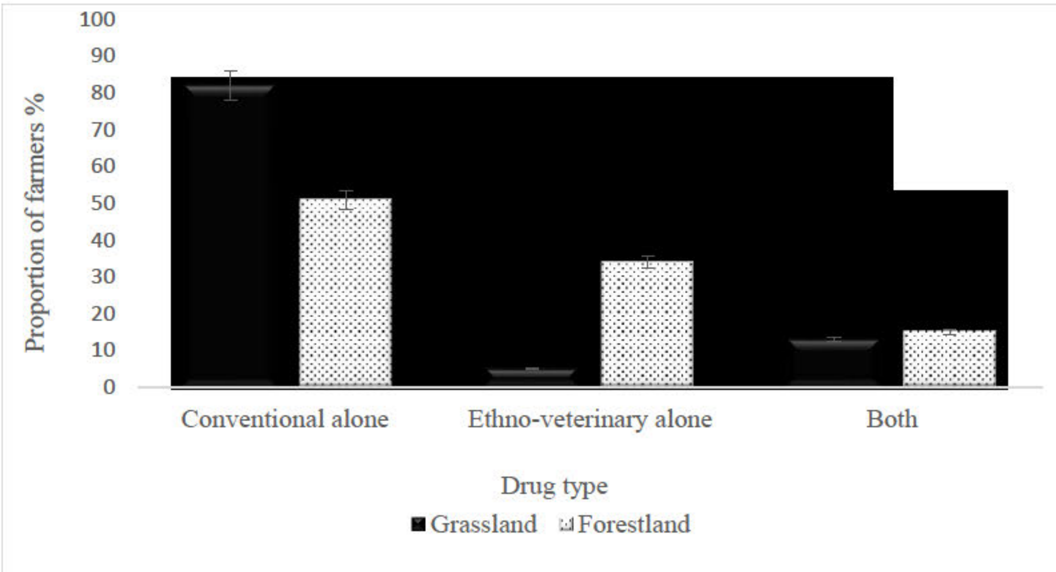

Figure 3.2: Type of drug used to control gastrointestinal nematodes in goats

3.4 Discussion

The current study was conducted to explore farmer perceptions on infestation and control of GIN in goats foraging in grassland relative to forestland. Understanding the perceptions of farmers on the infestation and control of GIN benefit policy makers and other stakeholders in goat production industry to implement strategies to manage and control GIN infestation in goats and lead to prolific goat productivity.

Level of education and socio-economic status had influence on the level of knowledge and understanding on the infestations and control of GIN amongst the vegetation types. This concurs with Khapayi and Celliers. (2016) who indicated that low level of education hinders farmers to understand dynamics of agriculture. Moreover, education measures the level of human capital of farmers (Nowak, and Kijek,2016).

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The majority of farmers reported that goats feeding in grassland vegetation type are more likely to be exposed on GIN infestation. These findings could be associated with re-infection in contaminated pastures under grassland vegetation type. This could be also exposure of grazing goats than browsers to GIN. These findings agree with Xhomfulana *et al.* (2009) who reported that Nguni cattle fed on the *Vachellia karroo* diet had low mean strongyles and total faecal egg counts. Both vegetation types reported higher infestation of GIN in tethered goats than free browsing. This higher infestation in tethered goats is associated with exposure to high larval loads on pasture, as farmers inadvertently tether goats on the lush patches which may expose goats to higher contamination on pastures. This situation is worsened by feeding system such as goat tethering which is mostly practiced by communal resource-limited farmers (Rumosa-Gwaze *et al.*, 2009), especially during cropping season. Moreover, tethered goats fail to withstand the GIN infestation due to inadequate nutrition access. These findings concurs with Magona and Musisi, (2002), who reported that tethered goats had higher mean worm-egg count than those kept under open grazing. mainly browsing on shrubs have lower gastrointestinal burdens, since the chances of picking infective larvae from pasture are reduced. This can be also attributed by the fact that trees and shrubs in the forestland vegetation type composed of tannin rich plants that are capable of reducing worm burden and improve goat performance.

High proportion of farmers in the grassland reported poor quality feed, more especially during cool-dry season compared to those in the forestland vegetation type. These study findings are in line with Gaday *et al.* (2018) who observed feed shortage around the months of March to June. Study conducted by Ben Salem and Smith (2008) and Thomas and Rangnekar, (2004) indicated that farming system in most developing countries are characterized by poor quality pastures that contribute to inadequate forage for livestock and further lead to low productivity. Moreover, this can be further attributed by the erratic rainfall during cool-dry season compared to rainy season. Susceptibility of goats to GIN can be worsen by the prolonged dry season coupled with drought which has a negative impact on goat health and productivity.

It is, therefore, important to come up with management strategies that will focus on feeding systems and health to enhance goat productivity of resource-limited farmers. Marume *et al*. (2011) also showed a marked decreased in faecal larva count and low worm counts at necropsy in goats that fed the *Vachellia* leaves. Moreover, this can be attributed to the fact that *Vachelli*a species have tannins that simple impair key biological process of the parasitic nematodes. Farmers additionally, emphasized that goats browsing on trees and shrubs with *Vachellia* species have good body confirmation, resistance to diseases and are more productivity. It is, therefore, necessary to determine effect of vegetation types on goat's performance. Study conducted by Idamokoro *et al*. (2016) reported that feeding goats with *Vachellia karroo* leave meals improve animal performance, reduce worm burden and increase growth rate. Maguraushe. (2015) further reported that goats browsing in the veld dominated by *Vachellia karroo* had higher number of offspring born compared to the herds in the open grassland.

High prevalence of diseases and parasites were major limiting factors on goat productivity. These findings are similar to earlier reports in Zimbabwe (Zvinorova *et al.*, 2016) and in South Africa (Mpofu *et al.*, 2020). These results also agreed with (Marufu *et al*., 2008); Mapiye *et al*., 2009a; Bath *et al.*, 2016) who reported high loads of gastrointestinal nematodes during hot-wet season in cattle. Roundworms were common internal parasites affecting goats, more precisely in hot-wet season. These results are similar to the findings of Marufu *et al*. (2011) who observed high egg loads during the hot-dry season in cattle and Zvinorova *et al.* (2016) who recorded higher prevalence of gastrointestinal nematodes in wet season than dry season in goats. This can be attributed to the fact that hot-dry and hot-wet season are favorable periods for the survival and development of parasites. Hot-dry season is period of the year where first rains fall and greater intake of infective larvae from the pasture occur. However, during this period goat productivity is highly negative impacted and this result to great economic losses, more precisely to resource-poor farmers of developing countries. Moreover, the current study revealed that kids are more susceptible to gastrointestinal nematodes infestation followed by weaners, these results are comparable with findings of Zvinorova *et al.* (2016) who observed higher prevalence of infestation in younger animal yearlings 78 % compared to the oldest goats 7 years to be 38 %.

The finding that *Aloe ferox*, *Vachellia karroo* and *Elephantorrhiza elephantina* were dominant medical plant species used to control gastrointestinal nematodes infestation in goats reared under forestland type, corroborate with findings of Masika *et al*. (2000). This study revealed that leaves were most used plant part for preparation of remedies (Sanhokwe, *et al.,* 2016; Masika *et al.*, 2000), this can be attributed by the fact that leaves are easily haversted without extensive harming plants. Most of farmers on both vegetation types seems to follow goat management practices. In contrast with the findings of (Forbes and Trollope, 1991), who stated that farmers are reluctant to adopt livestock and veld management practices and they cannot afford winter dietary supplementation.

The finding that most farmers on both vegetation types commonly use conventional medicines alone to treat their goats for gastrointestinal nematodes infestation, this suggest that conventional medicines are more effective than ethno-veterinary medicines. The findings from the current study are similar to Akkari *et al*. (2008) and Zvinorova *et al.* (2016) who reported that control of parasitic diseases is chiefly depends on the use broad-spectrum anthelmintic. However, frequently usage of same group of anthelmintic contributed to a widespread development of anthelmintic resistance in parasites. The results that majority of farmers used conventional medicine differ with Masika *et al*. (2000) who estimated that 75 % of the livestock farmers in the Eastern Cape Province use traditional medicine to treat their livestock. The minority farmers 21 and 13 % of farmers use both traditional and conversational medication. The use of herbal remedies can be attributed to the fact that traditional medicines are cheap, locally available and convenient to administer (Masika *et al*., 2000). The results that most farmers on both vegetation type indicated that goats frequently prone to gastrointestinal infestation were culled from the flock are similar to the report of Mushonga *et al*. (2018) who reported that gastrointestinal nematodes lead to forced culling of animals. Therefore, for successful management and control of gastrointestinal nematodes infestation in goats, there is need to determine actual faecal egg counts to give a better control regime.

3.5 Conclusions

Farmer perceptions on the infestation and control of gastrointestinal nematodes infestation differ with vegetation type. Grassland farmers perceived a higher infestation rate of gastrointestinal nematodes in goats than those in forestland, though they perceived to applying attitudes and practices to control gastrointestinal nematodes infestation. Implementation of deworming programmers should mainly target grassland farmers. Further research should focus on growth performance and prevalence of gastrointestinal parasites in indigenous goats raised in grassland and forestland vegetation type to validate farmer perceptions that indicate less gastrointestinal nematodes infestation and good growth performance in indigenous Xhosa lop-eared goats raised under forestland than those in the grassland vegetation type. Moreover, clear guidelines on the control of GIN in different vegetation types should be understood.

3.6 References

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Chapter 4: Growth performance and prevalence of gastrointestinal nematodes in indigenous goats raised in grassland and forestland vegetation type

Abstract

Gastrointestinal nematodes cause great loss in growth performance in the goat industry globally. This objective of the current study was to determine the effect of GIN on growth performance in indigenous Xhosa lop-eared goats raised in grassland and forestland vegetation types. Body condition scores (BCS), body weights (BW), and faecal egg counts (FEC) were evaluated in (n=165 and n =144 Xhosa lop-eared goats with an average age of 7 months raised in grassland and forestland vegetation types, respectively. Faecal samples were collected from the rectum and analysed using the modified McMaster technique. This study revealed significantly associations ($P < 0.05$) in BCS, BW and FEC among the goats in grassland and forestland vegetation types. Indigenous goats in the forestland had higher ($P < 0.05$) BCS, BW and lower FEC compared to those in grassland. Moreover, goats with good BCS and BW had lower FEC on both vegetation types. Generally, a higher ($P < 0.05$) prevalence of GIN eggs were recorded between January and February of 2019. Faecal egg counts for *Strongyloides* and *Nematodirus* showed a decline during March and April on both vegetation types. Age and sampling months significantly ($P < 0.05$) influenced FEC in indigenous goats. Loads of FEC were high in indigenous goats between 5 and 12 months of age. In conclusion, goats kept under grasslands were more susceptible to the GIN infestations than those raised in forestlands as indicated by high loads of FEC and lower BW and BCS.

Keywords: Xhosa lop-eared goats, Faecal egg counts, Body condition scores, Body weights

4.1 Introduction

In the Southern African region, goat rearing is one of the most common livestock farming enterprise with an estimation of 38 million population (Monau *et al*., 2020). Indigenous goats contribute significantly to the livelihoods of resource-limited farmers in developing countries (Mdletshe *et al.,* 2020). However, their productivity is still low due to variation in the quality and quantity of vegetation, prevalence of animal diseases and parasites and high mortality in goat kids (Zvinorova *et al.,* 2016).

In goat production, kids survival is considered as an mperative health trait that influences overall goat productivity (Tesema *et al*., 2020). The growth performance of goat kids is an important trait from both biological and economic perspectives. Andries *et al*. (2013) reported that survival and weight gain of goat kids from birth to weaning have a great impact on the lifetime productivity of the goats and the profitability of the goat industry. In Chapter 3, farmers perceived higher susceptible of goat kids to gastrointestinal nematode infestation. Yusof and Isa (2016) reported higher GIN infestation in goats, particularly in kids, that resulted high morbidity and mortality.

Forestland and grassland vegetation types play an imperative role in goat productivity in most developing countries.Goat performance is an important factor in smallholder stock management, since it ensures abundance and a higher number of goats producing foods for human consumption.

Gastrointestinal nematode infestation is one of the main challenges facing resource-limited farmers. Higher infestation with gastrointestinal parasites is strongly associated with great economic losses, decreased feed intake, reduced growth performance, reproduction and mortality

(Maqbool *et al*., 2017). The prevalence of gastrointestinal parasites in goats is highly influenced by management practices to vegetation, season, age (Singh *et al*., 2015; Mpofu *et al.*, 2020) and sex (Emiru *et al*., 2013). This situation is worsened by goat management strategies that include tethering, herding as explained in Chapter 3 and poor access of resource-limited farmers to veterinary support services (Dold and Cock, 2001; Marufu *et al*., 2011). Khapayi and Cellier (2016) reported that most farmers in developing countries are unable to afford commercial animal medicines as the results gastrointestinal nematodes infestation remains challenge in small ruminants. To date, there is no information available on the monthly changes in body weight, body condition score and loads of gastrointestinal nematodes in indigenous Xhosa lop-eared goats raised in forestlands relative to those grasslands. Understanding the effect of GIN loads on growth performance in goats raised on each vegetation type will contribute greatly to the development of effective control programs of goats in different age groups. Most studies conducted on prevalence and loads of gastrointestinal nematodes have focused more on the seasonal periods and not specifically on monthly basis. Moreover, no study has been documented on the growth performance and GIN in indigenous Xhosa lop-eared goat raised in the forestland and grassland vegetation type. Thus, the objective of the present study was to determine monthly changes in body weights, body condition scores and loads of GIN in Xhosa lop-eared goats raised in forestland and those in grassland vegetation types. The hypothesis tested was that vegetation type influences body weight, body condition score and faecal egg counts.

4.2 Materials and Methods

4.2.1 Description of study site and ethical clearance

The study was conducted with goat farmers in two communities of Mbizana local municipality in

Alfred Nzo district in the Eastern Cape Province of South Africa. Communities that participated in the study were Khanyayo representing forestlands and Mpetsheni representing grasslands. These communities were selected based on vegetation type, keeping goats and their willingness to participate in the study and on the assurance of availability of the goats throughout the study period. Farmers from these communities raise goats and other livestock species that include cattle, sheep, chicken and pigs. Alfred Nzo district lies 30^{o} 50"83' S and 28^{o} 58'97' E at an altitude of 1055 m above sea level. The average maximum and minimum mean annual temperatures are 24 $^{\circ}$C and 8.5 $^{\circ}$C, respectively. The district receives an annual rainfall range between 750 and 1100 mm per annum; the rainy season is between October and March.

Alfred Nzo district has a fragmented topography and consists of a wide-ranging ecotone between the grassland and forestland with *Vachellia* species. Vegetation in Alfred Nzo district is mostly temperate and transitional forest with scrub and some pure grassland vegetation Mpetsheni community that falls under grassland is dominated by the following grass species *Richardia humistrata, Eragrostis plana, E. chloromelas, Sporobolus africanus, Aristida congesta, Aristida juniformis, Cynodon dactylon, Themeda triandra, Eragrostis curvula* and *Cymbopogon plurinodis*. The dominant tree species at Khanyayo community which falls under forestlands, are *Sclerocarya birrea, Coddia rudis, Diospyros lysioides, Ehretia rigida, Cussonia spicuta, Vachellia karroo* and *Vachellia mearnsii (*Acocks, 1988; Mthi *et al*., 2021). The study complied with the standards required by the Animal Research Ethics Committee of the University of KwaZulu-Natal (Reference Number: 1434/018D). `

4.2.2 Experimental goats and their management

In each community, goat flock sizes per household ranged from 5 to 65. A total of 309 Xhosa lop-eared goats (n=165 for grassland and n =144 for forestland) were used in the study. All the experimental goats were ear-tagged for easy identification at the beginning of the study. The study was conducted for a period of five months from January 2019 to May 2019 and goats were in four goat flocks selected from both vegetation types. The experimental goats were classified according to age and sex. The age of each experimental goat was determined based on dentition (Stevens and Houston, 1989). The experimental goats were divided into 3 groups based on their age in months as follows: (2-4, 5-8, 9-12). The experimental goats were dosed against GIN using 1.9 % (m/v) Albendazole and 99 % (m/m) Levamisole hydrochloride at the start of the trial. Goats from the Mpetsheni community freely grazed in natural grasslands during the day whilst those in the Khanyayo community browsed from 1000 to 1800 h and penned at night. No supplementary feeding was provided throughout the study.

4.2.3 Data collection procedures

4.2.3.1 Faecal samples

Fresh faecal samples were collected from goats including all sexes once in the morning of every sampling month January to May 2019 between 0600 and 0900 h. The faeces were collected directly from the rectum through rectal palpation of each goat using a lubricated and gloved hand. Each faecal sample was placed in a labelled sealable plastic bag. The faecal samples were stored at 4 ^{o}C for 24 hours prior to laboratory analyses.

4.2.4 Measurements

4.2.4.1 Body weight and body condition scoring

For each Xhosa lop-eared goat body weight (BW) and body condition score (BCS) were measured once of every sampling month of January to May 2019 in the morning between 0600 and 0900 h during in the grassland and forestland vegetation types. The body weights were estimated using goat weigh-band (Asefa *et al*., 2017). The BCS was assessed visually and by palpation using the five-point scoring system with scores; 1= being emaciated, 2=thin, 3=average, 4=fat and 5=obese (Ghosh *et al*., 2019).

4.2.4.2 Faecal egg counts

Faecal egg counts (FEC) were determined using the modified McMaster technique with a saturated solution of 40 % sugar solution with a specific gravity of 1.27. Two grams of faeces were mixed with 58 ml of saturated sugar solution. The number of nematode eggs per gram (EPG) of faeces was obtained by multiplying the total number of eggs counted in the two-chamber squares of the McMaster slide by the dilution factor of 50 (Hanse and Perry, 1994). The McMaster technique detection limit was 50 eggs per gram of faeces.

4.2.5 Statistical analyses

The dependent variables analyzed were FEC, BCS, and BW. PROC UNIVARIATE (SAS, 2016) was used to check normality of BCS and FEC. Faecal egg counts data was not normal distributed, so transformation using log10 (x+1) was performed to confer normality. Data were analyzed by linear mixed models with repeated measures statements (SAS, 2016). Fixed effects fitted in the model included the effects of vegetation types (grassland and forestland), sampling month

(January, February, March, April and May), age (2-4, 5-8, 9-12); and sex, and two-way interactions between the main effects. Chi-squared test was used to determine association between prevalence of gastrointestinal nematodes, vegetation types and months of sampling using SAS (2016).

4.3 Results

The monthly changes in BCS of Xhosa lop-eared goats reared in the grassland and forestland vegetation types are shown in figure 4.1. There was a significantly association ($P < 0.05$) between sampling months and vegetation type on BCS of the goats. The BCS for goats were observed to be higher ($P < 0.05$) in the sampling month of April and May on both vegetation types. Lower BCS ($P > 0.05$) were observed in the month of March on both vegetation types. Goats in the forestland had higher ($P < 0.05$) BCS than those in the grassland in the month of April. Sex and age did not affect the BCS of the goats ($P > 0.05$) on both vegetation types. The effect of vegetation type, sampling month, sex and age on the body weight of study animals is shown in Table 4.1. Vegetation type, sampling month and age significantly affected ($P < 0.05$) body weight performance of goats. The body weights for the goats in the forestland were higher ($P < 0.05$) in the month of April, whereas in grassland it was in the month of May. Surprisingly, goats in the grassland had higher ($P < 0.05$) body weights gain in the month of May compared to other sampling months. Body weights for goats in forestland shown an increasing ($P < 0.05$) trend from the month of January to April. A decline in body weight performance was observed in the month of February and March in grassland goats even though it was not significant. Goats in the forestland were recorded higher ($P < 0.05$) body weights performance compared to those in the grassland. Male goats had higher body weights than females in the sampling month of May. There was a significantly association ($P < 0.05$) on the interaction of age and sampling month on body weights, with younger goat had lower body weights compared to older ones across the sampling months.

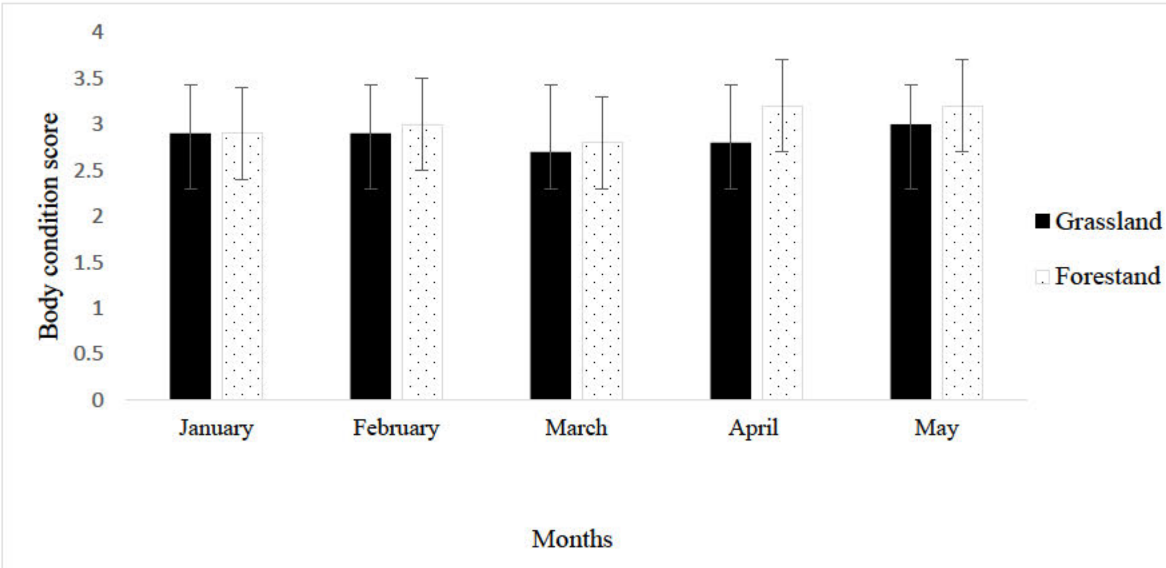

Figure 4.1: Least square mean on effect of months and vegetation types on body condition of goats

Table 4.1: Least square means (±Standard error) of month, vegetation type by sex and by age interaction on body weights (kg) of goats in grassland and forestland

Vegetation type	Months				
	January	February	March	April	May
Grassland	17.0 ± 0.84^{c}	16.4 ± 0.74^{c}	15.6 ± 0.89^{c}	18.1 ± 0.75^{b}	$19.1 \pm .34^{a}$
Forestland	17.5 ± 0.97^{d}	18.4 ± 0.85^{d}	19.0 ± 0.97^{c}	$21.2 \pm .03^{a}$	20.3 ± 1.01^{b}
Sex					
Male	18.2 ± 0.96^{b}	17.6 ± 0.88^{b}	18.3 ± 0.98^{b}	18.5 ± 0.88^{b}	20.3 ± 1.22^{a}
Female	16.6 ± 0.86^{b}	17.2 ± 0.73^{b}	16.7 ± 0.87^{b}	20.1 ± 0.83^{a}	18.9 ± 1.07^{b}
Age (Months)					
2-4	13.3 ± 1.04^{d}	14.6 ± 1.49^{c}	17.6 ± 3.51^{a}	15.6 ± 1.61^{c}	16.5 ± 1.91^{b}
5-8	17.6 ± 0.69^{b}	17.8 ± 0.62^{b}	16.7 ± 0.77^{b}	18.4 ± 0.97^{b}	22.6 ± 1.80^{a}
9-12	22.6 ± 1.59^{a}	16.8 ± 2.60^{c}	21.1 ± 1.63^{b}	20.6 ± 0.87^{b}	22.6 ± 1.81^{a}

^{abcd} Values with different superscripts in the same row are significant different ($P < 0.05$)

1

The results from this study showed that Strongyles and *Nematodirus* eggs were high ($P < 0.05$) in grassland than forestland in the month of January and February as shown in table 4.2. The interaction effect of sampling month and vegetation type was significantly ($P < 0.05$) different in the prevalence of Strongyles and *Nematodirus.* The most prevalent gastrointestinal parasite eggs observed in the current study were Coccidia oocysts 75 % and *Strongyloides spp.*, 58%. *Trichuris* eggs were observed in relatively small numbers on both vegetation types. However, there were significant differences ($P < 0.05$) between the prevalence of *Coccidia*, *Strongyloides* and *Trichuris* eggs during the sampling months and vegetation types throughout the study period.
Table 4.3 indicates the transformed (log10[x+1]) mean egg counts and standard error of strongyles, *Strongyloides*, *Nematodirus*, *Trichuris* and *Coccidia* in the grassland and forestland vegetation types. There was a significantly association ($P < 0.05$) in the interaction of sampling month and vegetation type on the faecal egg counts of strongyles. Figure 4.2 shows the monthly changes in egg counts in goats. The highest ($P < 0.05$) faecal egg counts were observed in the month of January and February on both vegetation types. In forestland type, the lowest ($P < 0.05$) faecal egg counts were recorded in the sampling month of March whilst in the grassland was in the month of May.

Age and sampling month significantly affected ($P < 0.05$) faecal egg counts in goats as shown in table 4.4. Goats with the age categories of zero to four months recorded less ($P < 0.05$) faecal egg counts across the sampling months. Slightly increase in loads of faecal egg counts was observed in goats from the age of 5-12 months of age.

Table 4.2: Prevalence (%) of gastrointestinal parasites of goats in grassland and forestland

Types of parasites	Grassland					Forestland				
	January	February	March	April	May	January	February	March	April	May
Coccidia	75.00	71.88	69.39	77.27	73.91	87.50	87.50	63.41	72.73	78.05
Strongyles	81.25	87.50	32.65	31.82	30.43	50.00	33.93	60.98	18.18	75.61
Strongyloides	78.50	87.50	34.69	25.00	30.43	91.67	95.83	53.66	45.45	53.66
Nematodirus	68.75	75.00	22.45	38.64	47.83	33.33	37.50	39.02	36.36	48.78
Trichuris	28.13	21.83	4.08	34.09	26.09	33.33	41.67	12.20	36.36	51.22

Table 4.3: Least square means (±Standard error) of gastrointestinal parasites [log10(x +1)] in Xhosa lop-eared goats

Parasites	Grassland					Forestland				
	January	February	March	April	May	January	February	March	April	May
Strongyles	0.7±0.09^{b}	0.8±0.08^{a}	0.4±0.07^{e}	0.5±0.08^{d}	0.2±0.06^{f}	0.4±0.09^{e}	0.7±0.07^{b}	0.6±0.07^{c}	0.6±0.15^{c}	0.4±0.04^{e}
Strongyloides	0.9±0.06^{b}	0.9±0.07^{b}	0.3±0.06^{e}	0.2±0.06^{f}	0.2±0.08^{f}	0.8±0.07^{c}	1.1±0.08^{a}	0.4±0.06^{d}	0.3±0.12^{e}	0.4±0.06^{d}
Nematodirus	0.6±0.08^{b}	0.7±0.09^{a}	0.2±0.06^{e}	0.5±0.09^{c}	0.3±0.09^{d}	0.3±0.09^{d}	0.3±0.09^{d}	0.3±0.07^{d}	0.3±9.12^{d}	0.3±0.07^{d}
Trichuris	0.2±0.05^{b}	0.2±0.06^{b}	0.0±0.02^{d}	0.2 ±0.05^{b}	0.1±0.05^{c}	0.2±0.06^{b}	0.2±0.07^{b}	0.0±0.02^{d}	0.1±0.09^{c}	0.3±0.04^{a}
Coccidia	1.0±0.22^{e}	1.4±0.39^{d}	1.7±0.16^{a}	1.4±0.21^{d}	1.7±0.42^{a}	1.1±0.25^{e}	1.6±0.45^{b}	1.5±0.18^{c}	1.7±0.42^{a}	1.4±0.17^{d}

^{abcdef} Values with different superscripts in the same row are significant different ($P < 0.05$)

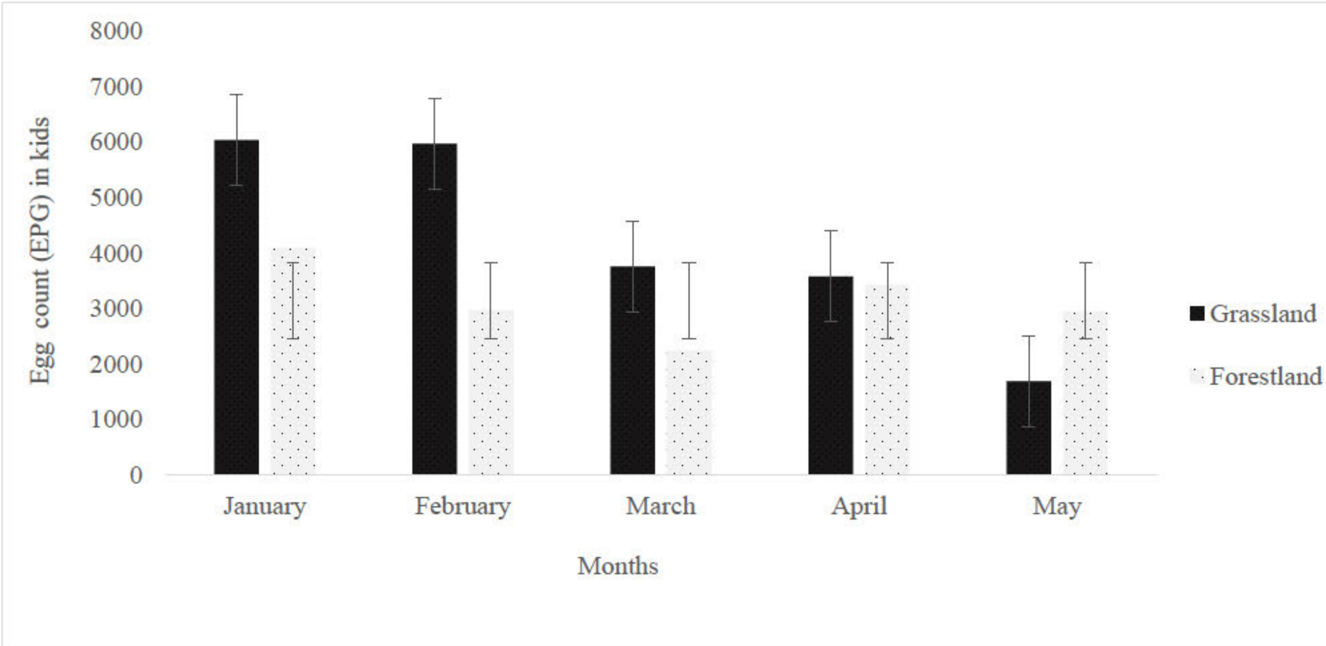

Figure 4.2. Least square mean on effect of month on the mean egg counts (EPG) in Xhosa lop-eared goats

Table 4.4: Least square means (Standard error) of FEC log10(x+1) in the different ages of Xhosa lop-eared goats

			Month		
Age	January	February	March	April	May
0-4	$1.5{\pm}0.11^{c}$	$1.5{\pm}0.09^{c}$	$2.1{\pm}0.17^{a}$	$1.9{\pm}0.10^{b}$	$1.6{\pm}0.36^{c}$
05-08	$1.6{\pm}0.10^{b}$	$1.6{\pm}0.14^{b}$	$3.0{\pm}0.24^{a}$	$1.8{\pm}0.13^{a}$	$1.9{\pm}0.34^{a}$
09-12	$1.2{\pm}0.11^{dc}$	$1.5{\pm}0.10^{c}$	$2.0{\pm}0.17^{a}$	$1.8{\pm}0.08^{b}$	$1.4{\pm}0.21^{c}$
>13	$1.4{\pm}0.11^{c}$	$1.6{\pm}0.15^{bb}$	$2.1{\pm}0.26^{b}$	$2.0{\pm}0.19^{a}$	$2.3{\pm}0.32^{b}$

^{abcd} different superscripts indicate significant differences in the mean (P<0.05).

4.4 Discussion

Body condition scoring is considered to be an important tool for effective management of animal's health status through estimation of body weight and lean muscle deposition to enhance performance (Asefa *et al*., 2017). The present study was conducted to investigate monthly changes in body weight and body condition scores and faecal egg counts in Xhosa lop-eared goats raised in grassland and forestland vegetation types. The results from this current study indicated lower body weights and body condition scores to January and February on both vegetation types, despite plenty and nutrious forage available during this period of the year. This could be linked to higher loads and prevalence of GIN infestation which is associated with with loss of condition and reduced weight gain in goats. These results can be attributed by the higher loads of gastrointestinal nematodes infestation during January and February. Moreover, findings by Dey *et al*. (2020) revealed a higher prevalence of gastrointestinal nematodes infestation during the rainy season in Bangladesh.

The higher body condition scores and body weights observed in the forestland compared to grassland was associated with a wide variety of trees and shrubs found in forestland vegetation type, which provide better nutrional plane, thus improving goat performance. This can be also attributed by the fact that browse forage species in the forestland are able to maintain their green leaves and nutritious during the dry season compared to grass species in grassland (Gxasheka *et al*., 2015). For example, Olafadehan and Okunade (2016) indicated that quality and quantity of forage availability influence growth performance in goats, thus the current study presented higher body weights in male goat than females during May. These findings are similar to those of Idamokoro *et al.* (2018) who reported male kids had superior weight than females.

Results from this study indicated that gastrointestinal parasite eggs collected were strongyles, *Strongyloides*, *Nematodirus, Trichuris* and Coccidial oocysts. This finding was comparable with the previous investigations conducted by Zvinorova *et al*. (2016) and Dey *et al*. (2020) who found *Strongyles, Strongyloides, Trichuris, Enterobius*, Coccidia and *Monieza* dominant in goats. This can be attributed to the fact that these parasites are prevalent in most developing countries in goats.

There were significantly higher loads of strongyles and *Nematodirus* eggs observed in the grassland than forestland during February. This study in chapter 3 farmers perceived higher infestation rate of gastrointestinal nematodes during hot-wet season. These results are similar to the findings of Zvinorova *et al*. (2016) who observed higher prevalence of *Eimeria spp* and *Strongyles* in goats from Zimbabwe. Moreover, these results are comparable with the findings of Dey *et al.* (2020) who recorded higher loads of faecal egg counts during hot-wet season in goats. The higher loads of faecal egg counts might be attributed by warm and wet region during this period of the year that provides a conducive environment for the development and survival of eggs. Secondly, external environmental conditions, such as temperature, relative humidity and rainfall of Alfred Nzo district during January and February favored the survival of infective larvae in the pasture that lead to higher loads of gastrointestinal nematodes infestation in goats. The variation in the infestation of gastrointestinal nematode in different months could be due to the changes in the weather condition and availability of host. Another contributing factor towards high prevalence of faecal egg counts might be goat management techniques that involves tethering and herding of goats to the same grazing areas for lengthy period.

The current study further documented a higher prevalence of Coccidia egg counts across sampling months on both vegetation types as recently reported by Mpofu *et al*. (2020). This might be associated with lack of veterinary services due financial instability in most goat keepers of developing countries (Bath *et al*., 2016) Coccidia is considered as the main challenge in young goats, this can be also attributed to the fact that young goats had not been exposed to internal parasites before and had low immune system. A low faecal egg counts of *Trichuris* observed in this study in both vegetation types across the sampling months was consistent with those findings of (Singh *et al*., 2015, Mpofu *et al*., 2020) in goats. As it was perceived in chapter 3 goats in chapter 4 showed significant association between the age of goats and sampling month. Goat kids with age catergory 0-4 months had lower FEC compared to 5-8, 9-12 and greater than 13 months of ge. This differences could be due to the fact that goat kids before weaning remain at homestedy during the day and have not yet started to browse or grazing. These findings of this study agree with those reported by Matsepe *et al*, (2021), who observed lower prevalence of gastrointestinal parasites in kids below 12 months of age. Goats with the age ranging from 5-12 months of age had higher loads of faecal egg counts. This finding was similar to a previous study done by Singh *et al*. (2015) who found that goats below 1-year-old carry significantly higher loads of gastrointestinal nematodes. Generally, younger animals are more susceptible to gastrointestinal nematodes infestation due to lower development of immune against nematodes.

4.5 Conclusions

The study identified interactions effect of sampling month, age and vegetation type as the factors influencing body condition score, body weight and faecal egg counts in Xhosa lop-eared goats reared in grassland and forestland. Goats foraging in grassland vegetation type were more susceptible in the gastrointestinal parasites infestation than those in forestland vegetation types as indicated by high loads of FEC in conjunction with lower body weight and body condition score during the sampling month of January and February.Based on these findings, it is recommended gastrointestinal parasites control strategies should be situated specific based on months' variation, age groups and vegetation type. Further studies can be done on the differences in burden of gastrointestinal nematodes infestations in indigenous does foraging in grassland and forestland vegetation type. That will help farmers to formulate an integrated control strategy that should consider the vegetation type that goats are reared on.

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Chapter 5: Differences in burden of gastrointestinal nematode infestations in indigenous does foraging in grassland and forestland vegetation types

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Abstract

Gastrointestinal nematode (GIN) infestations remain a major challenge to the health, productivity and reproductive performance of small ruminants. A longitudinal study was conducted to assess the effect of vegetation type, season and parity on the burden of GIN in indigenous does that were foraging in grassland and forestland vegetation types. Body condition scores (BCS), packed cell volume (PCV), FAMACHA score and faecal egg counts (FEC) were determined in Xhosa lop-eared does (n = 165) during the cool-dry, hot-wet and post-rainy seasons in both vegetation types. Faecal samples were collected from the rectum and analysed using the modified McMaster technique. There was a significant association between vegetation type and season on the recorded BCS, body weight (BW), FEC, PCV and FAMACHA scores. Xhosa lop-eared does in the forestland had higher ($P < 0.05$) BCS as compared to those in grassland. Higher FEC ($P < 0.05$) were observed in Xhosa lop-eared does in the grassland vegetation compared to those in forestland. Body condition scores, FEC and FAMACHA scores were significantly higher in the hot-wet season than cool-dry and post-rainy seasons, while PCV was significantly higher during the cool-dry compared to hot-wet season in forestland. Strongyles and *Strongyloides* eggs were higher in does grazing in the grassland than those in the forestland during the hot-wet season. Strategies for the effective control of GIN in goats should consider that infestation levels differ with vegetation type, season and parity. Controlling of GIN in goats, therefore, requires an integrated control strategy that should consider the vegetation type that the goats are reared on.

Key words: Does, Parity, Prevalence, Strongyle eggs, Vegetation Type

5.1 Introduction

Indigenous Xhosa lop-eared goats have been part of the livelihoods for resource-limited farmers for centuries. They improve food and nutrition security, income generation, savings and socioeconomic welfare (Devendra, 2013; Wodajo *et al.*, 2020). These goats adapt well to various agro-climatic conditions and vegetation types, and are tolerant to diseases and parasites. Goat productivity is generally low in developing countries (Mpofu *et al.*, 2020). The major constraints include high prevalence of diseases and gastrointestinal parasites, poor quality and quantity of feed and low levels of management.

Gastrointestinal nematode (GIN) infestation remains one of the limiting factors to goat productivity (Zvinorova *et al*., 2016a). The epidemiology of GIN in goats varies with climatic conditions, vegetation type, season and management practices (Giday *et al.*, 2018). In Southern Africa, common GIN affecting goats are strongyles including *Haemonchus contortus, Trichostronglylus colubriformis, Teladorsagia circumcincta* and *Nematodirus spp*. The GIN infestation has been associated with a reduction in meat quality, body weight gains and milk production and kid survival (Hassan *et al.,* 2019). The GIN also reduce feed conversion efficiency, doe fertility and income generation (Taylor *et al.,* 2007; Roeber *et al*., 2013).

Natural vegetation is the sole source of feed for goats in most communal production systems. Vegetation types found in Southern Africa include forestland, grassland, desert, shrublands, savanna, woodlands and tundra. Forestlands and grasslands are the most dominant in semi-arid environments (Dixon *et al*., 2014). The grassland vegetation type is dominated by grasses and lack of trees whilst forestland is characterised by the dominance of various species of trees. Trees and shrubs are rich in polyphenolic compounds, which reduce GIN burden (Max *et al*., 2003; Evitayani *et al*., 2004). Goats browsing in forestlands have lower chances of picking infective larvae from shrubs and trees than those in grasslands (Kumar *et al*., 2013; Giday *et al.*, 2018). Marume *et al*. (2012) highlighted that goats fed on *Vachellia* leaves had a markedly low faecal larval and worm counts at necropsy. Goats that forage in grasslands are constantly exposed to infective larvae and thus get re-infected in a cyclical fashion. Determining the likely differences in GIN burden due to the influence of vegetation type assist in could assist in the formulation of sustainable interventions for improved goat productivity.

High GIN loads leads to reduced packed cell volume (PCV), body weight and condition (Kurukulasuriya *et al*., 2018). The PCV in goats should range from 22 to 38 % (Onzima *et al*., 2017). The Faffa Malan Chart (FAMACHA) score system is the clinical assessment of anaemia by assessing the colour of the conjunctival mucous membrane (Van Wyk and Bath, 2002). Understanding the effects of vegetation type on anaemia, capacitates goat farmers in developing effective vegetation type-specific measures for GIN control. There is, however, no information on the interaction between vegetation type, season and parity on levels of anaemia and faecal egg counts in indigenous Xhosa lop-eared does reared in different vegetation types. Does are more susceptible to nematodoses than other goat classes (Rotimi *et al.*, 2017; Dey *et al*., 2020). The objective of the study was to assess the prevalence and loads of GIN in Xhosa lop-eared does foraging in grassland and forestland vegetation types. It was hypothesized that the seasonal GIN burden in Xhosa lop-eared does is influenced by vegetation type.

5.2 Material and methods

5.2.1 Description study site and ethical clearance

The study was conducted with goat farmers in two communities of Mbizana local municipality in Alfred Nzo district in the Eastern Cape Province of South Africa. Communities that participated in the study were Khanyayo representing forestlands and Mpetsheni representing grasslands. These communities were selected based on vegetation type, keeping goats and their willingness to participate in the study and on the assurance of availability of the goats throughout the study period. Farmers from these communities raise goats and other livestock species that include cattle, sheep, chicken and pigs. Alfred Nzo district lies 30^{o} 50”83’ S and 28^{o} 58’97’ E at an altitude of 1055 m above sea level. The average maximum and minimum mean annual temperatures are 24 ˚ C and 8.5 ˚ C, respectively. The district receives an annual rainfall range between 750 and 1100 mm per annum; the rainy season is between October and March.

Alfred Nzo district has a fragmented topography and consists of a wide-ranging ecotone between the grassland and forestland with *Vachellia* species. Vegetation in Alfred Nzo district is mostly temperate and transitional forest with scrub and some pure grassland vegetation Mpetsheni community that falls under grassland is dominated by the following grass species *Richardia humistrata, Eragrostis plana, E. chloromelas, Sporobolus africanus, Aristida congesta, Aristida juniformis, Cynodon dactylon, Themeda triandra, Eragrostis curvula* and *Cymbopogon plurinodis*. The dominant tree species at Khanyayo community which falls under forestlands, are *Sclerocarya birrea, Coddia rudis, Diospyros lysioides, Ehretia rigida, Cussonia spicuta, Vachellia karroo* and *Vachellia mearnsii (*Acocks, 1988; Mthi *et al*., 2021). The study complied with the standards required by the Animal Research Ethics Committee of the University of KwaZulu-Natal

(Reference Number: 1434/018D).

5.2.2 Experimental does and their management

In each community, goat flock sizes per household ranged from 5 to 65. A total of 165 Xhosa lop-eared does (n =80 for grassland and n=85 for forestland) where used in the study. Based on dentition (Stevens and Houston, 1989), the does were aged between 1 and 5 years (see Table 5.1). All the experimental does were ear tagged for easy identification at the beginning of the study. The does were selected based on free from diseases and at least from parity one to greater than four parity period. The body weight of does in the grassland vegetation type ranged between 28 and 39 kg (averaging 34 ± 7.6). Does from the forestland vegetation type weighed between 35 and 48 kg (averaging 38 ± 7.3). All the experimental does were clinically healthy at the commencement of the study. The experimental does had not been treated against GIN for at least six weeks prior to data collection. They were dosed against GIN using 1.9% (m/v) Albendazole and 99% (m/m) Levamisole hydrochloride at the start of the trial. Does from Mpetsheni community freely grazed in natural grasslands during the day whilst those in Khanyayo community browsed from 1000 to 1800 h and penned at night. Once in the season experimental does received a single oral dose of broad-spectrum anthelmintic to clear GIN infestation and no supplementary feed were provided throughout the study. Data were collected in the cool-dry, hot-wet and post-rainy season.

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Table 5.1: Allocation of Xhosa lop-eared does according to age (years) and parity into vegetation types (grassland and forestland)

Age (years)	Parity	Grassland	Forestland
1-2	1	14	16
>2-3	2	19	20
>3-4	3	22	19
>4-5	4	10	18
>5	>5	15	12

5.2.3 Sample Collection

Blood samples were collected from each experimental Xhosa lop-eared doe once in the cool-dry, hot-wet and post-rainy seasons between 0600 and 0900 h. For each doe, blood was collected from the jugular vein using a 21-gauge needle attached to a 5 ml syringe and immediately transferred into a blood tube containing ethylene diamine tetra acetic acid (EDTA) for PCV determination. The blood samples were stored in a cooler box with ice pack and transported at 4 ^{o} C to the Animal and Poultry Science laboratory of University of KwaZulu-Natal in Pietermaritzburg for analyses.

Fresh faecal samples were collected between 0600 and 0900 h once in the cool-dry, hot-wet and post-rainy seasons. The faeces were collected directly from the rectum of each doe using a lubricated and gloved hand. Each faecal sample was placed in a labelled sealable plastic bag. The faecal samples were stored at 4 ^{o}C for 24 hours before analyses.

5.2.5 Measurements

5.2.5.1 Body weights and body condition scoring

For each Xhosa lop-eared doe, body weight (BW) and body condition score (BCS) were measured from 0600 to 0900 h in the cool-dry, hot-wet and post-rainy seasons. The body weights were estimated using goat weigh-band (Asefa *et al*., 2017). The BCS was assessed visually and by palpation using the five-point scoring system with score 1= being emaciated, 2=thin, 3=average, 4=fat and 5=obese (Ghosh *et al*., 2019).

5.2.5.2 Packed cell volume

The PCV of the EDTA blood samples was measured using the micro-haematocrit method. Blood was drawn into non-heparinized micro haematocrit capillary tubes (1.40 x 1.60 x 75 mm, Lasec Pty Ltd Cape Town, South Africa) by capillary action, one end of the capillary tube was sealed before centrifugation in a micro-haematocrit centrifuge (MSE, London, Great Britain) for 3 min at 1 000 × g.

5.2.5.3 Faecal egg counts and FAMACHA scoring

Faecal egg counts (FEC) were determined using the modified McMaster technique with a saturated solution of 40 % sugar solution with a specific gravity of 1.27. Two grams of faeces were mixed with 58 ml of saturated sugar solution. The number of nematode eggs per gram (EPG) of faeces was obtained by multiplying the total number of eggs counted in the two chamber squares of the McMaster slide by the dilution factor of 50 (Hanse and Perry, 1994). The McMaster technique detection limit was 50 eggs per gram of faeces. The FAMACHA scoring system was used to determine the severity of parasite infestation by opening the lower eyelid of each doe and comparing the colour of the conjunctiva with a five-point scale (Van Wyk and Bath, 2002).

5.2.6 Statistical analyses

Data were checked for normality using the PROC UNIVARIATE of SAS (2016). To normalise data faecal egg count and body weight change were transformed using Log_{10} (x+1). Data were analysed using the generalized linear models for repeated measures of Statistical Analysis System (2016) to assess effect of vegetation type, season, age, parity and their first order interactions on FAMACHA scores, PCV, FEC, BCS and BW. The chi-square test was used to determine associations between loads of parasite and vegetation type, season, age and parity (SAS, 2016).

5.3 Results

5.3.1 Effect of vegetation type, season, parity and age on body weight changes

The effect of vegetation type on performance of does across the cool-dry, hot-wet and post-rainy seasons is depicted in Figure 5.1. Across all seasons, does foraging in forestland vegetation type had higher ($P < 0.05$) body weight gain than those in the grassland. During the cool-dry season, does from forestland gained more ($P < 0.05$) weight than those in grassland vegetation type. All does experienced body weight losses during the hot-wet season. Body weights of does were affected by age with young does weighing less ($P< 0.05$) than mature does across the seasons. There was a significantly association ($P < 0.05$) on the interaction of parity and season on body weight. Body weights of does were affected by parity with does on first parity had lower ($P< 0.05$) body weights compared to those fourth parity across seasons.

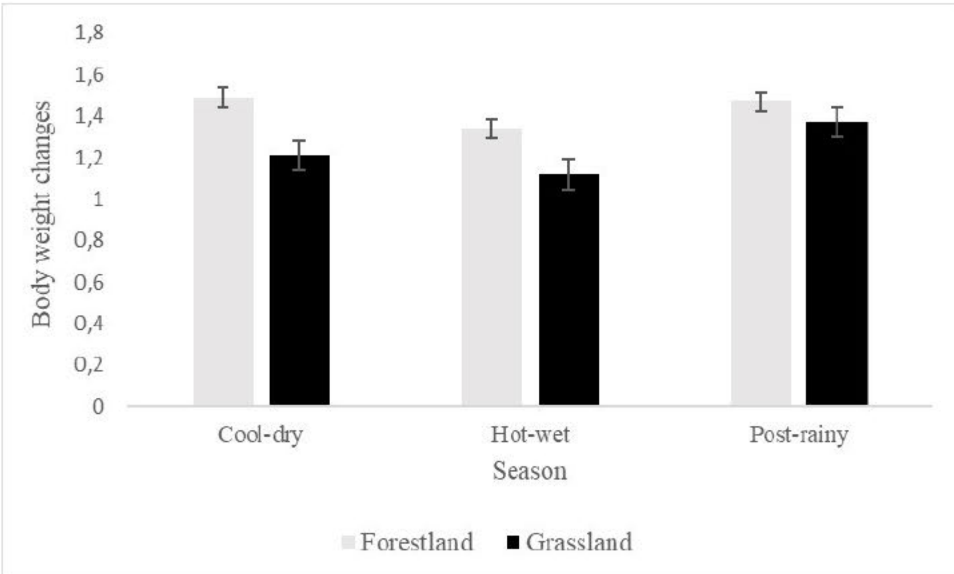

Figure 5.1: The overall effect of vegetation type on body weight change of does across the seasons

5.3.2 Effect of vegetation type and season on FEC, PCV, FAMACHA and BCS

The effects of vegetation type, season and their interaction on FEC, PCV, FS and body condition scores in does are shown in Table 5.2. There was an interaction between vegetation type and season on BCS ($P < 0.05$). Higher BCS were observed in does in the forestland vegetation type during the hot-wet and post-rainy seasons than for does in the grassland. The hot-wet season had higher ($P < 0.05$) FEC than cool-dry season in both vegetation types. There was also an interaction ($P < 0.05$) between vegetation type and season on PCV. In the forestland vegetation types, PCV was higher ($P < 0.05$) in the cool-dry season than the hot-wet season. In both vegetation types, PCV was highest in the post-rainy season. In the forestland vegetation type, FAMACHA scores were higher ($P < 0.05$) in the hot-wet than cool-dry season.

Table 5.2: Effect of vegetation type and season on the FEC, PCV, FS and BCS of Xhosa lop-eared does

Vegetation type	Season	LogFEC	PCV	FS	BCS
	Cool-dry	1.3 ± 0.49^{c}	19.7 ± 2.01^{c}	2.9 ± 0.12^{d}	3.3 ± 0.11^{b}
Grassland	Hot-wet	1.5 ± 0.03^{a}	27.1 ± 1.37^{a}	4.2 ± 0.13^{a}	3.3 ± 0.11^{b}
	Post-rainy	1.4 ± 0.02^{b}	28.4 ± 0.96^{a}	3.7 ± 0.11^{b}	3.1 ± 0.09^{c}
	Cool-dry	1.2 ± 0.53^{a}	24.5 ± 2.27^{b}	3.4 ± 0.14^{c}	3.0 ± 0.10^{c}
Forestland	Hot-wet	1.4 ± 0.03^{b}	20.9 ± 1.41^{c}	4.2 ± 0.13^{a}	3.5 ± 0.09^{a}
	Post-rainy	1.4 ± 0.01^{b}	25.7 ± 0.81^{b}	3.7 ± 0.09^{b}	3.3 ± 0.07^{b}

^{abcd} Values of the same parameter in the same column with different superscripts are significantly different ($P < 0.05$). FEC: faecal egg count, PCV: packed cell volume, FS: FAMACHA score and BCS: body condition score.

5.3.3 Effect of vegetation type and parity on FEC, PCV and FAMACHA scores

The interaction of vegetation and parity on FEC, FAMACHA scores and PCV in does foraging in both vegetation types are shown in Table 5.3. A higher FEC were observed in goats on parity 1 and 2 compared to those on parity 4 and greater on both vegetation types. Both vegetation type and parity had no significant ($P > 0.05$) effect on FAMACHA scores. Packed cell volume was, however, significantly higher in old does in the forestland vegetation type.

As shown in Table 5.4, strongyles, *Strongyloides, Nematodirus* and *Trichuris* were identified from does across both vegetation types. The counts of strongyles, *Strongyloide*s and *Nematodirus* eggs were higher ($P < 0.05$) in the grassland than forestland vegetation type. Vegetation types had no effect ($P > 0.05$) on the prevalence of *Trichuris* in both vegetation types. Table 5.5 indicates the transformed ($\log_{10}[x+1]$) seasonal changes in egg counts and standard errors of strongyles, *Strongyloides, Nematodirus* and *Trichuris* in the grassland and forestland vegetation types. There was an interaction of vegetation type and season on the prevalence of strongyles and *Strongyloides.* The highest ($P < 0.05$) egg counts of strongyles and *Strongyloides* were observed in the hot-wet season while the lowest ($P < 0.05$) were recorded in the cool-dry season for both vegetation types. Does in the grassland vegetation type had higher ($P < 0.05$) counts of strongyles, *Strongyloides* and *Nematodirus* eggs than those in the forestland.

Table 5.3: Least square means (± standard errors) on the effect of vegetation types and parity on $\log_{10}(x+1)$ FEC, PCV and FAMACHA scores in Xhosa lop-eared does foraging in grassland and forestland

Parity	Grassland			Forestland		
	FEC	FAMACHA	PCV	FEC	FAMACHA	PCV
1	1.24 ± 0.10^{d}	3.45 ± 0.22^{c}	28.18 ± 1.39^{a}	1.38 ± 0.15^{e}	3.50 ± 0.25^{c}	22.25 ± 1.63^{b}
2	1.35 ± 0.06^{d}	3.67 ± 0.11^{c}	25.23 ± 1.11^{a}	1.45 ± 0.06^{d}	3.98 ± 0.11^{c}	22.44 ± 1.07^{b}
3	1.18 ± 0.09^{d}	3.68 ± 0.17^{c}	27.40 ± 1.88^{a}	1.25 ± 0.07^{d}	3.75 ± 0.14^{c}	25.97 ± 1.57^{b}
>4	1.17 ± 0.13^{d}	3.61 ± 0.17^{c}	22.06 ± 1.77^{b}	1.09 ± 0.09^{d}	3.48 ± 0.14^{c}	25.60 ± 1.50^{a}

[abcd] Values in the same row with different superscripts are different ($P < 0.05$). FEC: faecal egg count, PCV: packed cell volume.

Table 5.4: Prevalence (%) of gastrointestinal nematodes of does reared in grassland relative to those in forestland

Nematodes	Grassland (%)	Forestland (%)	χ^2 value	Significance
Strongyles	62.5	48.2	4.62	*
Strongyloides	65	32.9	23.1	**
Nematodirus	46.3	21.2	14.9	**
Trichuris	17.5	17.7	0.00	NS

* $P < 0.05$; ** $P < 0.01$, NS: not significant ($P > 0.05$).

Table 5.5: Season changes in the mean ± standard error log-transformed faecal egg counts of gastrointestinal nematodes

Nematodes	Grassland			Forestland			
	Cool dry	Hot wet	Post rainy	Cool dry	Hot wet	Post rainy	Significance
Strongyles	0.27 ± 0.05^{a}	0.57 ± 0.05^{a}	0.04 ± 0.04^{d}	0.12 ± 0.06^{b}	0.37 ± 0.06^{a}	0.37 ± 0.05^{a}	*
Strongyloides	0.22 ± 0.05^{b}	0.37 ± 0.05^{b}	0.08 ± 0.05^{c}	0.17 ± 0.06^{a}	0.23 ± 0.06^{b}	0.18 ± 0.05^{b}	*
Nematodirus	0.14 ± 0.05^{c}	0.35 ± 0.05^{b}	0.18 ± 0.04^{a}	0.16 ± 0.06^{a}	0.37 ± 0.06^{a}	0.16 ± 0.05^{b}	*
Trichuris	0.01 ± 0.02^{d}	0.00 ± 0.02^{c}	0.11 ± 0.02^{b}	0.11 ± 0.04^{b}	0.00 ± 0.04^{c}	0.14 ± 0.03^{c}	*

^{abcd} Values in the same column with different superscripts are differ ($P < 0.05$).

5.4 Discussion

Understanding effect of vegetation type, season and parity of doe on the burdens of GIN capacitate farmers on the appropriate strategies to manage and control GIN infestation in goats. Forage quality and quantity of natural vegetation varies with season, management, soil characteristics and growth stage, thus resulting in seasonal variation in goat performance. During cool-dry season, grasses contain as low as 30 g/kg crude protein levels (Chimonyo *et al.,* 2000). Low availability of feeds is also another factor during the dry season (Safari *et al*., 2010). Loss of body weight during hot-wet season on both vegetation type was likely attributed to GIN infestation. Warm and humid environmental conditions are conducive for gastrointestinal nematodes to multiply more rapidly (Mpofu *et al.,* 2020). Factors that include humidity, rainfall, warm temperatures and vegetation cover tends to contribute grealy on nematodes prevalence and loads (Sun *et al*., 2018. Study conducted by Tamponi *et al*. (2022), indicated that negative correlation between body condition score and eggs per gram of GIN in sheep. The observed body weight gains during the post-rainy season in the grassland vegetation type could, therefore, be explained by the improved pasture availability and quality in conjunction with unfavorable conditions for GIN proliferation. Fodder trees and shrubs alleviate feed shortages and nutritional deficiencies during the cool-dry seasons, as reflected by the body weight gain in does during cool-dry season in the forestland vegetation type (Egea *et al.,* 2018). Idamokoro *et al.* (2016) reported that feeding goats with *Vachellia karroo* leaves improve animal performance, reduce worm burden and increase growth rate in kids. Marume *et al.* (2012) further indicated that goats foraging on *Acacia karroo* were able to maintain productivity compared to those only fed on hay. Rogosic *et al*. (2006) further highlighted that most trees and shrubs have high CP in their leaves and low fibre content.

The higher FEC, FAMACHA scores and low PCV levels in the hot-wet season than cool-dry season agree with earlier reports (Kaplan *et al*., 2004; Nadarajah *et al*., 2015; Seyoum *et al.*, 2018). The high FEC and low PCV values during the hot-wet season could be attributed to the high prevalence of *Haemonchus contortus* that suck approximately 0.05 mL of blood per day (Kaplan *et al.*, 2004; Brik *et al*., 2019). The climatic conditions of Alfred Nzo district were also conducive to worm proliferation. The higher FEC, FAMACHA scores and low PCV observed in does in the first parity compared to does in higher parities agree with May *et al*. (2017). Does in higher parities could have developed a stronger immunity against GIN (Zvinorova *et al*., 2016a, b). Low PCV levels were related to high faecal counts for strongyles and *Strongyloides* eggs.

Yuan *et al*. (2019) and Mpofu *et al*. (2020) also reported higher faecal egg counts in the wet than dry seasons. The low egg loads of strongyles, *Strongyloides* and *Nematodirus* in goats from the forestland vegetation type (Chapter 4) can be attributed to the presence of trees and shrubs that contain proanthocyanidins that possess anthelmintic properties (Min *et al.,* 2005). These results also agree with Xhomfulana *et al.* (2009) who observed low egg counts for the Nguni steers fed on *Acacia karroo*. Development of strategic deworming program at the beginning of the cool-dry season and towards the end of the hot-wet season more precisely on the grassland vegetation type and culling does with consistently high faecal egg counts and FAMACHA scores is essential. Deworming of does on first parity soon after kidding to prevent effects of lactation on faecal egg counts and body condition scores may be warranted. Moreover, further investigation of browse species in the control of GIN in goats is essential.

5.5 Conclusions

Differences in burden of GIN was significantly associated with vegetation type, season and parity. Higher loads of GIN and FAMACHA scores were observed in the hot-wet than cool-dry and post-rainy season, resulting in lower body weights and body condition scores in does foraging in grasslands compared to those in forestlands. To ensure effective control strategies of GIN loads in goat farming enterprise, one should integrate PCV, FAMACHA scores and faecal egg counts based on vegetation type and season. Since prevalence of gastrointestinal nematodes infestation is influenced by the interaction of vegetation type and season. On other hand forage availability and quality on both vegetation types vary with seasonal change. So further studies on the interaction effect of vegetation type and season on nutritionally related blood metabolites in indigenous Xhosa lop-eared does is necessary to improve goat performance and management practises in communal farming system.

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Chapter 6: Interaction of vegetation type and season on nutritionally-related blood metabolites in indigenous Xhosa lop-eared does

Abstract

Serum biochemical indices contribute greatly to assess and evaluate nutritional, health and physiological status of ruminants, especially those kept under different feeding systems. The objective of the current study was to determine interaction between vegetation type and season on nutritionally-related blood metabolites, liver enzymes and minerals in indigenous Xhosa lop-eared does. Blood was collected from 24 Xhosa lop-eared does once in the cool-dry and hot-wet season in each vegetation type. Blood was analysed for glucose, urea, creatinine, total protein, albumin, globulin, albumin/globulin ratio, alanine aminotransferase (ALT), gamma glutamyltransferase (GGT), lactate dehydrogenase (LDH), total bilirubin, calcium, phosphorus and magnesium. Xhosa lop-eared does in the forestland vegetation had higher ($P < 0.05$) serum concentration of total protein, globulin, albumin/globulin ratio and total bilirubin during the hot-wet than cool-dry season. The serum concentration of calcium was lower ($P < 0.05$) during the cool-dry season on both vegetation types. Phosphorus serum concentration was recorded higher ($P < 0.05$) in the grassland vegetation type during the cool-dry than hot-wet season. Albumin/globulin ration was lower ($P < 0.05$) in the forestland vegetation type during hot-wet than cool-dry season. The serum concentration of globulin was recorded higher ($P < 0.05$) during the hot-wet than col-dry season on both vegetation types. However, LDH, albumin, creatinine, urea, ALT and GGT showed no interaction ($P > 0.05$) between vegetation type and season. In conclusion, these results can be used to control a seasonal nutrition imbalance, health and metabolic status of indigenous Xhosa lop-eared does foraging in grassland and forestland vegetation type.

Key words: Glucose. Total protein. Bilirubin. Calcium. Phosphorus. Cool-dry. Hot-wet

6.1 Introduction

Goat production under communal farming system is mainly constrained by poor availability and quality of forage, more precisely in the dry season and high prevalence of gastrointestinal nematodes infestation. In the communal areas of the Eastern Cape Province of South Africa, indigenous Xhosa-lop-eared goats are known to adapt well under different vegetation types and resistant to parasites and diseases. Results from Chapter 4 and 5 have shown that kids and does have higher body weights and condition and lower gastrointestinal nematodes infestation in the forestland vegetation type compared to those in grassland vegetation type. The lower performance and higher prevalence of gastrointestinal nematodes infestation in indigenous goats observed in the grassland vegetation type could consequently lower goat productivity in communal farming system. For effective goat production in communal farming system, it is essential to determine nutritional status of indigenous Xhosa lop-eared does foraging in different vegetation types as the way to implement supplementary feeding programme based on vegetation type and season.

Natural vegetation in many developing countries serve as a main source of feed for goat production. Grasslands and forestlands are common vegetation types in Southern Africa (Dixon *et al.*, 2014). The forage availability and quality on both vegetation types vary with seasonal changes and geographical zones (Edwards *et al.,* 2012), water availability, soil nutrients and grazing management practices. Fodder trees and shrubs found in the forestland vegetation type consists of high crude protein (CP) (Gxasheka *et al.,* 2015) and other minerals (Mthi *et al*., 2021) and has anthelmintic properties (Xhomfulana *et al.,* 2009) which are essential for goat productivity. Moreover, Safari *et al*. (2010) highlighted close association of seasonal variations in the quality of forage, goat activity patterns and their productivity. Whilst grasses under grassland vegetation type have long been used as main source of forage for goat production, their availability abd nutritive value have been shown to be below the requirements for optimal goat performance (Wanapat *et al*., 2021).

Although grassland and forestland vegetation types contribute so greatly to goat production under resource-limited environment, interaction of vegetation type and season on nutritionally-related blood metabolites, liver enzymes and minerals in indigenous Xhosa lop-eared does foraging in grassland and forestland vegetation type is largely unknown. Study conducted by Tvarijonaviciute *et al.* (2017) reported that variations in the quality and quantity of forage significantly influence the values of blood metabolites in goats. Blood metabolites determine the efficiency of feed nutrients content and its utilization (Mohammed *et al.,* 2016); Soul *et al*., 2019). In other words, blood metabolites concentration reflect the balance between environmental supply and animal requirements for nutrients.

In the Eastern Cape Province of south Africa, the indigenous Xhosa lop-eared goat is one of the most popular breeds kept by resource-limited farmers to alleviate food insecurity. Does are more susceptible to gastrointestinal nematodes infestation, nutrients deficiency, metabolic disorders and reproductive diseases. Determination of glucose, urea, creatinine, total protein, albumin, globulin, albumin/globulin ratio, alanine transaminase, lactate dehydrogenase, total bilirubin, calcium and phosphorus in does foraging in grasslands and those in forestlands is necessary to improve goat productivity.

Blood constitutes are more likely to be influenced by vegetation type, season, (Thuthuzelwa and Brandly, 2020). However, there is limited information on the seasonal variations in the levels of nutritionally-related blood metabolites, liver enzymes and minerals in indigenous Xhosa lop-eared does foraging in grassland and forestland vegetation types. Determining these metabolites could contribute greatly on the strategic plans and implementations of goat health and nutrition programmes to ensure sustainable goat productivity based on vegetation type and season. Understanding this interaction is critical to detect nutritional imbalance, metabolic and health status of goats before the reproductive and productive capacity of goat can be negatively affected. The objective of the current study was to determine the interaction of vegetation type and season on nutritionally-related blood metabolites, liver enzymes and minerals in indigenous Xhosa lop-eared does. It was hypothesized that nutritionally related blood metabolites, liver enzymes and minerals in Xhosa lop-eared does are influenced by both the vegetation type and season.

6.2 Material and methods

6.2.1 Description of study site and ethical clearance

The study was conducted among goat farmers in two communities of Mbizana local Municipality in Alfred Nzo district in the Eastern Cape Province of South Africa. Communities that participated in the study were Khanyayo representing forestlands and Mpetsheni representing grasslands. These communities were selected based on vegetation type, goat ownership and their willingness to participate in the study and on the assurance of availability of the goats throughout the study period. Farmers from these communities raise goats and other livestock species that include cattle, sheep, chicken and pigs. Alfred Nzo district lies 30o 50"83' S and 28o 58'97' E at an altitude of 1055 m above sea level. The average maximum and minimum mean annual temperatures are 24 ^{0}C and 8.5 ^{0}C, respectively. The district receives an annual rainfall range between 750 and 1100 mm per annum; the rainy season is between October and March.

Vegetation in Alfred Nzo district is mostly temperate and transitional forest with scrub and some pure grassland vegetation. Alfred Nzo district has a fragmented topography and consists of a wide-ranging ecotone between the grassland and forestland with *Vachellia* species. Mpetsheni community that falls under grassland is dominated by the following grass species *Richardia humistrata, Eragrostis plana, E. chloromelas, Sporobolus africanus, Aristida congesta, Aristida juniformis, Cynodon dactylon, Themeda triandra, Eragrostis curvula* and *Cymbopogon plurinodis*. The dominant tree species at Khanyayo community which falls under forestlands, are *Sclerocarya birrea, Coddia rudis, Diospyros lysioides, Ehretia rigida, Cussonia spicuta, Vachellia karroo and Vachellia mearnsii (*Mthi *et al.,* 2021). The study complied with the standards required by the Animal Research Ethics Committee of the University of KwaZulu-Natal (Reference Number: 1434/018D).

6.2.2 Experimental does and their management

A total of 24 indigenous Xhosa lop-eared does (n =12 for grassland and n=12 for forestland) where used for this study. Does were between 1-5 years of age and was verified using the dentition estimation method by counting the number of permanent incisors erupted on the lower jaws of the mouth (Stevens and Houston, 1989). Goats were selected based on health status and showing no signs of diseases prior to study commencing by experienced state veterinarian. The goat flocks from Mpetsheni community were freely grazed in natural grasslands during the day whilst goat flocks in Khanyayo community browsed in natural forestlands as from 1000 to 1800 h and penned at night. No supplementary feeding was provided during study period. Data were collected in the cool-dry and hot-wet season on both grasslands and forestland vegetation type.

6.2.3 Blood collection

Blood samples were collected from each experimental doe once in the cool-dry and hot-wet seasons between 0600 and 0900 h. The study complied with the standards required by the

Animal Research Ethics Committee of the University of KwaZulu-Natal (Reference Number: 1434/018D). From each experimental doe, a 5 ml blood sample was collected from the jugular vein using a 21-gauge needle into tubes that contained no anticoagulants for determination of nutritionally related blood metabolites. After collection, the blood samples were stored in a cooler box with ice pack and transported at 4 º C to the laboratory of Animal and Poultry Science of University of KwaZulu-Natal in Pietermaritzburg.

6.2.4 Measurements

6.2.4.1 Body weights and body condition scoring

Body condition score (BCS) for each experimental doe was measured once in the morning from 0600 to 0900 h of cool-dry and hot-wet seasons. The experimental does were ear-tagged for easy identification and foraging in natural grasslands and forestlands. BCS was assessed using the five-point scoring system with score 1= being emaciated, 2=thin, 3=average, 4=fat and 5=obese (Ghosh *et al*., 2019).

6.2.4.2 Laboratory analyses of blood samples

The blood tubes without anticoagulant were allowed to coagulate in kaylite holders at 37 ºC for serum separation. After centrifugation (1000 x g for 10 minutes, at 25 ºC) within two hours of collection, the serum was stored in polypropylene tubes and kept at -20 ºC, pending analysis. Glucose was estimated in the serum using enzymatic methods (Gochman and Schmitz, 1972), in which NAE2-27 reagent was used following oxidation with glucose oxidase. The serum samples were analysed using a Chexcks machine (Next/Vetex Alfa Wasseman Analyser, Woerden, Netherlands) and commercially purchased kits (Siemens, South Africa). Serum was analysed spectrophotometrically for creatinine (Tietz, 1995) total protein and albumin (Pinnell and Northam, 1978), (Lowry *et al*., 1951) using colorimetric methods. Globulin concentrations were determined as a difference between total protein and albumin whilst albumin-globulin (A/G) ratio was obtained by dividing the albumin concentration by globulin concentration. Enzymatic methods were used for determination of urea analyses (Tietz, 1995). Ultraviolet methods were used for determination of Alanine aminotransferase (ALT), gamma glutamyltransferase (GGT) and Lactate dehydrogenase (LDH) (Horder *et al.,* 1991). Serum concentration for calcium, phosphorus and magnesium were analysed using 100/300 atomic absorption spectrophotometer according to operators manual (Analyst 300 Atomic Absorption Spectrometer-Hardware Guide). Total bilirubin was measured using commercial kits supplied by Spinreact (Spinreact, GIRONA, Spain), using a UV spectrophotometer (Optizen 3220 UV, Mecasys Co. Ltd, Korea).

6.2.5 Statistical analyses

All the data for the blood metabolites were checked for normality using the PROC UNIVARIATE of SAS (2016. The effect of vegetation type (grassland versus forestland), season (cool-dry versus hot-wet) on BW, BCS and blood metabolites of does were analysed using the general linear models procedure of SAS (2016). Pair-wise comparison of the least square means was performed using the PDIFF procedure of SAS, (2016).

6.3 Results

6.3.1 Interaction of vegetation type and season on nutritional-related blood metabolites

The effect of vegetation type, season and their interaction on the concentration of blood metabolites was determined in this current study and results are shown in Figure 6.1. There was a significant interaction between vegetation type and season on serum concentration of glucose ($P < 0.05$), total protein ($P < 0.05$), globulin ($P < 0.05$), albumin to globulin ratio ($P < 0.05$), and total bilirubin ($P < 0.01$). In the grassland vegetation type serum concentration of globulin was higher (P < 0.05) on both hot-wet and cool-dry season compared to forestland vegetation type which had higher (P < 0.05) serum concentration in the cool-dry than hot-wet season. Higher (P < 0.05) serum concentration of total protein was observed in the forestland vegetation type during the hot-wet season and lowest (P < 0.05) in the grassland during the cool-dry season. The serum concentration of globulin was higher (P < 0.05) in the hot-wet than col-dry season on both vegetation types. During the hot-wet season under forestland vegetation type, lower (P < 0.05) serum concentration of the albumin to globulin ratio was observed. Moreover, there were no significant (P > 0.05) interaction between vegetation and season in the serum concentration of albumin, creatinine and urea in Xhosa lop-eared does.

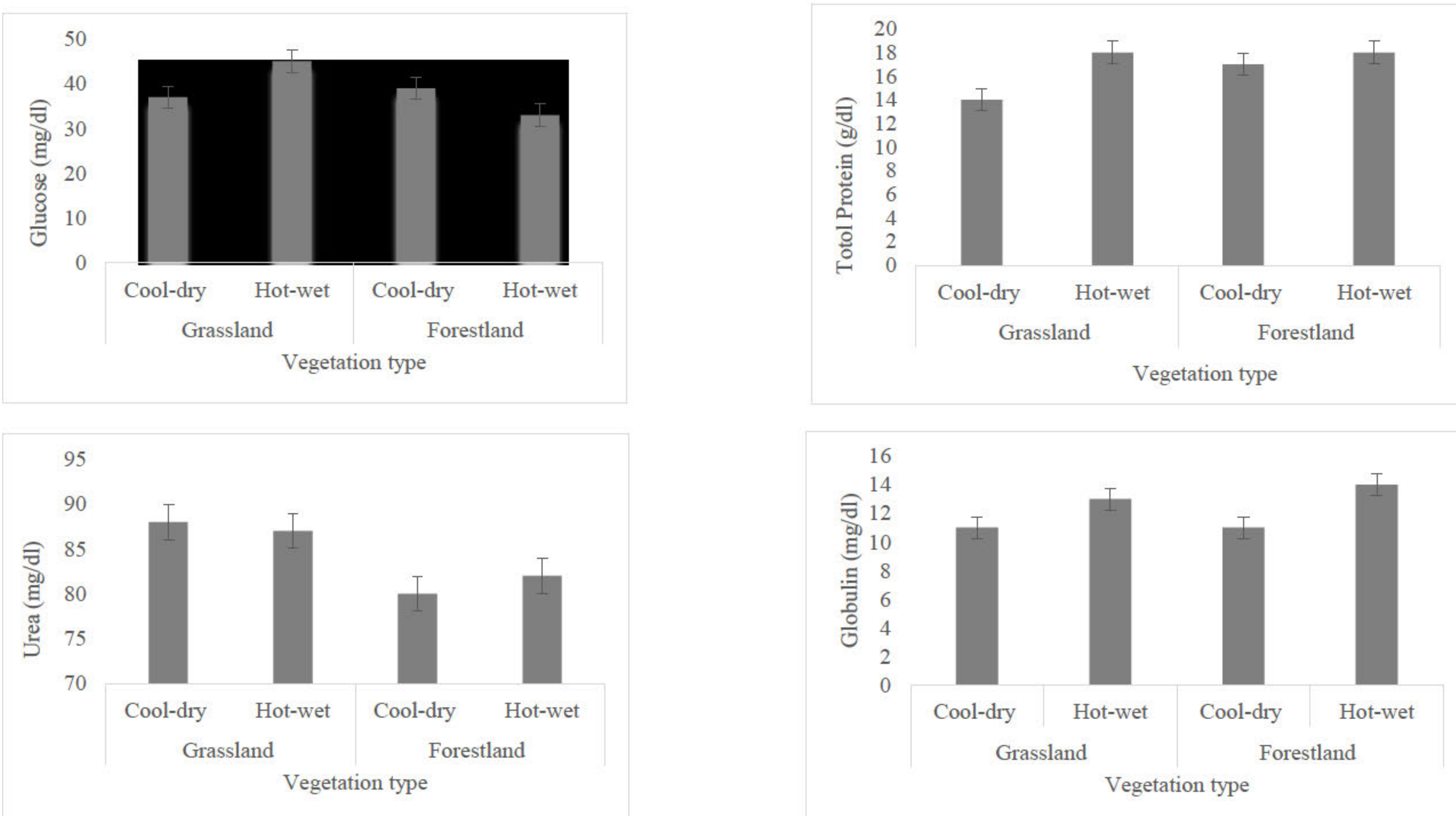
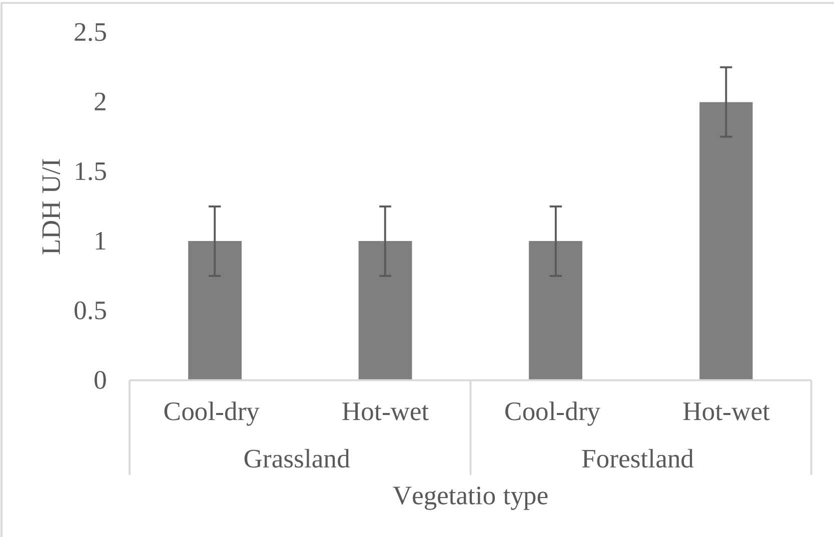


Figure 6.1: Interaction between vegetation type and season on serum concentration of glucose, total protein, urea and globulin concentrations

6.3.2 Effect of vegetation type and season on liver enzymes

There were no significant ($P > 0.05$) interaction between vegetation type and season in the serum concentration of lactate dehydrogenase (LDH), alanine aminotransferase (ALT) and gamma glutamyltransferase (GGT) in Xhosa lop-eared does as showed in Figure 6.2. However, does in the forestland had higher ($P < 0.05$) lactate dehydrogenase (LDH) serum concentration during hot-wet season compared to those grassland vegetation type. The serum concentration of ALT was observed to be higher during the hot-wet than cool-dry season on both vegetation types. The gamma glutamyltransferase (GGT) serum concentration in both vegetation types and seasons were higher than expected normal ranges of 0-30 u/l in healthy goats. The serum concentrations of total bilirubin were also higher ($P < 0.05$) during the hot-wet season than cool-dry season in the forestland.



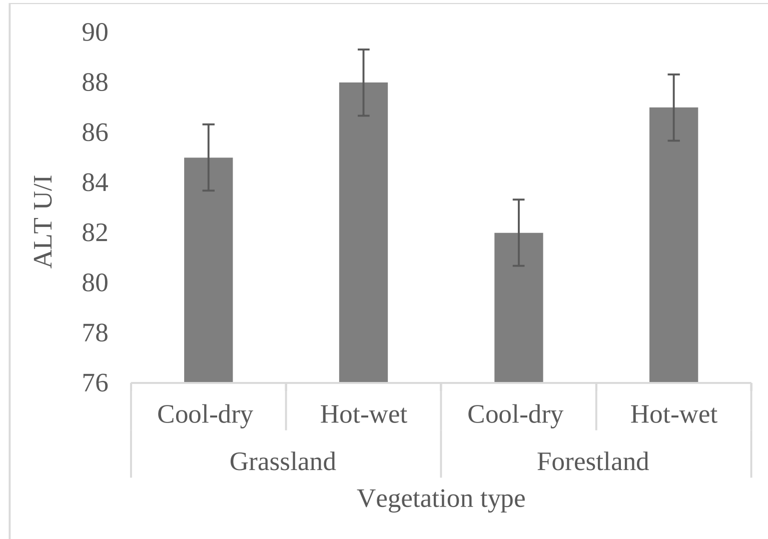
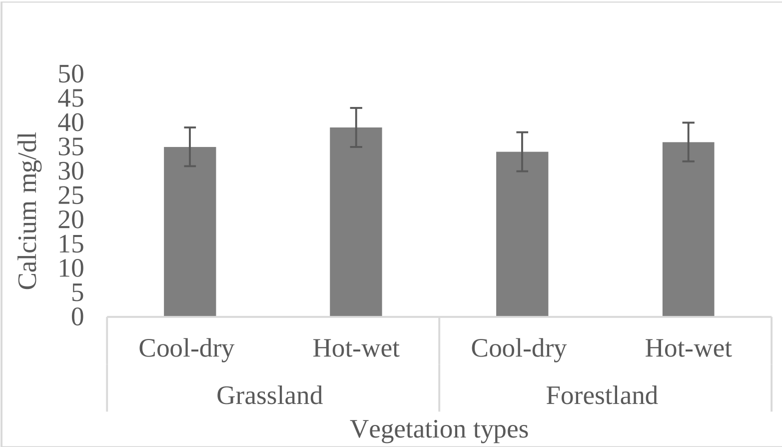


Figure 6.2: Interaction between vegetation type and season on serum concentration of lactate dehydrogenase and alanine aminotransferase

6.3.3 Effect of vegetation type and season on minerals

The interaction between vegetation type and season on minerals are presented in Figure 6.3. The interaction between vegetation type and season is significant different ($P < 0.05$) on calcium, phosphorus and magnesium serum concentration level. The serum concentration of calcium was lower ($P < 0.05$) during the cool-dry season than hot-wet season on both vegetation types. Does in the grassland vegetation type recorded higher ($P < 0.05$) serum concentration of phosphorus during the cool-dry season than hot-wet season. There were no significant interaction between vegetation type and season in the serum concentration of phosphorus during the hot-wet season than cool-dry season in the forestland vegetation types in Xhosa lop-eared does. There were no significant ($P > 0.05$) interaction between vegetation type and season in the serum concentration of magnesium observed in indigenous Xhosa lop-eared does. However, the serum concentration levels of magnesium for this present study was within the normal range of 3.5-5.2 mg/l in the grassland vegetation type on both cool-dry and hot-wet season.



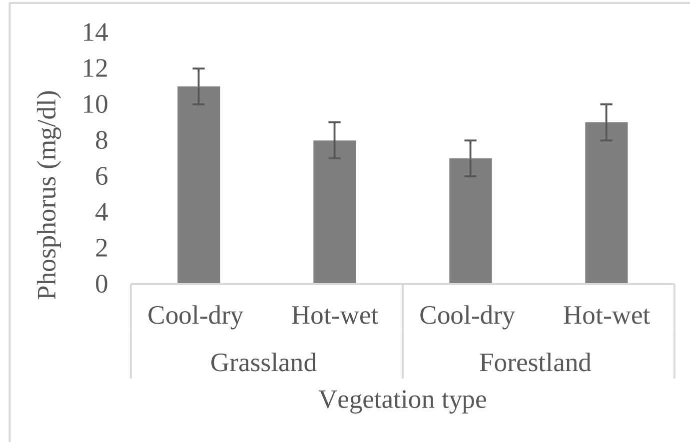


Figure 6.3: Interaction between vegetation type and season on serum concentration of calcium and phosphorus

6.4 Discussion

The study was conducted to determine the interaction between vegetation type and season on nutritional related blood metabolites, some liver enzymes and minerals in indigenous Xhosa lop-eared does. Understanding the interaction between vegetation type and season on nutritional related blood metabolites is essential for dietary supplements to meet the nutritional need of indigenous Xhosa lop-eared does. The serum concentration of blood metabolites is influenced by physiological status of animal, type of breed, nutrition, season and management practices (Ribeiro *et al*., 2018).

The serum concentration of glucose for does were observed to be low than the expected normal range of 50.09-74.96 mg/dl. However, that serum concentration of glucose was higher during hot-wet season than cool-dry season was expected. This is because forage species during this time of the year are highly nutritious, palatable and abundant. These findings are in line with Chimonyo *et al*. (2000) who observed significant reduction in the serum glucose concentration during winter season in cows. Moreover, Murillo-Ortiz *et al*. (2014) also reported highest serum glucose concentration during summer season. These results confirm that these vegetation types provide less nutritive values than required for optimal goat performance. The experimental does had higher total protein and globulin serum concentration in the forestland compared to grassland vegetation type. Hot-wet season recorded higher total protein and globulin serum concentration compared to cool-dry season. This in line with Rumosa-Gwaze *et al*., (2010b). These results contrast with Mapiye *et al.* (2010) who reported higher values of serum protein concentration in cattle during the cool-dry season. These values were far higher than the expected normal range of 6.2-7.9g/dl in healthy goat. The present results could be associated with the presents of various shrubs and trees species leaves in forestland vegetation types that are believed to be important source of protein for ruminants (Makkar and Becker, 1997). The high serum globulin concentration during hot-wet season could be attributed by the higher environmental temperatures (El-Harairy *et al*., loads of gastrointestinal nematodes infestation during this period, which favors nematodes activities).

The lower ($P < 0.05$) albumin to globulin ratio observed in the forestland is highly associated with lower albumin and higher globulin serum concentrations compared to the normal ranges observed by Chikwanda and Muchenje, (2017). Serum concentration of albumin to globulin ratio was found lower non-significant ($P > 0.05$) in the grassland were in line with Sharma and Puri, (2013). It has been reported that higher globulin and lower albumin serum concentrations are clear indicators of animal immune system fighting off infection (Ndlovu *et al*., 2009b). The albumin to globulin ration reflects protein synthesis ability in the liver. For effective goat productivity, supplementation of goats with well-balanced feed is recommended to improve concentration level of albumin on both vegetation type and season.

It has been explained that bilirubin is a yellowish pigment produced by the enzymatic degradation of heme (Omidi *et al*., 2017). The serum concentration of total bilirubin in the grassland vegetation type lies within the normal range of 0.0-0.90 mg/dl during the cool-dry and hot-wet season. Our results agree with the previous studies on Nigerian goats and dairy Saanen goat by Okonkwo *et al*. (2010) and Marutsova and Binev, (2020), respectively. The higher serum concentration of bilirubin observed during the hot-wet season in the forestland vegetation type are comparable with findings of Sharma and Puri, (2013). These results could indicate liver diseases in does foraging in the forestland, as some shrubs and trees contain a tremendous array of substance that are poisonous to goats compared to grass species in the grassland vegetation type. Moreover, study conducted by Zhu and Filippish, (1995) indicated that liver enzymes changes may be linked to high tannins content in the trees and shrubs. Singificant increase in liver enzyme aspartate amino transferase were reported in lambs fed on shrubs compared those fed hay (Badawy, 2002). In the present study, increased in GGT serum concentration was observed in both vegetation types and across the two sampling seasons. Does had higher serum concentration than the expected normal ranges of 0-30 u/l in healthy goats. These findings might signify the stress caused by gastrointestinal nematodes infestation in Xhosa lop-eared does (Shawaf *et al*., 2021).

Adequate mineral nutrient requirements are essential for processes such as reproduction and lactation in does. The serum concentration of calcium observed in this current study was below the normal range of 41.1-52.3 mg/dl. These results are similar to the previous study by Omidi *et al*. (2017) observed the mean values of calcium (6.32 ± 1.47 mg/dl) in Persian wild goats. However, hot-wet season recorded higher ranges of serum concentration of calcium compared to cool-dry season on both vegetation types. This can be explained by the dominance nutritious of grass species in grassland and browse species such *Coddia rudis* and *Diospyros lysiodes* containing crude protein above 8% in forestlands (Mthi *et al.,* 2021). Moreover, crude protein content of forage species is adequate for maintenance for the experimental does during hot-wet season. It has been reported that mean crude protein content was higher during the rainy season (116 g/kg DM) when compared to late dry seasons (<40 g/kg DM) in semi-arid area of Tanzania (Safari *et al*. 2011). The serum concentration of phosphorus observed in does foraging in grassland and forestland vegetation types were lower than the expected normal range of 18.02-43.24 mg/dl in healthy goat. These results are in line with Tahas *et al*. (2012) and Omidi *et al*. (2017) conducted in West African pymgny goats and Persian wild goats. These findings can be attributed by the fact that levels of phosphorus decreases as the does get older. Concerning serum concentration of magnesium, the present study findings demonstrated no significant interaction between vegetation type and season in serum concentrations of magnesium. However, serum concentration of magnesium were within the normal range of 3.5-5.4 of healthy goat. Lower serum concentration of magnesium was observed in Xhosa lop-eared does during the hot-wet season than cool-dry season in the forestland vegetation type. These results are in line with previous findings by Donia *et al*. (2014) who reported higher serum levels of magnesium during the dry season. The finding, that most does had mineral values were within the normal range might suggest that the Xhosa lop-eared does are adapted to the available forage on both vegetation types. Moreover, these results might indicate that studied does did not require supplementation of the minerals during the study period. For sustainable goat production in developing countries more precisely in communal farming system, determination of macro minerals is essential for diagnostic purposes of metabolic disorders.

6.5 Conclusions

Interaction between vegetation type and season significantly influenced serum concentration of glucose, total protein, globulin, albumin/globulin ratio, total bilirubin, calcium, magnesium and phosphorus. Higher serum concentration of glucose, total protein and calcium were observed during the hot-wet season than cool-dry season, signify adequate and nutritious forage for does maintenance requirements. Based on these findings supplementation of balanced diet to does is essential during cool-dry season, more precisely in the grassland vegetation type. A further study should consider determination of nutritional composition of dominant forage species in the grassland and forestland vegetation types.

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Chapter 7: General discussion, conclusion and recommendations

7.1 General discussion

The broad objective of the current study was to determine gastrointestinal nematodes infestation (GIN), kid's performance and nutritionally-related blood metabolites status of indigenous Xhosa lop-eared goats foraging in grasslands relative to those browsing in forestlands vegetation type. In order to improving indigenous goat production under communal farming system, it is however, important to understand farmer's attitude and practices on the control of gastrointestinal nematodes infestation as well the nutritional status and performance of indigenous goats foraging in the grassland and those in the forestland vegetation types.

First, a survey was conducted to investigate the perception of resource-limited goat farmers on the infestation and control of GIN infestation. Monthly changes in body condition scores, body weights and prevalence of GIN in Xhosa lop-eared goats raised in grassland relative to those in forestland was determined. The effect of vegetation type, season and parity on the burden of GIN in Xhosa lop-eared does that were foraging in grassland and forestland vegetation types were assessed. Interaction between vegetation type and season on the nutritionally-related blood metabolites, liver enzymes and minerals in Xhosa lop-eared does foraging in the grassland and forestland vegetation type were also determined. The main hypothesis tested in the current study was that gastrointestinal nematodes burden, goat performance and nutritionally-related blood metabolites of indigenous does lop-eared does influenced by vegetation types and season.

In chapter 3, a survey was conducted to investigate the perception of goat farmers on the infestation and control of gastrointestinal nematode infestation in goats foraging in grassland and forestland type. The majority of resource-limited goat farmers perceived that goat's foraging on grassland are exposed to gastrointestinal nematode infestation than those in the forestland vegetation types. Farmers on both vegetation types reported higher infestation of gastrointestinal nematode in tethered goats. Convention medicine was the most common method used to control gastrointestinal nematodes in goats compared to ethno-veterinary medicines (Zvinorova *et al*., 2016a). In order to improve goat productivity for resource-limited farmers under extensive farming system, it is essential to determine monthly changes on body weight, body condition scores and prevalence of gastrointestinal nematodes in goat kids raised under grassland and forestland types, since the size of future herd is also determined by survival rate of kids after weaning.

A monitoring study (Chapter 4) was determined to evaluate the variation in the prevalence of GIP and their effect on growth performance in indigenous Xhosa lop-eared goat raised in grassland and forestland vegetation types. There is limited information documented on the growth performance and gastrointestinal parasites in indigebous Xhosa lop-eared goat raised in the forestland and grassland vegetation type.

Xhosa lop-eared goat had higher body weights and body condition score during the month of May compared to January and February. Goats in the forestland had higher body weights and condition and lower faecal egg count compared to those in grassland vegetation type. This could be attributed by the presence of forage trees and shrubs that consists of high crude protein and some nutrients which certainly improve goat's performance. The dominant gastrointestinal parasite eggs collected during the study were strongyles, *Strongyloides, Nematodirus, Trichuris* and Coccidial oocysts. Higher prevalence of gastrointestinal parasites eggs was recorded between the month of January and February. For effective goat health programmes under communal based farming system, it is important to assess the prevalence and loads of gastrointestinal nematodes in Xhosa lop-eared does foraging in grassland and forestland vegetation types.

In chapter 5, it was hypothesized that the seasonal GIN burden in Xhosa lop-eared does is influenced by vegetation type. Xhosa lop-eared does in the forestland had higher body weight and body condition score as compared to those in grassland. Does faecal egg counts were higher in the grassland vegetation compared to those in the forestland. Body weight, faecal egg count and FAMACHA scores were higher in the hot-wet season than cool-dry and post-rainy season (Pfukenyi and Mukaratirwa, 2013). Strongyles and *Strongyloides* eggs were highest in does grazing in the grassland than those in the forestland during hot season. These results could suggest that forestland vegetation have effect on the prevalence and loads of GIN and doe performance.

In chapter 6, Since vegetation type and seasonal variations had significant effect on prevalence and loads of GIN infestation in Xhosa lop-eared does (Chapter 5), for sustainable goat productivity it is necessary to determine interaction of vegetation type and season on the serum concentration of nutritional related blood metabolites, liver enzymes and minerals in Xhosa lop-eared does. The higher serum concentration of glucose, total protein and calcium during the hot-wet season than cool-dry season were observed. These results could be inline with adequately, lush and nutritious forage plant species during the hot-wet season (Safari *et al*. 2010). Globulin serum concentration increased in the hot-wet season could explain higher prevalence and loads of gastrointestinal nematodes infestation in does (Ndlovu *et al*., 2009b). The lower serum concentration of phosphorus observed in does foraging in grassland and forestland vegetation types, simply because phosphorus serum concentration decrease with age and due to quality of forage (Abdolvahabi *et* *al*., 2016). Does had lower serum concentration of magnesium during the hot-wet season than cool-dry season in the forestland vegetation type, however, serum concentration levels of many does were within the normal range. These results might suggest that the Xhosa lop-eared does are adapted to the available forage on both vegetation types. Moreover, these results might indicate that studied does did not require supplementation of the minerals during the study period. Provision of glucose, protein, calcium supplements to Xhosa lop-eared does could be necessary, more precisely during the dry season in the grassland vegetation type.

7.2 Conclusions

Farmers from grassland vegetation type ranked GIN infestation as the major constraint than those in forestland, particularly during hot-wet season. However, farmers in the grassland perceive to apply attitudes and practices to control GIN infestation. The perceptions and knowledge on the burden and control of GIN infestation influence control and management practices of gastrointestinal nematode. Xhosa lop-eared goats in forestland were less susceptible in the GIN infestation as indicated by lower loads of faecal egg counts in conjunction with higher body weight and body condition score compared to those in grassland vegetation type. Goats had higher prevalence and loads of faecal egg counts during the period of January and February of 2019. Does in the grassland had higher loads of GIN and FAMACHA scores during the hot-wet than cool-dry and post-rainy season. Forestlands does had higher body weights and body condition scores compared to those foraging in grasslands. It was concluded that gastrointestinal nematode infestation was the major limiting factor in goat productivity, particularly during hot-wet season and in the grasslands vegetation types. Forestland vegetation type and hot-wet provide adequate and nutritious forage for Xhosa lop-eared does, as indicated by higher serum concentration of glucose, total protein and calcium, particularly during the hotwet season. Based on the study findings forage trees and shrubs found in the forestland vegetation types have the potential to supplement low quality natural grasses under grassland vegetation type, more precisely during dry season.

7.3 Recommendations and further research

It is recommended that goat farmers under resource-limited environment, should be empowered by awareness's and trainings through extension on the management and control of gastrointestinal nematodes based on season and vegetation type. Developing management and control strategies of gastrointestinal nematodes infestation based on month variations, age group of goats and vegetation type is fundamental. Alternative, resource-limited goat farmers should be advice take their goats to forestland vegetation type, more precisely during the cool-dry season, which is the cheapest source of nutrients supplementation and have the potential to reduce worm burden. It is recommended that, implementation of deworming and supplementation feeding programmes should mainly target goats foraging in grassland vegetation types due to higher prevalence of gastrointestinal nematodes, lower performance and serum concentration of nutritionally-related blood metabolites particularly during dry season. On other hand deworming programs should be at the beginning of the cool-dry season and towards the end of the hot-wet season more precisely on the grassland vegetation type and culling does with consistently high faecal egg counts and FAMACHA scores is recommended.

Areas that require further research includes:

Effect of gastrointestinal nematodes infestation on goat reproductivity performance under different vegetation type, since growth performance of goats was reduced due to high prevalence and loads of gastrointestinal nematodes.

1. Relationship between grazing behavior and prevalence and loads of gastrointestinal nematodes in goats foraging in different vegetation types, as goats in foresland vegetation type had low gastrointestinal nematodes infestation relatively to those in grassland.
2. Influence of different vegetation types on the resistance of gastrointestinal nematodes in indigenous Xhosa-lop eared does.

7.4 References

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8. Appendices

Appendix 8.1 Ethical clearance

UNIVERSITY OF KWAZULU-NATAL ™

INYUVESI YAKWAZULU-NATALI

28 November 2018

Mr Luxolo Qokweni (214577323)
School of Agricultural, Earth & Environmental Sciences
Pietermaritzburg Campus

Dear Mr Qokweni,

Protocol reference number: HSS/1434/018D
Project title: Farmer perceptions on the effect of *Vachellia karroo* and *Vachellia tortilis* on the gastrointestinal nematodes infection in goats

Approval Notification – Expedited Application

In response to your application received on 03 September 2018, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

[redacted]

....

Professor Shenuka Singh (Chair)

/ms

Cc Supervisor: Professor Michael Chimonyo and Dr Munyaradzi C Marufu
cc Academic Leader Research: Professor Hussein Shimelis
cc School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
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Appendix 8.2: Survey Questionnaire

The objective of the questionnaire was to investigate the perceptions of goat farmers on the infestation and control of gastrointestinal nematodes infestation.

Questionnaire No:………………… Enumerator…………….……………
Municipality:……………………..… Village …………………………………
Name of Farmer:…………………… Date of interview……………………….

A. Household Demography information

1. **Head of household**:

a. Sex M ☐ F ☐

b. **Marital status** Married ☐ Single ☐ Divorced ☐ Widow ☐ Never been married ☐

c. Age 21-30 ☐ > 30-45 ☐ >45-60 ☐ >60 ☐

d. **Highest education level**: Never attended school □ Primary □Secondary □ >Tertiary □

2. **Major source of income:** Formal employed ☐ Self-employed ☐ Social grant ☐ Pension ☐ Part time ☐ Unemployed ☐ Other specify………………………………..

3. **Religion**: Christian ☐ Traditional ☐ Moslem ☐ Other (specify)………..................….

4. **Is the head of the household resident on the farm**? Yes ☐ No ☐

5. **What is the size of the household**? Adults: M…. F……Children: M…….F………..

6. **How much land do you own** (ha)..............................

7. **Socio-economic status** Very poor ☐ Poor ☐ Less poor ☐

8. Goat ownership ……………..

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

Species(s)	**Cattle**	**Goats**	**Sheep**	**Chickens**	**Other(specify)**
Number					
Rank					

10. What is the composition of your goat flock?

Kids (less than 7 months) ☐…. Bucks…☐. ….Does ☐….. Wethers ☐…..

11. What goat breeds do you have?

Breed	**Boer**	**Nguni**	**Kalahari Red**	**Non-descript breed**	**Other (Specify)**
Number					

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

Use	Rank	Use	Rank
Meat		Status	
Milk		Ceremonies	
Manure		Other (specify)	
Skin			

B. GOAT HEALTH AND PARASITES

1. If your goat is sick, what do you do? Nothing ☐ Treat ☐ other specify…………….

2. If your goat is sick, who do you get advice from? (Tick one or more)
Neighbors ☐ Veterinarian☐ Drug suppliers ☐ Extension officer/ AHT ☐No one ☐……..Other (specify) ………………

3. Do you get technical advice regularly? Yes ☐ No ☐

4. What are the most prevalent diseases and parasites in your flock? (Rank 1 as the most common) State reason of high prevalence and control measures for the named diseases and parasites

Diseases/Parasites	**Rank**	**Reason of high prevalence**	**Control**
Intestinal parasites			
Ticks and tick-borne diseases			
Bluetongue			
Pulpy kidney			
Skin problem			
Plant poising			
Eye problem			
Other specify……			

5. What are common types of gastrointestinal parasites in your goats? (TICK)
(a) Round worm, (b) Flukes (c) Tape worms (d) Other (specify)…………………(Rank 1 as the most common)

Internal parasites	**Rank**
Round worms	
Flukes	
Tape worms	
Other (Specify)	

6. What are the common signs/symptoms of gastrointestinal infections in goats? (a) diarrhea (b) Anaemia , (c) Poor body condition, (d) Death) other specify…………………………..

7. Does occurrence of gastrointestinal infection related to seasons? Yes ☐ No☐
If yes which season? Summer ☐ autumn ☐winter☐ spring ☐

8. What are the negative consequences of gastrointestinal parasites? Reduce Productivity ☐ Cause sickness ☐ Mortality ☐Reduce growth rate ☐other specify………….

9. Do you treat goats for gastrointestinal parasites? Yes ☐ No ☐

10. If yes, how often do you treat your goats for gastrointestinal parasites? Weekly ☐ Monthly ☐ bi-annually ☐ Once a year ☐ When goat is sick☐ others (specify) ………………..

11. What type of medicine do you use to treat your goats for gastrointestinal parasites? Conventional ☐… Traditional ☐… Other (specify)…….…….and Why? ….Efficacy ☐ availability ☐ accessibility ☐ cost ☐ ease of use ☐ other (specify)……………………… (Rank 1 as the most important)

Reason(s)	**Rank**
Efficacy	
Availability	
Accessibility	
Cost	
Ease of use	
Other specify……	

12. If you use conventional medications which treatment practices do you use against GINs: such as

- ➢ Products……………………………………………………..…………
- ➢ Treatment times………………………………………………………
- ➢ Dosages of anthelmintic drugs…………………………………………
- ➢ Frequency …………………………………..……………………………

13. If they use traditional/herbal medicine which plants or herbs are commonly used? ……………………………………………………………………………………………

14. Is there any governmental or non-governmental program design for gastrointestinal parasite control strategy in your village? Yes☐ No☐.

b. if Yes please may you describe it……………..

15. Do you participate in any livestock project in your village? Yes☐ no ☐

b. If Yes please describe your involvement……………………………………………………………..

16. What are the other goat production constraints?

…………………………………………………………………………………………

C. GOAT FEEDING AND MANAGEMENT

1. What type of feeding system do you use?

Herding ☐… ….Free browsing ☐…Tethered ☐……other specify ☐

2. What problems do you face in management browsing /grazing area?

- Over browsing on the grazing area? Yes ☐ No ☐

- Poor quality and quantity of feed Yes ☐ No ☐
- Others specify………………………………………

3. Do you manage grazing in order to control GIN ?
4. Does GIN commonly occur during times of reduced or increased grazing?
5. Which *Vachellia* species do you know? *Vachellia karroo,* ☐ *Vachellia tortilis* ☐ other specify ……………………………
6. Which *Vachellia* species do goats prefer..
7. What effects does it have on your goats?...
8. Do *Vachellia* species reduce GIN? Yes☐ No ☐ not sure☐
9. If yes, which *vachellia* species effectively control GIN in goats?
10. Does v*achelli*a species works better in kids or adult goats? Kids ☐ adult ☐ both☐ not sure☐
11. Is there any difference on gastrointestinal nematodes infection on goats feeding on grass land compare to those browse on *vachellia* species Yes☐ No ☐ not sure☐.
12. Do you provide supplementary feed to your goats? Yes ☐ No ☐
13. If yes, when do you provide supplements for your goats? Rainy season ☐Winter ☐All year round ☐ in times of emergency ☐ other (specify)………………………………..
14. How often do you provide supplementary feeding? More than twice a day☐ once a day ☐ every 2 – 4 days ☐ Weekly ☐ Forty-nightly ☐ other (specify).…………………..
15. What type of supplements do you provide for your goats?

Type of supplements	**Tick**
Crop residues	
Bought-in feed	
Licks	
None	
Other (specify)…………..	

16. How does supplementing feed assist in controlling gastrointestinal parasites of goats: does not help ☐ reduce the frequency of treatment ☐ reduce the clinical signs ☐ increase the immunity of goats ☐ reduce mortalities ☐ other (specify)………………………………………………

17.

Goats Management to control gastrointestinal nematodes	**Yes**	**No**
Do you use of anthelmintics in new animals		
Do you yearly rotation of anthelmintic		
Do you deworm new goats before introduction to the flock		
Do you separate sick animals when showing signs of GIN infection		
Do you cull goats which are frequently prone to GIN infection/show signs despite regular treatment,		
Is it important to you to deworm does and kids during lactation		
Do you vaccinate goats against GIN		
Do you check goat faecal pats on pasture/in kraals for visible GIN regularly,		

Appendix 8.3: McMaster counting technique (for nematodes)

Principle

The McMaster counting technique is a quantitative technique to determine the number of eggs present per gram of faeces (E.P.G). A flotation fluid is used to separate eggs from faecal material in a counting chamber (McMaster) with two compartments. The technique described below detects 50 or more E.P.G. of faeces.

Application

This technique can be used to provide a quantitative estimate of egg output for nematodes, cestodes and coccidia. Its use to quantify levels of infection is limited by the factors governing egg excretion.

Equipment

Beakers or plastic containers, balance, a tea strainer or cheesecloth, measuring cylinder, stirring device (fork, tongue depressor), pasteur pipettes and (rubber) teats, flotation fluid (see the Appendix to this handbook for formulation), McMaster counting chamber, microscope.

Procedure

(a) Weigh 4 g of faeces and place into Container 1.

(b) Add 56 mL of flotation fluid.

(c) Mix (stir) the contents thoroughly with a stirring device (fork, tongue blade).

(d) Filter the faecal suspension through a tea strainer or a double-layer of cheesecloth into Container 2.

(e) While stirring the filtrate in Container 2, take a sub-sample with a Pasteur pipette.

(f) Fill both sides of the McMaster counting chamber with the sub-sample.

(g) Allow the counting chamber to stand for 5 minutes (this is important)

(h) Examine the sub-sample of the filtrate under a microscope at 10 x 10 magnification.

(i) Count all eggs and coccidia oocytes within the engraved area of both chambers.

(j) The number of eggs per gram of faeces can be calculated as follows: Add the egg counts of the two chambers together. Multiply the total by 50. This gives the E.P.G. of faeces. (Example: 12 eggs seen in chamber 1 and 15 eggs seen in chamber 2 = (23 + 17) x 50 = 2000 E.P.G).

(k) In the event that the McMaster is negative (no eggs seen), the filtrate in Container 2 can be used for the simple flotation method (section 3.2.2), steps f, g and h.

Appendix 8.4 Determination of blood metabolites

The blood tubes without anticoagulant were allowed to coagulate in kaylite holders at 37 ºC for serum separation. After centrifugation (1000 x g for 10 minutes, at 25 ºC) within two hours of collection, the serum was stored in polypropylene tubes and kept at -20 ºC, pending analysis. Glucose was estimated in the serum using enzymatic methods in which NAE2-27 reagent was used following oxidation with glucose oxidase. The serum samples were analysed using a Chexcks machine (Next/Vetex Alfa Wasseman Analyser, Woerden, Netherlands) and commercially purchased kits (Siemens, South Africa). Serum was analysed spectrophotometrically for creatinine total protein and albumin using colorimetric methods. Globulin concentrations were determined as a difference between total protein and albumin whilst albumin-globulin (A/G) ratio was obtained by dividing the albumin concentration by globulin concentration. Enzymatic methods were used for determination of urea analyses. Ultraviolet methods were used for determination of Alanine aminotransferase (ALT), gamma glutamyltransferase (GGT) and Lactate dehydrogenase (LDH). Serum concentration for calcium, phosphorus and magnesium were analysed using 100/300 atomic absorption spectrophotometer according to operators manual (Analyst 300 Atomic Absorption Spectrometer-Hardware Guide). Total bilirubin was measured using commercial kits supplied by Spinreact (Spinreact, GIRONA, Spain), using a UV spectrophotometer (Optizen 3220 UV, Mecasys Co. Ltd, Korea). The blood values were categorised into below, normal and above normal range considering the reference values.

Appendix 8.5 Conference attended

Poster presentation: Farmers' perceptions and knowledge on the loads and control of gastrointestinal nematodes infestation in goats under different vegetation types, South African Society for Animal Sciences, 51st Biannual congress, University of Free State, Bloemfontein, South Africa, 10-12 June 2019.

Paper Presentation: Differences in burden of gastrointestinal nematode infestations in indigenous does foraging in grassland and forestland vegetation types, South African Society for Agricultural Extension, 54th Conference, Ashanti Estate, Sunstraal Road, Paarl, Western Cape, South Africa, 11-14 October 2021.

Appendix 8.6: Publications related to this thesis

1. Qokweni, L., Chimonyo, M. and Marufu, M.C., 2020. Attitudes and practices of resource-limited farmers on the control of gastrointestinal nematodes in goats foraging in grassland and forestlands, Tropical Animal Health and Production, Manuscript number: TROP-D-20-00868.
2. Qokweni, L., Chimonyo, M. and Marufu, M.C., 2021. Differences in burden of gastrointestinal nematode infestations in indigenous does foraging in grassland and forestland vegetation types, Tropical Animal Health and Production, Manuscript number: TROP-D-20-01820.

Tropical Animal Health and Production
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REGULAR ARTICLES

Attitudes and practices of resource-limited farmers on the control of gastrointestinal nematodes in goats foraging in grasslands and forestlands

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Abstract

Gastrointestinal nematode infestations remain one of the main constraints to goat productivity. A cross-sectional survey was conducted to investigate the perceptions of goat farmers on the infestation and control of gastrointestinal nematode infestation. A total of 282 goat farmers from two villages of Mbizana local municipality in Alfred Nzo district were interviewed. Higher prevalence of diseases, parasites and feed availability were among the major constraints to goat productivity. Gastrointestinalparasites were ranked as the major constraint by farmers in the grassland than those in the forestland. Ordinal logistic regression analyses revealed that farmers in the grassland were 3.2 times more likely to experience gastrointestinal nematode infestation thanthose in the forestland ($P <$ 0.05). On both vegetation types, tethered goats were perceived to have higher ($P < 0.05$) GIN infestation compared with free browsing goats. Poor farmers were 3.1 times more ($P < 0.05$) likely to experience high GIN infestation compared with less poor farmers. Farmers in the grassland were 2.1 times more likely to control GI nematode infestation than to those in the forestland ($P < 0.05$). Intervention strategies to control gastrointestinal nematodes should mainly target farmers from the grassland vegetation since they experience higher infestation rates of gastrointestinal nematodes.

Keywords Forestlands · Grasslands · Disease · Gastrointestinal nematodes · Goats

Highlights
• High prevalence of diseases and parasites are main constraints in communal goat productivity.
• Farmers in the grassland were more likely to experience effect of GIN infestation than those in the forestland.
• Grassland farmers were more likely to control GIN infestation than to those in forestland.
• Educated farmers were more likely to be aware of the attitudes and practices to control GIN infestation compared with uneducated farmers.
• Tethered goats had high gastrointestinal nematode infestation both in the forestland and vegetation type.
• Majority of farmers use conversional medicine to control gastrointestinal nematodes.

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Introduction

Goat production in developing countries contributes significantly to the economic development and alleviation of hunger and poverty of resource-limited households. More than 60% of the total goat population are owned by resource-limited households (Devendra 2013). Goats are important in providing food security and income of between 49 and 86% in resource-limited households (Kumar et al. 2006; Manzi et al. 2013). Despite providing these benefits, goat production is highly impacted by parasitic diseases, feed availability and quality and low reproduction efficiency (Thornton et al. 2007; Scholtz et al. 2013).

Gastrointestinal nematode (GIN) infestations are among the important limiting factors to goat production (Calvete et al. 2014; Zvinorova et al. 2016; Mpofu et al. 2020). *Haemonchus contortus* is the major goat health challenge in developing countries (Vatta and Lindberg 2006; Spickett et al. 2012) and linked with great economic impact (Marume et al. 2011; Roeber et al. 2013). Infestation with GIN is highly associated with low productivity, reduced performance, weight gain, retarded growth, costs relative to treatment and mortality (Marume et al. 2011). Molento (2009) reported that GIN prevalence is higher where the level of management is low. Moreover, resource-limited farmers treat sick animals than adopting preventive measures (Idamokoro et al. 2016).

Vegetation type plays a significant role on goat production. Variations in the quality and quantity of vegetation vary with climate and soil characteristics, water availability, soil nutrients and grazing management. The most common types of vegetation in Southern Africa are grassland, desert, shrublands, savanna, woodlands, forestland and tundra (Dixon et al. 2014). Vegetation type affects nutrition, immunity of goats, worm cycle and stocking density (Kumar et al. 2013; Giday et al. 2018).

Grassland is a vegetation type that is dominated by grasses and lack of trees while forestland is characterized by dominance of various species of trees. Zvinorova et al. (2016) and Mpofu et al. (2020) indicated that GIN infestation is considered as the main challenge in goat production. To enhance goat productivity, it is essential to investigate perceptions on goat keepers on the infestation and control of GIN to assist policymakers and local municipalities to develop effective deworming programmes based on the type of vegetation in each environment. Understanding perceptions and attitudes of goat keepers on GIN assists in the formulation of sustainable and effective control strategies.

The forestlands have a great variety of medicinal plants that are likely to possess anthelmintic properties. Comparison of the perceptions of goat keepers in the grasslands and forestlands on the likelihood and burden of infestation, as well as control of gastrointestinal nematodes, provides a platform to assess whether goat health programmes could be vegetation-specific. The hypothesis tested was that perceptions on the infestation rate and control of gastrointestinal nematodes across vegetation types are similar.

Materials and methods

Description of study site

This study was conducted in two communities (Khanyayo and Mpetsheni) in Mbizana local municipality under Alfred Nzo district in the Eastern Cape Province, South Africa. Alfred Nzo district is located at 30° 50′ 83′ S and 28° 58′ 97′ E and lies at an altitude of 342 m above sea level. Climate ranges from pleasant warm summers to cold winters with snow in high lying areas. The study sites also experience climatic extremes in the form of storms, tornadoes and floods which normally occur once or twice in a year and resulted in soil erosion in some areas. Study sites receive an annual rainfall range between 650 and 1100 mm per annum; the rainy season is between October and March. The warmest month is February with an average temperature of 24 °C and lowest average temperature of 8 °C in July. Vegetation types are owned by community members and farmers have an equal opportunity to choice types of vegetation to feed their goats. The district has a fragmented topography and consists of a wide-ranging ecotone between the grassland and forestland with *Vachellia* species. In the grassland, the dominant grass species are *Richardia humistrata*, *Eragrostis plana*, *E. chloromelas*, *Sporobolus africanus*, *Aristida congesta*, *Aristida junciformis*, *Cynodon dactylon*, *Themeda triandra*, *Eragrostis curvula* and *Cybopogon plurinodis*. The dominant tree species in the forestland are *Sclerocarya birrea*, *Caddra rudis*, *Cussonia spicuta* and *Vachellia karroo* (Acocks 1988).

Sampling and data collection

These study sites were selected based on vegetation type, livestock production system and willingness of the communities to participate in the survey. Khanyayo village represented the forestland as goats are freely browsing on natural forestland while Mpetsheni village represented the grassland vegetation, as goat farmers practise goat herding and tethering on grassland. Goat farmers were selected using snowball sampling, based on willingness to participate in the study and on the number of goats owned per household. Preference was given to those farmers with four or more goats. A total of 282 goat farmers were interviewed in this study, 119 from Khanyayo village and 163 from Mpetsheni village. Informal interviews were conducted with the animal health technicians, extension officers, herbalists and community leaders to obtain more quality data and information for the study. Farmer's perceptions on gastrointestinal nematode infestation in goats foraging on natural grasslands and those browsing on forestlands were gathered using a structured questionnaire. Trained enumerators conducted the interviews using the local Xhosa vernacular to obtain the accurate information. Each farmer was interviewed individually in his/her homestead. Aspects covered in the questionnaires included household demography, goat health and parasites, goat feeding and management.

Statistical analyses

All the data were analysed using Statistical Analysis System (2012). Chi-square test was used to determine associations between demographic information and vegetation types. The general linear model procedure was used to determine the effect of vegetation type on livestock herd composition and size. Chi-square test was also used to determine the associations between household perceptions and vegetation types. Pairwise comparisons of the least square means were performed using the PDIFF option. An ordinal logistic regression model (PROC LOGISTIC) was used to predict the odds of a household's perceived infestation of GIN in goats between the vegetation types. The variables that fitted in the logit model included vegetation type, gender, marital status, age, level of education, religious and social status.

Table 1 Socio-economic status of farmers participated in the study

The model used is shown below:

$$\text{Ln } [p/1 - p] = \beta 0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_t x_t + \varepsilon$$

where p is the probability of a farmers perceived infestation of gastrointestinal nematode infestation, $[p/1 - p]$ is the odds ratio of a households perceived infestation GIN infestation, $\beta 0$ is the intercept, $\beta_1 \ldots \beta_t$ are the regression coefficients of predictors, $X_1 \ldots X_t$ are the predictor variables, and ε is the random residual error. When computing each predictor ($\beta_1 \ldots \beta_t$), the odds ratio for GIN infestation was interpreted as the proportion of households that experience GIN infesta-tion versus those households that experience no GIN infesta-tion. A similar model was performed to determine farmer perceptions on the control of GIN infestation, with P being the probability of a farmer perceiving to control GIN infestation.

Parameters	Grassland (%) (n = 163)	Forestland (%) (n = 119)	X^2 value	Significance
Gender				
Male	52	55	0.30	NS
Female	48	45		
Age				
21-30	7	10	3.56	NS
30-45	27	27		
45-60	41	43		
> 60	25	20		
Marital				
Married	68	70	6.61	NS
Single	22	22		
Widow	8	6		
Level of education				
Never attend school	37	20	15.34	*
Primary	41	40		
Secondary	21	33		
Tertiary	1	7		
Source of income				
Formal-employed	4	13	14.00	NS
Self-employed	14	13		
Social grant	59	41		
Pension	7	11		
Part-time	6	9		
Unemployed	10	13		
Religious				
Christian	64	67	0.36	NS
Traditional	36	33		
Socio-economic status				
Very poor	27	13	12.70	*
Poor	38	58		
Less poor	35	29		
Who own goats				
Male	53	60	1.10	NS
Female	47	40		

*Significant association at $P < 0.05$, *NS* not significant ($P > 0.05$)

Results

Social demographic information and constraints togoat productivity

Socio-economic demographics of farmers who participated in the study are shown in Table 1. Vegetation type was significantly associated with level of education ($P < 0.05$) and socio-economic status ($P < 0.05$). Most of the farmers in the grassland (41%) and the forestland (40%) had gone through primary education. Most of the farmers ($P < 0.05$) in the forestland (53%) were considered poor compared with 21% of the farmers in the grassland. High prevalence of diseases ($P < 0.05$) was the main limiting factor on goat production in both areas (Table 2). High prevalence of parasites was reported as the major constraint in grassland ($P < 0.05$) compared with forestland.

Burden of gastrointestinal nematode infestation

There was an association ($P < 0.05$) between feeding systems and the vegetation type. Tethered goats were reported to have higher ($P < 0.05$) infestation of GIN than free grazing goats from both vegetation types. Farmers across the vegetation types practised communal grazing for their goats. Unlimited browsing was the major goat (61%) in the forestland type while tethering was feeding system practiced (57 %) in the grassland type. Most of the farmers in the grassland (78%) and forestland (91%) reported that goat tethering lead to higher gastrointestinal nematode infestation. Farmer perceptions on the prevalence of gastrointestinal nematode infestation were significantly associated ($P < 0.05$) with vegetation types. Gastrointestinal nematode prevalence was higher in the grass-land (82%) than in the forestland (57%).

The odds ratio estimates of farmers who perceived to ex-perience effect of gastrointestinal nematode infestations in goats foraging in the grassland and those in the forestland were higher on vegetation type, age and social economic sta-tus (Table 3). Farmers in the grassland were 3.2 times more likely to experience the effects of gastrointestinal nematodes infestation than those in the forestland ($P < 0.05$). The proba-bility of experiencing GIN infestation by younger farmers between the vegetation types ($P < 0.05$) were four times more

Table 2 Constraints to goat production

Variables	Grassland (n = 163)	Forestland (n = 119)	Significance

Low feed availability	4 (3.16)	3 (3.11)	NS
High prevalence of diseases	1 (2.35)	1 (1.92)	*
High prevalence of parasites	2 (2.47)	4 (3.21)	*
Goat thefts and predation	3 (2.70)	2 (2.53)	NS
Poor marketing channels	5 (4.85)	5 (4.68)	NS

The lower the rank (mean rank score), the greater its importance values in parenthesis indicate means for ranks
*$P < 0.05$, *NS* not significant ($P > 0.05$)

likely compared with older farmers. Poor farmers were 3.1 times more ($P < 0.05$) likely to experience effect of GIN infestation compared with less poor farmers.

Control of gastrointestinal nematodes

Vegetation type, age, level of education and socio-economic status highly influence ($P < 0.05$) the household's likelihood to control GI nematodes (Table 4). Farmers in the grassland were 2.1 times more likely to control GI nematode infestation than those in the forestland ($P < 0.05$). Younger farmers (youth) were more likely to control GI nematode infestation than older farmers ($P < 0.05$). Educated farmers were more likely to be aware of the attitudes and practices to control GIN infestation compared with uneducated farmers ($P < 0.05$). Poor farmers were 3.1 times less likely to apply clearly the attitudes and practices to control GI nematode in-festation in goats ($P < 0.05$).

Farmer views on the goat management to control gastrointestinal nematodes were significant associated $P < 0.05$) as shown in Table 5. Most farmers in the grassland (98%) and forestland (74%) reported that they treat and vaccinate their goat flocks to control gastrointestinal nematode infestation. About 68% and 36% of farmers in the grassland and forestland, respectively, use anthelmintics in a newly introduced goat in the flock. A higher proportion of the farmers in the grassland (76%) reported to rotate the anthelmintics ($P < 0.05$) to control gastrointestinal nematodes in contrast to only 22% in the forestland type. Most ($P < 0.05$) of the farmers in the grassland (84%) and forestland (62%) highlighted that goats that are frequently prone to gastrointestinal infestation were culled from the flock. Moreover 58% and 60% of farmers in the grassland and forestland type, respectively, perceived to treat sick goats separately to avoid spread of disease to other goats. All the interviewed farmers from both vegetation types never weighed their goats before dosing.

Perceptions on gastrointestinal nematode controlmethods

There was a significant difference on roundworms between the vegetation types as shown in Table 6. Farmers from forestland type reported roundworms as the most common gastrointestinal parasites affecting goat flock. Farmer perceptions on seasons with high prevalence of gastrointestinal nematode infestation were different ($P < 0.05$) on cool-dry and hot-wet season. Most of the farmers in the grassland 60% and forestland 82% reported that kids and weaners are more susceptible to gastrointestinal nematode infestation. Most of the respondents in both grassland and forestland reported that they use conventional medicines to control gastrointestinal nematodes infection. About 35 and 29% of the farmers in the grassland

Table 3 Odds ratio estimates lower (L) and upper (U) confidence interval (CI) of household perceived infestation of gastrointestinal nematodes in goats fed kept in grassland and forestland vegetation types

Predictor	Odds ratio	L CI	U CI	Significance
Vegetation type (grassland vs forestland)	3.2	1.436	7.452	*
Gender (male vs female)	1.0	0.354	2.171	NS
Marital status (single vs married)	1.9	0.768	4.532	NS
Age (youth vs adult)	4.3	1.802	10.369	*
Education (educated vs uneducated)	1.0	0.329	1.543	NS
Source of income (Employed vs unemployed)	1.0	0.422	2.105	NS
Religious (Christian vs traditional)	1.8	0.567	5.730	NS
Social economic status (poor vs less poor)	3.1	1.425	6.714	*

The higher the odds ratio, the stronger the household perceive infestation of GIN infestation between vegetation types. *CI* confidence interval. NS: $P > 0.05$ *$P < 0.05$, *GIN* gastrointestinal nematodes

Table 4 Odds ratio estimates for control of gastrointestinal nematode infestation

Predictor	Odds ratio	L CI	U CI	Significance
Vegetation type (grassland vs forestland)	2.1	0.991	4.612	*
Gender (male vs female)	1.4	0.363	5.675	NS
Marital status (single vs married)	1.5	0.632	3.394	NS
Age (youth vs adult)	0.5	0.211	1.141	*
Education (educated vs uneducated	0.2	0.083	0.388	*
Source of income (employed vs unemployed)	1.2	0.590	2.587	NS
Religious (Christian vs traditional)	1.0	0.472	2.237	NS
Social economic status (poor vs less poor)	3.1	1.411	6.811	*

The higher the odds ratio, the stronger the predictions to control GIN infestation between vegetation types. *CI* confidence interval. NS: $P > 0.05$ *$P < 0.05$, *GIN* gastrointestinal nematodes

and forestland received advice from drug suppliers concerning sick goats, respectively.

Medicinal plants used to control gastrointestinalnematodes

There are several medical plants used to control gastrointestinal nematode infestation (Table 7). *Aloe ferox*, *Vachellia karroo*, *Asteraceae*, *Melia azedarach* and *Trema orientalis* (L.) *Blume* were dominant medical plant species used to control gastrointestinal nematode infestation in goats reared under forestland type as presented in Fig. 1. *Psidium guajava* and *Ziziphus mucronata* medical plant species were only reported in the grassland type to treat internal parasites. Plant parts used for preparation of traditional remedies include fruits, leaves, barks, stems and roots. Leaves were highlighted as the frequently used plant parts for preparation of medicine. Decoction and infusion preparation methods were highlighted as the common methods used for preparation of traditional medicine for goats. A few farmers, 8% and 9%, in the grassland and forestland highlighted that there is no difference on gastrointestinal nematode infestation on goats browsing in the forestland relative to those grazing on the grassland type. More farmers in the grassland type (1.3 ± 0.07) indicated to use conventional medicine against gastrointestinal nematode infestation compared with the farmers in the forestland type (1.0 ± 0.08). Moreover, 5% and 34% ($P < 0.05$) of the farmers in the grassland and forestland highlighted, respectively, to use both conventional and traditional medicine to control gastrointestinal nematode infestation as shown in Fig. 2.

Discussion

This study was conducted to explore farmer perceptions on infestation and control of gastrointestinal nematodes in goats foraging in the grassland relative to the forestland. Understanding the perceptions of farmers on the infestation and control of gastrointestinal nematodes benefits policymakers and other stakeholders in the goat production industry to implement strategies to manage and control gastrointestinal nematode infestation in goats and lead to prolific goat productivity.

From this study, level of education and socio-economic status had influence on the level of knowledge and understanding on the infestations and control of GIN among

Table 5 Measures to control gastrointestinal nematodes

Activities	Grassland	Forestland	Significance
Use of any anthelmintics in new animals	68	36	*
Rotation use of anthelmintics	76	22	*
Deworming new goats before introduction to the flock	48	58	*
Separation of sick animals when showing signs of GIN infestation	40	60	*
Culling of goats which frequently prone to GIN infestation	84	62	* Is it
important deworm does and kids during lactation?	91	91	NS
Vaccination of goats against GIN	2	5	NS
Evaluation of goat faecal pats on pasture/in kraals for visible GIN regularly	60	67	NS

*Indicate significant association at $P \leq 0.0$

Table 6 Ranks of common types of internal parasites and their seasonsof prevalence

Internal parasites	Grassland	Forestland	Significance
Roundworms	2 (1.68)	1 (1.41)	*
Tapeworms	1 (1.59)	2 (1.56)	NS
Fluke	3 (1.95)	3 (2.11)	NS
Seasons			
Hot-wet	1 (1.02)	1 (1.12)	NS
Post-rainy	2 (2.13)	3 (1.97)	NS
Cool-dry	4 (2.84)	4 (2.45)	*
Hot-dry	3 (2.26)	2 (1.76)	*

The lower the rank (mean rank score) of common types of GIP and seasons of prevalence, the greater its importance values in parenthesis indicates means for ranks, **P* < 0.05, *NS* not significant (*P* > 0.05)

the vegetation types. This concurs with Khapayi and Celliers (2016) who indicated that low level of education hinders farmers to understand the dynamics of agriculture. Moreover, education measures the level of human capital of farmers.

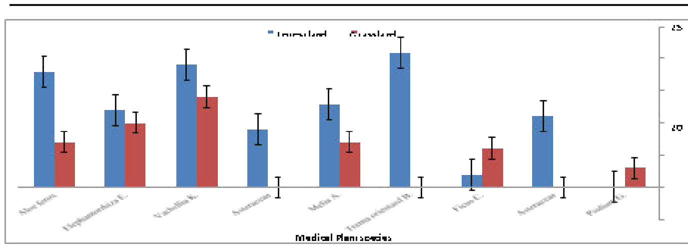
The majority of farmers reported that goats feeding in grassland type are more likely to be exposed on gastrointestinal nematode infestation. These findings could be associated with re-infection in contaminated pastures. These findings agree with Xhomfulana et al. (2009) who reported that Nguni cattle which fed on the *Vachellia karroo* diet had low mean strongyles and total faecal egg counts. A high proportion of farmers in the grassland reported poor quality feed, more especially during the cool-dry season, compared with those in the forestland. Giday et al. (2018) observed that feed shortage occurs almost around the months of March to June.

Ben Salem and Smith (2008) stated that farming systems in developing countries are characterized by poor quality pastures that contribute significantly to inadequate forage for livestock and further lead to low productivity (Thomas et al. 2004). Moreover, this can be attributed by the fact that there is less rainfall during the cool-dry season compared with the rainy season. This situation is worsened by the feeding system such as goat tethering which is mostly practiced by communal resource-limited farmers (Rumosa Gwaze et al. 2009), especially during cropping season. Both vegetation types reported higher infestation of gastrointestinal nematodes on tethered goats. These current study findings agree with Kahiya et al. (2003), Akkari et al. (2008), Xhomfulana et al. (2009) and Nsereko et al. 2015) who reported that goats mainly browsing on shrubs tend to have lower gastrointestinal burdens, since the chances of picking infective larvae from pasture are reduced. This can be also attributed by the fact that forestlands composed of tannin-rich plants that are capable of reducing worm burden and improve goat performance. Tethering is associated with exposure to high larval loads on pasture as farmers inadvertently tether goats on the lush patches which may expose goats to higher contamination on pastures. Moreover, tethered goats fail to withstand the GIN infestation due to inadequate nutrition access.

It is, therefore, important to come up with management strategies that will focus on feeding systems and health to enhance goat productivity of resource-limited farmers. A study conducted by Marume et al. (2011) also showed a marked decrease in faecal larva count and low worm counts at necropsy in goats that fed the *Vachellia* leaves. Moreover, this can be attributed to the fact that *Vachellia* species have tannins that simply impair the key biological process of the parasitic nematodes. Farmers additionally emphasized that

Table 7 Medicinal plants used to control gastrointestinal nematode infestation

Family	Scientific name	Local name	Part of plant used	Preparation method	Significance
Asphodelaceae	*Aloe ferox*	Ikhala elikhulu	Leaves	Decoction	*
Fabaceae	*Elephantorrhiza elephantina*	Intolwane	Roots	Decoction	NS
Fabaceae	*Vachellia karroo*	Umnga	Bark, leaves	Decoction	*
Cannabaceae	*Trema orientalis* (L.) *Blume*	Umbhangabhanga	Leaves, bark	Infusion	*
Fabaceae	Asteraceae	Udwabasini	Leaves	Decoction	*
Myrtaceae	*Psidium guajava*	Umgwava	Leaves	Infusion	NS
Rhamnaceae	*Ziziphus mucronata*	Umphafa	Leaves	Infusion	NS
Meliaceae	*Melia azedarach*	Umsilinga	Leaves	Decoction	*
Artermisia	Asteraceae	Umhlonyane	Leaves	Decoction	*
Moraceae	*Ficus craterostoma*	Intendekwane	Leaves, roots	Infusion	NS



Decoction, heating in water to boiling point; infusion, soaking in ambient water temperature overnight

**P* < 0.05; *NS* not significant (*P* > 0.05)

Fig. 1 Perceived medical plantsto control gastrointestinal nematodes in goats

goats browsing on trees and shrubs with *Vachellia* species have good body confirmation, resistance to diseases and are more productive. So it is necessary to determine the effect of vegetation types on a goat's performance. A study conducted by Idamokoro et al. (2016) reported that feeding goats with *Vachellia karroo* leaves improve animal performance, reduce worm burden and increase growth rate. Maguraushe (2015) further reported that goats browsing in the veld dominated by *Vachellia karroo* had higher numbers of offspring born compared with the herds in the open grassland.

High prevalence of diseases and parasites were major limiting factors on goat productivity. These findings are similar to earlier reports in Zimbabwe by Zvinorova et al. (2016)) and in South Africa by Mpofu et al. (2020)) in goats. These results also agreed with Marufu et al. (2008)), Mapiye et al. (2009), and Bath et al. (2016)) who reported high loads of gastrointestinal nematodes during the hot-wet season in cattle. Roundworms were common internal parasites affecting goats, more precisely in the hot-wet season. These results are similar to the findings of Marufu et al. (2011) who observed high egg loads during the hot-dry season in cattle and Zvinorova et al. (2016) who recorded higher prevalence of gastrointestinal nematodes in the wet season than in the dry season in goats. This can be attributed to the fact that hot-dry and hot-wet season are favourable periods for the survival and development of parasites. Hot-dry season is a period of the year where first rains fall and greater intake of infective larvae from the pasture occurs. However, during this period goat productivity is highly negative-impacted and this results to great economic losses, more precisely to resource-poor farmers of developing countries. Moreover, this current study revealed that kids are more susceptible to gastrointestinal nematode infestation followed by weaners; these results are comparable with the findings of Zvinorova et al. (2016) who observed higher prevalence of infestation in younger animal yearlings 78% compared with the oldest goats 7 years to be 38%.

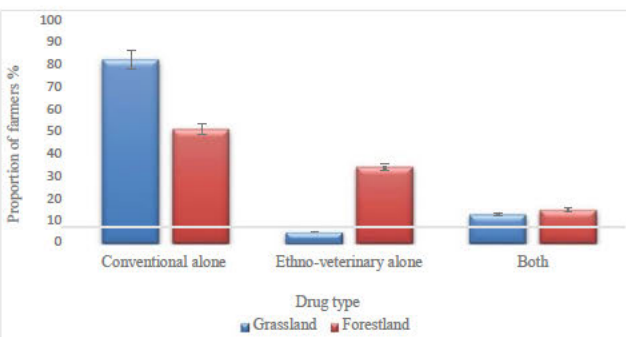


Fig. 2 Type of drug used to control gastrointestinal nematodes in goats

The findings show that *Aloe ferox*, *Vachellia karroo*, and *Elephantorrhiza elephantina* were dominant medical plant species used to control gastrointestinal nematode infestation in goats reared under the forestland type which corroborate with the findings of Masika et al. (2000). This study revealed that the leaves were the most used plant part for the preparation of remedies (Sanhokwe et al. 2016; Masika et al. 2000). Most of the farmers on both vegetation types seem to follow goat management practices. These findings are in contrast to Forbes and Trollope (1991), who reported that farmers are reluctant to adopt livestock and veld management practices and they cannot afford winter dietary supplementation.

The finding shows that most farmers on both vegetation types commonly use conventional medicines alone to treat their goats for gastrointestinal nematode infestation; this suggest that conventional medicines are more effective than ethno-veterinary medicines. The findings from the current study are similar to Akkari et al. (2008) and Zvinorova et al. (2016) who reported that control of parasitic diseases chiefly depends on the use of broad-spectrum anthelmintics. However, frequent usage of the same group of anthelmintics contributed to a widespread development of anthelmintic resistance in parasites. The results which show that majority of the farmers used conventional medicine differ with Masika et al. (2000) who estimated that 75% of the livestock farmers in the Eastern Cape Province use traditional medicine to treat their livestock. The minority, 21 and 13%, of farmers use both traditional and conversational medication. The use of herbal remedies can be attributed to the fact that traditional medicines are cheap, locally available and convenient to administer (Masika et al. 2000). The finding that farmers in both vegetation types culled goats that were susceptible to gastrointestinal infestation concurs with Mushonga et al. (2018) who reported that gastrointestinal nematodes lead to forced culling of animals. Therefore, for successful management and control of gastrointestinal nematode infestation in goats, there is a need to determine the actual faecal egg counts to give a better control regime.

Conclusions

Farmer perceptions on the infestation and control of gastrointestinal nematode infestation differ with vegetation type. Grassland farmers perceived a higher infestation rate of gastrointestinal nematodes in goats than those in the forestland, though they perceived to apply attitudes and practices to control gastrointestinal nematode infestation. Implementation of deworming programmers should mainly target grassland farmers. Further research should focus on loads of gastrointestinal nematode infestation in goats reared in grassland relative to forestland type.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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REGULAR ARTICLES

Differences in burden of gastrointestinal nematode infestations in indigenous does foraging in grassland and forestland vegetation types

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Abstract
Gastrointestinal nematode (GIN) infestations remain a major challenge to the health, productivity and reproductive perfor- mance of small ruminants. A longitudinal study was conducted to assess the effect of vegetation type, season and parity on the burden of GIN in indigenous does that were foraging in grassland and forestland vegetation types. Body condition scores(BCS), packed cell volume (PCV), FAMACHA score and faecal egg counts (FEC) were determined in Xhosa lop-eared does (n = 165) during the cool-dry, hot-wet and post-rainy seasons in both vegetation types. Faecal samples were collected fromthe rectum and analysed using the modified McMaster technique. There was a significant association between vegetation type and season on the recorded BCS, body weight (BW), FEC, PCV and FAMACHA scores. Xhosa lop-eared does in the forestland had higher ($P < 0.05$) BCS as compared to those in grassland. Higher FEC ($P < 0.05$) were observed in Xhosa lop-eared does in the grassland vegetation compared to those in forestland. Body condition scores, FEC and FAMACHA scores were significantly higher in the hot-wet season than cool-dry and post-rainy seasons, while PCV was significantly higher during the cool-dry compared to hot-wet season in forestland. Strongyles and *Strongyloides* eggs were higher in does grazing in the grassland than those in the forestland during the hot-wet season. Strategies for the effective control of GINin goats should consider that infestation levels differ with vegetation type, season and parity. Controlling of GIN in goats, therefore, requires an integrated control strategy that should consider the vegetation type that the goats are reared on.

Keywords Does · Indigenous goats · Parity · Prevalence · Strongyle eggs · Vegetation type

Highlights
- Vegetation type affects body condition score, packed cell volume, FAMACHA scores and FEC.
- Body condition scores were higher, while FEC and FAMACHA scores were lower in the forestland vegetation type.
- Does in the forestland vegetation types had lower faecal egg counts for strongyles species than those in grassland vegetation type.

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Introduction

Indigenous Xhosa lop-eared goats have been part of the livelihoods for resource-limited farmers for centuries. They improve food and nutrition security, income generation, savings and socioeconomic welfare (Devendra 2013; Wodajo et al. 2020). These goats adapt well to various agro-climatic conditions and vegetation types and are tolerant to diseases and parasites. Goat productivity is generally low in developing countries (Mpofu et al. 2020; Qokweni et al. 2020). The major constraints include high prevalence of diseases and gastrointestinal parasites, poor quality and quantity of feed and low levels of management.

Gastrointestinal nematode (GIN) infestation remains oneof the limiting factors to goat productivity (Zvinorova et al., 2016a, b). The epidemiology of GIN in goats varies with climatic conditions, vegetation type, season and management practices (Giday et al. 2018). In Southern Africa, common GIN affecting goats are strongyles including *Haemonchus contortus*, *Trichostronglylus colubriformis*, *Teladorsagia circumcincta* and *Nematodirus* spp. The GIN infestation has been associated with a reduction in meat quality, body weight gainsand

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milk production and kid survival (Hassan et al. 2019). TheGIN also reduce feed conversion efficiency, doe fertility andincome generation (Taylor et al. 2007; Roeber et al. 2013).

Natural vegetation is the sole source of feed for goats in most communal production systems. Vegetation types found in Southern Africa include forestland, grassland, desert, shrublands, savanna, woodlands and tundra. Forestlandsand grasslands are the most dominant in semi-arid environ-ments (Dixon et al. 2014). The grassland vegetation type is dominated by grasses and lack of trees, while forestland is characterized by the dominance of various species of trees (Qokweni et al. 2020). Trees and shrubs are rich in poly-phenolic compounds, which reduce GIN burden (Max et al. 2003; Evitayani et al. 2004). Goats browsing in forestlands have lower chances of picking infective larvae from shrubs and trees than those in grasslands (Kumar et al. 2013; Gidayet al. 2018). Marume et al. (2012) highlighted that goats fedon *Vachellia* leaves had a markedly low faecal larval and worm counts at necropsy. Goats that forage in grasslands are constantly exposed to infective larvae and thus get re-infected in a cyclical fashion. Determining the likely differ-ences in GIN burden due to the influence of vegetation type could assist in the formulation of sustainable interventions for improved goat productivity.

High GIN loads lead to reduced packed cell volume (PCV), body weight and condition (Kurukulasuriya et al. 2018). The PCV in goats should range from 22 to 38% (Onzima et al. 2017). The Faffa Malan Chart (FAMACHA) score system is the clinical assessment of anaemia by assess-ing the colour of the conjunctival mucous membrane (Van Wyk and Bath 2002). There is, however, no information on the interaction between vegetation type, season and parity on levels of anaemia and faecal egg counts in indigenous Xhosa lop-eared does reared in different vegetation types. Does are more susceptible to nematodes than other goat classes (Rotimi et al. 2017; Dey et al. 2020). Understand- ing the effects of vegetation type on anaemia capacitates goat farmers in developing effective vegetation type-specific measures for GIN control. The objective of the study was to assess the prevalence and loads of GIN in Xhosa lop-eared does foraging in grassland and forestland vegetation types. It was hypothesized that the seasonal GIN burden in Xhosalop-eared does is influenced by vegetation type.

Material and methods

Study site

The study was conducted with goat farmers in two commu-nities of Mbizana local municipality in Alfred Nzo district in the Eastern Cape Province of South Africa. Khanyayo and Mpetsheni communities used the forestland and grass- land vegetation types, respectively. These communities were selected based on their willingness to participate in thestudy. Alfred Nzo district lies 30° 50″83′ S and 28° 58″97′ Eat 1055 m above sea level. The average maximum and mini-mum annual temperatures were 24 °C and 8.5 °C, respec- tively. The district received an annual rainfall of between 750 and 1100 m. The rainy season is between October and March (Agriculture Geo-Referenced Information System, 2017). Alfred Nzo district had a fragmented topography andconsists of a wide-ranging ecotone between the grassland and forestland with *Vachellia* species. Mpetsheni communitywas dominated by *Richardia humistrata*, *Eragrostis plana*, *E. chloromelas*, *Sporobolus africanus*, *Aristida congesta*, *Aristida junciformis*, *Cynodon dactylon*, *Themeda triandra*, *Eragrostis curvula* and *Cymbopogon plurinodis*. The domi-nant tree species at Khanyayo community were *Sclerocarya birrea*, *Caddra rudis*, *Ehretia rigida*, *Cussonia spicata* and *Vachellia karroo* (Acocks 1988). The vegetation in Khan-yayo and Mpetsheni is sourveld and sweetveld, respectively.In the grasslands, forages are largely unpalatable during cool-dry season.

Experimental does and their management

In each community, goat flock sizes per household ranged from 5 to 65. A total of 165 Xhosa lop-eared does (n = 80 for grassland and n = 85 for forestland) were used in the study. Based on dentition (Stevens and Houston 1989), the does were aged between 1 and 5 years (see Table 1). All the experimental does were ear tagged for easy identificationat the beginning of the study. The body weight of does in the grassland vegetation type ranged between 28 and 39 kg (averaging 34 ± 7.6). Does from the forestland vegetation type weighed between 35 and 48 kg (averaging 38 ± 7.3). All the experimental does were clinically healthy at the commencement of the study. The experimental does had not been treated against GIN for at least 6 weeks prior to data collection. They were dosed against GIN using alben- dazole and levamisole hydrochloride at the beginning of thetrial. Does from the Mpetsheni community freely grazed in natural grasslands during the day, while those in the Khan-yayo community browsed from 1000 to 1800 h and pennedat night. Once in the season, experimental does receiveda single oral dose of broad-spectrum anthelmintic to clear GIN infestation, and no supplementary feed were provided

Table 1 Allocation of Xhosa lop-eared does according to age (years) into vegetation types (grassland and forestland)

Age (years)	Grassland	Forestland
1–2	14	16
> 2–3	19	20
> 3–4	22	19
> 4–5	10	18
> 5	15	12

throughout the study. Data were collected in the cool-dry, hot-wet and post-rainy seasons. The study complied with the standards required by the Animal Research Ethics Committee of the University of KwaZulu-Natal (Reference Number: 1434/018D).

Blood collection

Blood samples were collected from each experimental Xhosa lop-eared doe once in the cool-dry, hot-wet and post-rainy seasons between 0600 and 0900 h. For each doe, blood was collected from the jugular vein using a 21-gauge needle attached to a 5-ml syringe and immediately transferred intoa blood tube containing ethylene diamine tetra acetic acid (EDTA) for PCV determination. The blood samples were stored in a cooler box with ice pack and transported at 4 °Cto the Animal and Poultry Science laboratory of the Uni- versity of KwaZulu-Natal in Pietermaritzburg for analyses.

Faecal collection

Fresh faecal samples were collected between 0600 and0900 h in the cool-dry, hot-wet and post-rainy seasons. Thefaeces were collected directly from the rectum of each doe using a lubricated and gloved hand. Each faecal sample wasplaced in a labelled sealable plastic bag. The faecal sampleswere stored at 4 °C for 24 h before analyses.

Measurements

Body weights and body condition scoring

For each Xhosalop-eared doe, body weight (BW) and body condition score(BCS) were measured from 0600 to 0900 h in the cool-dry, hot-wet and post-rainy seasons. The body weights were esti-mated using goat weigh-band (Asefa et al. 2017). The BCSwas assessed visually and by palpation using the 5-point scoring system with score 1 = being emaciated, 2 = thin,3 = average, 4 = fat and 5 = obese (Ghosh et al. 2019).

Packed cell volume The PCV of the EDTA blood samples was measured using the micro-haematocrit method. Blood was drawn into non-heparinized micro-haematocrit capillary tubes (1.40 × 1.60 × 75 mm, Lasec Pty Ltd, Cape Town, South Africa) by capillary action; one end of the capillary tube was sealed before centrifugation in a micro-haemato- crit centrifuge (MSE, London, Great Britain) for 3 min at 1000 × *g*.

Faecal egg counts and FAMACHA scoring Faecal egg counts (FEC) were determined using the modified McMaster technique with a saturated solution of 40% sugar solution with a specific gravity of 1.27. Two grams of faeces was mixed with 58 ml of saturated sugar solution. The number of nematode eggs per gram (EPG) of faeces was obtained by multiplying the total number of eggs counted in the two chamber squares of the McMaster slide by the dilution fac-tor of 50 (Hanse and Perry 1994). The McMaster technique detection limit was 50 eggs per gram of faeces. The FAMACHA scoring system was used to determine the severity of parasite infestation by opening the lower eyelid of each doe and comparing the colour of the conjunctiva with a 5-point scale (Van Wyk and Bath 2002).

Statistical analyses

Data were checked for normality using the PROC UNIVARIATE of SAS (2016). To normalize data, faecal egg count and body weight change were transformed using $\log_{10}(x+1)$.Data were analysed using the generalized linear models for repeated measures of Statistical Analysis System (2016) to assess effect of vegetation type, season, age, parity and their first-order interactions on FAMACHA scores, PCV, FEC, BCS and BW. The chi-square test was used to determine associations between loads of parasite and vegetation type, season, age and parity (SAS 2016).

Results

Effect of vegetation type, season, parity and age on bodyweight changes

The effect of vegetation type on performance of does across the cool-dry, hot-wet and post-rainy seasons is depicted in Fig. 1. Across all seasons, does foraging in forestland vegetation type had higher ($P < 0.05$) body weight gain than those in the grassland. During the cool-dry season, does from forestland gained more ($P < 0.05$) weight than those in grassland vegetation type. All does experienced body weight losses during the hot-wet season.

Effect of vegetation type and season on FEC, PCV,FAMACHA and BCS

The effects of vegetation type, season and their interaction on FEC, PCV, FS and body condition scores in does are shown in Table 2. There was an interaction between vegeta-tion type and season on BCS ($P < 0.05$). Higher BCS were observed in does in the forestland vegetation type during thehot-wet and post-rainy seasons than for does in the grass- land. The hot-wet season had higher ($P < 0.05$) FEC than cool-dry season in both vegetation types. There was also an

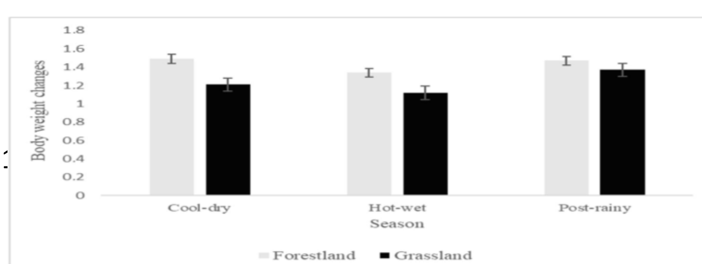

Fig. 1 The overall effect of vegetation type on body weightchange of does across the seasons

interaction ($P < 0.05$) between vegetation type and season on PCV. In the forestland vegetation types, PCV was higher($P <$ 0.05) in the cool-dry season than in the hot-wet season.In both vegetation types, PCV was highest in the post-rainyseason. In the forestland vegetation type, FAMACHA scoreswere higher ($P < 0.05$) in the hot-wet than cool-dry season.There was also a significant interaction between vegetationtypes and season on BCS.

Effect of vegetation type and parity on FEC, PCVand FAMACHA scores

The interaction of vegetation and parity on FEC, FAMACHA scores and PCV in does foraging in both vegetation types are shown in Table 3. Faecal egg counts were significantly affected by both vegetation type and parity of does (P < 0.05). Both vegetation type and parity had significant ($P <$ 0.05) effect on FAMACHA scores. Packed cell volumewas, however, significantly higher in old does in the forest-land vegetation type.

Prevalence of gastrointestinal parasites

As shown in Table 4, strongyles, *Strongyloides*, *Nematodirus* and *Trichuris* were identified from does across both vegetation types. The counts of strongyles, *Strongyloide*s and *Nematodirus* eggs were higher ($P < 0.05$) in the grass- land than forestland vegetation type. Vegetation types had noeffect ($P > 0.05$) on the prevalence of *Trichuris* in both veg-etation types. Table 5 indicates the transformed ($\log_{10}[x+1]$) seasonal changes in egg counts and standard errors of strongyles, *Strongyloides*, *Nematodirus* and *Trichuris* inthe grassland and forestland vegetation types. There was aninteraction of vegetation type and season on the prevalenceof strongyles and *Strongyloides.* The highest ($P < 0.05$) eggcounts of strongyles and *Strongyloides* were observed in thehot-wet season, while the lowest ($P < 0.05$) were recorded in the cool-dry season for both vegetation types. Does in thegrassland vegetation type had higher ($P < 0.05$) counts of strongyles, *Strongyloides* and *Nematodirus* eggs than thosein the forestland.

Table 2 Effect of vegetation type and season on the FEC, PCV, FS and BCS of Xhosa lop-eared does

Vegetation type	Season	LogFEC	PCV	FS	BCS
Cool-dry		1.3 ± 0.49^{c}	19.7 ± 2.01^{c}	2.9 ± 0.12^{d}	3.3 ± 0.11^{b}
Grassland	Hot-wet	1.5 ± 0.03^{a}	27.1 ± 1.37^{a}	4.2 ± 0.13^{a}	3.3 ± 0.11^{b}
	Post-rainy	1.4 ± 0.02^{b}	28.4 ± 0.96^{a}	3.7 ± 0.11^{b}	3.1 ± 0.09^{c}
	Cool-dry	1.2 ± 0.53^{a}	24.5 ± 2.27^{b}	3.4 ± 0.14^{c}	3.0 ± 0.10^{c}
Forestland	Hot-wet	1.4 ± 0.03^{b}	20.9 ± 1.41^{c}	4.2 ± 0.13^{a}	3.5 ± 0.09^{a}
	Post-rainy	1.4 ± 0.01^{b}	25.7 ± 0.81^{b}	3.7 ± 0.09^{b}	3.3 ± 0.07^{b}

[abcd]Values of the same parameter in the same column with different superscripts are significantly different (P < 0.05). *FEC* faecal egg count, *PCV* packed cell volume, *FS* FAMACHA score, *BCS* body condition score

Table 3 Least square means (± standard errors) on the effect of vegetation types and parity on $\log_{10}(x + 1)$ FEC, PCV and FAMACHA scores in Xhosa lop-eared does foraging in grassland and forestland

Parity	Grassland			Forestland		
	FEC	FAMACHA	PCV	FEC	FAMACHA	PCV
1	1.24 ± 0.10^{d}	3.45 ± 0.22^{c}	28.18 ± 1.39^{a}	1.38 ± 0.15^{e}	3.50 ± 0.25^{c}	22.25 ± 1.63^{b}
2	1.35 ± 0.06^{d}	3.67 ± 0.11^{c}	25.23 ± 1.11^{a}	1.45 ± 0.06^{d}	3.98 ± 0.11^{c}	22.44 ± 1.07^{b}
3	1.18 ± 0.09^{d}	3.68 ± 0.17^{c}	27.40 ± 1.88^{a}	1.25 ± 0.07^{d}	3.75 ± 0.14^{c}	25.97 ± 1.57^{b}
> 4	1.17 ± 0.13^{d}	3.61 ± 0.17^{c}	22.06 ± 1.77^{b}	1.09 ± 0.09^{d}	3.48 ± 0.14^{c}	25.60 ± 1.50^{a}

[abcd]Values in the same row with different superscripts are different ($P < 0.05$). *FEC* faecal egg count, *PCV* packed cell volume

Table 4 Prevalence (%) of gastrointestinal parasites of does reared in grassland relative to those in forestland

Parasites (%)	Grassland	Forestland (%)	χ^2 value	Significance
Strongyles	62.5	48.2	4.62	*
Strongyloi-des	65	32.9	23.1	**
Nematodirus	46.3	21.2	14.9	**
Trichuris	17.5	17.7	0.00	NS

body weight gains during the post-rainy season in the grassland vegetation type could, therefore, be explained by the improved pasture availability and quality in conjunction with unfavourable conditions for GIN prolifera- tion. Fodder trees and shrubs alleviate feed shortages and nutritional deficiencies during the cool-dry seasons, as reflected by the body weight gain in does during cool-dry season in the forestland vegetation type (Egea et al. 2018).

*$P < 0.05$; ** $P < 0.01$, *NS* not significant ($P > 0.05$)

Discussion

Understanding effect of vegetation type, season and parity of doe on the burdens of GIN capacitate farmers on the appropriate strategies to manage and control GIN infesta- tion in goats. Forage quality and quantity of natural veg- etation vary with season, management, soil characteristics and growth stage, thus resulting in seasonal variation in goat performance. The observed body weight losses ofdoes during the cool-dry season in the grassland vegeta- tion type could be attributed to the reduced quality and palatability of forages during this period. During cool-dry season, grasses contain as low as 30 g/kg crude protein levels (Chimonyo et al. 2000). Low availability of feedsis also another factor during the dry season (Safari et al. 2010). Loss of body weight during hot-wet season on both vegetation types was likely attributed to GIN infestation. Warm and humid environmental conditions are conducive for GIN proliferation (Mpofu et al. 2020). The observed Idamokoro et al. (2016) reported that feeding goats with *Vachellia karroo* leaves improve animal performance, reduce worm burden and increase growth rate in kids. Marume et al. (2012) further indicated that goats forag- ing on *Acacia karroo* were able to maintain productivity compared to those only fed on hay. Rogosic et al. (2006) further highlighted that most trees and shrubs have highCP in their leaves and low fibre content.

The higher FEC, FAMACHA scores and low PCV levelsin the hot-wet season than cool-dry season agree with earlierreports (Kaplan et al. 2004; Nadarajah et al. 2015; Seyoum et al. 2018). The high FEC and low PCV values during the hot-wet season could be attributed to the high prevalence of *Haemonchus contortus* that suck approximately 0.05 ml of blood per day (Kaplan et al. 2004; Brik et al. 2019). The cli- matic conditions of Alfred Nzo district were also conduciveto worm proliferation. The higher FEC, FAMACHA scoresand low PCV observed in does in the first parity compared to does in higher parities agree with May et al. (2017). Doesin higher parities could have developed a stronger immunity against GIN (Zvinorova et al. 2016a, 2016b; Qokweni et al.2020). Low PCV levels were related to high faecal counts for strongyles and *Strongyloides* eggs.

Table 5 Season changes in the mean ± standard error log-transformed faecal egg counts of gastrointestinal nematodes

Parasites	Grassland			Forestland			
	Cool-dry	Hot-wet	Post-rainy	Cool-dry	Hot-wet	Post-rainy	Significance
Strongyles	0.27 ± 0.05 [a]	0.57 ± 0.05[a]	0.04 ± 0.04[d]	0.12 ± 0.06[b]	0.37 ± 0.06[a]	0.37 ± 0.05[a]	*
Strongyloides	0.22 ± 0.05[b]	0.37 ± 0.05[b]	0.08 ± 0.05[c]	0.17 ± 0.06[a]	0.23 ± 0.06[b]	0.18 ± 0.05[b]	*
Nematodirus	0.14 ± 0.05[c]	0.35 ± 0.05[b]	0.18 ± 0.04[a]	0.16 ± 0.06[a]	0.37 ± 0.06[a]	0.16 ± 0.05[b]	*
Trichuris	0.01 ± 0.02[d]	0.00 ± 0.02[c]	0.11 ± 0.02[b]	0.11 ± 0.04[b]	0.00 ± 0.04[c]	0.14 ± 0.03[c]	*

[abcd]Values in the same column with different superscripts differ ($P < 0.05$)

The observed high counts for strongyles and *Strongyloi-des* eggs in the hot-wet season than in the cool-dry season in both vegetation types agree with Zvinorova et al. (2016a,b). Yuan et al. (2019) and Mpofu et al. (2020) also reported higher faecal egg counts in the wet than dry seasons. The lowfaecal egg counts in the cool-dry season might be attributed to unfavourable climatic conditions. The low egg loads of strongyles, *Strongyloides* and *Nematodirus* in goats from the forestland vegetation type can be attributed to the presence of trees and shrubs that contain proanthocyanidins that pos-sess anthelmintic properties (Min et al. 2005). These resultsalso agree with Xhomfulana et al. (2009) who observed lowegg counts for the Nguni steers fed on *Acacia karroo*.

Development of strategic deworming program at the beginning of the cool-dry season and towards the end of the hot-wet season more precisely on the grassland vegeta- tion type and culling does with consistently high faecal egg counts and FAMACHA scores is essential. Deworming of does on first parity soon after kidding to prevent effects of lactation on faecal egg counts and body condition scores may be warranted. Moreover, further investigation of browsespecies in the control of GIN in goats is essential.

Conclusions

Differences in burden of GIN were significantly associated with vegetation type, season and parity. Higher loads of GIN and FAMACHA scores were observed in the hot-wet than cool-dry and post-rainy season, resulting in lower bodyweights and body condition scores in does foraging in grass- lands compared to those in forestlands. To ensure effective control strategies of GIN loads in goat farming enterprise, one should integrate PCV, FAMACHA scores and faecal eggcounts based on vegetation type and season. Further stud- ies should be conducted to assess nutritional related blood metabolites and some liver enzymes in goats foraging in grassland relative to those in forestland.

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Data availability The data that support the findings of this study are available on request from the corresponding author (MC).

Declarations

Conflict of interest The authors declare no competing interests.

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