Declaration

I, the undersigned, declare that this dissertation has not been submitted to any university, and that it is my original work conducted under the supervision of Professors M. Chimonyo and K. Dzama. All assistance towards the production of this piece of work has been acknowledged in the Acknowledgements and Reference sections.

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LIST OF ABBREVIATIONS

ALP	alkaline phosphatase
ALT	alanine transaminase
AST	Aspartate aminotransferase
BCS	Body condition score
BHB	Beta-hydroxybutyrate
CK	creatinine kinase
GGT	gamma-glutamyl transferase
GPE	goat production efficiency
GPP	goat production potential
NEFA	Non-esterified fatty acids
PCV	packed cell volume
TP	total protein

Abstract

Communal Production Systems of Goats Raised by Resource-Poor Farmers in the Eastern Cape Province of South Africa

By

F. Rumosa Gwaze

Goats significantly contribute towards the subsistence, economic and social livelihoods of many resource-poor farmers in developing countries, the majority of which own goats. There, however, is dearth of information on communal goat production potential and roles to the rural populace. The broad objective of the study was to evaluate production practices, constraints, production efficiency and to determine nutritional and health status of goats raised by resource-poor communal farmers in the Eastern Cape Province of South Africa. Roles and management systems of goats, goat flock dynamics and, prevalence and loads of gastrointestinal infections and the nutritional status of goats in the study areas were determined. The relationships among body weight, body condition score, faecal egg counts and, haematological and biochemical profiles were also determined. Mean goat flock sizes per household were similar between the two districts studied; Amatole (14.0 ± 0.31) and Alfred Nzo (14.1 ± 1.42). Seventy-nine percent of households in Amatole and 78% in Alfred Nzo kept goats for ceremonies, such as the initiation ceremonies. Goat houses in the two districts were poorly constructed. Thirty two percent of farmers in Alfred Nzo district and 27% in Amatole district reported low buck to doe ratios, suggesting that inbreeding might have been reducing productivity of their flocks. Kid mortality had two major peaks; in May (21%) and in September (21%). Goat production potential (GPP), the proportion of mature and growing goats to the total flock size, was affected by gender of owner of goats. Goats owned by female had a significantly lower GPP value of 0.63 ± 0.015 than goats owned by male farmers (0.70 ± 0.010). Month also significantly affected GPP with the highest ($P < 0.05$) GPP recorded in May, June and July and the lowest in March and April. Village affected GPP with values for Nkosana and Qawukeni being significantly higher than for Mankone. Goat production potential was also higher ($P < 0.05$) in small flocks (0.04 ± 0.008) than in large flocks (0.02 ± 0.008). Goat production efficiency (GPE) ranged from 0.11 ± 0.193 in April to 1.55 ± 0.193 in December. The most prevalent gastrointestinal eggs were the strongyle egg type (68.4 ± 8.49 in Qawukeni and 96.1 ± 12.01 in Nkosana) followed by coccidia (53.3 ± 8.76 in Qawukeni and 68.8 ± 8.00 in Mankone). The other identified nematodes were *Strongyloides* and *Trichostrongylus* egg types. The trematodes observed were *Fasciola* and *Paramphistomum* species. High loads of strongyle eggs were observed in the hot-wet season and the post-rainy season, whilst the other egg types showed a peak in the hot-wet season only. For most of the gastrointestinal parasite eggs, prevalence was higher ($P < 0.05$) in the sour rangeland compared to the sweet rangeland. Higher ($P < 0.05$) levels of total protein (TP), globulin, aspartate aminotransferase (AST) and creatinine kinase (CK) levels were recorded in the wet than in the dry season. Body condition scores were positively correlated ($P < 0.05$) to albumin, body weight and packed cell volume. However, body condition scores were negatively correlated to TP, glucose, alanine transaminase (ALT) and AST. Strongyle egg loads were positively correlated to FAMACHA scores, packed cell volume, body weight and body condition score. The observed high globulin levels suggested a chronic health challenge. Thus, it is fundamental to devise affordable interventions for the control of gastrointestinal parasites in communal goats leading to improved goat productivity and hence rural livelihood.

Dedication

To my dear husband, Tawanda and our two daughters, Kudzai and Melody

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CHAPTER 1: Introduction

1.1 Background

Reduction of poverty by fifty percent, particularly in sub-Saharan Africa, in the proportion of people living in extreme poverty by 2015 is one of the millennium development goals (Garforth *et al*., 2005). About 248 million people in Sub-Saharan Africa are resource-poor and live in the communal areas (Owen *et al*., 2005). In South Africa, overall unemployment is approximately 30%, with even higher levels in communal areas (Klasen and Woolard, 2008). It, therefore, is imperative to improve productivity of livestock in communal areas to increase the availability of animal protein leading to improved food security and wealth creation by boosting livestock production.

Goats (*Capra hircus*) can be used as a pathway out of poverty as they are owned by almost every resource-poor farmer (Peacock *et al*., 2005; Hassan *et al*., 2007). Of the 223 million goats in Sub-Saharan Africa, over 70% are located in rural arid and semi-arid agro-ecological zones (Lebbie and Ramsay, 1999), where 65% of the people live (FAOSTAT, 2006). There are approximately 4.8 million goats in South Africa of which 50% is found in the communal areas (Shabalala and Mosima, 2002). About 3 million of these goats are found in the Eastern Cape Province (Estimated Livestock Numbers in the RSA, 2007). The greater proportion of goats in the Eastern Cape Province is owned by the resource-poor communal farmers, and these goats are characteristic of poor management and low productivity (Masika and Mafu, 2004). Since most resource-poor farmers own goats, this invaluable genetic resource can be used in boosting these farmers' household economy. Albeit, improvement of goat production can also be of benefit to the rich, remarkable benefits are realized by the resource-poor farmers.

Goats are important to the subsistence, economic and social livelihoods of many resource-poor farmers in developing countries (Kosgey, 2004). They produce about 17 and 12% of tropical Africa’s meat and milk, respectively (Lebbie, 2004), which are likely to be underestimates, given that most of the utilization of goats goes unrecorded. Communal goats fulfil multiple roles that include provision of meat, manure, milk and cash from sales of the goats and their by-products (Thornton *et al*., 2002). Goats also play a major role in traditional ceremonies (Ayalew *et al*., 2003). The relative importance of goats is, however, specific to particular cultures, regions, agro-ecological zones and countries, for example, in some countries, such as South Africa, people discriminate against goat meat (Alexandre *et al*., 2008).

Goats in communal areas are less susceptible to droughts than cattle and, have lower feed and capital requirements than larger ruminants (Iniguez, 2004). They are better able to utilize a variety of feedstuffs, including fibrous crop residues (Holst, 1999). In addition, goats have shorter generation intervals, reaching puberty at five to nine months of age (Saico and Abul, 2007) and have a higher prolificacy in comparison with the larger ruminants. Goats are renowned for controlling bush encroachment (Mahanjana and Cronje, 2000). Despite these attributes, goats are still sidelined, even at household level (Devendra, 2002; Lebbie, 2004).

Regardless of the special attributes that goats possess, there is scarcity of information on the productivity and production systems of goats in the communal areas. There are various reasons for the underestimation of the value of goats. For example, contribution of goats at household level is not well known. The current valuation systems rely on monetary standards that often ignore the non-monetary contribution of goats to households. There are currently few, if any, accurate estimates of the contribution of goats to human food security and sustainable livelihoods (Peacock *et al*., 2005).

1.2 Justification

Much work has been conducted on cattle and crop production than on goats with the argument that cattle and crops make a larger aggregate contribution to the formal national economy than goats. However, improvement of goat productivity offers opportunities for most resource-poor people to earn better returns in terms of cash and improved nutritional status. To design feasible and sustainable developmental programmes, it is crucial to understand the smallholder farm characteristics and the communal farming systems and processes. This research is an effort to close the gap between the research systems agenda and the resource farmers' needs. By conducting on-farm research, strategies to improve goat productivity will be devised in collaboration with farmers and would presumably be easily adopted.

The contribution of goats to the livelihoods of resource-poor farmers and the on-farm production performance of these animals is not clear. The study will further help with the knowledge of the actual contribution of goats to household economy rather than identifying constraints to goat productivity *per se*. It is, therefore, crucial to conduct in-depth research on flock sizes and structures and how they vary with season as an attempt to quantify the contribution of goats to the livelihoods of the smallholder farmers. Productivity of communal goats is generally low due to constraints of which the major ones are; diseases and parasites, use of inappropriate breeds, poor marketing management and limited feed availability. It, therefore, is imperative to investigate the nature of these constraints before instituting programmes that are aimed at improving goat productivity. For example, to adopt adequate health management strategies, it is important to investigate the prevalence of gastrointestinal parasites by type and dynamics. Information generated by this research will be of assistance in designing appropriate strategies and approaches to improved goat production that will ultimately, lead to the transformation of livelihoods of resource-poor farmers from poverty to relative prosperity.

1.3 Objectives

The broad objective of the study was to evaluate production practices, constraints, production efficiency and to determine nutritional and health status of goats raised by resource-poor communal farmers in the Eastern Cape Province of South Africa.

The specific objectives were to:

1. Determine goat production practices in the communal areas;
2. Assess the production efficiency and contribution of goats to communal households;
3. Estimate prevalence of gastrointestinal helminth infestations in communal goats; and
4. Determine the levels of nutritionally-related blood metabolites of goats.

1.4 Hypotheses

The hypotheses to be tested were that:

1. Goat production practices in communal areas of the Eastern Cape Province are the same;
2. Production efficiency and contribution of goats to communal households are the same;
3. Intensity of gastrointestinal helminths in goats raised in the communal areas of the Eastern Cape Province are the same; and
4. There is no relationship between season, age and sex, and nutritionally related blood metabolites of goats.

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2 CHAPTER 2: Literature Review

(Part of this review has been accepted as a review paper by *Tropical Animal Health and Production,* see Appendix 8.4)

2.1 Introduction

The world goat population is estimated at 746 million (FAOSTAT, 2003), with 96% of these being kept in developing countries. Of the 223 million goats in Sub Saharan Africa, about 64% are found in arid (38%) and semi-arid (26%) agro-ecological zones (Lebbie and Ramsay, 1999) with the majority (more than 90%) being owned by smallholder farmers (Lebbie, 2004). In South Africa, however, about 50% of the goats' population is kept under small-scale conditions (Shabalala and Mosima, 2002).

The goat genetic resources in Southern Africa are reputable for their hardiness (Celi *et al.*, 2008; Kouakou *et al.,* 2008; Lachica *et al.*, 2008), prolific breeding (Simela and Merkel, 2008), early attainment of maturity and low requirement for inputs (Olivier, 2002). Furthermore, goat meat contains less fat and cholesterol than most other types of meat (Saico and Abul, 2007) with desirable fatty acids since goats have the ability to deposit higher amounts of polyunsaturated fatty acids (PUFA) than other ruminants (Koyuncu *et al.*, 2007). Regardless of these important aspects pertaining goats, these invaluable genotypes are sidelined. This review discusses goat production systems, goat breeds and constraints faced by goat-keepers in communal areas of Southern Africa. It also discusses methods that can be used to assess the health and/or nutritional status of goats.

2.2 Characteristics of smallholder goat production in Southern Africa

Smallholder farming systems are characterised by minimal resources in terms of land and capital, low income, poor food security, diversified agriculture and informal labour arrangements derived from family members (de Sherbinin *et al.,* 2008). The household economy of smallholder farmers is often multi-sectoral, with income arising from non-agricultural activities such as handicrafts, trade, wage labour, remittances or pensions (Bayer *et al*., 2001). Smallholder farming systems are also characteristic of poor access to conventional knowledge and information, and little or no mechanization (Boyazoglu *et al*., 2005). In the low rainfall communal areas of Southern Africa, for example, goats represent the principal economic output, contributing a large proportion of income of the resource-poor farmers (Ben Salem and Smith, 2008). Regardless of such contributions, communal goats are neglected by researchers, veterinarians, extension workers, sources of credit and various other stakeholders (de Vries, 2008), leading to lack of improvement in productivity of these invaluable genetic resources.

Smallholder goat production systems consist of sedentary resource-poor farmers, each with a small piece of land on which they practice mixed farming (Kosgey *et al*., 2006). Most households keep only a few goats, along with other livestock species such as cattle, sheep, pigs, horses/donkeys and chickens. The integration of goats with other enterprises indicates a way of diversification so as to improve food security (Mashatise *et al.,* 2005). In Sub-Saharan Africa, most of the resource-poor farmers are found in marginal drought-prone areas (Bayer *et al*., 2001), where animal and crop production potential is low. Efforts to improve agricultural output in these areas have often been biased towards crop and cattle production enterprises, with little attention being paid to other livestock species, particularly goat production (Iniguez, 2004; Lebbie, 2004). This flawed approach ignores the fact that crop and goat production interact at the farm level (Chianu *et al*., 2007).

The neglect of the goat enterprise is due to various reasons. Most goat products flow through the informal markets (Lebbie, 2004) where they are not taxed, thus leading to non-recognition of their contribution to the national economy. In addition, goat-keepers are often resource-poor, and are economically and politically marginalized (Peacock *et al*., 2005). Bayer *et al.* (2001) and Kosgey (2004) argue that some agricultural extension practitioners, policy makers and scientists, in Southern Africa perceive communal goat farming as primitive. It entails, therefore, that much effort is required to change the way goats are perceived. In addition, it is also pertinent to describe the goat production systems and breeds used.

2.2.1 Communal goat production systems

Goat rearing is an integral part of the extensive farming in most countries in Southern Africa (Banda *et al*., 1993; Loforte, 1999; Wason and Hall, 2002), with herding and tethering as the main feeding systems. Most goats are herded during the day and penned at night. In cases where there is limited grazing land, all the goats from the entire village may be considered as a single interbreeding flock with no attempts of controlling mating (Manyema *et al*., 2008). Flocks from different households of the same village, however, may graze separately where there are vast tracts of grazing land. Following crop harvesting, goats feed on crop residues until the beginning of the rainy season, when the goats have to be herded. This livestock species is rarely provided with supplementary feeding. In Mozambique, however, Loforte (1999), reported that farmers supplemented their goats with a variety of fruit trees, maize and cassava crop residues. In most communal areas, school children are responsible for herding goats, implying that grazing depends on the school timetable (Loforte, 1999), whilst in some cases, for example in Lesotho, men can be employed as shepherds (Wason and Hall, 2002).

Tethering of goats is common in Southern African countries such as Zambia (Lovelace *et al.,* 1993), South Africa (Webb and Mamabolo, 2004) and Malawi (Banda *et al*., 1993). Tethered goats are secured with a rope and tied to a peg to prevent them from destroying crops and to enable farmers to conduct other farm activities. Tethering can also be practised in areas where goats are herded (Mbuh *et al*., 2008). In Malawi, for example, in the hot-dry season, tethering of goats is the main feeding system (Banda *et al*., 1993). In some cases, however, goats are tethered in the morning hours and then herded in the afternoon when school children are back from school (Wilson and Azeb, 1989). Since tethering restricts a goat to a specific area, the animal will have little choice of feed, resulting in poor body condition, inferior weight gains and higher predisposition of the goat to heavy helminth burdens (Caldeira *et al*., 2007) indicating how a production system can impact on productivity levels of the goats.

2.2.2 Communal goats and their productivity levels

Indigenous goats are invaluable reservoirs of genes for adaptive and economic traits (National Agricultural Marketing Council, 2005; Ben Salem and Smith, 2008) that provide diversified genetic pool. These genotypes can help in meeting future challenges resulting from possible changes in production systems and consumer requirements (Kosgey and Okeyo, 2007). Preston and Murgueitio (1992) revealed that indigenous goat breeds are better able to utilise low quality feeds and can walk for longer distances, in search of water and feed, than imported breeds. Indigenous goat breeds can tolerate local diseases such as pulpy kidney, tick-borne diseases (Webb and Mamabolo, 2004) and gastrointestinal parasite infestation (Baker *et al*., 1998). It is ideal that such breeds be utilised (Kosgey *et al.*, 2006) in the communal setting. Table 2.1 summarises characteristics of indigenous breeds found in Southern Africa, indicating low productivity of these genotypes.

Genetic potential for indigenous goats is, at times, confounded by the low standard of management under which indigenous livestock are usually kept. Nonetheless, when a productivity index, which combines fertility, survival and yield traits, is used to compare breeds, indigenous breeds raised under range conditions outperform imported breeds (Mpofu, 2002). Performance by indigenous goat breeds is generally low, partly as a result of high disease and parasite challenge and a low plane of nutrition (Peacock, 1996). The pre-weaning and reproductive performance levels of indigenous goats in Southern Africa are shown in Tables 2.2 and 2.3, respectively. High mortality among kids and slow growth rate among those that survive are major constraints to goat production (Sebei *et al.*, 2004). Weaning percentage, a measure of survivability of kids from birth to weaning, is low (Sebei *et al.*, 2004) in the communal goats. In Zimbabwe, Shumba (1993) reported a pre-weaning mortality rate as high as 33%, with disease accounting for 55% of the mortality. Pre-weaning kid mortality is one of the principal causes of economic losses of communal goats (Hailu *et al.*, 2006) and should, therefore, be reduced to insignificant levels. Reduction of pre-weaning kid mortality is likely to boost production of goats that play important roles in the lives of smallholder farmers.

2.3 Importance of goats to smallholder communities

Communal goats fulfil multiple roles that include the provision of meat, milk, manure, skins, cashmere, mohair (Haenlein and Ramirez, 2007), draught power (Saico and Abul, 2007) and barter trade (Morand-Fehr *et al.*, 2004).

Table 2.1: Main characteristics of indigenous goat breeds

Breed	**Location**	**Adult weight (kg)**		**Other phenotypic characteristics**	**Sources**
		Male	***Female***		
Landim goats	Mozambique	50	35 – 40	Horned; medium-sized ears; bearded; variable coat colours; short and fine hair.	DAGRIS (2007)
Malawi goats	Malawi	29	21	Horned; sharp and pointed ears; variable coat colour.	DAGRIS (2007) Banda *et al.* (1993)
Mashona	Zimbabwe	30	25	Height at withers of about 60 cm; horned, short ears; variable coat colour; short and fine hair	Ndlovu and Royer (1988) DAGRIS (2007)
Matabele	Zimbabwe	50–55	39	Bearded; rarely horned; broad, lopped ears; White and cream coat colours	DAGRIS (2007)
Nguni	Swaziland, Lesotho, South Africa	40	30	Medium-sized ears; horned; variable coat colours.	Epstein (1971)
Tswana goats	Botswana Zimbabwe, South Africa	44	40	Height at withers of 60–75 cm; horned; broad lopped ears; variable coat colours; lactation length averages 180 days.	DAGRIS (2007) Gray (1987)

Goat skins are used to make mats, footwear, water/grain containers, tents and drums (Peacock, 2005). In Namibia, Yaron *et al.* (1992) revealed that goats, together with cattle, are used as investments and status symbols. Goats, thus, generate income for communal households through *ad hoc* sales of the animals (Sweet, 2008) and/or their milk and meat to meet emergency needs for cash (Kosgey, 2004).

Improvement in goat production and commercialization of goats can create employment for people as individuals are hired to process and sell goats and goat products. In addition to provision of tangible products, goats contribute towards the livelihoods of the poor through risk mitigation and accumulation of wealth (Peacock, 2005). Therefore, goats are an ideal vehicle for generating cash returns to meet food security needs and improve welfare among communal families.

Goats play a pivotal role in cultural and ceremonial purposes (Kosgey, 2004; Simela and Merkel, 2008). They are also useful in controlling bush encroachment in natural rangelands of Southern Africa (Saico and Abul, 2007). Goats can be exchanged or loaned to neighbours to enhance kinship ties (de Vries and Pelant, 1987). In other communities, goats are used for guiding sheep during herding of the latter (Peacock *et al.,* 2005). Manure and urine from goats are invaluable sources of organic fertilizer for maintaining or improving agricultural production and they become quite important when resource-poor farmers cannot afford the expensive inorganic fertilizers for use in their fields. It should also be appreciated that manure is becoming important as there is a global move towards organic agricultural products (Hansson and Fredriksson, 2004). The actual contribution of goats at household level is, however, not well known because the current valuation systems rely on monetary standards that often ignore the non-monetary contribution of goats to households.

Table 2.2: Pre-weaning performance of selected indigenous goats in Southern Africa under communal conditions

Breed	Kid BW[1]	Kid mortality[2]	Kid WW[3]	GR[4]	Source
Matabele	2.5	30	15.9	98	Sibanda (1988)
Mashona	-	30	11.5	40	Ndlovu and Royer (1988)
Malawi	2.5	-	15.6	-	Ayoade and Butterworth (1982); Nsoso *et al*. (2004)
Landim	2.35	16	8.5	-	Kamwanja *et al*. (1985)

[1] Kid birth weight (kg)

[2] Kid mortality (%)

[3] Kid weaning weight (kg)

[4] Growth rate (birth to weaning in g/day)

Table 2.3: Doe fertility of indigenous goats in Southern Africa under communal conditions

Breed	Age at first kidding (months)	Gestation length (d)	Kidding interval (d)	Weaning rate (%)	Source
Matabele	23	-	-	119	Sibanda (1988)
Mashona	18-19	-	370	94	Ndlovu and Royer (1988)
Nguni	16 – 18	145-148	258	-	Webb and Mamabolo (2004)
Malawi	15.6	-	365	-	Kamwanja *et al.* (1985)
Landim	-	-	394	-	DAGRIS (2007)

Information on the real contribution of goats to human food security and livelihoods is scarce (Saico and Abul, 2007), and therefore, warrants investigation.

Conventional productivity evaluation criteria fail to precisely evaluate subsistence goat production due to non-recognition of non-marketable benefits of this enterprise. Goat functions (physical and socio-economic) and inputs should be aggregated into monetary values and related to the resources used, irrespective of whether these "products" are marketed, home-consumed or maintained for later use (Ayalew *et al*., 2001).

Conventionally, the efficiency relating to a production system is calculated as a ratio of units of outputs per unit of inputs in the system (James and Carles, 1996). Under communal production systems, however, efficiencies are difficult to determine due to the complex crop-livestock intergrations and lack of records on cost of inputs incurred in goat production. Off-take, a measure that considers the total number of goats sold and/or slaughtered as a proportion of the whole flock, has been traditionally used to measure efficiency of livestock production systems (Chikagwa-Malunga and Banda, 2006). This measure, however, disregards whether the goats sold and/or slaughtered were saleable, growing and mature goats, or not.

Muchadeyi and co-workers (2005) and Chiduwa *et al*. (2008) have developed a more appropriate production efficiency index that estimates the productivity of livestock in communal areas. Production potential refers to the proportion of mature and growing animals to the total flock/herd size and is crucial in the computation of production efficiency. The production efficiency reflects the proportion of potentially saleable animals sold and/or slaughtered by farmers. The index is more informative compared to off-take since the former measures both the extent to which the resource-poor farmer produces saleable animals and the proportion of saleable goats that they dispose through sales and/or consumption. The efficiency takes factors of production into consideration and, thus, can aid in identifying constraints to livestock production. There is little, if any, information on the production potentials and efficiencies in communal goat production systems of South Africa. It, therefore, is crucial to determine the efficiency of goat production in the communal areas. A low efficiency of production can aid in the identification of constraints that affect goat productivity. In addition, communal goats contribute multiple roles to the rural farmers, but the alleged most important role by farmers is not known. It is thus, imperative to rank the roles of goats in view of determining the most important role.

2.4 Constraints to increased goat production in the communal areas

Goat production and productivity in communal areas is faced with numerous challenges; the magnitude of which varies with areas, countries, regions or geographical locations (Kosgey, 2004). The main constraints are high prevalence of diseases and parasites (Ben Salem and Smith, 2008), inappropriate housing and lack of records and, use of inappropriate breeds and inbreeding, limited forage availability (Raghuvansi *et al.*, 2007) and poor marketing strategy (Kusina and Kusina, 1999).

2.4.1 High prevalence of diseases and parasites

Diseases and parasites are major constraints to communal goat production and safe utilization of goat products. These diseases and parasites are endemic in many regions of Southern Africa (Githiori *et al.*, 2006). Loforte (1999) ranked diseases and parasites as the major constraint to goat production in Mozambique. The impact of diseases and parasites may be through high morbidity, mortalities, abortions or subclinical effects manifested as weight loss or reduced gains. The negative impact of diseases and parasites may also be through the financial implications involved in controlling or overcoming the effects of disease and mortality (Mahusson *et al.,* 2004; Sissay *et al.*, 2006). In addition, zoonotic diseases, such as anthrax negatively affect the health and wellbeing of the household members involved in goat rearing of infected flocks (Kusiluka and Kambarage, 1996). Diseases and parasites have a heavy impact on kids because of the poor immunity status of these young animals leading to an increased susceptibility (Sebei *et al*., 2004). High kid mortality diminishes the benefits of the high reproductive performance of does. Pre-weaning mortality of up to 30 % has been recorded with kids in Malawi (Ficarelli, 1995). Diseases also cause abortions and stillbirths (Aitken, 2007).

Lack of hygiene which allows the build-up of infective agents and use of contaminated water are major contributory factors to high kid mortality (Peacock, 1996). Poor housing negatively impacts on goat productivity as goats are exposed to extreme weather conditions. In Zimbabwe, Shumba (1993) observed that goat houses of 15% of the respondents had no protection against extreme heat, cold and rain. Ficarelli (1995), in Malawi, revealed that goat producers lose 30% of their young stock during the rainy season, the main reasons being poor housing and prevalence of diseases. van Niekerk and Pimentel (2004) attributed the incidence of diseases and high mortality to poor hygiene and precarious housing conditions.

Incidences of diarrhoea are high at the beginning of the rainy season, especially in kids. The problem of parasitism is compounded by the fact that, under the communal system, livestock are usually reared extensively (Bayer *et al*., 2001). This increases infestation and makes control measures difficult to implement. Helminths are associated with sub-clinical production losses and have profound depressive impacts upon long-term animal productivity.

Helminth infestations contribute immensely to anaemia (Vatta *et al.,* 2001; van Wyk *et al.,* 2006). Parasites also reduce voluntary feed intake, efficiency of feed utilisation and increase the endogenous loss of protein in the gastrointestinal tract (Alexandre and Mandonnet, 2005). Prevalence of goat diseases and parasites in communal areas is largely unknown. It is crucial to investigate the prevalence and type of different helminths affecting goats prior to devising control strategies against gastrointestinal parasites in the communal areas.

There is little government support for control programmes and research on diseases and parasites in goats in many African countries. Veterinary and goat improvement programmes are minimal (Alexandre and Mandonnet, 2005). The situation is compounded by the unavailability and high cost of veterinary services (de Vries, 2008). In Malawi, 89% of farmers raising goats, for example, had never been visited by a veterinarian or a veterinary assistant (Mwanza and Mapemba, 2000). To adopt adequate health management strategies, however, it is fundamental to identify causes of morbidity and mortality and to investigate the prevalence of diseases by type and by dynamics (Chiejina *et al*., 2002), so as to curb mortality of kids that may reach more than 50% (Kusiluka and Kambarage, 1996; Aumont *et al*., 1997).

2.4.2 Lack of records

Farmers rarely keep records on goat production. For improved goat production, however, farmers should keep records of the performance of their goats. Such records should capture information such as age of the goat, animal weights and diseases that each goat might have suffered from. In addition, female goats should also have records that indicate age at first kidding, kidding interval(s) and whether it produces twins, triplets or singles. By using records, farmers can also rank goats in each class, a useful tool in culling. Records should also capture goat numbers and breed(s). Other important records that can be kept by farmers include costs incurred, for instance in buying drugs and vaccines and cash obtained from sale of goats and/or their products. In addition to lack of records, there is poor management of goats and/or their products.

2.4.3 Poor marketing management

There are little national investments on marketing inputs and services, research and advocacy (Lebbie, 2004) on marketing of goats and their products, in most developing countries. Formal goat marketing, in most communal areas, is characterised by absent or ill-functioning markets (Kusina and Kusina, 1999; Seleka, 2001; Moll *et al.*, 2007). Smallholder households are often located in marginal areas with poor infrastructure and poor access to the market; thereby limiting goat farmers' capacity to transport goats to the few available slaughter facilities (Bayer *et al*., 2001). Communal farmers, therefore, resort to the informal way of marketing their goats where pricing is based on an arbitrary scale, with reference to visual assessment of the animal. Intermediaries in most countries (Kusina and Kusina, 1999; Lovelace *et al*., 2000; Simela and Merkel, 2008), purchase live animals from farmers for resale in other areas, such as towns and schools. All these transactions are not captured in official statistics leading to underestimation of production and consumption of chevon in Sub-Saharan Africa (Sebei *et al.*, 2004; Simela and Merkel, 2008).

Wealth for goat-keepers can be boosted significantly by adding value to goat products, identification of niche markets and by alerting the population about the health benefits associated with consumption of goat meat (Peacock *et al*., 2005) through promotion and advertisement. Because of the small flock sizes of most communal farmers, hiring vehicles for transporting their goats to the auction floors is not economically viable. Hence, the ideal solution would be that farmers form co-operatives and pool their resources together (Kusina and Kusina, 1999).

2.4.4 Inappropriate breeds and high levels of inbreeding

A crucial component of any production system is the utilisation of appropriate and adapted goat breeds. Exploitation of suitable, well adapted breeds is important, if feed resources are to be optimally utilised. To fulfill the function of savings, for example, it is important that the type of goats being kept does not require much management input and veterinary care and can be kept at a low cost (Bayer *et al*., 2001). This invites communal goat farmers to consider traits other than fast growth but hardiness. In addition, goats of a particular colour may be preferred for cultural or ceremonial purposes. These are rational, non-commercial objectives that are of great importance to the resource-poor farmers where breeds are chosen to suit production objectives.

Regardless of the different objectives farmers might rear goats for, in communities of most countries in Southern Africa, there are no structured breeding seasons and, therefore, does and bucks run together all year round (Tefera *et al.*, 2004). Inbreeding is a challenge for many communal goat flocks. It results in poor growth rates (Saico and Abul, 2007) and abortions among other negative effects. Inbreeding, a manifestation of mating closely related individuals, is exacerbated by the small flock sizes, confinement of goats during the cropping season and the long periods that bucks stay in the flocks before they are culled (Masika and Mafu, 2004). Exchange of bucks between farmers from different villages can reduce inbreeding. It, however, is imperative to investigate the inbreeding levels in communal goats. Apart from inbreeding, limited availability of feed has a negative impact on the productivity of goats.

2.4.5 Limited forage availability

Poor management of rangelands (Papachristou *et al*., 2005), inappropriate grazing management (Quinn *et al*., 2007), rangeland fires and seasonal droughts limit the availability of fodder (Ben Salem and Smith, 2008) in the communal areas. The quality and availability of natural pastures is highly variable in the tropics with crude protein dropping below 8% in dry mature tropical grasses, especially during the dry season (Bakshi and Wadhwa, 2007; Raghuvansi *et al.,* 2007; Ben Salem and Smith, 2008). In the wet season, forage is of high quality but because of the high temperatures, rapid physiological maturation follows, leading to early lignifications and reduced digestibility of the grasses. In the sour rangeland, which is mainly a grassveld, grass is of good quality in the hot-wet season and becomes unpalatable in the cold-dry season (Botsime, 2006). However, in the sweet rangeland, which is maily characterised by natural browse with a crude protein content of approximately 20%, there is not much variation in protein content of feed with season (Peacock *et al*., 2005).

For sustained goat production as well as survival of the animals during the dry season, feeds ought to be preserved during the period that they are abundant (Ben Salem and Smith, 2008). Classes of goats with higher nutrient requirements need to be supplemented when there is feed scarcity. This may take simple forms like utilizing deferred pastures, lopping branches and providing leguminous tree pods to goats. It might also involve utilization of conserved materials like silage, hay, foggage, crop residues and food processing by-products (Garcia-Torres *et al*., 2003). Natural browse, such as *Acacia karroo* available in some communal areas can also form part of supplementary ingredients for goats. Any form of dietary supplementation intensifies management but increases productivity of the goats. The economic benefits of any supplementation programme may have to be considered. The effects of supplementation on goats need to be assessed. Several methods of determining the nutritional and health status of goats exist.

2.5 Measures of assessing nutritional and health status of goats

Early proper diagnosis of diseases and poor nutrition is a pre-requisite to reduce losses in communal areas (Tibbo *et al.,* 2004). Methods that can be employed in determining health and nutritional status of goats include body weights and condition changes, worm burdens, packed cell volume, the FAMACHA technique and use of nutritionally-related blood metabolites.

2.5.1 Body weights and condition

Use of body weights and condition scores in the determination of health and/or nutritional status of livestock has been reviewed by several authors (Oulun, 2005; Sakkinen, 2005; Ndlovu *et al*., 2007). Cisse *et al*. (2002) reported that body condition score is indicative of body fats more than body weight (Morand-Fehr, 2003; Mannathoko, 2002). In addition, since most resource-poor farmers do not have scales for weighing their goats, research should focus on the applicability of condition scoring as a health and/or nutritional status indicator in the communal goats. Of importance are the relationships that exist between body condition and weights on one hand and other parameters such as egg worm counts on the other hand, with the main aim of determining the best method to use in the assessment of health and nutrition status of goats.

2.5.2 Egg worm counts

An estimation of the numbers and species of eggs, larvae or oocysts produced by endo-parasites infecting the liver, digestive and respiratory tract of goats is a practical aid to the diagnosis of gastrointestinal parasitism (Aitken, 2007). Results obtained can provide epidemiological evidence for the time of build-up of high levels and survival of nematode parasites in goat flocks. Information generated could be useful in designing strategic anthelmintic treatment against prevailing helminths (Githigia *et al.,* 2001).

Faecal egg counting is the most common ante-mortem means of diagnosis for nematodosis (Kusiluka and Kambarage, 1996). Eggs are, however, less valuable in drawing conclusions about clinical conditions of an individual goat. This might be ascribed to many factors that affect the level of egg production, for example, the consistence of the faeces may affect the number of eggs per gram of faeces markedly as the more watery the faeces are, the more diluted the eggs are. Biotic potential of the nematode species, season of the year, and resistance of the host and developmental stage of the parasite also influence the number of eggs per gram. The prevalences of goats infested with strongyles, in the communal areas is variable. In a Nigerian goat flock, Nwosu *et al*. (2007) observed 35.4% of the goats to be positive for strongyles. However, in other studies (Chiejina *et al.,* 2002; Mbuh *et al*., 2008), strongyle prevalence ranged from 77 to 100%. The variation in the strongyle prevalences can possibly be due to factors such as climate and production system (Nwosu *et al*., 2007). It, therefore, is imperative to determine the parasite load and the prevalence of goats in each communal area.

The identification of parasite species present in a goat flock is an important component of the investigation of clinical diseases caused by gastrointestinal parasites (Papadopoulos *et al*., 2007). Considering that eggs per gram have a diagnostic value, a more specific diagnosis in helminths can be obtained by culturing the eggs to yield third stage larvae which can be identified to generic level. Examples are eggs from species such as *Haemonchus contortus*, and *Trichostrongylus* which are known as strongyles (Sissay *et al*., 2006). Their infective larvae differ morphologically (Kusiluka and Kambarage, 1996) and their examination permits a specific diagnosis of nematode infections. Estimation of infective larvae population provides a clue of the intensity of infestation to which grazing goats are exposed. The larval population in herbage is dependent on stocking density, rainfall and herbage cover (Kusiluka and Kambarage, 1996). It should be noted, however, that the land tenure systems prevailing in most communal areas and the high cost of acquiring and maintaining tracer goats deter utilization of this method by resource-poor farmers. This implies that other parameters such as packed cell volume can be considered in the assessment of the status of goats.

2.5.3 Packed cell volume

Packed cell volume (PCV), the proportion of erythrocytes expressed as a percentage of the volume of whole blood per given sample (Kusiluka and Kambarage, 1996), is the most precise means of determining red blood cell volume and can be used to deduce total blood volume and haemoglobin levels. Analysis of normal haematocrit values of goats is fundamental in diagnosing the various pathological and metabolic disorders (Grunwaldt *et al*., 2005). Packed cell volume is indicative of anaemia, haemorrhage, bone marrow failure, leukaemia, malnutrition or specific nutritional deficiency, multiple myeloma and rheumatoid arthritis (Kaneko, 1997). Packed cell volume values higher than the reference values could indicate dehydration due to diarrhoea, erythrosis and polycythermiavera. Packed cell volume is influenced by sex of the goat and altitude (Tibbo *et al*., 2004), management, age (Grunwaldt *et al.,* 2005), sex, breed, health status, ambient temperature, and physiological status (excitement, muscular exercise, pregnancy, estrus, parturition, water balance and transportation) (Kaneko, 1997). Diurnal and seasonal variations also modulate PCV values (Osaer *et al*., 2000).

Reduced oxygen tension, in mountaineous regions, leads to an increased production and release of erythropoietin, thereby, stimulating erythropoiesis as a coping or adaptive mechanism to low oxygen level in such an environment (Tibbo *et al.,* 2004). Therefore, the higher PCV values exhibited in indigenous breeds in a study by Tibbo *et al.* (2004) under high altitudes (1650 and 2800 m above sea level) could provide evidence of adaptation of these breeds to low atmospheric oxygen. This might signify that climbing of mountains by such adapted goats, in search of feed, might not affect the physiology of the goats. On the other extreme, it is also important to note that some indigenous goats exhibited a minimum PCV value of 16.5 % without any clinical manifestation of anaemia, the value lower than the lower limit reported for the species. Higher PCV values observed in does than bucks might be attributed to various physiological factors associated with females (Tibbo *et al*., 2004). For example, during estrous does are in a restless and excited condition, where splenic contraction may increase the erythrocyte values.

Daramola *et al*. (2005) and, Taiwo and Ogunsanmi (2003) reported different PCV values for clinically healthy West African Dwarf goats signifying that many other factors, apart from breed, greatly influence packed cell volume. Even though considerable information is available on the normal blood parameters of domestic animals, the values are for exotic goat breeds kept under different environment and management conditions (Tibbo *et al*., 2004). Reference levels for PCV in indigenous goats of South Africa raised under communal production conditions are unavailable. For proper management, feeding, breeding, prevention and treatment of diseases; it is desirable to know the reference values under local conditions. In situations where it is difficult to collect blood for PCV determination, detection of anaemia can be employed to assess the health status of goats.

2.5.4 Detection of anaemia

Haemonchosis can develop so rapidly that a reduction in body condition or body weight will likely not be apparent during an acute infection. Vatta *et al*. (2002) indicated that BCS on its own is not a good indicator of infection with *H. contortus*. In another study, Vatta *et al*. (2001) reported that there was no relationship between BCS and FEC whilst Roberts and Swan (1982) found no correlation between body weight and worm counts when *H. contortus* was the predominant nematode. This indicates that other methods of assessment of goat health and productivity should be implemented, in situations where *H. contortus* is the main gastrointestinal parasite, to increase the efficiency of identification of goats in poor health.

It is, therefore, imperative to devise easy methods for the determination of anaemia in goats. One such option is the FAMACHA system (Kaplan *et al*., 2004) which was developed in South Africa for classifying sheep into categories based on different levels of anaemia (Bath *et al*., 2001). The FAMACHA technique has since been used on goat flocks in countries such as South Africa (van Wyk *et al*., 2006) and southern USA (Kaplan *et al*., 2004; Burke *et al*., 2007). These trials have confirmed the practicality of this technique on-farm application. The effectiveness of the technique has also been evaluated in identification of parasite resilient and/or resistant breeding bucks, and thus identification of stud rams with greater resilience/resistance (Burke and Miller, 2008) to gastrointestinal parasites. The use of this system may be recommended as part of an integrated approach to worm control in goats kept by resource-poor farmers. It, however, is fundamental to test this technique widely in goats owned by communal farmers. Although the FAMACHA system is useful in predicting the health status of goats, it can not be used in isolation since it only detects presence of *H. contortus* in a goat flock. It, therefore, implies that it should be coupled with methods such as use of blood metabolites, in predicting the condition of the goat.

2.5.5 *Use of blood chemical constituents in assessment of health and nutritional status of goats*

The chemical constituents of blood have been shown to assist in the assessment of the health and nutritional status of goats in Southern Africa. Metabolic profiling has been applied in Saanen goats (Bagliacca *et al*., 1988), African Dwarf goats (Lohle, 1994) and Mozambican goats (Harun *et al.,* 1996). Reference values for blood parameters in goats are shown in Table 2.4. There is no information on the levels of blood parameters in communal goats of the Eastern Cape Province of South Africa. Blood metabolites that can be used in the assessment of goat status can be categorized into three classes; carbohydrate and, lipid metabolism-linked, protein-metabolism linked and mineral-metabolism linked metabolites.

2.5.5.1 Blood chemical constituents related to carbohydrate and lipid metabolism

Blood glucose, β-hydroxy butyrate and non-esterified fatty acids are the most common metabolites used to assess the energy status of animals. Due to homeostatic regulation, blood glucose has a moderate variability and, therefore, has an intermediate diagnostic value in the assessment of nutritional status of goats. Lowered feed intake results in decreased blood levels of propionate and other glucose precursors derived from the diet decrease resulting in a reduction of the rate of glucose synthesis (Reynolds *et al.,* 2003). The energy metabolism of goats is largely dependent on the utilization of volatile fatty acids as an energy source (Kaneko, 1997; Agenas *et al.,* 2006). There is need, however, to establish reference levels for indigenous goat breeds which can be used as standard values when assessing the status of these breeds, instead of making reference to the values meant for exotic breeds.

The growth rate of animals influences glucose requirement (Zubcic, 2001; Reynolds *et al.,* 2003) whereas in mature animals only maintenance energy is required.

Table 2.4: Reference values of selected blood chemistry measurements in clinically health goats

Blood parameter	Reference values
Glucose (mmol/l)	2.78 – 4.16
Cholesterol (mmol/l)	-
Creatinine (µmol/l)	88.4 0 – 159.00
Total protein (g/l)	64.00 – 70.00
Albumin (g/l)	27.00 – 39.00
Globulin (g/l)	27.00 – 41.00
A/G (albumin:globulin ratio)	6.30 – 12.60
Urea (mmol/l)	3.57 – 7.14
Aspartate aminotransferase (U/l)	167.00 – 513.00
Alkaline phosphatase (U/l)	93.00 – 387.00
Alanine transaminase (U/l)	6.00 – 19.00
Creatinine kinase (U/l)	0.80 – 8.90
Gamma glutamyl transferase (U/l)	20.00 – 56.00
Calcium (mmol/l)	2.23 – 2.93
Magnesium (mmol/l)	0.31 – 1.48

Source: Kaneko (1997)

However, the physiological status of an animal also has an effect on the glucose requirement (Otto *et al.*, 2000) depending on energy requirements for production.

Glucose concentrations were reported to be lower in lactating than in non-lactating does during the first two months of lactation (Pambu-Golla *et al*., 2000). Grunwaldt *et al*. (2005) reported an effect of season on serum glucose levels shown by a significant increase in blood glucose levels in the post-rainy season as compared to the hot-wet season. Although feed quality also affects blood glucose levels, an increase in body temperature and respiration rate of animals normally experienced in the hot-wet season season leads to a reduction in blood glucose in cattle (Grunwaldt *et al*., 2005). It is not known if goats are also affected in the same manner. Turner *et al.* (2005) reported glucose values of 66.3 mg/dl, 60.9 mg/dl and 63.6 mg/dl for Nubian goats, Boer goat crosses and Spanish goats, respectively. Observations by this author indicate that breed of goat affects blood glucose levels. Such information, however, is not available for indigenous goats of South Africa. It, therefore, is imperative to generate such values for the goat breeds found in the different agroecological zones and production systems characteristic of different communal areas.

Lipids that are important in the assessment of nutritional status of goats are non-esterified fatty acids, β- hydroxybutyrate, cholesterol, and lipoproteins. There is low variability in the blood levels of non-esterified fatty acids as compared to cholesterol which has a moderate variability (Sakkinen, 2005). Elevated NEFA levels indicate dietary energy deficit. Concentration of NEFA then directly reflects the amount of adipose (fat) tissue breakdown taking place (Caldeira *et al*., 2007). Circulating NEFAs are absorbed and metabolized for energy by the liver and other tissues. Beta-hydroxybutyrate (BHB) is a ketone body with a high prognostic value due to its low variability in serum or plasma. Blood ketone bodies are elevated in association with poor carbohydrate status in circumstances related to a negative energy balance (Agenas *et al.*, 2006). Beta–hydroxybutyrate elevated concentrations indicate short-term negative energy balance and adipose tissue catabolism. However, BHB concentrations may not be predictive enough and can arise from dietary sources (Agenas *et al.*, 2006). It, therefore, is fundamental to determine the reference values of NEFA and BHB in communal goats raised in South Africa.

Cholesterol, a major constituent of animal cell membranes, is of endogenous origin. It arises from acetate from the adipose tissue and the small intestines (D'Mello, 2000). High plasma cholesterol concentrations in the absence of excess dietary energy intake are considered to reflect the capacity of the animal to mobilize body fat reserves. Physiological status of a goat affects cholesterol levels. Iriadam (2007) reported an increase in blood cholesterol in goats from 104 mg/dl in early pregnancy to 110.67 and 114.87 mg/dl during mid and late pregnancy, respectively. The increase in cholesterol levels with advancing pregnancy is ascribed to stress which predisposes the animal to gluconeogenesis with an associated rise in transaminases. The elevated levels of transaminases result in a higher level of cholesterol (Iriadam, 2007). Elevated levels of cholesterol, triglycerides, and phospholipids, however, could be indicative of copper deficiency. The essential nature of copper is due to its cofactor role at the active site of a number of enzymes (Cham *et al.*, 2005). A study with Malabari, Alpine, Saanen and their crosses revealed that goat breed affects serum cholesterol levels. Malabari goats had the highest mean (123.21mg/100 ml) whilst the Alpine X Malabari breed had the lowest (101.39 mg/100 ml) level (Nandakumar and Anilkumar, 1997). Cholesterol levels of communal goats of South Africa are largely unknown and, therefore, warrant investigation. In addition, levels of blood metabolites that are linked to protein metabolism warrant investigation.

2.5.5.2 Blood chemical constituents linked to protein metabolism

The total protein (TP) concentration represents all proteins dissolved in blood plasma or serum (Sakkinen, 2005). Albumin, synthesized by the liver from amino acid derivatives is responsible for the colloid-osmotic pressure that inhibits leakage of blood plasma from capillaries into tissues (Kaneko, 1997). Protein deficiency impairs both humoral and cell mediated immunity, thus predisposing an animal to diseases (Titgemeyer *et al*., 2001). Blood TP and albumin concentrations indicate the nutritional condition in domestic ruminants (Kaneko, 1997) due to their stability in blood. Low levels of albumin and TP in plasma are interpreted as protein deficiency and undernutrition. Seasonal variations in TP and albumin have, therefore, been ascribed to changes in the quality and quantity of diet (DelGiudice *et al.*, 1992). Total protein reference values are unavailable for most communal goat breeds and, thus, merit determination.

Plasma albumin is considered a general indicator of nutritional status, related to both feed intake and body weight (Sakkinen, 2005). Albumin levels are affected by physiological status of the goat. Celi *et al*. (2008) indicated that albumin levels were higher three weeks before kidding compared to four weeks after kidding in goats. Due to the long half-life of albumin (Kaneko, 1997), inadequate dietary protein intake leads to a slow, gradual decrease in the blood albumin concentration when insufficient amino acids are supplied to the liver cells for albumin synthesis. Therefore, the plasma albumin is a long-term measure of protein status in ruminants (Agenas *et al.*, 2006).

The effect of undernutrition on serum globulins is highly modulated by the duration of feed scarcity. Plasma globulin concentration may increase in chronic infections caused by, for example, gastrointestinal parasites. Consequently, gastrointestinal parasites can cause a significant reduction in plasma albumin concentration due to a loss of albumin from the host animal (Kaneko, 1997), reducing the albumin:globulin (A:G) ratio. A low A:G ratio may signify an increase in the blood globulin concentration caused by chronic parasitism or compensation for the albumin loss present in protein malnutrition (Payne, 1987), with higher ratios indicating a response to hyperalbuminaemia caused by dehydration. This indicates that caution is required in interpreting such circumstances, implying that other parameters, such as urea, should concurrently be considered.

Urea is a nitrogenous compound synthesized in the liver and excreted through urine so as to prevent the excess nitrogen released in protein metabolism from becoming toxic and harmful to the animal (Kida *et al*., 2007). Urea production is indicative of short-term changes in protein metabolism and complements the information provided by the analysis of blood TP and albumin concentrations (Payne, 1987). A decrease in the blood urea concentration of ruminant animals has been related to low dietary intake of protein due to the recycling of urea from blood back to the rumen under low protein intake circumstances (Kaur and Arora, 1995). Blood urea nitrogen is used as a retrospective diagnostic tool to analyse biological to protein or energy supplementation, change in pasture or forage on offer, or change in pasture management (Hammond, 2006) for dairy cows, beef cattle, sheep and dairy goats. It, also, is important to establish values for goats raised in the communal areas.

Creatinine is a compound produced in muscle tissue metabolism, released into circulation and filtered freely through the kidneys into urine (Grunwaldt *et al*., 2005). It is an indirect indicator of renal function and has an impact on concentration of blood urea nitrogen. Creatinine has a lower diagnostic value compared to albumin and TP due to its high variability in blood (Agenas *et al.*, 2006). Variation in serum creatinine concentration may be due to an animals’ diet, breed, muscle mass and sex (Otto *et al.*, 2000). Reduced blood creatinine concentrations indicate prolonged active tissue protein catabolism which might be due to either fasting or food restriction coupled with reduced filtration in the kidneys (Agenas *et al.*, 2006). However, not only is creatinine the determinant of renal function and normal body function, but mineral metabolism also ultimately influences the function of the kidneys, thus they also warrant investigation to attain a complete overview of the nutritional status of the animal and the function of its kidneys.

2.5.5.3 Blood chemical constituents linked to mineral metabolism

Aspartate aminotransferases (AST) and alkaline phosphatase (ALP) are mostly produced by the liver. In addition, ALP is also produced by the bone and placenta whilst AST is also present in many tissues, particularly striated and cardiac muscle, making it a valuable indicator of soft tissue damage (Otto *et al.*, 2000). Red blood cells contain AST which can leak into plasma before there is any visual evidence of haemolysis (Abutarbush and Radostits, 2003), thereby exaggerating the condition of the goat. Due to its high blood variability, AST has a low prognostic value for nutritional status. Blood levels of AST are, however, elevated under disease and morbid conditions involving injuries (Ikhimioya and Imasuen, 2007).

There exists an inverse relationship between AST and levels of selenium and Vitamins C and E. Vitamin E and selenium deficiency in the diet cause nutritional muscular dystrophy and diagnosis is usually based on high levels of CK and AST (Kannan *et al.*, 2000; Abutarbush and Radostits, 2003). This implies that the serum enzyme activity is low or absent in healthy goats. Hussain *et al*. (2003) revealed that blood levels of AST and ALP increased during the hot-wet season indicating that environmental changes can affect metabolic activities of bucks, resulting in a change in various body functions. Ikhimioya and Imasuen (2007) observed that

ALP level in the blood is a good indicator of bone formation since osteoblasts secrete large quantities of this enzyme. Age was also observed to have a significant effect on ALP in Red Sokoto goats (Tambuwal *et al.,* 2002) with higher values in adult animals compared to young animals. Although some reference values of liver enzyme levels in clinically healthy goats exist, such values may be inapplicable to goats of different breeds raised in a different production system.

Minerals play a fundamental role in forage digestion, reproductive performance, and the development of bones, muscle, and teeth (Mcdowell, 2003). Sub-clinical trace mineral deficiencies occur more frequently than recognized by most livestock producers (Underwood and Suttle, 1999). Most nutrients are homeostatically regulated; therefore their value in profile testing for monitoring and assessment of nutritional status is limited, with the exception of calcium, phosphorus and magnesium (Grunwaldt *et al.*, 2005). Mahusoon *et al*. (2004) revealed a marked breed difference in mineral metabolism in goats. Blood mineral levels vary with seasons (Yokus and Cakir, 2006). Seasonal changes in blood mineral concentrations are ascribed to seasonal changes in feed quantity and/or quality (DelGiudice *et al.*, 1992).

Calcium, the most abundant mineral in the body, functions as a structural component of bones and teeth, and plays a significant role in cardiac regulation and membrane permeability among other functions (Invartsen and Andersen, 2000). Physiological status has been shown to influence calcium levels in goats with reduced levels in pregnant goats, a situation that can be ascribed to increased demand for calcium for mineralization of the foetal skeleton (Azab and Abdel-Maksoud, 1999). Phosphorus plays a central role in efficient use of feed and in the digestion of cellulose and synthesis of microbial protein. It, also, is important for bone and teeth development. Serum phosphorus concentrations in kids are almost double the levels in mature goats (Mcdowell, 2003). Mineral absorption increases in the gastrointestinal tract while mobilization is increased in the bones (Invartsen and Andersen, 2000).

Magnesium, a major cofactor in many enzymatic reactions, is involved in protein synthesis, maintenance of the integrity of membranes, nervous tissue conductions, hormone secretion, and in intermediary metabolism (Laires *et al.*, 2004). Prolonged lack of magnesium induces withdrawal of the nutrient from the bone to maintain serum magnesium concentration by exchanging part of its content with extracellular fluid (Laires *et al.*, 2004). Serum magnesium levels reflect current daily intake of the mineral rather than reserves (Whitaker *et al.*, 1998). Grass tetany occurs when the level of magnesium in blood falls below a critical threshold (Herdt *et al.*, 2000). Determination of mineral levels in blood of communal goats is essential and will lead to supplementation in cases were minerals are deficient and in withdrawal of mineral sources if toxicity of minerals is detected.

2.6 Summary of literature review

Southern Africa is endowed with various indigenous goat breeds. Goat production is hampered by many constraints that include high disease and parasite prevalence, poor marketing management, use of inappropriate breeds and limited forage availability. It, therefore, is fundamental to investigate constraints affecting goats in a particular locality in order to devise developmental programmes to address the obstacles to improved goat productivity. Much of the work on goats has been carried out under controlled conditions at research stations and the results are usually inapplicable to communal production systems in communal areas. Information on productivity of goats can be captured through close monitoring of changes in flock sizes and productivity for at least one year. There is need to investigate constraints to goat production and goat production practices, evaluate the nutritional status in communal goats and to establish correlations between blood metabolites, faecal egg counts, body weights, body condition and packed cell volume.

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3 CHAPTER 3: Communal goat production practices and roles to rural households in the Eastern Cape Province of South Africa

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Abstract

The objective of the study was to determine the roles and management systems of goats in Amatole and Alfred Nzo districts of the Eastern Cape Province of South Africa. Data were collected using participatory rural appraisal techniques, direct observations and structured questionnaires from 212 households as follows; 69 from Alfred Nzo (a sour rangeland) district and 144 from Amatole (a sweet rangeland) district. More women (43% in Amatole, 39% in Alfred Nzo) than men owned goats, with the other few in joint ownership. Mean goat flock sizes per household were not significantly different between the two districts; Amatole (14.0 ± 0.31) and Alfred Nzo (14.1 ± 1.42). There were positive correlations ($r = 0.30$ for Amatole, $r = 0.34$ for Alfred Nzo; $P < 0.05$) between goat flock sizes and cattle herd sizes kept per household. Seventy-nine percent of households in Amatole and 78% in Alfred Nzo kept goats for ceremonies, such as the initiation ceremonies. Goat houses in the two districts were poorly constructed. Farmers' perceptions showed that most goat mortalities were mainly caused by gastrointestinal parasites and tick-borne diseases, especially heartwater. Thirty two percent of farmers in Alfred Nzo district and 27% in Amatole district owned a few bucks, suggesting that inbreeding might have affected productivity of their flocks. There were no formal markets for goats in the two districts. Differences in the importance of goats in different rangeland types should be borne in mind when designing goat improvement programmes.

Key words: bucks, ceremonies, coat colour, household consumption

3.1 Introduction

With about 25% of people in Sub-Saharan Africa being undernourished (Food and Agriculture Organisation, 2005); more efforts should be channelled towards increasing animal protein supply for the improvement of nutritional status and rural livelihoods (Tacher *et al.*, 2000). Goats play an important role in both commercial and subsistent farming systems in South Africa (Lehloenya *et al.*, 2005). South Africa has approximately 4.8 million goats, with 50% of these goats being raised by communal farmers (Shabalala and Mosima, 2002).

The roles of goats to the communal farmers are fairly well established (Gutierrez-A, 1986; Thornton *et al*., 2002; Peacock *et al.*, 2005; Haenlein and Ramirez, 2007; Saico and Abul, 2007). The relative roles of the different functions and products from goats vary, however, with regions, countries, agro-ecological zones, production systems, cultural values and socio-economic status of households (Kosgey *et al*., 2008). These differences should be understood prior to initiation of sustainable development programmes for the resource-limited farmers. For example, in areas where chevon is highly valued, appropriate meat-producing breeds that are adaptable in that particular area should be identified. Where a particular colour of goats is preferred either for ceremonial functions or for its perceived relationship with growth performance, breeding strategies should promote the production of such colours (Dossa *et al*., 2007). The objective of this study, therefore, was to determine goat production practices and the different roles played by goats in communal areas of South Africa.

3.2 Materials and Methods

3.2.1 Description of study sites

The study was conducted in Peddie of Amatole district and Matatiele of Alfred Nzo district of the Eastern Cape Province of South Africa. Two sites were randomly selected from the major veld types of South Africa. Peddie is found in a sweet rangeland whilst Matatiele is located in a sour rangeland.

Peddie, located 27°E and 33°S, lies in the Amatole district. It has an average annual rainfall that ranges from 450 to 900 mm per annum, occurring mainly in the hot-wet season (October to January) but more evenly distributed throughout the year. Temperatures vary between -2 and 42°C, with an average of 18°C. The area is characterised by deep loamy soils derived from shale, mudstone and sandstone of the Beaufort Group of the Karoo Sequence. The vegetation is characterised by small (less than 3 m tall) *Acacia karroo* trees and invasive thicket species such as Karroo Bluebush (*Diospyros lycioides)* (Bredenkamp *et al*., 1996).

Matatiele, located 29°E and 30°S, is situated in Alfred Nzo district which is in the North Eastern part of the Eastern Cape Province. The temperature ranges from 7 to 10°C in the cold-dry season when it may be snowy and between 18 to 24°C in the hot-wet season. The rainfall season is between October and January with the latter being the wettest month. Rainfall ranges between 750 and 1050 mm per annum in the hot-wet season. This climate is conducive to crop production. Alfred Nzo is mostly temperate and transitional forest with scrub and some pure grassveld vegetation (Agriculture Geo-Referenced Information System, 2007). Farmers from the chosen sites are known to raise goats together with other livestock species such as cattle, sheep, chickens and pigs.

3.2.2 Sampling of households

A structured questionnaire was administered to 212 goat owners; 69 in Matatiele and 144 in Peddie from February to April, 2007. For each district, 10% of the wards were randomly selected from which 30% of the villages were further randomly selected. From the selected villages, all the farmers who were willing to participate and had goats were considered. The villages were selected from a household goat ownership register from the Department of Agriculture, South Africa. The questionnaire was pre-tested for accuracy and clarity of questions.

3.2.3 Data collection

The structured questionnaire used in this study captured information such as household characteristics, livestock species and numbers kept, roles of goats, housing, feeding and health management and the goat breeds used (See Appendix 8.1). Farmers were also requested to rank the different livestock species, sources of income and roles of goats with respect to their perceived importance. Secondary data on role of agriculture, livestock species kept and cultural beliefs and some aspects of goat production were collected from key informants; the chiefs, headmen, veterinary personnel and agricultural extension officers who were based in the areas. Some of the information pertaining goat production in the study areas was generated from a workshop that was held in East London from 08 to 09 February, 2007 and participatory rural appraisal (PRA) meetings held in the two districts. Direct observations of the goat breeds used, housing structures, grazing areas and the body condition of the goats were made at most of the homesteads.

3.2.4 Statistical analyses

Frequencies for farmer profile, management practices and participation of the different gender groups in smallholder goat production were determined using PROC FREQ procedures of the Statistical Analysis Sytems (2003). A chi-square test (PROC FREQ) of SAS (2003) was computed to determine association between sex of head of household and goat flock sizes. Household demography, and flock sizes between the districts were compared using generalised linear model (GLM) procedures of SAS (2003). Relationships between flock sizes and other livestock species were determined using the Pearson's correlation (SAS, 2003). Ranks of functions of goats within each district were compared using Kendall's (W) analysis using Statistical Package for the Social Sciences (SPSS 15.0 for Windows, 1999). Factor analysis (SPSS 15.0 for Windows, 1999), was used to classify the uses of goats, with the principal component analysis as the extraction method. Traits considered when buying and culling goats were compared using the Friedman test of SPSS.

3.3 Results

3.3.1 Household demography and goat flock characteristics

As shown in Table 3.1, household sizes in Amatole district were smaller ($P < 0.05$) than in Alfred Nzo district. There was a significant difference in number of female heads of households between the two districts. Most ($P < 0.05$) of the farmers, in both districts, were above 50 years of age. There were significantly larger cattle herds in Amatole than in Alfred Nzo district.

Sheep and goat flock sizes were similar ($P > 0.05$) in the two districts (Table 3.1). In addition to goat production, farmers produced maize and vegetables in both districts. As shown in Table 3.2, there were positive correlations ($r=0.1$; $P < 0.05$) between cattle herd and goat flock sizes and, between cattle herd and sheep flock sizes in both districts. There were positive correlations between cattle herd sizes and chicken flock sizes in both districts. However, there was no correlation ($P>0.05$) between sheep and goat flock sizes in both districts. Goat and chicken flock sizes were positively correlated in the two districts.

Table 3.1: Household characteristics and livestock herd sizes of farmers

Characteristic	**District**	
	Amatole	**Alfred Nzo**
Sample size	144	69
Household size	5.3[b]	5.9[a]
% Age distribution		
30 to 50	25[a]	17[b]
Goat ownership by sex		
Females	43	39
Males	41	33
Mixed (both males and females)	16	28
% of farmers that did no practise planned breeding	51	49
% farmers owning bucks	15[b]	29[a]
% female heads	42	32
% farmers that did not vaccinate their goats	68	77
Herd sizes		
Goat	14.0	14.1
Cattle	10.1[a]	6.3[b]
Sheep	3.3	4.6

[ab] Values within a row with different superscripts are significantly different at $P < 0.05$

NS – not significant ($P > 0.05$)

Mean goat flock sizes were not different ($P > 0.05$) for Amatole and Alfred Nzo as indicated in Table 3.1. Sex of head of household did not ($P > 0.05$) have an effect on goat flock sizes irrespective of district. Seventy-four percent of farmers in Alfred Nzo kept the crossbreds between the Angora and Nguni goats whilst 70% of the farmers in Amatole kept the Nguni goat breed. Farmers in the two districts did not exchange their bucks. As shown in Table 3.1, most farmers used the community buck on their does with a few owning bucks. It emerged from the PRAs that a few farmers in Alfred Nzo also needed the milk-producing Saanen goats. The majority of farmers in Amatole reported that they were in need of Boer bucks.

3.3.2 Roles of goats in household livelihoods

Farmers from each of the two districts ranked livestock as their second most important source of income (33% from Alfred Nzo, 41% from Amatole). Old age pensions (US$100 per month and child grants US$21 per month (US$1: R9.36) were the most important sources of income in the two districts.

Farmers in both districts placed the same emphasis on tangible benefits from their goats as shown in Table 3.3. They also placed the same emphasis on the nature of products i.e. whether the product obtained was edible (for example, for home consumption) or not (for example, dowry).

As shown in Table 3.4, farmers in both villages ranked ($P < 0.05$) ceremonies, sales, meat and manure in that order. However, the least important use of goats in Alfred Nzo was use of goats as investment whilst farmers in Amatole considered use of goats as part of dowry to be the least important function.

Table 3.2: Pearson's correlation coefficients of numbers of different livestock species kept by goat owners

Livestock species		District	
		Amatole	*Alfred Nzo*
Cattle			
	Sheep	0.29*	0.36*
	Goats	0.30*	0.34*
	Chickens	0.18*	0.41*
	Pigs	0.05	0.44
Sheep			
	Goats	0.61*	-0.00
	Chickens	0.37*	0.07
	Pigs	0.86	0.13
Goats			
	Chickens	0.38**	0.41**
	Pigs	0.45	0.36**

[1]Values with an asterisk show statistically correlations at $P < 0.05$ for * and $P < 0.01$ for **

Farmers in Amatole district valued goat milk more ($P < 0.05$) than farmers in Alfred Nzo district whilst farmers in Alfred Nzo placed more importance on goat meat than those in Amatole (Table 3.4). Manure was considered more important in Alfred Nzo than in Amatole district. There was no difference in the importance placed on goat skins by farmers from both districts. Sales of live goats were equally ($P > 0.05$) important in the two districts as indicated in Table 3.4. The use of goats for ceremonies was equally ($P > 0.05$) important in both districts.

3.3.3 Gender participation in smallholder goat production

The PRAs revealed that a few women (adult females) in Amatole (35 %) and Alfred Nzo (28 %) owned goats. It was also established that women in in the two districts were not concerned about their husbands owning goats, arguing that goats are largely ceremonial animals. The ceremonies have no direct benefits to the women.

The questionaire, however, revealed that there was no difference between goat ownership by female farmers in the two districts (43% in Amatole and 41% in Alfred Nzo) as shown in Table 3.1. Joint goat ownership was 16 and 28% for Amatole and Alfred Nzo district respectively. Involvement of women in the management of goats was less ($P < 0.05$) than that of men. Female youths had significantly less participation in the management of goats than male youths in both districts. Male youths in Alfred Nzo were more involved in the herding of cattle than male youths in Amatole district as indicated in Table 3.5.

More females in the Amatole than in Alfred Nzo district herded goats (Table 3.5). However, males were mostly involved in herding of the goats. A combination of men and women were involved in the selling and treatment of sick goats, in the two districts.

Table 3.3: Factor analysis of scores for reasons of keeping goats by farmers

Reason for keeping goats	**District**	
	Amatole	***Alfred Nzo***
Tangible benefit	5.97 ± 0.235	4.49 ± 0.233
Nature of product	0.06 ± 0.339	0.24 ± 0.186
Income generation	6.00 ± 0.184^{b}	7.35 ± 0.265^{a}
Consumption of meat	-2.69 ± 0.190	-3.47 ± 0.281^{b}

^{ab}Means in the same row with different superscripts are significantly different at P < 0.05

The lower the value the more important the trait is.

Table 3.4: Reasons for keeping goats as ranked by communal famers of the Eastern Cape Province

	District	
Function	***Alfred Nzo***	***Amatole***
Sample size	69	212
Meat	3.36[b] (3)[a]	3.85 (3)
Milk	6.00 (6)	5.01 (5)
Manure	4.24 (4)	4.99 (4)
Skin	6.17 (7)	5.82 (6)
Sales	3.14 (2)	2.22 (2)
Investment	6.20 (8)	5.86 (7)
Dowry	4.92 (5)	6.31 (8)
Ceremonies	1.96 (1)	1.93 (1)
Kendall's Coefficient (W)	0.58*[c]	0.65*

[a]The lower the rank, the greater the importance of the trait

[b]The mean rank

[c]*W* ranges from 0 (no agreement) to 1 (complete agreement) and the higher its value the higher is the level of agreement between individual farmers

* Significant at $P < 0.05$

Values in parenthes indicate the rank of the function

Where it was practiced, controlled breeding was supervised by men.

3.3.4 Management of communal goats

Goats in Amatole (81% of the respondents) and Alfred Nzo (83%) were allowed to graze freely in unfenced grazing areas. Ninety-two percent of the households interviewed in Amatole housed their goats in kraals overnight, whilst more farmers in Alfred Nzo (55%) kept their goats in stalls overnight. Participatory rural appraisal meetings and direct observations revealed that of the households that provided goat housing, *Acacia karroo* branches were the most common material used for the construction of goat houses in Amatole whilst corrugated iron sheets were used in Alfred Nzo. Over 90% of the farmers in the two districts had earth as the floor for goat houses. The majority of the goat houses had no roofs.

Ninety seven percent of the farmers in Alfred Nzo and 83% in Amatole castrated their goats. The main reasons for castration of goats by farmers from both districts were to control breeding and improve meat quality. Most (84% in Amatole, 83% in Alfred Nzo) goat farmers mentioned that diseases were the major cause of deaths of their goats. The most important health problems, from PRAs, were gastrointestinal parasites, gallsickness and maggots in Amatole and, gastrointestinal parasites, abscesses and gallsickness in Alfred Nzo district in that order. Farmers from the two districts also reported goat health problems such as diarrhoea and mange. Most farmers reported that they did not vaccinate their goats against the important diseases (Table 3.1) due to lack of funds. The PRAs established that farmers from the two districts used ethnoveterinary medicines to treat their goats when they fell ill. Male adult farmers in Amatole (81%) and Alfred Nzo (76%) were responsible for looking for ethnoveterinary medicines. Women, from the two districts, however, also knew how to prepare ethnoveterinary concortions and how to administer them to sick goats.

Table 3.5: Participation (% of farmers) of different gender groups in goat production

Characteristic	District	
	Amatole	***Alfred Nzo***
Herding		
Men	39	42
Women	22[a]	4[b]
Male youths	36[b]	51[a]
Female youths	3	3
Selling		
Men	49	49
Women	36	37
Male youths	12	13
Female youths	3	1

[ab]Means in the same row with different superscripts are significantly different at $P < 0.05$

All the farmers considered particular traits when culling their goats. In Amatole the most important reason for culling was the size of the goat, while reproductive performance was ranked as the most important trait in Alfred Nzo district. Age and size of both sexes were considered important when culling goats in both districts (Table 3.6). Reproductive perfomance was lowly ranked for male goats in both districts. Farmers from the two districts did not put much emphasis on temperament and body condition score (BCS) in culling their goats, as shown in Table 3.6. Coat colour of the goats was ranked lowly in both districts. The main coat colour varied and could be entirely black, brown or white in Amatole and mainly white in Alfred Nzo district. In both districts farmers reported of few breeding bucks leading to the problem of inbreeding. Researchers noted of poorly constructed goat housing, and the major constraint mentioned by famers was diseases and parasite infestation.

3.4 Discussion

The finding that males headed most households concurs with earlier reports (Habtemariam *et al.*, 2003; Chawatama *et al.*, 2005; Chiduwa *et al.*, 2008) that reported that men are, by custom, traditional heads of households in many communal areas in most Sub-Saharan countries. Most men make decisions pertaining to agriculture regardless of whether they are resident on the farm or not. The observations that most men were resident on the farms and depended on agriculture for their living are consistent with an observation by Mashatise *et al.* (2005) in their study in north-eastern Zimbabwe. This might explain mens' interest in management of goats which would have been done by women had these men been away from their farms. The observation that more women owned goats concurs with findings from a study by Saico and Abul (2007) in a communal area of Swaziland. Although more women owned most of the goats, the management of the goats was mostly done by men.

Table 3.6: Traits considered by farmers in culling goats

Trait	District			
	Amatole		***Alfred Nzo***	
	Male	Female	Male	Female
Size	3.50[2] (2) [1]	2.38 (1)	2.38 (1)	3.62 (3)
Conformation	5.54 (7)	4.51 (3)	4.50 (3)	5.93 (6)
Coat colour	5.38 (6)	5.73 (6)	5.73 (6)	5.88 (5)
Temperament	5.85 (8)	6.06 (7)	6.06 (7)	6.24 (7)
Health	4.98 (3)	4.86 (4)	4.86 (4)	4.67 (4)
Performance	5.35 (4)	4.96 (5)	4.88 (5)	2.43 (1)
BCS[3]	5.40 (5)	6.41 (8)	6.40 (8)	6.32 (8)
Age	3.09 (1)	3.44 (2)	3.44 (2)	3.36 (2)

The lower the mean rank, the greater is its importance at $P < 0.05$

[3]Body condition score

[1]The figures outside the parenthes are the ranks of the trait indicated per given district

[2]The figures inside the parenthes are the mean ranks of the trait indicated

Efforts should, therefore, be made to ensure that women get full knowledge on goat production so that they are better able to manage goats in the absence of men. The high proportion of farmers, who were at least 50 years old, could be perceived in two ways. Firstly, the aging population has extensive experience and traditional knowledge about agriculture. Such aged farmers, however, might not be in a position to adopt new technologies (Agwu *et al.*, 2008) that are meant to improve agricultural production. Younger farmers are more likely to be receptive to new technologies faster than old farmers and the younger the farmers, the more active and innovative they will be.

On the other hand, Starkey (1996) argued that the younger generation views farming systems in smallholder areas as backward and old-fashioned and prefer to be formally employed in urban areas. This indicates that there will be a gap that will be difficult to fill once the aging farmers are retired, possibly leading to the collapse of communal agriculture. It, therefore, entails that stakeholders such as extension officers, non-governmental organisations and policy makers should educate the youths on the importance of agriculture so that they can take over from the elderly when the latter are too old to do any farming.

The larger goat flock sizes in the two districts compared to a flock size of 9.7 reported by Van Niekerk (2004), 7.5 goats per flock in Nigeria reported by Francis (1988) and 5 goats in Cameroon (Ndamukong *et al.*, 1989) could probably be due to availability of grazing land, that is not used for cropping in the two districts of the current study, where goats can graze and browse. This could also explain why most of the farmers allowed their goats to graze freely. Farmers in this study also attributed the larger goat flock sizes to unreliable rainfall in the area. Since feasibility of crop production in these areas is limited, farmers found it worthwhile to capitalize on livestock production enterprises, especially goats.

Findings from this study reveal that, as expected, farmers have different sources of income. Apart from getting income from the sale of goats and other livestock, farmers also obtained income from crop production, grants and pensions and in some cases, salaries. A study by Perret (2000) indicated that farmers in the Eastern Cape Province are only able to grow 30% of crops that they would require annually. This implies that they would require other sources to augment food and other requirements. Apart from sales of livestock, which is usually rare, these extra requirements are met by salaries, for the employed and pensions and grants for the unemployed.

The observation that farmers do not farm with goats only, but with cattle, sheep, chickens, pigs and ducks, owning a few of each species is typical of most African rural communities (Mashatise *et al.*, 2005). This is of great importance since diversification averts risks and promotes sustainable development in rural areas. According to Francis and Sibanda (2001), smallholder farmers diversify their enterprises to fulfil the multiple obligations from agriculture. The integration of goats with other enterprises indicates a way of diversification in order to improve food security.

The positive correlation between cattle and goat herd sizes in all the districts could be attributed to the fact that the two livestock species are usually herded together in most smallholder areas and, therefore, do not compete for labour. Since cattle are grazers and goats are browsers, the two enterprises complement each other and can, thus, co-exist on the same grazing area. The same conclusions were also arrived at in Zimbabwe by Sikosana and Gambiza (1994). The positive correlation between cattle herd sizes and chicken flock sizes, irrespective of district indicates that as farmers acquired more cattle, they became less poor and it, therefore, was easy for them to acquire more chickens.

The finding that the farmers in the two districts prioritized the reasons for keeping goats differently could be attributed to cultural differences among the districts and hence diversity in the value they attach to goats. It was observed that goats, in the two districts, are mainly reared for ceremonies. This finding is in harmony with observations by several authors (Akingbade *et al.,* 2001; Timmermans, 2004; Kunene and Fossey, 2006). These authors revealed that goats, in the Eastern Cape Province, are important in bestowing good fortune at households, to ward off evil, and to enable rites of passage and are rarely slaughtered outside of a ceremonial context. In both districts, goats are mainly slaughtered at funerals and for boys when they go for the initiation ceremonies.

Goats fit well with crop production since manure from goats can be applied to gardens and small cropping fields and the goats can then feed on crop residues. The observation that goat manure was more important in Alfred Nzo than in Amatole district could be attributed to the higher number of goats in Alfred Nzo than cattle compared to flock sizes in Amatole district. This meant that farmers in Amatole district would use manure from their cattle to fertilise their gardens. In addition, more cropping is done in Alfred Nzo district than in Amatole such that farmers in Alfred Nzo would use any available source of nutrients for their crops.

Manure from goats is an invaluable source of organic fertilizer for improving agricultural production. While this contribution is limited, it is of great importance to most resource-poor farmers who cannot afford expensive inorganic fertilizers for use in their crop fields. Manure collection becomes important when farmers employ intensive system of goat production (Lebbie, 2004) and farmers should be encouraged to use it. Collection of manure for gardening, although demanding in terms of labour, has been proven to be a successful way of controlling diseases and integrating goat rearing into the whole farm (de Vries, 2008). It, therefore, is imperative to urge farmers to make use of goat manure.

The finding that milk, in both districts, was lowly ranked agrees with Masika and Mafu (2004) who reported that farmers in the Eastern Cape Province do not consider provision of milk as a major reason for keeping goats. Tefera *et al.* (2004) also reported low goat milk consumption in other smallholder areas of South Africa, where only 3% of the respondents milked their goats. Many cultures in Africa still associate goats with poverty and cattle with wealth. Many men will not admit that their goats are milked, believing it to be a sign of poverty and something of which to be ashamed of (Tefera *et al.*, 2004). It, however, is important to note that goat milk has therapeutic properties and is more easily digestible than cow milk (Haenlein and Ramirez, 2007). The other advantages of milk production over meat production are that milk is produced on a daily basis and the efficiency of utilization of nutrients to produce milk is high. On this basis, communal farmers should be encouraged to milk their goats (Gatenbuy, 1982) in order to provide children and the aged with this important source of protein.

The observation that farmers from the two areas did not value goat skins could be ascribed to lack of ready markets and, therefore, would be left to rot after slaughters. The other reason for the skins not being marketed and processed is that slaughtering is done in an informal manner for ceremonies, religion and home consumption purposes and not in abattoirs. Goats are slaughtered in low numbers which might not support a viable business. This implies that farmers can, if many slaughters from different households take place at the same time, combine the goat skins and market them. Farmers in the Eastern Cape Province might not be aware that they can obtain US$0.08/kg for a dry salted skin. Skins can be used in the production of carpets, seat covers, ropes and bags (Gatenbuy, 1982). If the skin is cured it can be sold for US$8.30. If the skins are further processed into leather handbags and other items decorated with rural or tribal motives, the finished product has a potential value of US$166.70 especially in tourism industry (Tefera *et al*., 2004). There is, therefore, a potential to commercialise goats which can improve the livelihoods of the smallholder farmers through sales of the skins and provision of employment.

Observations from this study indicate that farmers in the two districts did not separate breeding females from bucks implying that they neither made use of breeding seasons nor implemented selective mating. Uncontrolled breeding makes it difficult to keep reproductive records in communal areas. Controlled breeding can be achieved by separating the breeding males from the females all the other time of the year except during the breeding season. Controlled breeding, if carefully planned, will ensure uniform crops of kids that are born when there is plenty of feed. Uncontrolled breeding can promote inbreeding. The levels of inbreeding in the goat populations studied are probably high because of the limited gene flow between villages. Dossa *et al.* (2007) had similar findings in a study on goats in Benin where farmers did not exchange goats. Furthermore, there are very few breeding bucks and this increases the chance of bucks mating their relatives. Communal goat farmers should be educated on the negative impacts associated with inbreeding. They should also participate in designing practices that reduce the level of inbreeding, such as exchange of bucks.

For the ceremonies, larger goats were required as using the smaller ones would indicate lack of respect for their ancestors. Farmers, from the two districts, reported that they were afraid that their goats would die due to old age if they did not cull them earlier. Old age could be taken as an indicator for longevity. Body size and age are important in selecting animals.

Small framed does are also culled since they are most likely to produce small kids (Dossa *et al.*, 2007). It is important for farmers to cull goats whose productivity is no longer efficient and remain with a flock composed of goats that are productive as breeding or growing animals. It, also, is important to understand the traits that are of economic importance to potential beneficiaries before designing any goat improvement programme.

The reason why coat colour of goats was important is unclear. However, it is likely that the farmers in the two districts prefer white goats for ceremonies and, therefore, cull their goats in favour of the white individuals. White goats are slaughtered for boys when they undergo the initiation ceremonies (Manton, 2005) or for other ceremonial purposes. This implies that colour is an important trait when considering breeding programmes for such farmers indicating that the Angora goat or white indigenous goats may be breeds of choice. An in-depth understanding of factors influencing the decision of resource-poor farmers to keep goats is fundamental prior to formulation of technologies and policies that empower communal farmers.

Farmers complained about the high prevalence of gastrointestinal parasites which are usually devastating at a sub-clinical stage. Gastrointestinal parasites are considered the most important causes of morbidity and mortality in goats *(*Mahusoon *et al.*, 2004). Farmers from both districts considered the health of the animal and reported that they slaughtered the diseased animals or those that had broken legs, so that they would remain with the healthy ones. Impaired productivity in goats, especially the non-descript and imported breeds, can be attributed to infection by gastrointestinal parasites. The diseases mentioned by farmers from the two districts are in line with findings by Masika and Mafu (2004). Farmers should be made aware that they need to vaccinate their goats in order to reduce disease incidences.

Identification of prevalence and the species of helminths affecting goats in the specific areas should be sought before a dosing schedule is planned (Sissay, 2007). Management, such as housing, should also be improved to reduce pathogenicity. Another alternative is to advocate for the local genotypes and educate the farmers that these breeds are better able to deal with diseases and parasites that prevail in these areas through resistance and resilience.

The poorly constructed housing can cause adverse effects in goats resulting in pneumonia, footrot and increased parasitic infestation (Devendra and McLeroy, 1982). Goat houses from the two districts did not have roofs and this resulted in accumulation of water and muddy floors. Ficarelli (1995) reported that in Malawi goat farmers lose 30% of their young stock during the rainy season because of poor housing. A proper housing is meant to protect goats from predation and harsh weather conditions, and confine the goats during the cropping season. A good housing structure should provide goats with the best micro-climate that can impede the spreading of diseases and parasites (Sebei *et al.*, 2004). This calls for the need to improve the floors of the goat houses and to provide a roof in order to reduce kid mortality during the rainy season. An improvement in goat housing can help reduce financial input used to purchase drugs as the health of the animals would have improved.

3.5 Conclusions

Communal farmers kept goats for several reasons that were ranked differently in the two studied districts. Farmers in the Eastern Cape Province kept goats mainly for ceremonies and sales. Goats grazed freely since there is an expanse grazing land. All these factors should be taken into consideration when designing breeding programmes. It is fundamental to evaluate the contribution of goats to their owners, although their production systems are complex. Complexity of goat production systems calls for the determination of the efficiency of goat production systems for devising intervention strategies to improve goat productivity and hence rural livelihood.

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4 CHAPTER 4: Goat flock dynamics in the resource-poor communal areas of the Eastern Cape Province of South Africa

(Submitted to *Journal of Arid Environments*)

Abstract

A longitudinal survey was conducted to characterise flock dynamics for goats in communal areas of the Eastern Cape Province of South Africa. A monthly questionnaire was administered to randomly selected farmers between May 2007 and April, 2008. Nineteen, 21 and 13 farmers were monitored in Matatiele, Qawukeni and Mankone, respectively. The parameters assessed were the entries and exits to and from each flock. The mean buck to doe ratios, at the beginning of the experiment were 1:15, 1:19 and 1:11 for Qawukeni, Nkosana and Mankone, respectively. Most kids were born in August (4.92 ± 0.362 for large flocks and 2.03 ± 0.329) for small flocks. Total entries were higher ($P < 0.05$) in August, September and October than in the other months. Kid mortality had two major peaks; in May (21 %) and in September (21 %). Adult mortality was not different from zero ($P > 0.05$) throughout the study period. Main causes of death of kids were deprivation of milk, cold, gallsickness, gastrointestinal parasites, and accidents in the three villages. In addition, predation of goat kids was reported in Qawukeni and Mankone. Most ($P > 0.05$) goats, regardless of flock size, were sold in December, a month in the hot-wet season, (1.06 ± 0.127 for large flocks and 0.23 ± 0.135 for small flocks), and followed closely by June, a month in the cold-dry season, (0.43 ± 0.144 for large flocks and 0.18 ± 0.124 for small flocks) in comparison with other months. The average GPE values were 0.50 ± 0.116, 0.50 ± 0.096 and 0.50 ± 0.091 for Mankone, Nkosana and Qawukeni, respectively. Goat Production Efficiency values ranged from 0.11 ± 0.193 in April to 1.55 ± 0.193 in December. Generally, off-take and GPE were low in the three communities due to high mortality and multifunctionality of goats. Kid mortalities were

high especially in May and June but the causes of the high kid mortalities were not clear. Therefore, further research is needed to identify the causes of mortality in goat flocks.

Keywords: Entries; exits; goat production potential; goat production efficiency; kid mortality.

4.1 Introduction

The importance and extent of contribution of communal goats, at household and community level, are poorly understood (Peacock *et al.,* 2005). It is often inappropriately assumed that the contributions of goats to household economies are similar across communities, rangeland types, production systems and flock sizes (Verbeek *et al.,* 2007).

Cognisant of the complexity of communal goat production systems, Muchadeyi *et al.* (2005) and Chiduwa *et al.* (2008) have developed indices such as production potential and production efficiency. Production potential refers to the proportion of mature and growing goats to the total flock/herd size and is crucial in the computation of production efficiency. Production efficiency is a variable that reflects the proportion of potentially saleable animals sold and/or slaughtered by farmers. Production potential and efficiency have been applied in the description of communal chickens (Muchadeyi *et al.,* 2005) and pigs (Chiduwa *et al.,* 2008). Variation in efficiency over time and/or areas can be indicative of constraints to communal goat production, and can be used to compare different production systems. Determination of efficiency of goat production systems is crucial in devising intervention strategies to improve goat productivity.

In Chapter 3, farmers' perceptions on goat production were retrieved. The contribution of the goats to household food security and income was, however, not adequately captured. It, therefore, is fundamental to monitor goat flock dynamics and identify the major constraints to goat production, with the active participation of farmers. The objective of the study was to estimate goat flock demographics in two rural communities of the Eastern Cape Province of South Africa.

4.2 Materials and methods

4.2.1 Study sites

The study was conducted in Matatiele, in Alfred Nzo district and Peddie of Amatole district. Details on the description of the sites are described in Section 3.2.1.

4.2.2 Household selection

Selection of farmers was on the basis of owning at least three mature goats, willingness to participate in the study and presence of a literate member in the household who would be able to keep accurate records. Literacy was defined as the ability to record goat entries and exits in the booklets provided. Selection of the farmers was done with the assistance of the extension officers. Nineteen, 21 and 13 households were selected from Nkosana, Qawukeni and Mankone, respectively.

4.2.3 Monitoring flock sizes

Assessment of goat flock inventory and productivity were accomplished through conducting monthly visits for a year, from May 2007 to April 2008. Flocks in each village were classified into small and large flocks. Flocks with more than 13 adult goats were considered large. The willing farmers were also categorized into those less than or over 40 years of age. The goats were classified into five categories; adult females (female goats older than one year), bucks (entire males older than one year), castrates (castrated male goats older than one year), female kids (female goats less than one year) and male kids (male goats less than one year). Sixteen, eight and seven farmers in Qawukeni, Nkosana and Mankone, respectively, owned at least one buck. The distribution of goat classes, in each of the villages, is indicated in Table 4.1. Table 4.2 shows the mean sizes of the various goat classes and the total number of goats at the beginning of the study in the three villages.

At the beginning of the trial each farmer was issued with a notebook and trained on how to record all the entries and exits that occurred in their goat flocks (See Appendix 8.2). The entries recorded were births and purchases. Goat sales, mortalities, missing goats and slaughters comprised the exits. Exchanges, gifts and goats entrusted were recorded as either entries or exits depending on whether the goats involved were exiting or joining the flock.

4.2.4 Goat off-take, goat production potential and goat production efficiency

Off-take was defined as the total number of goats that were sold and/or slaughtered plus animals gifted-out permanently as a proportion of the flock size (Wilson, 1986). Goat production potential (GPP) and goat production efficiency (GPE) for each flock were calculated every month, as described by Amanor (1995) and Chiduwa *et al*. (2008).

The GPP was computed as the proportion of mature and growing goats to the total flock size. It was calculated as:

$$GPP = \frac{N}{H}$$; Where

GPP = goat production potential;

N = number of mature goats and growing goats; and

H = herd size.

Table 4.1: Distribution of participating farmers per village in the Eastern Cape Province at the beginning of the trial

	Village					
	Mankone		***Nkosana***		***Qawukeni***	
Characteristic	LF	SF	LF	SF	LF	SF
Gender of farmer						
Male	5	3	5	8	7	9
Female	2	3	3	3	2	3
Age of farmer						
≤ 40	2	3	4	6	1	2
> 40	5	3	4	5	8	10

LF- Large flocks

SF- Small flocks

Table 4.2: Average flock structure in Mankone, Nkosana and Qawukeni villages at the beginning of the trial

	Flock structure				
	Kids	***Female adults***	***Bucks***	***Castrates***	***Flock size***
Village					
Mankone					
Large flock	6.6 ± 1.02	8.7 ± 3.13 [a]	0.9 ± 0.23 [a]	2.4 ± 0.86 [a]	18.6 ± 3.40 [a]
Small flock	1.3 ± 1.01	6.5 ± 3.37 [b]	0.3 ± 0.25 [b]	0.7 ± 0.92 [b]	8.8 ± 3.67 [b]
Nkosana					
Large flock	3.40 ± 0.85	16.5 ± 1.60 [a]	0.5 ± 0.18	4.0 ± 0.85 [a]	25.5 ± 2.09 [a]
Small flock	2.75 ± 0.95	5.4 ± 1.87 [b]	0.4 ± 0.22	1.1 ± 1.00 [b]	7.9 ± 2.45 [b]
Qawukeni					
Large flock	1.33 ± 0.77	18.9 ± 2.48 [a]	1.7 ± 0.22 [a]	3.3 ± 0.89 [a]	25.9 ± 3.14 [a]
Small flock	0.77 ± 0.89	5.9 ± 2.15 [b]	0.7 ± 0.19 [b]	0.8 ± 0.77 [b]	7.5 ± 2.72 [b]

[ab]Values within a column, for a particular village, with different superscripts are significantly different ($P < 0.05$)

The GPE was defined as the proportion of mature goats sold and/or consumed as a proportion of GPP, and calculated as:

$$GPE = \left(\frac{M}{GPP}\right)100$$; Where

GPE = goat production efficiency;

M = number of mature goats consumed or sold; and

GPP = goat production potential.

4.2.5 Statistical analyses

The effects of month, village, gender and age of head of household and flock size on entries, exits, GPP, GPE and off-take were determined using the GLM procedure of SAS (2003). The linear statistical model used was:

$Y_{ijklmn} = \mu + M_i + V_j + S_k + A_l + F_m + (M \times V)_{ij} + (M \times F)_{im} + E_{ijklmn}$

Where

Y_{ijklmn} = response variable (GPE, GPP, off-take, kid mortality, adult mortality, sales, slaughters, goats entrusted out, births, purchases, exchanges, goats entrusted in, gifts and number of goats missing),

μ = constant mean common to all observations;

M_i = effect of month (i = May, June……..April);

V_j = effect of village (j = Qawukeni, Nkosana, Mankone);

S_k = effect of gender of farmer (k = male, female);

A_l = effect of age group ($l = \leq 40, > 40$);

F_m = effect of flock size (m = small flocks, large flocks);

$(M \times V)_{ij}$ = month x village interaction;

$(M \times F)_{im}$ = month x flock size interaction and

E_{ijklmn} = random residual error, assumed to be normally distributed

The effect of presence or absence of a buck in the flock on births and the effects of month, village, flock size, gender and age of head on proportion of kids to does were also determined using the GLM procedure of SAS (2003).

4.3 Results

4.3.1 Flock sizes and structure

Figure 4.1 shows how the number of goats per household varied with month in both the small and large flocks of goats. Flock sizes peaked between August and November and remained constant throughout the study period. Buck to doe ratios for the three villages were 1:15, 1:19 and 1:11 for Qawukeni, Nkosana and Mankone, respectively.

4.3.2 Factors affecting entries

The numbers of goats that joined flocks through entrusting, exchanges and gifts were not affected by village (Table 4.3), flock size, gender and age of farmer. Month, however, significantly affected total entries for both flock sizes, as shown in Figure 4.2. For each flock size, the pattern of births followed closely the pattern of total entries. The total entries were higher ($P > 0.05$) in August, September and October than in the other months.

Kidding was significantly affected by month, flock size and the interaction between the two whilst village, as indicated in Table 4.3, age of farmer and gender of head of household had no effect ($P > 0.05$) on births. As depicted in Figure 4.2, births were significantly higher in August (4.92 ± 0.362), September (4.75 ± 0.313) and October (2.48 ± 0.318) than in the other months. On average, does kidded once a year.

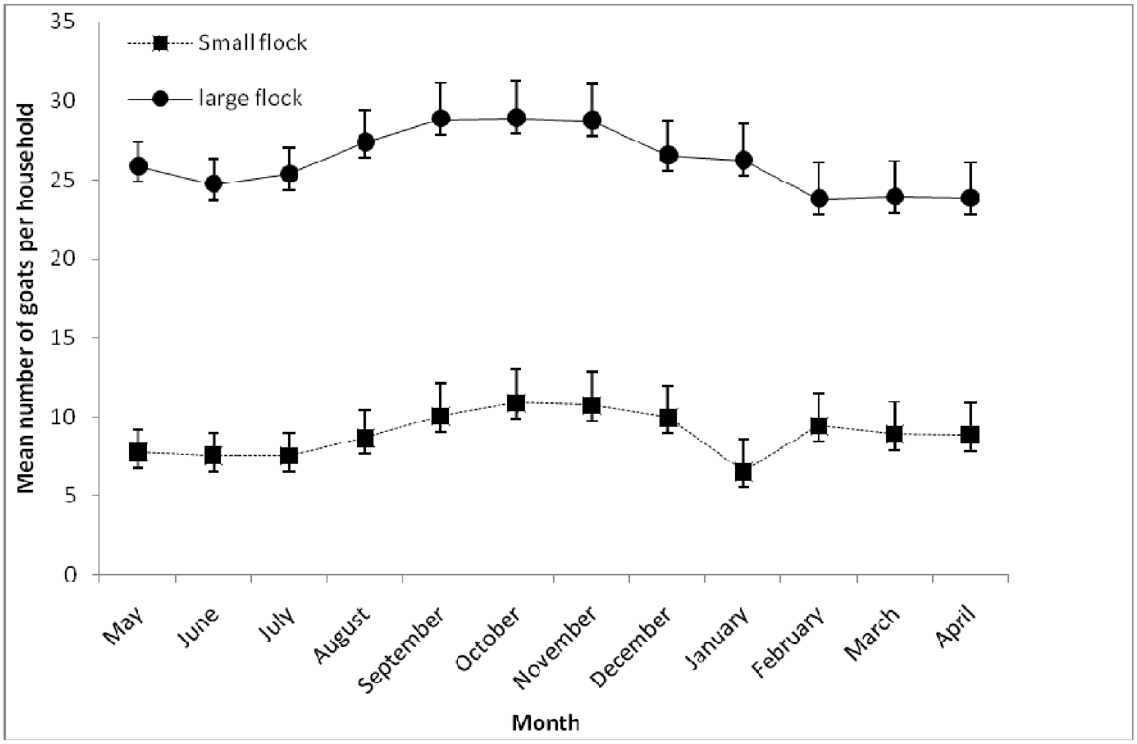

Figure 4.1: Monthly flock dynamics from May 2007 to April 2008 in the small and large flock groups across the three villages

The presence or absence of a buck in a flock had an effect ($P < 0.05$) on the number of kids in the flock. Flocks without bucks had 4.3 ± 0.34 kids compared to 6.1 ± 0.33 kids in flocks whose owners had at least one buck.

Flock size, gender and age of head of household had no effect ($P > 0.05$) on the proportion of kids to does in the flock. The proportion of kids to does was significantly affected by month, as indicated in Table 4.3. Significantly higher proportions of kids to the number of does were recorded in August (57.0 ± 0.05), September (41.0 ± 0.05) and October (31.0 ± 0.05) than in the other months. The proportion of kids to does was also affected by village, with a significantly higher proportion of kids to does for goats raised in Mankone (22.0 ± 0.03) than in Nkosana (9.8 ± 0.03) and Qawukeni (14.9 ± 0.03).

Owners of large flocks bought 0.02 ± 0.007 bucks per month per farmer, whilst owners of small flocks did not purchase bucks at all. Month, village, gender and age of head of household did not affect ($P > 0.05$) number of bucks purchased. Purchase of the other classes of goats was not significantly affected by any of the fixed factors.

4.3.3 Factors influencing outflow of goats

The number of goats that exited flocks through missing, exchanges, gifts and goats entrusted were not affected ($P > 0.05$) by village (Table 4.3), month, flock size, age and gender of the farmer. Slaughters were significantly affected by village. Month affected ($P < 0.05$) kid mortality. The monthly changes in goat mortality are depicted in Figure 4.3. Kid mortality had two major peaks; in May (21%) and September (21%). The proportions of kids to does were lowest ($P < 0.05$) in January to May and highest ($P < 0.05$) in August to October as indicated in Table 4.4.

Table 4.3: Effect of village on GPP, GPE, off-take, entries and exits in goat flocks

	Village		
Characteristic	***Mankone***	***Nkosana***	***Qawukeni***
Entries			
Births	0.95 ± 0.178	0.86 ± 0.148	0.95 ± 0.140
Purchases	0.04 ± 0.030	0.11 ± 0.030	0.04 ± 0.028
Goats received as gifts	0.01 ± 0.092	0.00 ± 0.076	0.00 ± 0.073
Goats received as exchange	0.00 ± 0.006	0.01 ± 0.005	0.00 ± 0.005
Goats entrusted in	0.00 ± 0.003	0.00 ± 0.027	0.00 ± 0.003
Exits			
Sales	0.12 ± 0.056	0.21 ± 0.046	0.25 ± 0.044
Slaughters	0.10 ± 0.030^{b}	0.18 ± 0.027^{a}	0.08 ± 0.030^{b}
Missing	0.20 ± 0.128	0.41 ± 0.106	0.24 ± 0.101
Deaths	0.46 ± 0.090	0.40 ± 0.077	0.50 ± 0.070
Goats given as gifts	0.01 ± 0.017	0.03 ± 0.014	0.00 ± 0.013
Goats given out as exchange	0.00 ± 0.022	0.08 ± 0.019	0.00 ± 0.018
Goats entrusted out	0.00 ± 0.003	0.00 ± 0.003	0.00 ± 0.002
GPP[1]	0.57 ± 0.016^{b}	0.75 ± 0.013^{a}	0.69 ± 0.015^{a}
GPE[2]	0.51 ± 0.116	0.51 ± 0.096	0.50 ± 0.091
Offtake	0.01 ± 0.010	0.04 ± 0.09	0.02 ± 0.08

^{ab}Values within a row with different superscripts are different ($P < 0.05$)

[1] Goat production potential

[2] Goat production efficiency

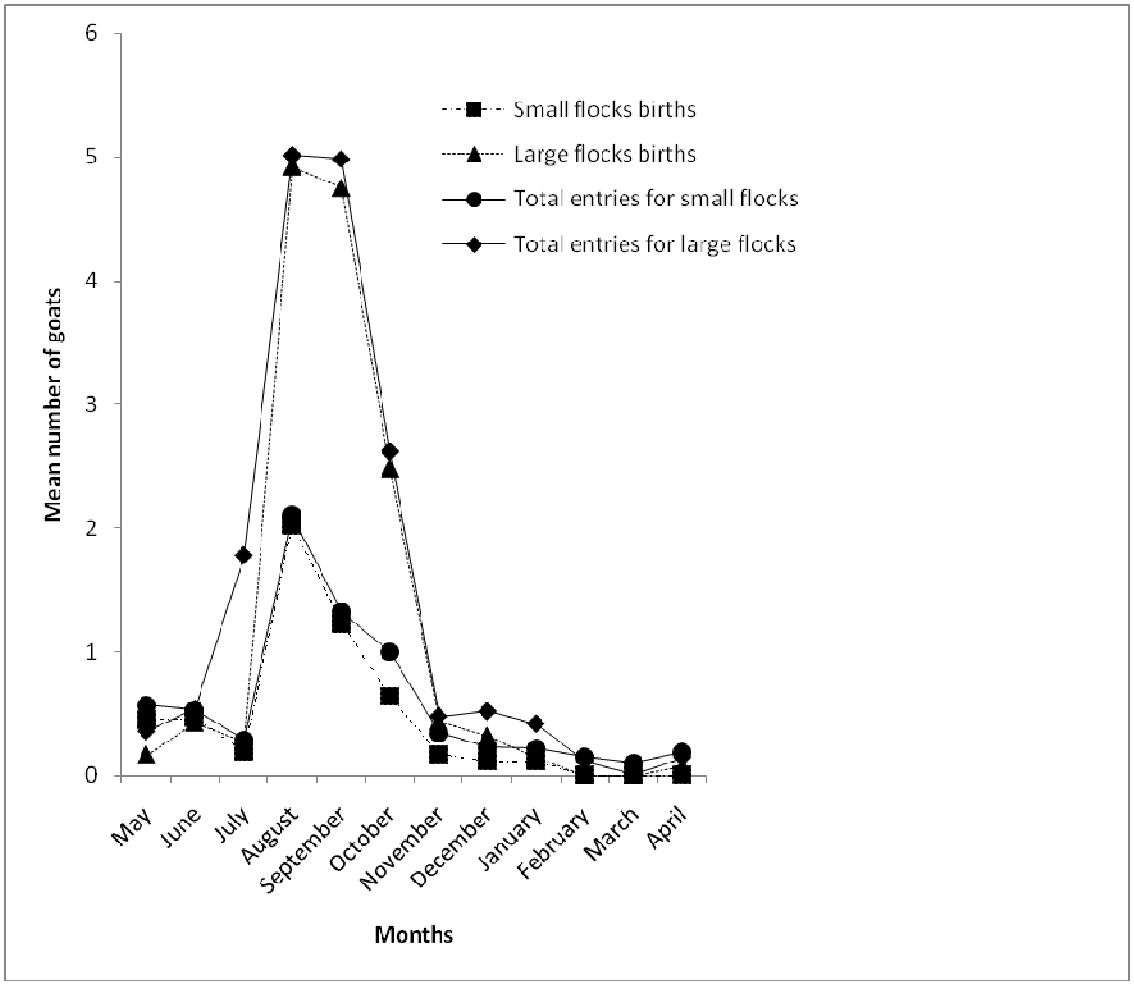

Figure 4.2: Mean monthly births and entries for large and small flocks in the three villages

Adult mortality was not different from zero ($P > 0.05$) throughout the study period. Kid mortality was higher than adult mortality except in August, November and from January to April when they were the same (Figure 4.3).

Village and gender of owner of goats did not have an effect ($P > 0.05$) on both kid and adult mortality. The age of farmer affected kid mortality with a higher ($P < 0.05$) kid mortality in flocks owned by the elderly (13.2 ± 0.02) than in those owned by the young (0.1 ± 0.026) farmers. Main causes of death of kids, as reported by the farmers, were deprivation of milk, gallsickness, gastrointestinal parasites, and accidents in the three villages. In addition, predation was also reported in Qawukeni and Mankone and cold was reported in Nkosana. Kid mortality was higher ($P < 0.05$) in small flocks at 0.13 ± 0.023 compared to 0.07 ± 0.020 in large flocks.

Sales of goats, other than castrates, were not affected by any of the fixed effects tested. There was a significant interaction between month and flock size on sale of castrates. The monthly changes in the mean sales (per household) of castrates for the two flock sizes are indicated in Figure 4.4. The highest ($P < 0.05$) number of castrates were sold in December (0.05 ± 0.084 and 0.67 ± 0.079 for small and large flocks, respectively), followed by June (0.16 ± 0.076 and 0.67 ± 0.079 for small and large flocks, respectively).

Total sales of goats during the study period followed the trend for sale of castrates. There, also was a significant interaction between month and flock size on total number of goats sold.

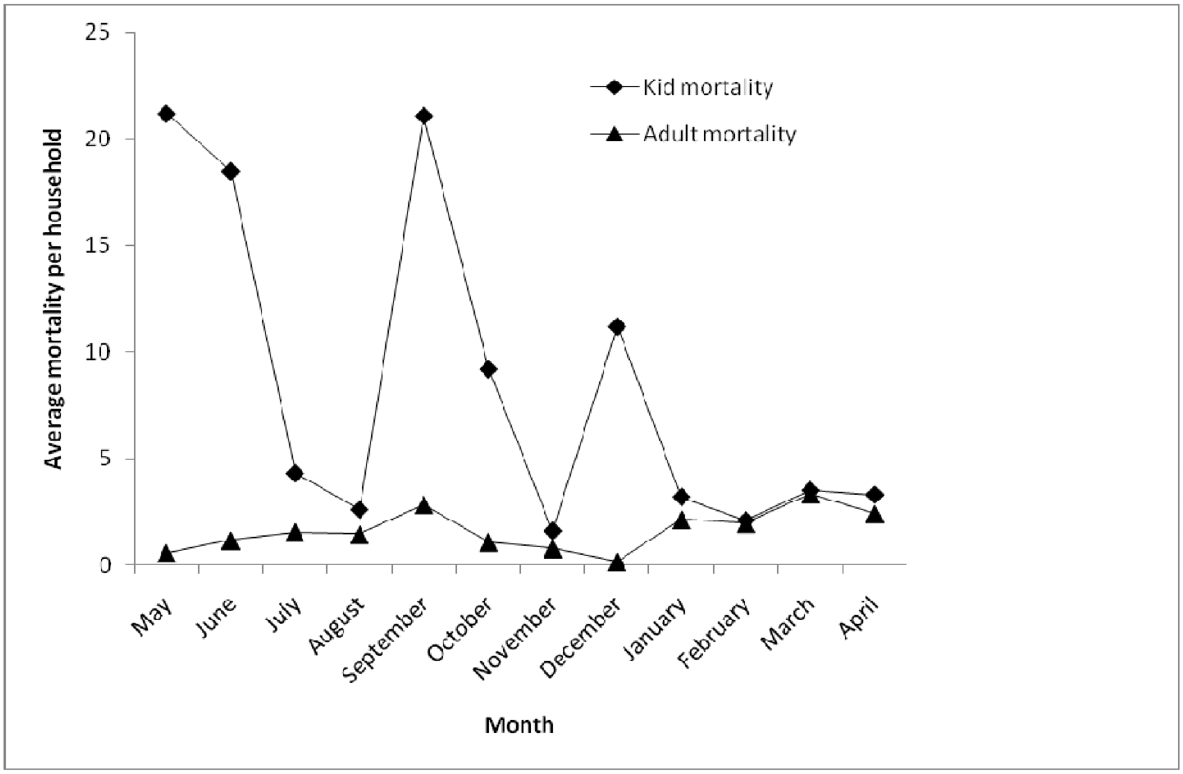

Figure 4.3: Monthly kid and adult mortality for the three villages

Table 4.4: Least square means (± standard errors) of proportion of kids to does in goat flocks in the Eastern Cape villages

Month	Proportion of kids to does (%)
January	6^{c}
February	3^{c}
March	3^{c}
April	3.2^{c}
May	7^{c}
June	12^{b}
July	6^{c}
August	57^{a}
September	41^{a}
October	31^{a}
November	11^{b}
December	9^{b}
Standard Error	0.05

^{abc} Values with different superscripts are significantly different ($P < 0.05$)

As indicated in Figure 4.5, most goats, regardless of flock size, were sold in December (1.06 ± 0.127 and 0.23 ± 0.135 for large and small flocks, respectively), and followed closely by June (0.43 ± 0.144 and 0.18 ± 0.124 for large and small flocks, respectively) in comparison with other months. Goats were sold for R500 to R1200 (US$53.4 to US$128, IUS$ = R9.36) per goat depending on the age, gender and/or size of the goat. Most farmers were unwilling to sell female goats unless they were unproductive or very old.

4.3.4 Factors affecting off-take, goat production potential and efficiency

Gender of owner of goats had an effect ($P < 0.05$) on GPP. Female owners of goats had a significantly lower GPP value of 0.63 ± 0.015 than for male owners (0.70 ± 0.010). Month also significantly affected GPP as indicated in Figure 4.6, with the highest ($P < 0.05$) GPP recorded in May, June and July and the lowest in March and April. Village affected GPP with values for Nkosana and Qawukeni being significantly higher than for Mankone. Goat production potential was higher ($P < 0.05$) in small flocks (0.04 ± 0.008) than in large flocks (0.02 ± 0.008).

Off-take was not affected by any of the factors tested. Goat Production Efficiency was affected ($P < 0.05$) by month and flock size. The GPE values ranged from 0.11 ± 0.193 in April to 1.55 ± 0.193 in December as indicated in Figure 4.7. The GPE was higher ($P < 0.05$) in large flocks (0.68 ± 0.086) than in small flocks (0.32 ± 0.085). The GPE was not affected by village and gender of owner of goats. Goat production efficiency and off-take values for each village are shown in Table 4.3.

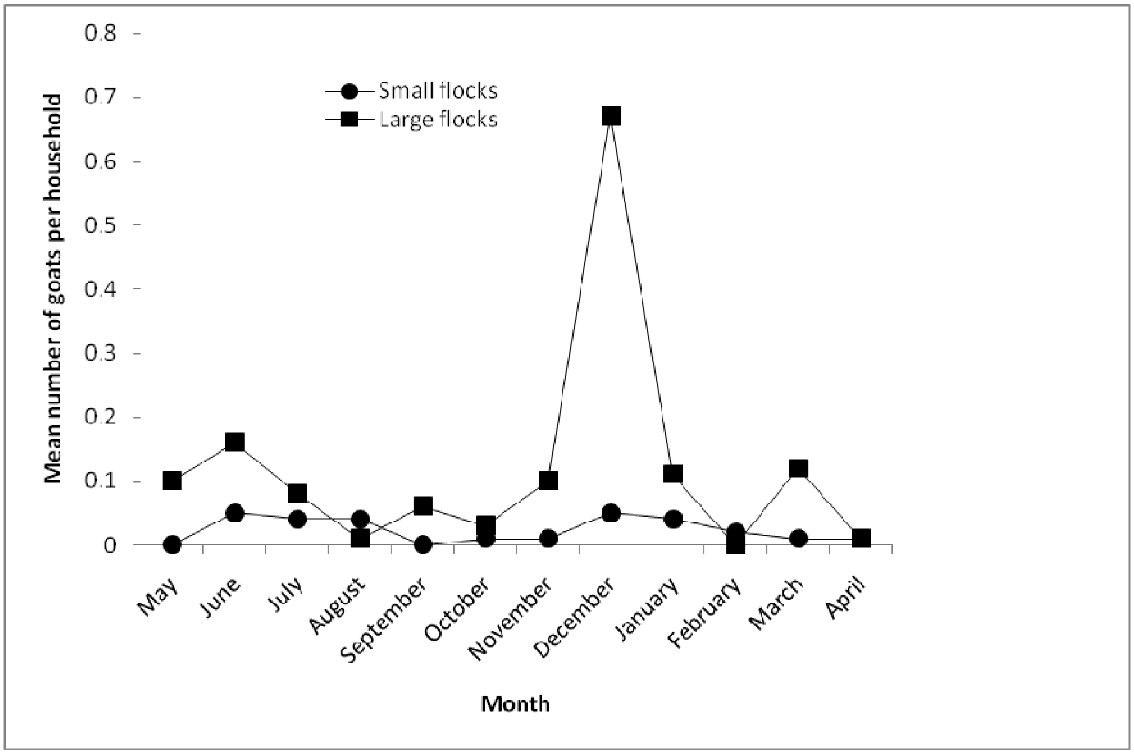

Figure 4.4: Monthly sales of castrates in the small and large flocks for the three villages

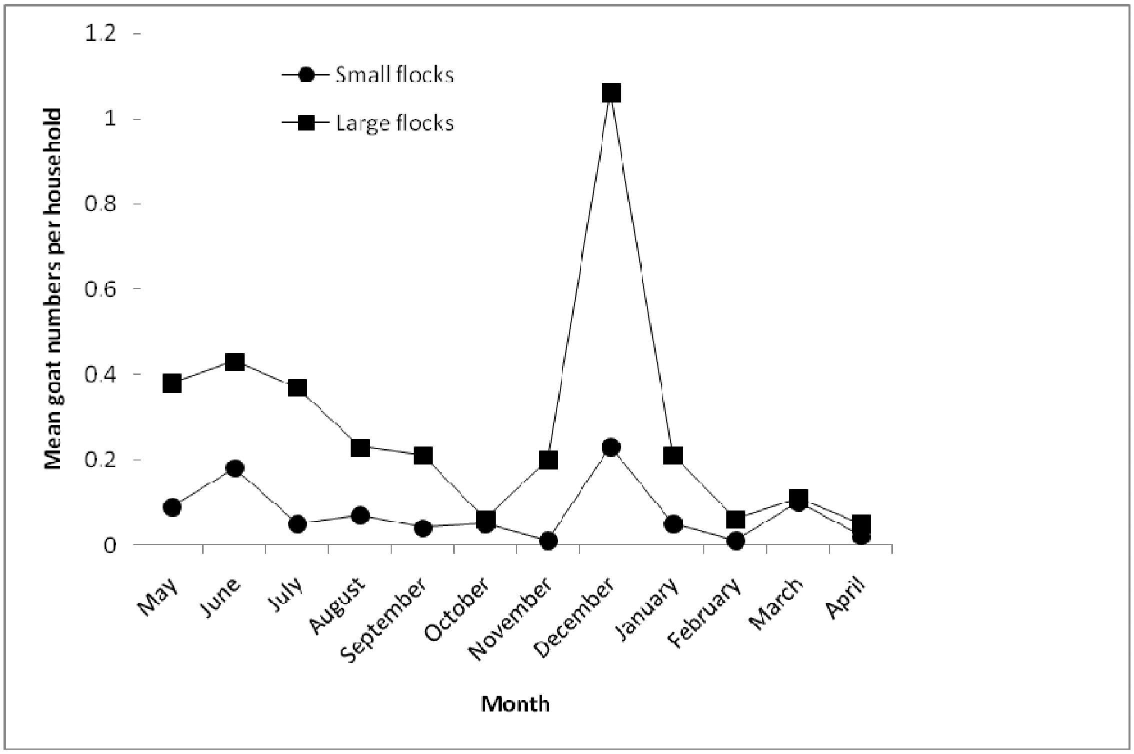

Figure 4.5: Monthly total sales of goats in the small and large flocks of the three villages

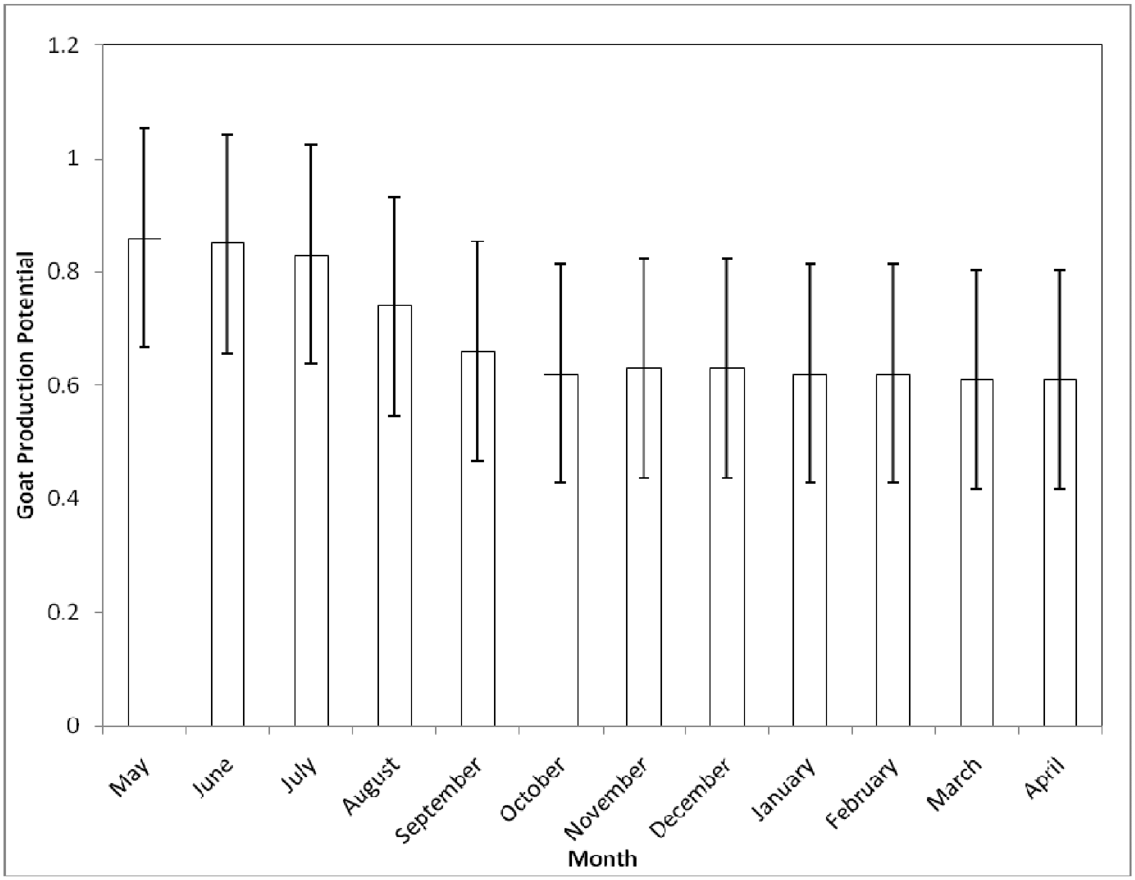

Figure 4.6: Effect of month on goat production potential for goat flocks in the three villages

4.4 Discussion

Information on the contribution of goats to household economies in Southern Africa is largely scarce. The monitoring of goat flock dynamics aids in the estimation of contribution of goats to the livelihood of resource-poor farmers and on-farm production performance of the animals. Most of the available literature is from one-off surveys, based on recall by the farmers. It, therefore, is crucial to determine how flock sizes and structures vary with season, in an attempt to quantify the contribution of goats to the livelihoods of the resource-poor farmers.

The finding that female goats constituted about 70 % of the flock concurs with an observation from a study in Swaziland where a similar flock composition of 70 % females was reported (Lebbie and Manzini, 1989). The greater proportion of females in goat flocks is also in agreement with earlier reports (Ndamukong *et al*., 1989; Reynolds and Adediran, 1994; Loforte, 1999). Wilson and Durkin (1988) established that, under communal production systems, female goats were mostly retained for breeding purposes whilst castrates were sold most.

The greater number of breeding female goats enhances a faster growth of the flock due to increased number of births (Ahmadu and Lovelace, 2002). However, the increase in births can be accomplished when the goat farmers ensure that the female goats have access to bucks when the need to be bred arises, among other constraints to production. The buck to doe ratios observed agree with Lebbie and Manzini (1989) who reported a ratio of 1:12 for Swaziland. Ahmadu and Lovelace (2002), however, reported a ratio of 1:30. The recommended buck to doe ratio for goats under traditional production system is 1:25 (Ahmadu and Lovelace, 2002).

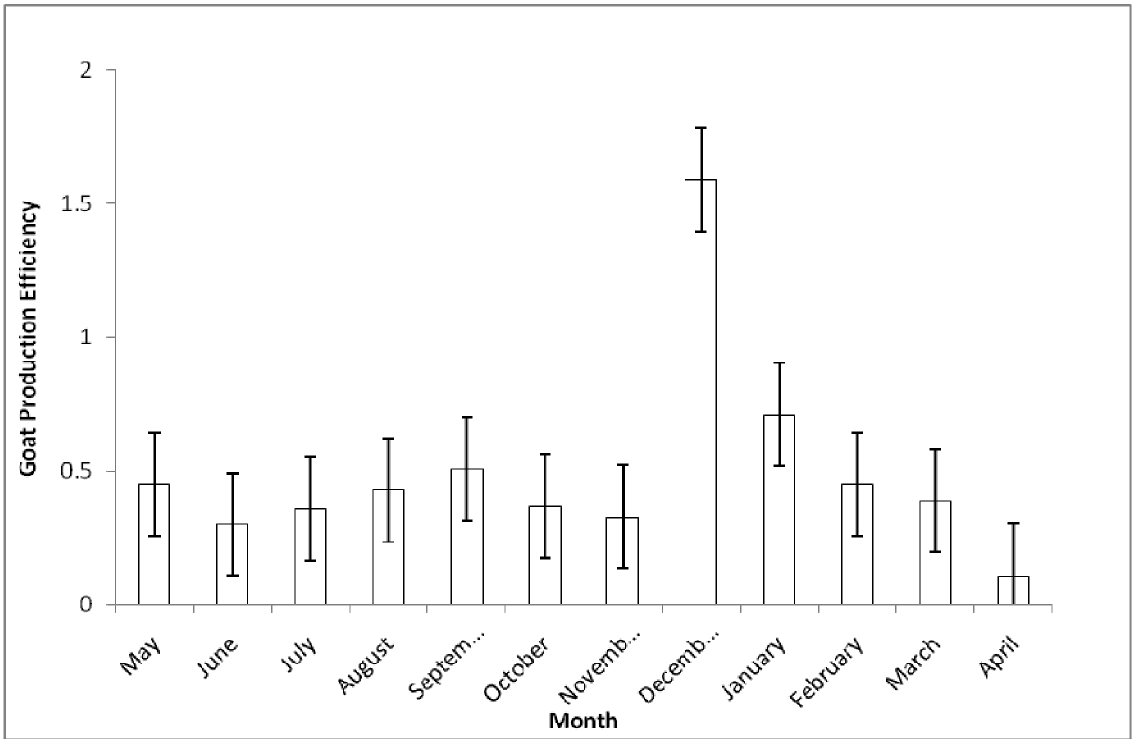

Figure 4.7: Effect of month on goat production efficiency for goat flocks in the three villages

Although the buck to doe ratios in the current study might be desirable, the number of bucks could be insufficient under the communal production system where individual communal farmers keep small flocks and, therefore, most of the flocks do not have a buck of their own (Saddul *et al*., 2003). Does from flocks without bucks have access to bucks from other flocks in the communal grazing areas. However, it is worth noting that during the cropping season, goats from different flocks do not mix (Maiga, 1992; Ahmadu and Lovelace, 2002) since they are herded in different areas, away from crop fields. The lack of mixing of flocks suggests that flocks without bucks have limited or no access to bucks during the cropping season.

The uneven distribution of bucks might explain the observation that most does kidded from August to October indicating a late post-rainy season to cold-dry season breeding. It implies that most does in the current study conceived from March to May, soon after harvest when bucks and does were no longer confined and would, therefore, intermingle resulting in higher chances of a doe being mated when it required a buck. It, however, is important to note that fertility of goats reaches its peak in autumn (Ahmadu and Lovelace, 2002). For those flocks that had bucks, kidding took place throughout the year as indicated by the higher number of births in such flocks compared to those that did not have. It, therefore, is imperative that each farmer has at least a buck in his/her flock or bucks should be managed in such a way that they are available to all does when required, for example, by lending each other if a farmer without a buck discovers any doe(s) on heat in his/her flock. This might increase the observed kiddings of once per year to three kiddings in two years. Besides availability of bucks, it is fundamental to investigate the effect of other factors such as gastrointestinal parasites and nutrition on fertility of bucks and does over a period of time.

The observation that the elderly farmers did not buy bucks can be ascribed to the fact that age of a farmer is inversely related to the probability of a positive response. It should be appreciated that older people are less vigorous and are comfortable with what they have yet the younger farmers are still active and are prepared to keep increasing their flock sizes. However, the value of owning bucks should be explained to all farmers so that they do not entirely rely on bucks from other flocks for breeding their does.

The observation that sales occurred mainly during ceremonial periods (June and December) indicates that communal farmers in the Eastern Cape Province place much value on the goat as a customary animal. The main ceremony performed during the indicated period is the rite of passage for boys. Even higher exits were witnessed in December because, besides being a traditional ceremony period, it is also a festive season and the demand for goat meat during this period is high. These findings concur with observations by Masika and Mafu (2004), who established that goats are mainly kept for ceremonies and for slaughter during the festive season and are therefore sold in June and December. Several studies in the Eastern Cape Province (Mahanjana and Cronje, 2000; Timmermans, 2004) and Kwazulu-Natal (Akingbade *et al.,* 2001; Kunene and Fossey, 2006) have confirmed that goats are rarely slaughtered outside a ceremonial context.

Apart from the high sales in June and December, farmers sold goats in January to raise funds for school fees for their children. Otherwise other sales of goats were restricted to those occasions when there was an urgent need for cash. It is important to note that apart from the socio-economic importance of goats, communal goat keepers tend to be both producers and consumers of goats and their products indicating the multiple livelihood functions (Dorward *et al.*, 2001) of this valuable species. Knowledge of reasons why resource-poor farmers keep goats enhances policy formulations that may be used to increase the productivity of goats.

The observation that sales were mainly restricted to castrated males is in line with findings by Webb and Mamabolo (2004) who reported that more males are sold off or slaughtered from goat flocks for home consumption. Findings by Wilson and Durkin (1988), however, indicated that females were usually slaughtered after kidding five to six times, or when they produced offspring with defects. As indicated by the farmers, castration of goats was mainly to ensure that castrated goats reached a saleable age faster. It, therefore, is crucial to cull non-performing female goats and to sell castrates, after reaching mature weight, so that all goats in the flock are productive either as growing animals or fertile bucks and does. It, however, is fundamental to increase the flock to a manageable size that will not compromise on management to enhance the survival of kids born.

The communal system of goat management is characteristic of low survivability and high mortalities of kids (Sebei, 2004). The high kid mortalities, which included even fairly grown up kids, observed in May and June could be due to the cold weather experienced during the cold-dry season months. These findings concur with observations by Erasmus (2000) and Sebei *et al*. (2004) who reported high kid mortalities in the cold season.

The high kid mortalities in August and September are because this is when most kids were born. Most of the resource-poor farmers do not provide appropriate housing facilities for their goats, as many of the houses do not have roofs and the floors are not slatted. It, therefore, is crucial to protect kids from vagaries of weather, especially cold and rain by provision of appropriate housing. A raised slatted floor will drastically lead to a reduction in worm burden by allowing contaminated faeces to fall under the floor, while well positioned and properly ventilated houses can reduce incidences of pneumonia (Braker *et al.*, 2002). Housing in Mankone and Qawukeni villages was mainly made of thorny bushes whilst better housing, made from corrugated iron sheets and roofed was observed in Nkosana village. Farmers in Nkosana were trying to cushion their animals from cold since the area sometimes experiences snow and the temperatures are generally lower than that of Mankone and Qawukeni.

Farmers also indicated that kids died due to lack of milk from undernourished dams, and small body weight for the kids leading to reduced chances of survival. The higher kid mortality observed in the small flocks compared to large flocks could indicate the possibility of inbreeding (Peacock, 1996), especially when the production system dictates that breeding goats do not mix freely during a particular period of the year. The implication is that if there is a single buck in a particular small flock, it will end up mating its relatives thereby reducing the survivability of kids (Peacock, 1996). In addition, owners of large flocks paid much attention to the health of their goats as they even sold some of their goats in order to purchase drugs for use on the remaining animals.

It is fundamental to establish the causes of high mortality in different communal areas so that interventions can be recommended to increase survival of kids in the specific areas. Seasonal variations are a key factor in goat production where their extensive management is directly linked to environmental conditions. Seasonal changes, although predictable in their occurrence, are less predictable in intensity of particular factors, for example, amount of rainfall and their impact (Lesnoff, 1999) on productivity of goats. Supplementation of pregnant does in the last trimester, so that kids have a better weight, will also go a long way in increasing the chances of survival for kids.

The low values obtained for off-take were not surprising since this measure indicates the number of goats that exited the flocks through sales and/or slaughters as a proportion of the whole flocks, which is inclusive of kids. The observation that large flocks had a higher GPE can be attributed to the fact that large flocks had a lot more goats to dispose than small flocks. Large flocks might have been trying to reduce the number of goats to manageable sizes. Generally, GPE was low indicating that farmers are not always prepared to sell or consume their goats. The low GPE values obtained in this study do not signify that goats are unimportant to the resource-poor farmers but that they are multifunctional. Goats, in South Africa, are usually retained for their socio-economic importance rather than their terminal benefit of cash and meat. Goats are sold mainly when the need for cash arises, for instance in case of emergency (insurance function) or to cover expected expenses (buffering function) (Dossa *et al.*, 2007). The production potential takes into account goats that were sold and/or slaughtered but disregards other contributions such as supply of milk, manure, skins and status symbol. It, therefore, is imperative to device other computations where these neglected contributions are factored in.

The finding that GPP was higher for Nkosana and Qawukeni villages compared to Mankone village yet GPE was not different among the three villages indicates that a higher proportion of mature and growing goats in a flock does not always imply that farmers will sell or consume more of their goats. These findings indicate that farmers from Mankone were more willing to sell their goats compared to farmers from the other two villages. Since most of the farmers from Nkosana and Qawukeni were employed as builders, their dependence on cash from sales of goats was less than that of farmers from Mankone. This was further underlined by the higher consumption of goat meat by farmers from Nkosana. It implies that, in general, as sources of income become fewer, resource-poor livestock producers attempt to offset diseconomies of scale by relying more on their animals (Hary *et al*., 2003). It is important that farmers diversify enterprises so that they are not disadvantaged when disaster strikes their only enterprise.

The decision to sell is dependent on the reasons why farmers keep goats. Our findings indicate that farmers in Nkosana and Qawukeni might have been raising their goats as an insurance against emergencies and would, thus, sell their goats when the need arose or when the demand was high. It, however, is imperative to improve the productivity of goats as increases in flock size might allow them to sell more and lead to the betterment of their lives.

4.5 Conclusions

Although large flocks had a higher GPE value, generally off-take and GPE was low in the three communities due to high mortality and multifunctionality of goats. However, GPP was higher for Nkosana and Qawukeni villages compared to Mankone village. The sales occurred mainly during ceremonial periods. Improvement on husbandry practices, including provision of appropriate housing, is likely to increase goat production efficiency. This indicates that production efficiency is an ideal measure of assessing efficiency of production in resource-poor livestock production systems as it allows evaluation of factors affecting production. Confinement of bucks during the cropping season restricts conception of most does to the period when the flocks mingle, i.e. after harvest. This results in most of the does kidding in the hot-dry season. This indicates that if means of availing the bucks throughout the year are devised, kidding might take place throughout the year and hence improve flock productivity. In this study, the quantities of goats exiting or entering goat flocks were determined. Kid mortalities were high especially in May and June but the cause of high kid mortality is not known. Therefore, further research is needed to identify the causes of mortality in goat flocks.

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5 CHAPTER 5: Prevalence and loads of gastrointestinal parasites of goats in the communal areas of the Eastern Cape Province of South Africa

Abstract

A longitudinal survey was conducted to determine the prevalence and loads of gastrointestinal infections in goats raised by communal farmers in the sweet and sour rangelands of the Eastern Cape Province of South Africa between June 2007 and April 2008. A total of 171 goats were body conditioned, weighed and had faecal samples collected from their recta in a cold-dry season, the hot-dry, hot-wet and the post-rainy seasons. The samples were examined by the modified McMaster technique for nematode egg types and sedimentation for trematode egg types. Body condition scores followed the same pattern as body weights and were lowest ($P < 0.05$) in the cold-dry season for both rangeland types. The most frequently detected gastrointestinal eggs were the strongyle egg type (68.4 ± 8.49 in the sweet and 96.1 ± 12.01 in the sour rangeland) being the most prevalent followed by coccidia (53.3 ± 8.76 in the sweet rangeland and 68.8 ± 8.00 in the sour rangeland). The trematodes observed were *Fasciola* and *Paramphistomum* species. High loads of strongyle eggs were observed in the hot-wet season and the post-rainy seasons, whilst the other egg types showed a peak in the hot-wet season. The prevalence for most of the gastrointestinal parasite eggs was higher ($P < 0.05$) in the sour rangeland compared to the sweet rangeland. The mean egg counts for all the nematodes were negatively ($P < 0.05$) correlated to age and body condition score of the goats. The results indicate that strongyles and coccidia are the major contributors to goat helminthiosis in the study areas. The study has indicated that helminths negatively affect the productivity of goats.

Keywords: coccidia, nematodes, season, strongyles

5.1 Introduction

Gastrointestinal parasite infestations constitute serious health challenges and limitations to the productivity of goats, especially in the communal areas of developing countries, compared to any other type of parasites (Kusiluka and Kambarage, 1996; Githiori *et al.*, 2006). This is mainly because developing countries are associated with warm temperatures, poor management practices and inadequate health control measures (Akhtar *et al*., 2000). The impact of helminths is manifested through morbidity, mortality (Mahusoon *et al*., 2004) and, cost of treatment and control measures (Nwosu *et al*., 2007) against the helminths. In fact, most of the economic losses caused by gastrointestinal parasites are mainly due to production losses (Waller, 2004) instead of mortality, since helminths are related to sub-clinical production losses which induce intense negative impacts upon long-term goat productivity. Helminthiosis rarely gets medical attention due to its chronic and insidious nature (Sanyal, 1998; Dimander *et al.*, 2000) and clinical signs may develop just prior to the death of the goat (Valentine *et al*., 2007).

Communal goats have the ability to tolerate helminths and this can be assessed through changes in body weights and body condition over time (Chiejina *et al*., 2002). There is, however, scanty information on the epidemiology of gastrointestinal parasites and their effects on goats raised by resource-poor farmers in the Eastern Cape Province. Extrapolation of control strategies designed for one geo-climatic region and production system may not necessarily be appropriate for other agro-ecological zones and production systems due to differences in climatic and management factors.

The previous chapter was based on the numbers of goats that were entering and exiting goat flocks and mortality was the main cause of exits. However, the causes of mortality are not known but presumed to be due to gastrointestinal parasite infestation. It is fundamental to identify helminths affecting goats so as to better identify appropriate tactical strategies for helminth control in goats. The current chapter describes identification and determination of egg loads of nematode and fluke parasites in communal areas of the Eastern Cape Province.

5.2 Materials and Methods

5.2.1 Study sites

Nkosana village of Matatiele and Qawukeni village of Peddie were used for this study. Mankone village was dropped from this study since only two farmers were willing to avail their goats for this experiment. The description of the two study sites are given in Section 3.2.1.

5.2.2 Selection of households

Nkosana and Qawukeni villages were selected from five communities in Matatiele and 10 communities in Peddie, respectively. Selection of these communities was based on the fact that most of the farmers from these communities reported, in a participatory rural appraisal meeting, helminthiosis as the major goat health problem. Selection of farmers was also on the basis of ownership of at least four clinically healthy does, one male kid and 1 female kid and willingness to participate. Using these criteria, 15 and 13 households were selected from Nkosana and Qawukeni villages, respectively. Goats were classified into two categories; adult and young goats. Adult goats were defined as goats above the age of one year.

5.2.3 Experimental animals

Animals used in this study were communal goats from willing households. Each household provided four does, one female kid and one male kid with some providing less as they did not have indigenous goats. At the beginning of the study, there were 81 adult goats and 29 kids in Qawukeni and, 84 experimental adult goats and 30 kids in Nkosana. The selected goats were aged by dentition and ear tagged for identification.

The experimental animals were weighed and faecal samples collected per recta in June (cold-dry season) and September (hot-dry season) in 2007 and, January (hot-wet season) and April (post-rainy season) in 2008. In addition, does were condition scored on a scale of 1-5, with a score of 1 indicating a thin and emaciated goat whilst a condition of 5 indicated an obese goat (Friedricks, 1993). A body condition score was assigned after visual appraisal and palpation on the lumbar and sternum areas as indicated in Table 5.1.

5.2.4 Collection of faecal samples

Faecal egg counts were determined by the modified McMaster technique (see Appendix 8.3) with saturated solution of sodium chloride as the floating medium. Four grams of faeces were mixed in 56 ml of saturated solution of sodium chloride. The number of nematode eggs per gram of faeces was obtained by multiplying the total number of eggs counted in the two squares of the McMaster slide by the dilution factor of 50 (Whitlock, 1948). The McMaster technique detects 50 or more eggs per gram of faeces. Samples were screened for flukes by means of the sedimentation method described by Soulsby (1982). Details on the McMaster technique used are given in Appendix 8.3. Nematode egg types were determined using the sedimentation technique and identified using keys developed by Soulsby (1982), Uhlinger (1991) and Foreyt (2001).

Table 5.1: Body condition score descriptions as used in the assessment of the experimental goats

Score	Body condition
1	*Very poor* Deep cavity under tail and around tail head No fatty tissue felt at loin Pins, hooks and short ribs can be felt Edges feel sharp
2	*Poor* Cavity around the tail head is evident No fatty tissue is felt between skin and pelvis End of short ribs are sharp Bones can be felt
3	*Good* Slight cavity lined with fatty tissue apparent at tail head Area between pins not very well pronounced End of short ribs can be felt with moderate pressure Hooks and pins can be felt but are covered with some flesh Hook, pin and back bones appear smooth
4	*Fatty* Depression between pin and tail not pronounced Pelvis felt with firm pressure Short ribs can not be felt even with firm pressure No depression is visible between the backbone and hip bones
5	*Grossly fat (obese)* Tail head buried in fatty tissue Area between pins and tailbone is rounded No part of the pelvis can be felt, even with firm pressure

Sources: Friedricks (1993) for the description of body condition scores

The prevalence of each species of gastrointestinal parasite was calculated as:

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

Where: P is the prevalence, d is the number of animals infested with the gastrointestinal parasite at a given time; and n is the number of animals in the population at risk at that particular time.

5.2.5 Statistical analyses

Data were analysed using GLM procedures of SAS (2003) to determine the effect of rangeland type, season, age of goat and their interactions on faecal egg counts (FEC), body condition score and body weight. The FEC were logarithmically transformed using $\log_{10}$ (FEC + 1), whilst body condition scores were square root transformed to normalize the data. The effect of sex was tested on data for kids since the adult goats were all females. Comparison of means was done using the PDIFF procedure (SAS, 2003). PROC CORR (SAS, 2003) was used to determine the correlations among body weight, BCS and faecal egg counts of helminths. Prevalence of parasite species was analysed by chi-square (SAS, 2003). An odds ratio analysis was conducted on the prevalence of coccidia and strongyle egg output using PROC LOGISTIC (SAS, 2003) from which relative risk of coccidia and strongyle infection based on faecal egg positivity was assessed according to Schwabe *et al*. (1977).

5.3 Results

5.3.1 Factors affecting body weight and body condition scores

An interaction of season by age of goats significantly affected body weights of the goats as illustrated in Figure 5.1. Body weights were highest ($P < 0.05$) in the post-rainy season for both age classes as depicted in Figure 5.1.

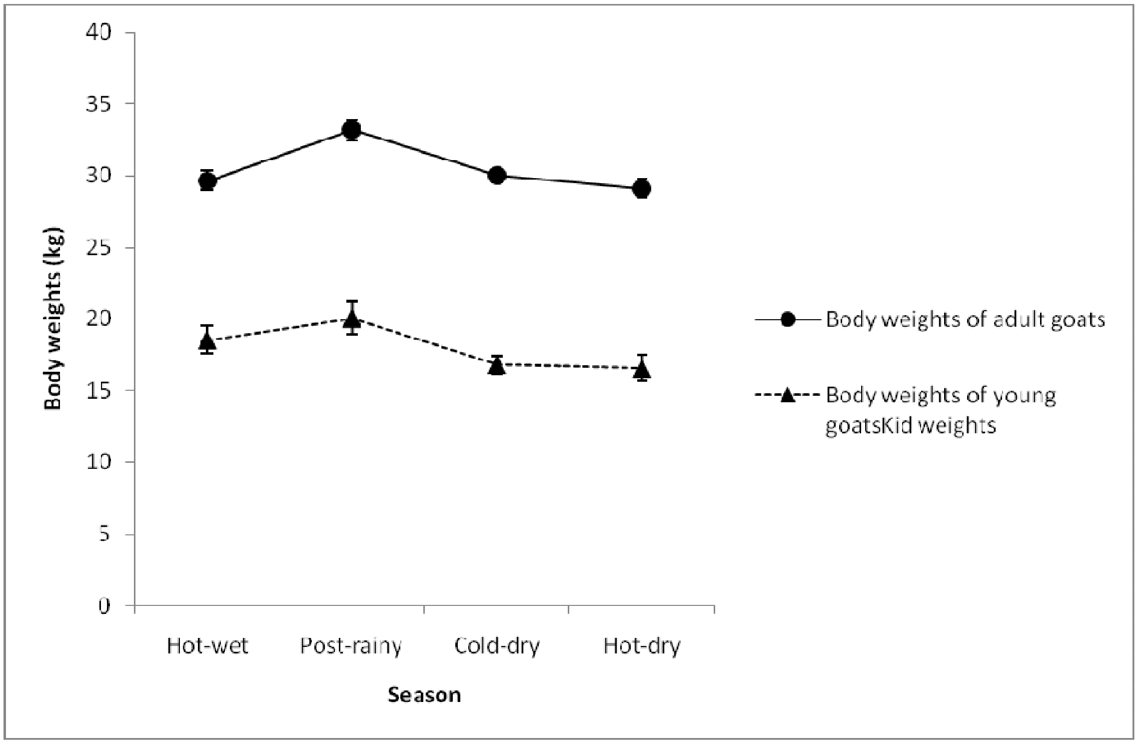

Figure 5.1: Seasonal changes of body weight in adult and young goats

The mean egg counts for the nematodes were negatively ($P < 0.05$) correlated with age class of the goat and body condition score as indicated in Table 5.2.

5.3.2 Prevalence of gastrointestinal parasites

The gastrointestinal egg types identified raised in the two rangeland types were strongyle, coccidia, *Strongyloides*, *Trichostrongylus*, *Paramphistomum* and *Fasciola* egg types in their order of abundance (Table 5.3). Goats in Nkosana had more ($P < 0.05$) strongyles egg loads than goats in Qawukeni village. There were higher counts of *Strongyloides* ($P < 0.05$) in goats from Qawukeni than in goats from Nkosana village as shown in Table 5.3. There, however, were no significant differences in prevalence of the other different egg types between goats from the two villages. As indicated in Table 5.4, the odds of a goat being infested by coccidia or strongyles were higher (at 95% confidence interval) for goats in Nkosana (sour rangeland) than for goats in Qawukeni (sweet rangeland) and for kids than for adult goats. Table 5.4 also shows that goats were at a higher risk of infestation by coccidia and strongyles in the hot-wet and post-rainy seasons than in the cold-dry season. However, the goats were at a higher risk of infestation by coccidia in the hot-dry season than in the hot-wet season.

There was a significant interaction of rangeland type and season on body weights and body condition scores of the study animals as shown in Figure 5.2. Body weights of goats in Qawukeni had higher ($P < 0.05$) weights than those in Nkosana in the post-rainy, cold-dry and hot-dry seasons. However, goats in Qawukeni had higher body weights and better body condition scores compared to those in Nkosana during the hot-wet season. Body condition scores and body weights followed the same trend and were lowest ($P < 0.05$) in the cold-dry season for both villages (Figure 5.2).

Table 5.2: Correlations among age class of goat, body condition score and mean egg counts of the gastrointestinal parasites

	Age	*BCS*	*Trichostrongylus*	*Strongyloides*	*Strongyles*	*Coccidia*
Age		-	-0.098***	-0.151***	-0.420***	-0.201***
BCS[1]	-		-0.086	0.089	-0.489**	-0.201**
Trichostrongylus				0.113	0.211**	0.231**
Strongyloides					0.122**	0.322
Strongyles						0.325***

** Indicates significance at $P < 0.05$. *** Indicates significance at $P < 0.01$.

[1] Body condition score

Table 5.3: Prevalence of gastrointestinal parasites of goats raised in Nkosana and Qawukeni communal areas

Parasite species	Nkosana	Qawukeni
Coccidia	68.8 ± 12.39	53.3 ± 8.76
Trichostrongylus	15.3 ± 4.94	10.9 ± 3.50
Strongyloides	13.4 ± 10.86	20.6 ± 7.70
Strongyles	97.0 ± 12.01[a]	68.4 ± 8.50[b]
Paramphistomum	6.08 ± 6.091	5.02 ± 5.30
Fasciola	3.08 ± 3.064	2.18 ± 4.23

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

Table 5.4: Relative risk (odds ratio) for coccidial and strongyle quantitative egg output in relation to rangeland type, season and age of goats

	Relative risk of infestatio by helminths	
Variables	***Coccidia***	***Strongyles***
Rangeland type		
Sourveld versus sweetveld	0.4 (0.25 - 0.53)*	0.5 (0.34 - 0.81)
Season		
Post-rainy versus cold-dry	0.1 (0.03 - 0.18)	0.0 (0.01 - 0.08)
Hot-dry versus cold-dry	1.1 (0.72 - 1.77)	0.1 (0.07 - 0.22)
Hot-wet versus cold-dry	0.3 (0.91 - 0.55)	0.1 (0.04 - 0.14)
Age		
Adult versus kid	1.3 (0.81 - 2.00)	1.9 (1.26 - 2.93)

*The figures in parentheses indicate 95 % confidence level of the odds ratio point estimate

5.3.3 Factors affecting coccidia and gastrointestinal nematode egg counts

There was a significant interaction of village and age on egg counts of coccidia, *Strongyloides*, strongyles and total nematodes as indicated in Table 5.5. Higher values ($P < 0.05$) of coccidial egg counts and strongyle egg counts were recorded in kids raised in Nkosana with lower ($P < 0.05$) values observed in adult goats raised in Qawukeni as shown in Table 5.5. However, kids raised in Nkosana had lower *Strongyloides* egg counts compared to kids raised in Qawukeni. There was no significant difference between total nematode counts between kids from the two villages as indicated in Table 5.5.

Season had an effect ($P < 0.05$) on counts of *Strongyloides* (Table 5.5), strongyle and total nematode as shown in Figure 5.3. Highest *Strongyloides* egg types were recorded in the cold-dry season (0.80 ± 0.055) whilst strongyle and total nematode egg counts were lowest ($P < 0.05$) in the cold-dry season with the highest ($P < 0.05$) values being attained in the hot-wet season. Age of goat also affected strongyle egg counts and total nematode egg counts, as illustrated in Figure 5.3. Total faecal egg counts for nematodes were higher ($P < 0.05$) for kids compared to adult goats, regardless of the rangeland type.

There was a significant interaction of season by age of goat on coccidial egg counts as indicated in Figure 5.4. The coccidial egg counts were highest ($P < 0.05$) in the post-rainy season for both classes of goats, attaining the lowest ($P < 0.05$) value in the cold-dry season for adult goats and in the hot-dry season for young goats as depicted in Figure 5.4. An interaction between age of goat and season significantly affected *Trichostrongylus* egg counts as depicted in Figure 5.5.

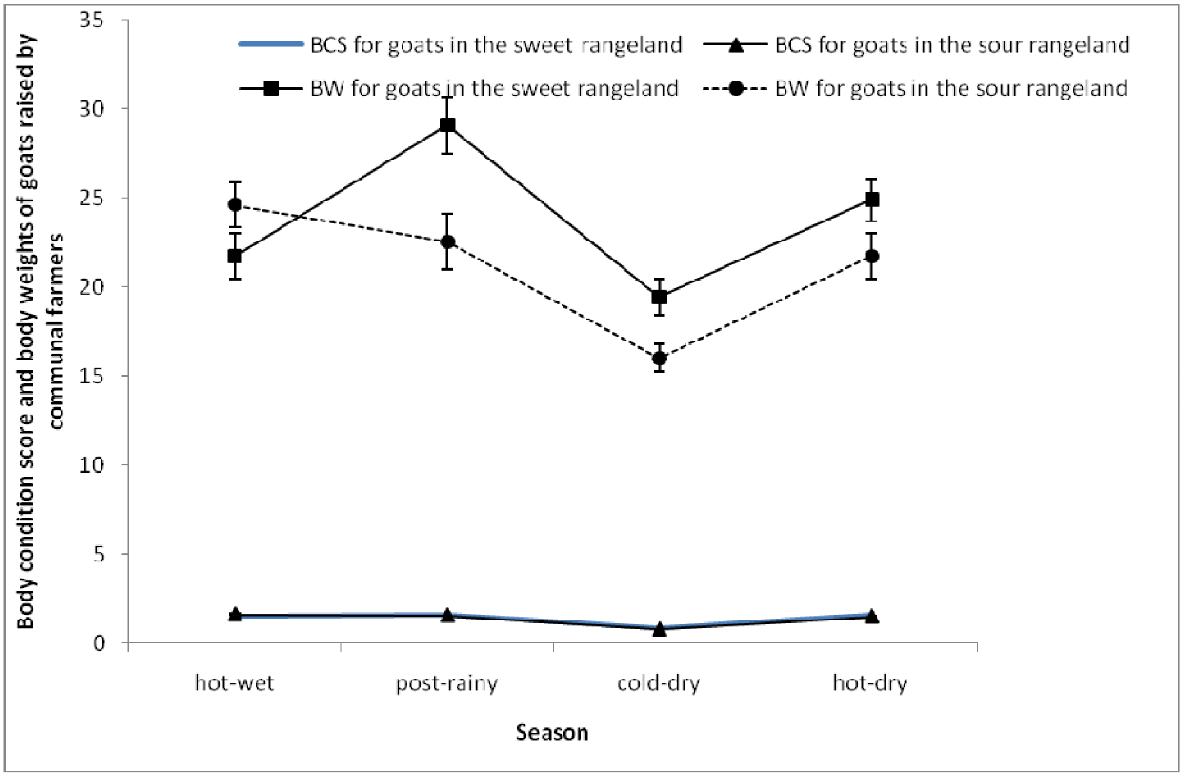

Figure 5.2: Effect of season on body condition score and body weights of goats in the sweet and sour rangeland areas

Table 5.5: Effect of village (rangeland type) and age on $\log_{10}$ (FEC + 1) transformed nematode faecal egg counts

	Community			
	Qawukeni		***Nkosana***	
	Kids	*Adults*	*Kids*	*Adults*
Coccidia	1.50 ± 0.138^{b}	1.14 ± 0.097^{c}	2.10 ± 0.110^{a}	1.51 ± 0.079^{b}
Trichostrongylus	0.36 ± 0.080^{ab}	0.18 ± 0.057^{c}	0.42 ± 0.065^{a}	0.27 ± 0.046^{b}
Strongyloides	0.78 ± 0.101^{a}	0.42 ± 0.071^{c}	0.55 ± 0.081^{b}	0.25 ± 0.058^{d}
Strongyles	1.74 ± 0.147^{b}	1.53 ± 0.103^{c}	2.02 ± 0.118^{a}	1.61 ± 0.084^{c}
Total nematodes	2.20 ± 0.111^{a}	1.70 ± 0.079^{b}	2.26 ± 0.141^{a}	1.77 ± 0.100^{b}

^{a,b,c} Values in the same row with different superscripts are different ($P < 0.05$)

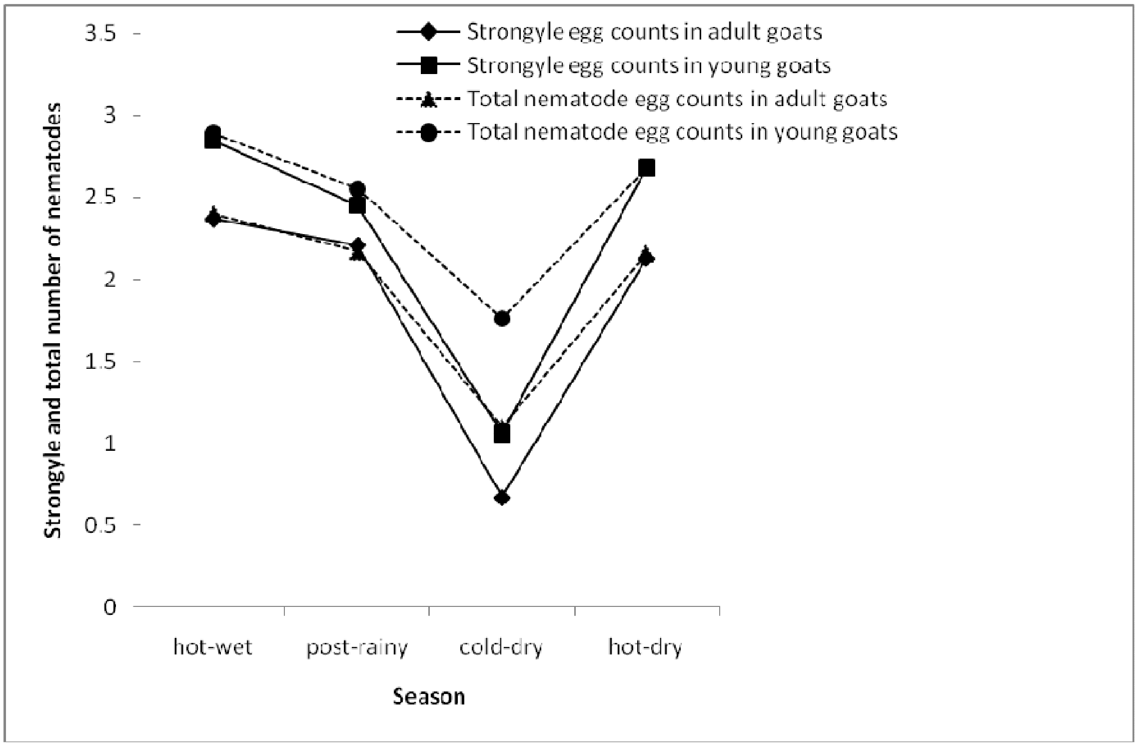

Figure 5.3: Effect of age and season on strongyle and total nematode egg counts in goats raised in communal areas of the Eastern Cape Province

The highest ($P < 0.05$) number of *Trichostrongylus* eggs was recorded in the hot-wet season for both young and adult goats. Infestation of goats by this helminth species followed the same trend in both age classes except that there was a drop in counts for young goats in the hot-dry season whilst adult goats maintained their load. The lowest ($P < 0.05$) egg counts were recorded in the post-rainy season for young goats and in the hot-dry season for adult goats.

5.3.4 Factors affecting gastrointestinal trematode egg counts

Rangeland type and season significantly affected egg counts of *Fasciola.* Egg counts of this helminth were highest in the hot-dry season (1.4 ± 0.21) and lowest in the cold-dry season (0.4 ± 0.71) in the sour rangeland. The same trend was also observed in the sweet rangeland with values of logarithm transformed faecal egg counts ranging from 0.1 ± 0.73 in the cold dry season to 0.4 ± 1.23 in the hot-wet season. None of the tested fixed effects or their interactions had an effect on the load of *Paramphistomum.*

5.4 Discussion

Information on the species of gastrointestinal parasites affecting goats and factors that influence their epidemiology in communal areas of Southern Africa is largely scarce. Determination of parasite species, prevalence and loads of gastrointestinal infections in goats raised by communal farmers is crucial in designing control strategies to reduce infestation with nematodes and trematodes. A reduction in gastrointestinal parasites is likely to lead to higher goat productivity.

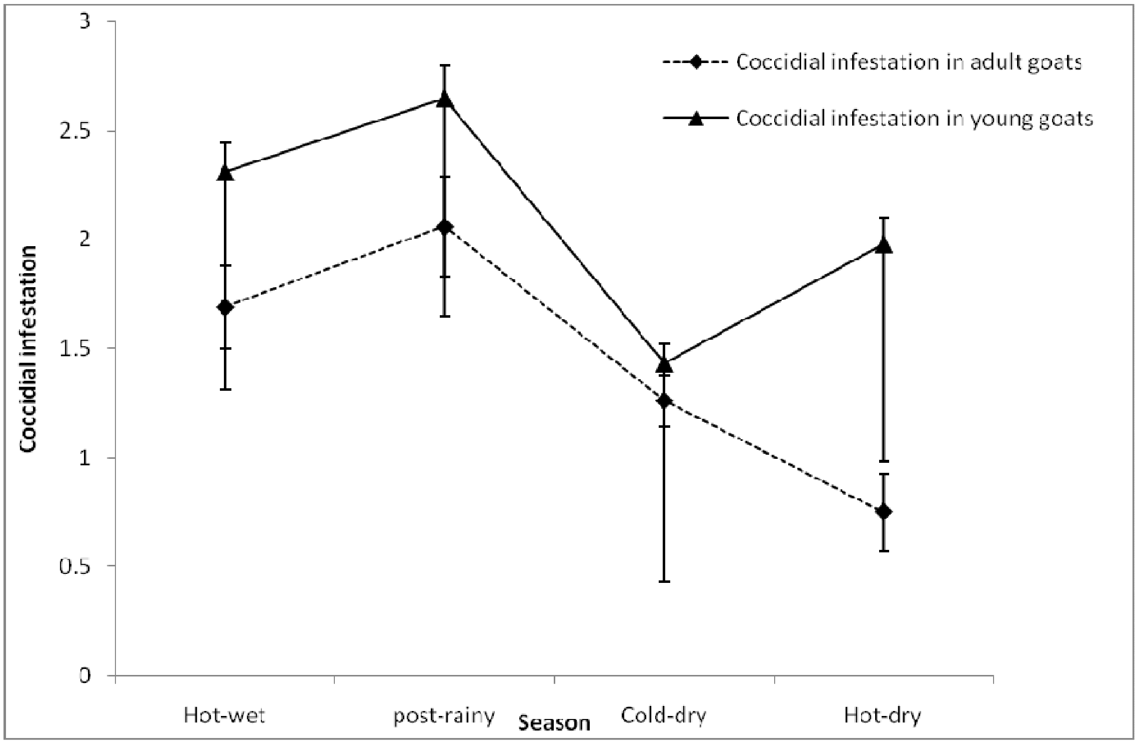

Figure 5.4: Seasonal changes in coccidial egg counts in adult and young goats

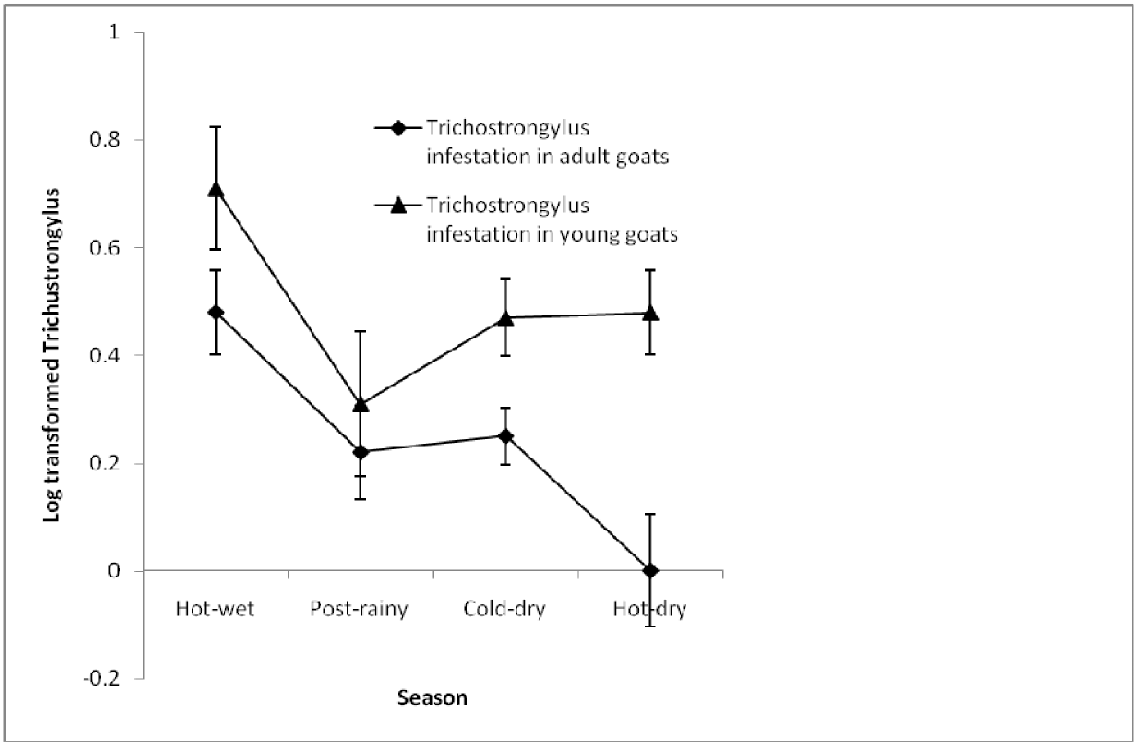

Figure 5.5: Effect of age and season on *Trichostrongylus* egg counts in goats raised in communal areas of the Eastern Cape Province

The finding that goats in Qawukeni had higher body weights and better body condition scores in the post-rainy season, the cold-dry season and the hot-dry season than those raised in Nkosana could be attributed to the better plane of nutrition during these seasons and lower nematode egg counts, compared to what was available to the goats in the sour rangelands during the same period. That body condition scores and body weights were higher in the sour than in the sweet rangeland during the hot-wet season could be attributed to abundance of lush pastures consisting of young shoots and legumes compared to the quantity of grass available in the sweet rangeland during the hot-wet season period. Increased plane of nutrition increases the immunity of goats against gastrointestinal parasites and reduces the fecundity of worms (Bisset *et al*., 1996). The poor body conditions and weights in the cold-dry season, regardless of the low helminth infection, for both rangeland types indicate that vegetation is of poor quality in the cold-dry season (Raats, 1999) and, therefore, goats require supplementation. Hoste *et al*. (2005) confirmed that a high plane of nutrition can result in improved resilience in goats.

The observation that goats raised in the sweet rangeland were in better body condition and had higher body weights in the hot-wet season than in the other seasons could be attributed to the browse that was available in the sweet rangeland during those periods compared to the poor quality of grass found in the sour rangeland during that period. The negative correlations that existed between the different gastrointestinal egg type loads and body weight and body condition score indicate the negative effects of the gastrointestinal parasites on the productivity of goats. These findings are in harmony with Chauhan *et al*. (2003).

The finding that higher body weights were attained in the post-rainy season for both the young and adult goats might be ascribed to the lower egg counts of strongyles coupled with better nutrition due to lush pastures that prevailed during that period compared to the high levels of strongyles in the hot-wet season. This probably indicate that better nutrition offsets the negative effects induced by gastrointestinal parasites (Githigia *et al*., 2001) during the post-rainy season. The lower body weights observed in the hot-wet season, regardless of the lush pastures could indicate that the higher faecal egg counts negatively affected utilization of feed by the goats resulting in reduced body weights. The lower body weights attained in the cold-dry season and the hot-dry season compared to the post-rainy season might be attributed to poor feed quality and quantity, regardless of the low faecal egg counts during these seasons. Parasitism causes inappetence (Coop and Kyriazakis, 2001), alters feed utilization and metabolism (Mahusoon *et al*., 2004) and induces loss of protein from the blood of the animal into the gastrointestinal tract. Such adverse effects could have been taking place in the study animals thereby resulting in the observed reduction in body weight and a loss in body condition. The finding that body condition scores in the hot-wet season were higher than scores in the cold-dry season agrees with observations by Maingi *et al*. (2006).

The prevalences of strongyles obtained in the current study are higher than what was observed by Nwosu *et al*. (2007) in a Nigerian goat flock where the prevalence of strongyles was 35.4%. In other studies (Chiejina, 1986; Nwosu *et al*., 1996a, b; Mbuh *et al*., 2008), strongyle prevalence ranged from 77 to 100%. The variation in the strongyle prevalences can possibly be due to differences in climate and vegetation type. In addition, production systems and age classes of goats used in the experiments (Nwosu *et al*., 2007) can have an effect on strongyle prevalences. The variation of nematode prevalence in the current study may be attributed to different rangelands with their associated climatic patterns. The nematode species observed in this study coincide with species observed by Nwosu *et al*. (2007).

The finding that both prevalence and loads of coccidia were higher in young goats compared to adult goats agrees with reports by several authors (Craig, 1986; Smith and Sherman, 1994; Jalila *et al*., 1998; Abo Shehada, 2003; Regassa *et al.*, 2006; Mbuh *et al*., 2008). Coccidiosis is mainly a disease of young goats that are still to develop immunity against coccidia (Matjila and Penzhorn, 2003). Apart from increased susceptibility to coccidia, the poor immunity status of the young goats increases their load of nematodes such as strongyles and *Strongyloides*. The rise in coccidial egg counts in the hot-dry season in young goats may be attributed to the fact that most kids were born in the hot-dry season; August (4.92 ± 0.362) and September (4.75 ± 0.313) (Chapter 4) than in the other months and their lack of immunity resulted in them being susceptible to coccidia.

The observation that higher faecal egg counts for gastrointestinal nematodes and coccidia occurred on the sour rangeland compared to the sweet rangeland could be ascribed to higher rainfall in the former rangeland type which is favourable for the proliferation of gastrointestinal parasites. Since vegetation in the sweet rangeland is more nutritious than that in the sour rangeland for the greater part of the year, goats in the sweet rangeland may have been able to better control establishment of new parasites and rendered the existing parasites less fecund (Coop and Kyriazakis, 2001). On the other hand, lower values reported for nematodes in the sweet rangeland could be due to access to *A. karroo* which was available in Qawukeni. The indigenous tree legume, *A. karroo* contains condensed tannins which are reported to reduce nematode eggs and coccidian oocyst counts. Hur *et al*. (2005) observed a reduction in coccidial oocyst production after feeding goats with *A. karroo*. In another study, Kahiya *et al.* (2003) showed that *A. karroo* had an inhibitory activity on the development of *O. circumcincta* and *H. contortus*. This might indicate that *A. karroo*, which contains condensed tannins, produced an anti-coccidial effect in the current study resulting in lower faecal egg counts in goats raised in the sweet rangeland. It might, therefore, be imperative to supplement goats with legumes containing anti-parasitic factors in areas where such plants are not readily available.

The observation that most nematode egg counts were highest during the hot-wet season indicates that rainfall, humidity and temperature play significant roles in the life cycles of helminths. These findings agree with earlier reports (Regassa *et al*., 2006; Mbuh *et al*., 2008) who also recorded higher incidences of parasitic infection during the rainy season. Environmental conditions are usually favourable for the development, survival and translocation of pre-parasitic stages of gastrointestinal nematodes and trematodes during the rainy season. Therefore, there is a steady build up of adult worms in grazing goats resulting in peak worm loads being recorded at about the peak of the rainy season (Mbuh *et al*., 2008) with the crowding in pens increasing the risk of infestation of other healthy goats. Thereafter, worm populations decline with the lowest numbers being encountered in the cold-dry season where conditions are not favourable (Nwosu *et al*., 2007).

The unexpected high prevalence of *Strongyloides* species in the cold-dry season could be due to the poor management system of the animals. Contamination of feed and water can take place when goats are supplemented (Nwosu *et al*., 2007). According to these authors, localised contamination of watering and feeding areas may predispose the animals to infestation by *Strongyloides* species. Such species actively penetrate the skin of the host prior to an infestation. In the study areas, especially Nkosana, the goats were supplemented in the cold-dry season when it was snowing whilst, in both villages, goats were supplied with water in the cold-dry season and might, therefore, have been infested during that period.

The lower values obtained for trematodes might be attributed to the preferred browsing behaviour of goats (Sissay, 2007). The browsing behaviour of goats dictates that goats obtain most of their feed from browse yet trematodes are found in the grazing material. Few trematodes were identified in this study since they are less pathogenic than the nematodes and most of them require a wide range of hosts. In addition, the conditions in the studied areas were probably not conducive for the perpertuation of the intermediate hosts of the trematodes for the life cycles to be completed. However, high prevalence of *Fasciola* could be because the amount of rainfall received was sufficient for the rapid perpertuation of the snails (intermediate hosts) leading to high infestation and probably re-infestation.

5.5 Conclusions

The major parasites infesting goats in the study areas were strongyles, coccidia, *Strongyloides, Trichostrongylus, Fasciola* and *Paramphistomum*. The study has shown that helminths reduced body weights and loss of body condition. The chief constraint to indigenous goat production in both the sweet and sour rangelands was the interaction of gastrointestinal parasite infestation and low nutritional levels which calls for intervention through appropriate strategies for the control of nematodes, trematodes and coccidia in goats. Gastrointestinal parasites and nutritional status of goats are linked and are major determinants of goat productivity. Monitoring of these parameters is crucial for the improvement of goat performance. Therefore, the relationship between blood chemical constituents and faecal egg counts of indigenous goats of the Eastern Cape Province of South Africa warrants investigation.

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6 CHAPTER 6: Relationship of biochemical properties and faecal egg counts for indigenous goats of the Eastern Cape Province, South Africa

Abstract

The objective of the current study was to determine the effect of season, sex and age on body weight, body condition score, faecal egg counts and, haematological and biochemical profiles in Nguni goats raised on a sweet rangeland area. Ninety-six Nguni goats raised on-station were weighed, body conditioned, assigned FAMACHA scores, had faecal and blood samples collected from them in the wet and dry seasons. Faecal samples were analysed using the modified McMaster technique for nematodes and the sedimentation method for trematodes. Blood was analysed for PCV, glucose, cholesterol, total protein, albumin, urea, creatinine, alkaline phosphatase (ALP), aspartate aminotransferase (AST), creatinine kinase (CK), calcium, inorganic phosphorus and magnesium. Season affected total protein, globulin, AST and CK levels with higher ($P < 0.05$) values recorded in the wet than the dry season. Body condition scores were positively correlated ($P < 0.05$) to albumin, body weight and PCV and negatively correlated to TP, glucose, ALT and AST. Strongyle egg loads were positively correlated to FAMACHA scores, PCV, body weights and body condition scores. High levels of TP in this study, especially in the wet season, did not signify better nutrition but a chronic health challenge, evidenced by elevated levels of globulin. Since the high globulin levels were not accompanied by clinical cases, the reference levels used might be inappropriate for these goats. Findings from this study indicate that these goats were infested with *H. contortus.* The FAMACHA score can be used to assess anaemia caused by *H. contortus.*

Keywords: Alkaline phosphatase, Creatinine, FAMACHA scores, Total protein

6.1 Introduction

Health and nutritional status of goat are major determinants of goat productivity. Monitoring of these parameters is fundamental in addressing anomalies that might adversely affect performance of goats. The advantages of using changes in live-weight, body conditioning (Ndlovu *et al*., 2007) and worm identification (Kusiluka and Kambarage, 1996) in the determination of the health and nutritional status of livestock have been reviewed. These methods, however, fail to indicate the status of the goat at that point in time (Schroder and Staufenbiel, 2006). Further knowledge of the metabolic pathways behind the body-based methods could be useful in predicting and avoiding metabolic shortages before a serious or even irreparable animal status is presented (Kida *et al*., 2007). It, therefore, is important to employ metabolic profiling, a method that yields the actual status of the animal (Caldeira *et al*., 2007).

Analysis of haematological properties of goats is essential in diagnosing the various nutritional, pathological and metabolic disorders whilst biochemical parameters are useful in determining the nutritional status (Daramola *et al.,* 2005) of goats. Haematological and biochemical changes are routinely used to determine the status of the body and to determine stresses due to environmental, nutritional and/or pathological factors. Haematological and biochemical values of goats are influenced by age, sex, breed, nutritional status and present the status of individual and other physiological factors (Daramola *et al.,* 2005). The information obtained from the blood parameters aids in the determination of the nature of the disease, the extent of tissue and organ damage, the response of the defense mechanism of the goat, and aid in diagnosing the type of possible anaemia. The haematological examination is among the methods which may contribute to the detection of some changes in health status, which may not be apparent during physical examination but which affect the fitness of the goat. Relationship of blood metabolites and nematode egg counts can assist the farmer on how best to supplement the goats for the reduction in helminths and hence improvement of goat productivity.

In Chapter 5, body-based methods and faecal egg counts were used to determine the health status of goats. It, however, is important to compliment these methods with metabolic profiling which will also result in development of reference values of the blood metabolites for the communal goats. In this chapter, the intention was to determine reference values in indigenous goats that can then be used in the determination of health status of these genotypes, instead of referring to values that were generated from exotic breeds that might be inappropriate for communal goats. The objective of the study was, therefore, to determine the effect of season, sex and age on body weight, body condition score, faecal egg counts and, haematological and biochemical profiles in indigenous Nguni goats.

6.2 Materials and Methods

6.2.1 Description of the study site

The study was conducted at Honeydale Farm, University of Fort Hare. The farm is situated in the False Thornveld of the Eastern Cape Province. The average annual rainfall is 480 mm with most of it falling in the hot-wet season. The mean annual temperature on the farm is 18.7^{o}C. The vegetation is composed of several trees, shrubs and grass species. *Acacia karroo, Themeda triandra, Panicum maximum, Digitaria eriantha, Eragrostis* species and *Cynodon dactylon* are the main browse species found in the area. The soil types in this area are loam, sand and clay soils. The topography of the area is generally flat with a few steep slopes.

6.2.2 Experimental goats and their management

Fifty-six female and forty male Nguni goats were randomly selected for the study. The goats were clinically health throughout the study period. Animals were subjected to routine sanitary control programme i.e. vaccination against heartwater and dosing once every fortnight in the rainy season and once a month in the dry season. The animals were allowed to graze and browse on natural pastures from 0900h and were penned at 1700hrs. No supplementary feeding was provided. The goats were classified into young (≤ one year) and mature (>one year) goats.

6.2.3 Body weights, body condition scores and FAMACHA scores

The goats were weighed using a digital scale and conditioned in January (wet season) and August (dry season) in 2007. Body condition scores were determined as in Chapter 5; section 5.2.3. The FAMACHA scores were determined by opening the lower eyelid of the goat and comparing the colour of the conjunctivae with five different scores on a chart. The colours associated with the different FAMACHA scores are described in Table 6.1. Two veterinarians were responsible for body conditioning and FAMACHA scoring throughout the study period.

6.2.4 Faecal sample collection and laboratory analyses

Faecal samples were collected in the dry (August, 2007) and hot (January, 2008) season, and examined in the laboratory as per the procedure delineated in Chapter 5; section 5.2.4.

6.2.5 Blood collection and laboratory analyses

Blood samples were collected in January and August (i.e. in the wet and dry season, respectively).

Table 6.1: FAMACHA score descriptions as used in the assessment of the experimental goats

Score	FAMACHA
1	*Optimal* Red colour Non-anaemic
2	*Acceptable* Red-pink colour Non-anaemic
3	*Borderline* Pink Mildly anaemic
4	*Dangerous* Pink-white Anaemic
5	*Fatal* Porcelain white Severely anaemic

Sources Kaplan *et al*. (2004)

For each goat, blood samples were taken via the jugular vein into a plain test tube (for biochemical assays) and one containing ethylene diamine tetra acetic acid (EDTA) to obtain uncoagulated blood for PCV determination. Within two hours after collection, blood from EDTA-containing tubes was mixed gently for 2 minutes before drawing it up a 75 x 1.5 mm capillary tube for three-quarters of its length. One end of the capillary tube was sealed before the capillary tubes were then placed in the micro-haematocrit centrifuge before centrifuging at 2000 g for 10 minutes at room temperature. The tubes were then put in the haematocrit reader to note the reading. The reading was expressed as a percentage of packed red cells in the total volume of whole blood.

Plain test tubes containing blood for biochemical assays were centrifuged at 1000 g for 10 minutes to obtain serum, which was stored at -20^{o}C until analysis. Serum was analysed at the University of Pretoria in South Africa, using commercially available kits (Siemens, South Africa) and a Chexcks machine (Next/Vetex Alfa Wasseman Analyser, Woerden, Netherlands). Serum samples were analysed spectrophotometrically for total protein (TP) (Wechselbaum, 1946), albumin (Doumas, 1972), creatinine (Tietz, 1995), alkaline phosphatase (Tietz *et al*., 1993) inorganic phosphorus (Young, 1990), calcium (Cali *et al.*, 1972) and magnesium (Tietz, 1976) by use of colorimetric methods. Globulin concentrations were computed as a difference between TP and albumin, whilst albumin/globulin (A/G) ratio was obtained by dividing the albumin value by the globulin concentration.

For the determination of total protein content, biuret reagent AE5-23 was allowed to complex with the peptide bonds of protein from the sample under alkaline condition to form a violet-coloured compound. Sodium potassium tartrate was used as an alkaline stabilizer, and potassium iodide was used to prevent autoreduction of the copper sulfate. The amount of the violet complex formed was proportional to the increase in absorbance when measured bichromatically at 544 nm/692 nm. For albumin, reagent AE5-2 was allowed to complex with the sample and the increase in absorbance which was measured bichromatically at 629 nm/692 nm, was proportional to the amount of albumin present in the sample. For the determination of creatinine concentration, reagent NAE2-15 was complexed with the sample and the change in absorbance measured at 505 nm was proportional to the creatinine concentration in the sample (Tietz, 1976).

The rate of increase in absorbance, monitored bichromatically at 408 nm/486 nm, was directly proportional to the alkaline phosphatase activity when the sample was allowed to react with reagent RX1002. For the determination of inorganic phosphate, reagent AE5-18 was allowed to react with the sample and at completion of the reaction, the absorbance of the sample reagent mixture was read bichromatically at 340 nm/378 nm. The difference between these two absorbance values was proportional to the amount of phosphorus present in the sample. For the determination of calcium, Arsenazo was used, whilst xylidyl blue in an alkaline medium was used for the determination of magnesium. The colour intensities were read off bichromatically and were proportional to the amount of the mineral present in the sample (Tietz, 1976).

Glucose was analysed using the method described by Gochman and Schmitz (1972) where reagent NAE2-27 was used after enzymatic oxidation in the presence of glucose oxidase. Blood urea nitrogen (BUN) analysis (Tietz, 1995) was quantified using enzymatic kinetic UV method. Ultraviolet methods were used for determinations of creatinine kinase (CK) (Horder *et al.*, 1991) and aspartate aminotransferase (AST) (Bergmeyer *et al.*, 1986). Reagent AE1-13 was allowed to react with the sample and the reaction rate was measured at 340 nm. Reagent

AEI-36 was allowed to react with the sample and the rate of conversion of NADH to NAD^+ was determined by observing the change in absorbance at 340 nm as NADH forms NAD^+. This rate of conversion was a function of the AST activity in serum. The blood values were categorized into below, within and above normal range considering the reference values as presented in Table 2.4 (Chapter 2).

6.2.6 Statistical analyses

Data were analyzed using the GLM procedures of SAS (2003) to determine the effect of season, age and sex of goat on body weight, body condition score (BCS), FAMACHA scores, faecal egg counts (FEC) and levels of blood parameters. Body condition scores and FAMACHA scores were square root transformed whilst FEC were transformed using $\log_{10}$ (FEC + 1) to normalise the data. The linear model used was:

$Y_{ijkl} = \mu + W_i + S_j + L_k + e_{ijkl}$

Where Y_{ijkl} = body weight, BCS, FAMACHA score, FEC, PCV and blood biochemical measurements on each goat;

μ = overall mean;

W_i= effect of the i^{th} season (i = wet, dry);

S_j= effect of the ^{j}th sex of animal (j = male, female);

L_k= effect of age of the goat (k=young, mature) and

e_{ijkl}= the random error term

Comparison of means was done using the PDIFF procedure (SAS, 2003). PROC CORR (SAS, 2003) was used to determine the correlations among body weight, BCS, PCV, FAMACHA score, FEC and levels of each blood metabolite. The effect of season on prevalence of each parasite species was determined by the chi-square test (SAS, 2003). The chi-square test was also used to compare frequencies of goats that had values normal, below and above the reference value for each metabolite.

6.3 Results

6.3.1 Body weights, body condition and FAMACHA scores and packed cell volume

Body weights of the goats were significantly affected by sex with males weighing more ($P < 0.05$) than females and age with young goats weighing less ($P < 0.05$) than mature goats as shown in Table 6.2. Season did not ($P > 0.05$) affect body weights. Body condition scores were significantly affected by sex and, age (Table 6.2) and the interaction between the two factors as indicated in Table 6.3. Female goats and young male goats had BCS that were lower ($P < 0.05$) than for mature male goats. Season had no effect ($P > 0.05$) on BCS. FAMACHA scores were significantly influenced by season with significantly higher (1.96 ± 0.071) scores in the wet season than during the dry season (1.31 ± 0.050). Age and sex did not ($P > 0.05$) have an effect on FAMACHA scores. Packed cell volume was affected by season, sex and age as indicated in Table 6.2 and an interaction between sex and age as shown in Table 6.3.

6.3.2 Faecal egg counts

The total egg counts were significantly affected by season and age of the goats. There were higher ($P < 0.05$) egg counts in the wet season (2.99 ± 0.071) than in the dry season (1.58 ± 0.178). Significantly higher counts were observed in young (3.13 ± 0.178) than in mature (2.44 ± 1.108) goats.

Table 6.2: Effect of season, sex and age on packed cell volume and body weight of the experimental indigenous Nguni goats

Parameter	**Packed cell volume**	**Body weight**
Season		
Dry	31.32 ± 0.635	36.032 ± 1.148
Wet	24.34 ± 0.934	35.36 ± 1.440
Significance	*	NS
Sex		
Female	24.81 ± 0.698	31.64 ± 1.181
Male	30.84 ± 0.960	39.75 ± 1.140
Significance	*	*
Age		
Young	25.17 ± 1.008	19.07 ± 1.758
Mature	30.48 ± 0.628	52.32 ± 1.031
Significance	*	*

NS: not significant

*P < 0.05

Table 6.3: Interaction of sex and age on BCS and PCV concentrations

Parameter	Sex			
	Females		Males	
	Young	Mature	Young	Mature
BCS[1]	1.53 ± 0.035^{b}	1.60 ± 0.014^{b}	1.50 ± 0.060^{b}	1.81 ± 0.023^{a}
PCV[2]	24.76 ± 1.189^{b}	24.88 ± 0.648^{b}	25.59 ± 1.586^{b}	36.09 ± 1.041^{a}

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

[1] Body condition score

[2] Packed cell volume

Season had an effect ($P < 0.05$) on *Trichlostrongylus* egg type with higher egg counts in the wet season than in the dry season as shown in Figure 6.1. Sex and age had no effect ($P > 0.05$) on counts of *Trichlostrongylus*. Strongyle egg counts were affected ($P < 0.05$) by season and age. Significantly higher strongyle egg type counts were recorded in the wet than in the dry season, as shown in Figure 6.1. Young goats had significantly higher (2.49 ± 0.710) strongyle egg counts compared to mature (2.01 ± 0.167) goats.

Paramphistomum egg type counts were significantly affected by age with higher counts in the young (1.55 ± 0.173) than in mature (0.69 ± 0.111) goats. Sex and season did not affect ($P > 0.05$) *Paramphistomum* egg type counts. *Fasciola* egg type counts were not ($P > 0.05$) affected by the fixed factors tested. Coccidial egg counts were affected ($P < 0.05$) by season and age. Higher ($P < 0.05$) egg counts were observed in the wet season than in the dry season, as shown in Figure 6.1. Coccidial egg counts were higher ($P < 0.05$) in young (1.70 ± 0.727) than in mature goats (1.11 ± 0.110).

6.3.3 Blood metabolites

6.3.3.1 Glucose and cholesterol

Most ($P < 0.05$) of the goats had blood glucose levels below the normal range in the wet season, as shown in Table 6.4. Blood glucose levels were significantly affected by season and sex of the goat. Glucose concentrations were higher ($P < 0.05$) in the dry compared to the wet season (Table 6.5). As shown in Table 6.6, glucose levels were higher ($P < 0.05$) in females than males. Cholesterol levels were not affected ($P > 0.05$) by any of the tested effects as indicated in Tables 6.5, 6.6 and 6.7.

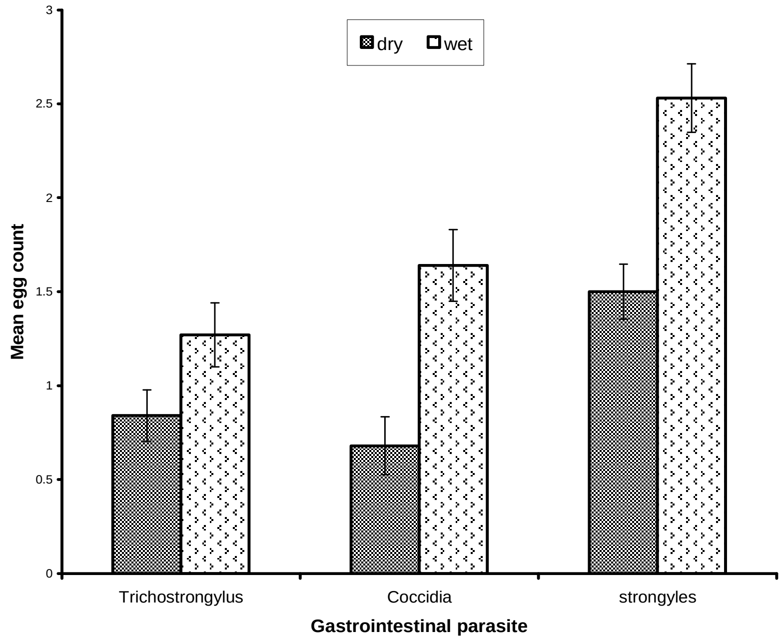

Figure 6.1: Variation of levels of faecal egg counts for different parasites with season

Table 6.4: Proportions (%) of goats that had normal, below and above reference range values for the different blood metabolites

Parameter	Wet				Dry			
	Below	***Normal***	***Above***	***SL***	***Below***	***Normal***	***Above***	***SL***
Glucose	65.9 (27)	34.2 (14)	0	**	47.3 (26)	46.6 (24)	9.1 (5)	NS
TP	0	2.4 (1)	97.6 (40)	**	0	12.7 (7)	87.3 (48)	**
Albumin	85.4 (35)	14.63 (6)	0	**	36.4 (20)	63.6 (35)	0	*
Globulin	0	0	100 (41)	**	0	3.6 (2)	86.4 (53)	**
Creatinine	87.8 (36)	12.2 (5)	0	**	68.5 (37)	31.5 (17)	0	**
Urea	0	73.2 (30)	26.8 (11)	*	9.1 (5)	52.7 (29)	38.2 (21)	*
A/G ratio	100	0	0	**	100 (55)	0	0	**
ALT	0	78.0 (32)	22.0 (9)	**	0	90.9 (50)	9.1 (5)	**
ALP	82.9 (34)	14.6 (6)	2.4 (1)	**	58.2 (32)	38.2 (21)	3.64 (2)	**
AST	97.6 (40)	2.4 (1)	0	**	98.2 (54)	1.82 91)	0	**
CK	0	0	100 (41)	**	1.8 (1)	98.2 (54)	0	**
GGT	0	92.7 (38)	7.3 (3)	**	7.3 (4)	90.9 (50)	1.8 (1)	**
Calcium	19.5 (8)	80.5 (33)	0	**	9.1 (5)	90.9 (50)	0	**
Magnesium	0	100 (41)	0	**	1.8 (1)	98.2 (54)	0	**

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

* indicates significance at P < 0.05

** indicates significance at P < 0.01

SL: significance level

NS: not significant.

TP: Total protein

A/G: albumin:globulin

ALT: Alanine transaminase

ALP: Alkaline phosphatase

AST: Aspartate aminotransferase

CK: Creatinine kinase

GGT: Gamma-glutamyl transferase

Table 6.5: Lsmeans (± standard errors) of blood chemistry measurements of Nguni goats in the dry and wet seasons

Parameter	Season	
	Dry	***Wet***
Glucose (mmol/L)	2.99 ± 0.076[a]	2.65 ± 0.109[b]
Cholesterol (mmol/L)	2.01 ± 0.088	1.99 ± 0.125
Total protein (g/L)	75.28 ± 1.046[b]	87.87 ± 1.471[a]
Albumin (g/L)	27.48 ± 0.378[a]	24.06 ± 0.535[b]
Globulin (g/L)	48.21 ± 1.046[b]	63.86 ± 1.479[a]
Albumin/Globulin ratio	0.64 ± 0.119	0.34 ± 0.169
Creatinine (μmol/L)	77.31 ± 1.950[a]	69.27 ± 2.750[b]
Urea (mmol/L)	7.22 ± 0.690	6.17 ± 0.976
Calcium (mmol/L)	2.45 ± 0.032	2.37 ± 0.046
Magnesium (mmol/L)	1.03 ± 0.022	0.96 ± 0.031
Phosphorus (mmol/L)	2.02 ± 0.040	2.08 ± 0.058
ALT (U/L)	15.07 ± 1.633	16.91 ± 2.297
ALP (U/L)	83.49 ± 8.870	84.88 ± 12.540
AST (U/L)	69.60 ± 3.139[b]	85.26 ± 4.438[a]
CK (U/L)	148.47 ± 18.126[b]	256.69 ± 25.630[a]
GGT (U/L)	35.44 ± 1.422[b]	45.86 ± 2.010[a]

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

ALT: Alanine transaminase

ALP: Alkaline phosphatase

AST: Aspartate aminotransferase

CK: Creatinine kinase

GGT: Gamma-glutamyl transferase

Table 6.6: Lsmeans (± standard errors) of blood chemistry measurements of the different sexes of goats

Parameter	Sex	
	Male	*Female*
Glucose (mmol/L)	2.39 ± 0.070[b]	3.25 ± 0.118[a]
Cholesterol (mmol/L)	2.07 ± 0.090	1.92 ± 0.136
Total protein (g/L)	81.08 ± 1.080	82.07 ± 1.606
Albumin (g/L)	25.43 ± 0.388	26.11 ± 0.580
Globulin (g/L)	56.16 ± 1.070	55.90 ± 1.006
Albumin/Globulin ratio	0.51 ± 0.123	0.47 ± 0.185
Urea (mmol/L)	6.89 ± 0.700	6.49 ± 0.166
Creatinine (μmol/L)	68.33 ± 2.000[b]	78.25 ± 3.010[a]
Calcium (mmol/L)	2.34 ± 0.030[b]	2.48 ± 0.050[a]
Magnesium (mmol/L)	1.00 ± 0.023	0.99 ± 0.030
Phosphorus (mmol/L)	2.04 ± 0.040	2.06 ± 0.060
ALT (U/L)	16.43 ± 1.687	15.54 ± 2.508
ALP (U/L)	74.31 ± 8.070[b]	114.06 ± 6.851[a]
AST (U/L)	80.86 ± 3.191[a]	74.00 ± 2.109[b]
CK (U/L)	206.01 ± 18.100[a]	199.09 ± 18.126[b]
GGT (U/L)	41.20 ± 1.460	40.01 ± 1.402

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

ALT: Alanine transaminase

ALP: Alkaline phosphatase

AST: Aspartate aminotransferase

CK: Creatinine kinase

GGT: Gamma-glutamyl transferase

Table 6.7: Lsmeans and standard errors of blood chemistry measurements of young and mature experimental goats

Characteristic	Age	
	Young	***Mature***
Glucose (mmol/L)	2.80 ± 0.122	2.84 ± 0.070
Cholesterol (mmol/L)	1.95 ± 0.140	2.04 ± 0.081
Total protein (g/L)	80.34 ± 1.662	82.82 ± 0.994
Albumin (g/L)	25.43 ± 0.600	26.11 ± 0.360
Globulin (g/L)	55.30 ± 0.990	55.76 ± 1.000
Albumin/Globulin ratio	0.45 ± 0.190	0.53 ± 0.110
Urea (mmol/L)	6.88 ± 1.090	6.51 ± 0.660
Creatinine (μmol/L)	67.9 ± 3.100^{b}	78.7 ± 1.870^{a}
Calcium (mmol/L)	2.40 ± 0.050	2.4 ± 0.030
Magnesium (mmol/L)	1.00 ± 0.035	0.99 ± 0.020
Phosphorus (mmol/L)	2.13 ± 0.060	1.96 ± 0.030
ALT (U/L)	15.43 ± 2.590	16.54 ± 1.550
ALP (U/L)	109.25 ± 14.001^{a}	79.32 ± 3.003^{b}
AST (U/L)	78.55 ±4.900	76.32 ± 3.022
CK (U/L)	208.20 ± 28.801	196.75 ± 17.513
GGT (U/L)	42.17 ± 2.260	39.14 ± 1.360

^{a,b} Values in the same row with different superscripts are different ($P < 0.05$)

ALT: Alanine transaminase

ALP: Alkaline phosphatase

AST: Aspartate aminotransferase

CK: Creatinine kinase

GGT: Gamma-glutamyl transferase

6.3.3.2 Nutritionally-related protein metabolites

About ninety-eight percent of the goats had TP values above the reference range in both seasons, as shown in Table 6.4. Season affected TP level with higher ($P < 0.05$) values in the wet than in the dry season as indicated in Table 6.5. Sex and age had no ($P < 0.05$) effect on the level of TP. As shown in Table 6.4, the majority (about 85%, $P < 0.05$) of the goats had albumin levels below the normal range during the wet season and values within the normal range during the dry season. Season had an effect on the albumin levels with significantly higher levels in the dry season compared to the wet season as indicated in Table 6.5. Sex and age did not ($P > 0.05$) affect albumin levels. All the goats had globulin levels above the reference range in the wet season, with the proportion dropping slightly in the dry season, as indicated in Table 6.4. All the animals had A/G ratios below the normal range as shown in Table 6.4. Season, sex and their interactions did not ($P > 0.05$) affect A/G ratio.

Most ($P < 0.05$) of the goats had creatinine levels below the normal range in both seasons as shown in Table 6.4. Blood creatinine concentrations were significantly affected by the main effects of season (Table 6.5), sex (Table 6.6) and age (Table 6.7). Creatinine levels were higher ($P < 0.05$) in the dry than in the wet season, in males than in females and in the mature than in young goats. None of the fixed effects tested affected ($P > 0.05$) urea levels.

6.3.3.3 Serum calcium, magnesium and phosphorus

The majority (about 81%) ($P < 0.05$) of the goats were within the reference range for calcium in the wet and dry seasons. Blood calcium concentrations were significantly affected by sex whilst season and age had no ($P > 0.05$) effect on calcium levels of the goats. Calcium levels were higher ($P < 0.05$) in male goats compared to female goats, as indicated in Table 6.6. Blood magnesium levels of the goats were significantly affected by season (Table 6.6).

Season, sex and age had no ($P > 0.05$) effect on magnesium concentrations. Serum levels of magnesium were within the reference range for most ($P < 0.05$) of the goats. Phosphorus concentrations were affected by age with higher ($P < 0.05$) levels in the young compared to the adult goats. Season and sex had no effect ($P > 0.05$) on blood phosphorus concentrations.

6.3.3.4 Liver enzymes

Alanine aminotransferase values for most ($P < 0.05$) of the goats were within the reference range as indicated in Table 6.3. None of the fixed effects tested affected ALT concentrations. The majority ($P < 0.05$) of the goats had ALP values below the reference range in both seasons (Table 6.3). Season had no effect ($P > 0.05$) on ALP whilst main effects of sex and age affected ($P < 0.05$) the ALP concentrations. Alkaline phosphatase levels were higher ($P < 0.05$) in females than in males (Tables 6.6) and in young than in mature goats as indicated in Table 6.7.

Aspartate aminotransferase values were below the normal range in both seasons. Higher ($P < 0.05$) AST concentrations were recorded in the wet season than in the dry season (Table 6.5) and in male than in female goats (Table 6.6). For most ($P < 0.05$) of the goats, CK levels were below the normal range in both seasons. Creatinine kinase was significantly affected by season with a higher ($P < 0.05$) concentration in the wet compared to the dry season, as indicated in Table 6.5. Age and sex had no effect ($P>0.05$) on serum CK levels.

6.3.4 Correlations amongst blood and physical examination parameters

Correlation coefficients among age, PCV, BCS, FAMACHA scores and blood metabolites and enzymes are shown in Tables 6.8 and 6.9. Body weights were positively correlated to BCS, PCV (Table 6.8), urea and cholesterol levels. Body weights were negatively correlated

($P < 0.05$) to strongyle egg counts and FEC as indicated in Table 6.8. There, however, were no correlations ($P > 0.05$) between body weights and several blood metabolites; ALP, TP, albumin, globulin, CK, glucose and creatinine as shown in Table 6.9. Body condition scores were positively correlated ($P < 0.05$) to albumin, body weight and PCV (Table 6.8) and negatively correlated to TP, glucose, ALT and AST (Table 6.9). As shown in Table 6.8, body condition scores were not ($P > 0.05$) correlated to FAMACHA scores, FEC, ALP, CK, cholesterol. Body condition scores were, however, negatively correlated ($P < 0.05$) to albumin levels as indicated in Table 6.9.

Packed cell volumes were positively correlated ($P < 0.05$) to body weights, BCS (Table 6.8), albumin, glucose and creatinine (Table 6.9). Packed cell volumes were negatively correlated ($P < 0.05$) to FAMACHA scores, strongyle egg counts, FEC as shown in Table 6.8 and globulin (Table 6.9). No correlations existed between ALP, TP, CK, urea and cholesterol and, PCV as shown in Table 6.9. In addition to the negative correlation ($P < 0.05$) that existed between FAMACHA scores and PCV, FAMACHA scores were positively correlated ($P < 0.05$) to ALP and globulin levels (Table 6.9) and strongyle egg counts (Table 6.8).

Cholesterol levels were positively correlated ($P < 0.05$) to body weights and FEC. There, however, were no correlations ($P > 0.05$) between cholesterol levels with the following parameters; BCS, PCV, FAMACHA scores and strongyle egg counts as indicated in Table 6.8. Negative correlations ($P < 0.05$) existed between cholesterol and other blood metabolites; TP, albumin, globulin, urea and creatinine. Glucose was positively correlated ($P < 0.05$) to creatinine and negatively correlated ($P < 0.05$) to cholesterol. There also existed a negative correlation ($P < 0.05$) between urea and creatinine.

Table 6.8: Correlations among body weight, body condition, packed cell volume, FAMACHA score, faecal egg counts and blood metabolites

Parameter	BW	BCS	PCV	F-score	Strongyles	FEC
BW		0.58**	0.37**	0.02	-0.24*	-0.34**
BCS	0.38**		0.42**	-0.03	-0.21*	-0.22
PCV	0.37**	0.42**		-0.43**	-0.28*	-0.23*
F. score	0.02	-0.03	-0.43**		0.41*	0.10
Strongyles	-0.24*	-0.21*	-0.28**	-0.41*		0.92**
FEC	-0.34**	-0.22	-0.23	0.10	0.92**	
Glucose	-0.07	-0.40**	0.29**	0.08	-0.14	-0.08
Cholesterol	0.31*	-0.01	-0.04	0.08	-0.19	0.26*
TP	0.06	-0.47**	-0.09	-0.04	-0.02	-1.10
Albumin	0.06	-0.81**	0.34**	0.14	-0.16	-0.16
Globulin	0.09	-0.72**	-0.21*	0.21*	0.10	0.03
Urea	0.22*	-0.49**	0.11	0.01	0.11	0.18
Creatinine	0.15	-0.66**	0.43**	0.01	-0.13	-0.15
ALP	-0.18	-0.17	0.15	0.18*	0.21*	0.31*
CK	-0.05	-0.14	-0.06	-0.05	0.17	0.16

F-score indicates FAMACHA score

* indicates significance at P < 0.05 ** indicates significance at P < 0.01

BW: Body weight BCS: Body condition score PCV: Packed cell volume

TP: Total protein FEC: Feacal egg count ALP: Alkaline phosphatase

CK: Creatinine kinase

Table 6.9: Correlations among body weight, body condition, packed cell volume, FAMACHA score, faecal egg counts and blood metabolite levels

Parameter	ALP	TP	Albumin	Globulin	CK	Glucose	Urea	Creatinine	Cholesterol
Body Weight	-0.19	0.06	0.06	0.09	-0.05	-0.07	0.22*	0.15	0.31*
Body Condition Score	-0.17	-0.47**	-0.18**	-0.72**	-0.14	-0.40**	-0.49**	-0.66**	-0.01
PCV	0.15	-0.09	0.34**	-0.21*	-0.06	0.29**	0.11	0.43**	-0.04
F-score	0.18*	-0.04	0.14	0.21*	-0.05	0.08	0.01	0.11	0.08
Strongyles	-0.11	-0.02	-0.16	-0.14	0.17	-0.14	0.11	-0.13	-0.19
FEC	0.31*	-0.10	-0.16	0.03	0.16	-0.08	0.18	-0.15	-0.26*
ALP		-0.04	0.41**	0.01	0.13	0.14	0.04	0.16	-0.07
TP	-0.04		0.46**	0.95**	0.18	0.26**	0.06	0.34**	-0.39**
Albumin	0.41**	0.46**		0.58**	0.13	0.45	0.39*	0.72**	-0.23*
Globulin	0.01	0.95**	0.58**		0.20*	0.06	0.26	0.49**	-0.20*
CK	0.13	0.18	0.13	0.20*		0.16	0.17	0.02	-0.10
Glucose	0.14	0.26**	0.45	0.06	0.16		0.17	0.44**	-0.28**
Urea	0.04	0.06	0.39*	0.26	0.17	0.17		-0.25*	-0.25*
Creatinine	0.16	0.34*	0.72**	0.49**	0.02	0.44**	0.46**		-0.25*
Cholesterol	-0.07	-0.39*	-0.23*	-0.20*	-0.10	-0.28**	-0.25*	-0.25*	

F-score indicates FAMACHA score, * indicates significance at P < 0.05, ** indicates significance at P < 0.01. PCV: Packed cell volume, TP: Total protein, FEC: Faecal egg count, ALP: Alkaline phosphatase

CK: Creatinine kinase

6.4 Discussion

The body weights did not improve in the wet season regardless of the availability of lush pasture, indicating that goats were adversely affected by the heavy infestation of gastrointestinal parasites. The FAMACHA technique estimates level of infection by *H. contortus* by assessing the anaemic level of the mucous membranes of the goat. High levels of strongyles in the wet season, obtained in this study, accompanied by higher FAMACHA scores and low PCV values indicated that *H. contortus* was a health challenge for the flock during the wet season. This indicates that either *H. contortus* that infested this flock had a high fecundity or it exhibited antihelminthic resistance to the drug used to control against it, regarding that the flock was dosed after every fortnight. These findings agree with Kaplan *et al*. (2004) and Dawo and Tibbo (2005) who reported positive correlations between FAMACHA eye scores and worm burden of *H. contortus* and a negative correlation between eye scores and PCV. A high *H. contortus* level of infestation entails a reduction in the volume of red blood cells due to the blood-sucking nature of this helminth (Kaplan *et al*., 2004).

The higher urea levels could, however, be attributed to increased production of ammonia in the rumen due to a high feed intake (Caldeira *et al*., 2007). If urea levels are high in blood it implies that under restricted feeding situations, inferences about dietary intake of protein based solely on blood urea might be inappropriate (Mellado *et al*., 2004).

The finding that eggs for gastrointestinal parasites were significantly higher in the wet season than in the dry season is in agreement with observations by several authors (Abo

Shehada, 2003; Regassa *et al.*, 2006; Mbuh *et al.*, 2008). Wet environmental conditions are favourable for the development, survival and translocation of pre-parasitic stages of gastrointestinal nematodes and trematodes during the wet season. Therefore, there is a steady build up of adult worms in grazing goats resulting in peak worm loads being recorded in the wet season (Mbuh *et al*., 2008) with the crowding in pens increasing the risk of infestation of other healthy goats. Thereafter, worm populations decline with the lowest numbers being encountered in the dry season (Nwosu *et al*., 2007). The higher levels of egg counts in the younger goats is ascribed to the poor immunity status of the young (Matjila and Penzhorn, 2003) goats which increases their susceptibility to gastrointestinal parasites. The negative correlation between BCS and strongyle egg type load indicates that strongyles have a debilitating effect on body reserves which is manifested as a loss in condition.

The finding that blood glucose concentrations in goats were lower in the wet season than the dry season may be attributed to the increase in body temperatures and respiration rate of the animals as a physiological response to thermal stress that is characteristic of the wet season in the study area.

The observed seasonal variation in TP could partly be explained by fluctuations of grass quality with season. However, it is important to note that globulin levels were above the reference range in both seasons, thereby contributing to the high values of TP. The even higher globulin levels in the wet season, probably due to helminth infestation, might have contributed to the higher TP values in the wet season compared to values in the dry season. This is further evidenced by a negative correlation between TP and BCS which indicates that the goats that had high levels of TP, which composed mainly of globulin, were in poor condition. Additionally, a positive correlation between TP and creatinine indicated that the goats were stressed and had, therefore, high levels of both globulin and creatinine. It, therefore, is important to use several blood metabolites in the assessment of the nutritional status of goats in order to obtain a precise understanding of the situation.

The higher globulin values obtained in the wet season compared to the dry season might be attributed to inflammation due to gastrointestinal parasites whose load was higher in the wet season. However, the high values, regardless of season, warrant investigation to determine what chronic health challenge is affecting this goat flock. The finding that globulin was negatively correlated to BCS indicates that goats in poor condition usually experience feed scarcity. Initially, the globulin concentration remains steady but may become elevated to counterbalance the lower concentrations of albumin to support osmotic pressure (Payne and Payne, 1987). However, as the protein scarcity persists, globulin levels will drop, probably due to utilization as protein body reserves and a reduction in its synthesis.

Globulin levels were also positively correlated to FAMACHA scores indicating that infestation with strongyles leading to inflammation induces production of globulin and at the same time induces anaemia in goats. The negative correlation between globulin levels and PCV indicates that it is in goats that are stressed; with low PCV values that elevated levels of globulin will be produced. The low A/G ratio can be ascribed to an increase in globulin concentration caused by chronic parasitism or compensation for the ALB loss characteristic of protein malnutrition which might be characteristic of helminthosis (van Hutert and Sykes, 1996).

The elevated levels of creatinine in the dry season could be attributed to recycling of urea which is a response to limited dietary protein intake as indicated by the lower TP in the dry season compared to the wet season. Higher creatinine values are indicative of disorders of renal origin (Wisloff *et al*., 2003). Blood creatinine concentrations are related to reduced filtration in the kidneys and increased production due to muscle catabolism.

The positive correlations between globulin and creatinine levels can be ascribed to the fact that the two are produced in similar conditions; when the animals are stressed. The positive correlation between PCV and creatinine levels in this study is in line with observations by Daramola *et al*. (2005) who reported that PCV varied proportionately with creatinine in West African Dwarf goats. Reduced concentrations of creatinine indicate prolonged active tissue protein catabolism, high creatinine values are therefore indicative of high PCV values. The finding that male goats had higher values of creatinine compared to female goats is in line with findings by Mbassa and Poulsen (1991). It may be ascribed to the fact that the male goats could have been more mobile than female goats.

The observation that there was no difference in blood calcium and phosphorus levels in goats between seasons might indicate that *A. karroo* plays a significant role during the dry season and supplies the goats with calcium and phosphorus that they would not have obtained had they relied on natural grass only. *A. karroo* has calcium and phosphorus contents of around 1.73% and 0.13%, respectively, which augment the lower values of grass in the dry season. It might also indicate that these minerals are regulated homeostatically and are therefore maintained within narrow limits (Honhold *et al*., 1989).

The finding that body weights were positively correlated to body condition might be ascribed to the fact that kids (that had lower body weights) had higher helminths egg loads and were therefore in poor condition as opposed to mature goats that had a less burden of helminths resulting in a better condition. The positive correlation of body weight and body condition agrees with Honhold *et al*. (1989), who reported an increase of 21% in body weight for every change of condition score of 1 (one) in the Small East African goat. Nsoso *et al*. (2004), however, reported a negative correlation between body weights and condition scores, while Cisse *et al*. (2002) observed that body condition scores did not always parallel body weights in Senegalese goats.

The observed positive correlation between BCS and body weights, PCV, glucose and albumin levels indicates that BCS is a useful tool in estimating the energy and protein status of goats (Cabiddu *et al*., 1999). This improvement of body condition score with an increase in such blood metabolite level indicates that goats in good condition have a better nutritional status compared to goats in poor condition. The observed negative correlations between BCS and urea might indicate that for the goats that were in poor condition, nutrient requirements were partly met through mobilization of body reserves (Marini and Van Amburgh, 2003). The observed negative correlation between BCS level and globulin concentration could probably mean that goats in good condition had less faecal egg counts and, therefore, would have little of globulin being produced in response to the inflammation caused by helminths.

The positive correlations between BCS with serum minerals; calcium, magnesium and phosphorus indicate that goats in good condition will have higher values of these minerals compared to goats in poor condition. The finding that phosphorus was higher in younger goats compared to mature goats is in line with observations by Mbassa and Poulsen (1991) who reported a decrease in phosphorus level of goats with an increase in age. The lower serum phosphorus concentration in mature goats could be ascribed to a lessened capacity to assimilate phosphorus from diet as the animal grows (Blood and Radostits, 1989). In addition, serum phosphorus may be higher in younger animals because the growth hormone increases renal phosphate resorption (Kaneko, *et al.,* 1997). The finding that most goats had mineral values within the reference ranges might indicate that this goat flock does not require supplementation of the minerals studied.

Liver enzymes have an extracellular function and, thus, occur in low quantities with increases signifying damage in the tissues in which they are lodged (Grunwaldt *et al*., 2005). The observed lower values of ALP in mature goats correspond with the lower values of phosphorus recorded for the mature animals compared to the young goats. The finding that ALP decreased with age concurs with observations by Antunovic *et al.* (2004) who reported a decrease in ALP level with an increase in age of goats. In young growing animals, osseus ALP is the predominant form of serum ALP which diminishes as maturation progresses until the epishysis closes (Kaneko *et al.,* 1997). The observed negative correlations between BCS with ALT and AST indicate that goats in a better condition will have lower levels of these liver enzymes compared to goats in poor condition. The concentration of serum enzymes reflects enzymes that are either in transit from the site of synthesis to the site of action or which have been released from the damaged cells. The high values in the young animals is due to the fast growth rate of the growing animals that results in leakage of the enzyme from the growing bones and intestines into the blood (Kaneko *et al.,* 1997).

6.5 Conclusions

Season had no effect on the body weights of goats. FAMACHA scores and strongyles were high in the wet season. The negative correlation that existed between BCS and strongyle egg type load indicates that strongyles have a debilitating effect on body reserves which is manifested as a loss in condition. High levels of globulin in this goat flock indicate that the goats have a chronic health challenge. The globulin levels were above the reference range in both seasons and were positively correlated to FAMACHA scores, thereby contributing to the high values of TP. Since the high globulin levels were, however, not accompanied by clinical cases, these findings may suggest that the reference levels used are inappropriate for these goats. Findings from this study indicate that the goat flock is probably infested with *H. contortus.*

Lower ALP values were observed in mature goats, corresponding with the lower values of phosphorus recorded for the mature animals compared to the young goats. The observed negative correlations between BCS with ALT and AST indicate that goats in a better condition will have lower levels of these liver enzymes compared to goats in poor condition. Therefore, blood parameters such as TP, globulin and albumin, can be used in monitoring nutritional status of Nguni goats whilst liver enzymes such as ALT and ALP are important in determining the negative effects induced by nematodes in communal goats. However, it should be noted that high TP levels do not always signify that the animals are in good condition. If the greater proportion of the TP is globulin, it indicates that the goats are experiencing some inflammation, probably due to parasite infestation.

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7 CHAPTER 7: General discussion, conclusions and recommendations

7.1 General discussion

Goats are important to the resource-poor farmers (Haenlein and Ramirez, 2007; Saico and Abul, 2007). Their productivity is, however, undermined by gastrointestinal parasite infestation and low levels of management. For implementation of sustainable intervention in goat production, it is crucial to evaluate the production systems, farmer pecerptions on the constraints hampering goat productivity, determine the causes of high kid mortality and assess the nutritional and health status of all classes of goats. Improvement of goat productivity offers opportunities for most resource-poor people to earn better returns in terms of cash and improved livelihoods. To design feasible and sustainable developmental programmes, it is crucial to understand the smallholder farm characteristics and the communal farming systems and processes, and to fully understand the roles goats can play in poverty alleviation and wealth creation. In other words, it is crucial to fully understand the actual contribution of goats to household economy rather than identifying constraints to goat productivity *per se*. The broad objective of the study was to evaluate production practices, constraints, production efficiency and to determine nutritional and health status of goats raised by resource-poor communal farmers from the Eastern Cape Province of South Africa. This objective was addressed through four trials.

The functions and roles of goat products vary with regions, countries, agro-ecological zones, production systems, cultural values and socio-economic status of the households

(Kosgey *et al*., 2008). In Chapter 3, the roles and management systems of goats in communal sweet and sour rangelands were assessed. Goat flock sizes did not differ between the two communities of the Eastern Cape Province. There were significant positive correlations between goat flock sizes and cattle herd sizes. Farmers from both districts kept goats mainly for ceremonies. Constraints to goat productivity that were reported by farmers included few bucks, which could lead to inbreeding and low kidding rate, high disease and gastrointestinal parasite infestation and high kid mortality. To augment the information presented in Chapter 3, it was imperative to carry out a monitoring study. Since the survey did not assist in retrieving information on how goat flock sizes varied with seasons, monitoring changes in the flock sizes could establish the major causes of losses and gains of goats to communal households.

To estimate the contribution of goats to household food security and income generation, goat flock demographics in each community were determined (Chapter 4). Kid mortalities were high in May, probably due to cold, and in September when most of the kids were born. The main causes of deaths were deprivation of milk, cold, gall sickness and gastrointestinal parasites. Generally, GPE values were low, regardless of high GPP in some villages. The low GPE values indicated that farmers are not always prepared to sell and/or consume goats. Low GPE values, however, do not signify that goats are unimportant but that they are multifunctional. Goat production efficiencies were higher in larger flocks compared to smaller flocks because of the greater number of goats to dispose by owners of the larger flocks. Owners of large flocks bought more bucks compared to owners of small flocks. The distribution of the bucks affected the number of kids that were born in any flock. Flocks that owned at least one buck had a higher proportion of kids in their goat flocks compared to those that did not own any buck. The kidding season (August to September) is in response to the improved availability of bucks after crops were removed from the fields and goats were grazing freely with a higher exposure of does to bucks. Availability of bucks after harvesting indicated that most does conceived in April to May. These findings confirmed observations from Chapter 3 were questionnaires retrieved that farmers owned a few bucks that were unevenly distributed.

One of the major concerns that emerged from the findings of Chapter 4 was high kid mortality. It, therefore, was imperative to determine the quality and causes of mortality in goats raised by the communal farmers. In Chapter 5, prevalences and loads of gastrointestinal parasites in communal goats across seasons were estimated. Body condition scores, weights and faecal samples were collected from 171 goats in the cold-dry, hot-dry, hot-wet and the post-rainy seasons. The most frequently detected helminth eggs were the strongyle egg type. The other identified nematodes were *Strongyloides* and *Trichostrongylus* egg tpes. Trematodes observed were *Fasciola* and *Paramphistomum*, although their loads were generally low. Generally, egg counts were higher in the sour than the sweet rangeland area. High loads of strongyle eggs were observed in the hot-wet season and the post-rainy season, whilst the other egg types showed a peak in the hot-wet season. The mean egg counts for all the nematodes were negatively correlated to age and BCS. The following correlations were found between age class of goat and *Trichostrongylus* (r= -0.098; $P < 0.01$), *Strongyloides* (r=-0.151; $P < 0.01$), *Strongyles* (r=-0.420; P < 0.01) and Coccidia (r= -0.201; P < 0.01). These results indicate that strongyles and coccidia may be the major contributors to goat helminthosis in the study areas. The loss in condition of goats with higher FEC has indicated that helminths negatively affected the productivity of goats. The higher helminth infestation in young goats obtained in Chapter 5 confirmed complains that the farmers raised in Chapter 3, that gastrointestinal parasites were amongst the major health problems affecting their goats. Higher strongyle egg counts that were obtained in Chapter 5 were further confirmed by high values of the FAMACHA scores that were obtained in Chapter 6 indicating that *H. contortus* might be a problem in goats raised in the Eastern Cape Province.

The relationship among body weight, BCS, faecal egg counts and haematological and biochemical profiles in Nguni goats, which are commonly kept in the communal areas, was presented in Chapter 6. Faecal egg counts were significantly higher in the wet than in the dry season and in young than in mature goats. Serum TP values were above the normal range in both seasons. The TP composed mainly of globulin indicating that the goats have a chronic health challenge that became elevated in the wet season.

Serum calcium and magnesium for the goats were within the reference range in both seasons. These findings indicate that there is no need for mineral supplementation in this goat flock. For liver enzymes, the serum concentrations of most of the goats, in both seasons, were below the reference range. However, higher AST and CK concentrations were recorded in the wet than in the dry season, probably arising from the stress induced by gastrointestinal parasites. The finding that most of the goats had liver enzyme concentrations below the normal reference range, yet they had high levels of globulin might indicate that the reference range for liver enzymes might be inapplicable to this goal flock. It implies, therefore, that there is need to establish more appropriate and relevant reference values for the indigenous goats in the Eastern Cape Province.

A negative correlation existed between BCS and strongyle egg type load indicating that strongyles have a debilitating effect on body reserves which is manifested as a loss in condition. However, if communal farmers supply their goats with quality supplementary feeds, they could be more capable of resisting parasite infestations. Lower ALP values were observed in mature goats, corresponding with the lower values of phosphorus recorded for the mature animals compared to the young goats. The observed negative correlations between BCS with ALT and AST indicate that goats in a better condition will have lower levels of these liver enzymes compared to goats in poor condition. Therefore, blood parameters such as TP, globulin and albumin, can be used in monitoring nutritional status of Nguni goats whilst liver enzymes such as ALT and ALP are important in determining the negative effects induced by nematodes in communal goats. However, if the greater proportion of the TP is globulin, it indicates that the goats are experiencing some inflammation, probably due to parasite infestation; hence farmers can urgently intervene by treating their animals.

7.2 Conclusions

Communal farmers kept goats for several reasons that were ranked differently in the two studied districts. Farmers in the Eastern Cape Province, however, kept goats mainly for ceremonies and sales. A few farmers owned bucks. The observed low GPE values might not be indicative of inefficiency of the goat production systems in the areas under study. The farmers should be encouraged to sell and/or consume most of their goats so that at any one point the flock consists of growing goats or breeding animals. That goats were highly infested with helminths during the rainy season indicates that goats have to be dosed against the specific helminths identified for each area. The findings from this study indicate that some blood metabolites can be used in the assessment of health and nutritional status of goats. Some metabolites, such as total protein, need to be used in conjuction with other metabolites or methods since a single level might be interpreted in several ways. That the goat flock used in this study had globulin far below the normal suggested reference range but did not show and clinical signs might indicate the need to establish reference values for different breeds in different communal areas.

7.3 Recommendations

It can be recommended that women be trained in aspects of goat production since they own most of the goats in the studied two districts. Training of farmers requires cooperation of the agricultural departments, non-governmental organizations, research institutions, universities and other stakeholders. The training of extension officers who will, in turn, train communal goat farmers will go a long way in realizing and exploiting the potential of goat production. The training of farmers should target household members who are directly involved in goat production. Farmers should be provided with manuals that are written in vernacular to facilitate their comprehension of the information being taught. Youths should also be convinced that goat farming can be used as a pathway out of poverty. It is also fundamental to encourage farmers to construct appropriate goat houses, with proper roofs, to curb morbidity and mortalities due to pneumonia, footrot and parasitic infections that are associated with poor housing. Improvement in goat housing can greatly reduce financial losses that might be used towards treatment against diseases that occur due to poor housing.

Farmers are recommended to exchange bucks so as to reduce inbreeding. This can be accomplished by educating farmers on the negative effects associated with inbreeding. It also is recommended that bucks be available to does throughout the year by encouraging farmers to buy bucks. The farmers who cannot afford to buy bucks can borrow when they identify does on heat.

It can also be recommended that goats require strategic control against helminthes such as strongyles. The young can be protected against infestations by herding them in separate areas from adult goats that might be having heavy loads It can also be recommended that blood parameters such as TP, globulin, albumin can be used in monitoring nutritional status of goats and liver enzymes such as ALT and ALP in the determination of the negative effects induced by nematodes in communal goats.

Areas that require further research include:

1. The development of the reference ranges that are specific to different communal flocks as those developed using exotic breeds might be inapplicable to goats raised in the communal areas. It is of importance to generate reference values for communal goats so that they are used in the determination of the nutritional and health status of that particular genotype.
2. Determinantion of differential blood counts to augument the studied blood parameters.
3. The effect of supplementation on gastrointestinal parasite loads and blood metabolite levels. The study should focus on supplementation of goats artificially infested with a particular helminthes and then comparing their productivity and/or performance with a similarly infested group but without supplementation.
4. Breed effect on faecal egg counts and blood metabolites in the communal areas should be established. The study should focus on determination of faecal eggs counts across different goat breeds raised in the communal area.
5. The effect of gastrointestinal infestation, through challenging the goats, on blood metabolite should be investigated. Goats of different sexes, ages and breeds and/or physiological statuses should be compared. The goats should be challenged with particular helminthes and the blood metabolite levels should be noted.
6. Investigation of other factors, apart from nutrition, that have an effect on goat fertility.

7. Adaptation traits and their inheritance in communal goat breeds. This study should focus on the identification of adaptation traits characteristic to communal goat breeds. There is need to determine the heritability of such traits.

7.4 References

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8 8: Appendices

Appendix 8.1: Survey questionnaire on goat production by smallholder farmers in the Eastern Cape Province

Enumerator Number …………………… Ward Name ……………………..

Village Name …………………….. Household Name ……………………..

A. GENERAL INFORMATION

1. Head of household

a) Sex F ☐ M ☐ b) Age <18 ☐ 18-30 ☐ 30-50 ☐ >50 ☐

c) Level of education Did not go to school ☐ Grade 7 ☐ "O" Level ☐ Beyond "O" Level ☐

d) Any agricultural training Yes ☐ No ☐ e) Is the head resident on the farm? Yes ☐ No ☐

2. How many people reside in your homestead? M ☐ F ☐

3. What are your sources of income? (Tick first column as appropriate and rank levels of source of income in the second column – 1 for highest income)

Crops		
Livestock and products		
Salary/wages		
………………		
………………		

4. What crops do you grow? (Tick first column as appropriate and rank levels of crops grown in the second column – 1 for mostly grown crop)

1. Maize		
2………………		
3………………		
4………………		
5………………		

5. Numbers and livestock species kept

Cattle ☐ Sheep ☐ Goats ☐ Chickens ☐ Pigs ☐ Others (specify) …………………….

6. Rank the livestock species that you keep

Cattle	
Sheep	
Goats	
Chickens	

Pigs	
Others	

7. What is the structure of your goat flock? Give numbers
Male kids(less than one year) ☐ Female kids(less than one year) ☐ Adult Males ☐ Adult Female ☐

B. GOAT PRODUCTION SYSTEM

2. **Why do you keep goats?** (The first column is for the purpose and the second column is for the rank)

Meat		
Milk		
Manure		
Skin		
Sales		
Investment		
Dowry		
Ceremonies		

3. Who owns the goats? (Can tick more than one)
Head ☐ Spouse ☐ Head/spouse together ☐ Child/Children ☐

4. What role(s) does each family member play in goat production? (Tick as appropriate, more than one column in a row may be ticked)

	Adults		Boys	Girls	Hired labour
	Males	Females			
a. Purchasing goats					
b. Selling/slaughtering goats					
c. Herding					
d. Breeding decisions					
e. Feeding					
f. Animal health					

5. How are the goats fed/grazed?
Herded ☐ Paddock ☐ Tethered ☐ Stall ☐ Yard ☐ Free grazing ☐ Others (specify)……………………

6. What form of housing do you have for your goats?
Kraaling ☐ Stall/shed ☐ Yard ☐ None ☐

7. If animals are housed, what materials have been used? (Tick one or more)
Untreated wood/bush ☐ Treated wood ☐ Iron sheets ☐
Bricks ☐ Mud ☐ Wire ☐ Others (specify)…………………..

8. Form of housing (Tick if present)
a) Roof ☐ **b) Solid wall** ☐ **c) Floor:** concrete☐ wooden ☐ earth ☐

9. What supplementary feeds do you give your goats? (Tick one or more)
Roughage/crop residue ☐ Minerals (salts)/ vitamins☐ Bought in feed / concentrates ☐
None☐

10. **How do your goats have access to drinking water?**
Animals go to water ☐ water is provided ☐ Both ☐

11. What are the sources of water for goats? (Tick one or more)
Borehole ☐ Dam/pond ☐ River ☐ Water well ☐ Spring ☐ Others (specify)………………………..

12. What is the distance to farthest water point?

At household ☐ < I km ☐ 1 to 5 km ☐ 6 to 10 km ☐ > 10 km ☐

13. What is your frequency of water supply to your goats?
Freely available ☐ once a day ☐ Twice a day ☐ Every other day ☐
Once in three days ☐ Others (specify)………………………

14. What is the quality of water that your goats drink? (Tick one or more)
Good/clear ☐ Muddy ☐ Salty ☐ Smelly ☐

C. HEALTH

1. If your goats are sick whose advice do you seek?
Government veterinary ☐ Private veterinary ☐ Veterinary drug suppliers ☐
Extension service ☐ None ☐ Others (specify) ……………………….

2. What are the major causes of mortality of your goats?
Old age ☐ Poor diet ☐ Extreme conditions ☐ Predators ☐ Diseases ☐

3. Prevalent diseases that occur on farm ………………………………….

Local name or symptoms of the disease (Rank, most common first) — Are animal treated when sick?

	Yes	No
1…………………………………		
2……………………………………		

3. Vaccinations
If none, tick this box ☐

Local name or symptoms of the disease (Rank, most common first) — Are animal treated when sick?

	Yes	No
1…………………………………		
2……………………………………		

D. BREEDING

1. What goat breeds do you use? ....

2. What is your reason for the choice when purchasing bucks? (First column is for the reason of choice, second column is for ranking the choice)

Size		
Conformation		
Colour		
Horns		
Temperament		
Performance		
Availability (No choice)		

3. How do you mate your goats?
uncontrolled ☐ hand mating ☐ group mating ☐ artificial insemination ☐ Others (specify)…………………….

4. Do you ever exchange your bucks with other farmers within your villages?

If no, tick this box ☐
If yes, after how long? >1 yr ☐ 1 to 2 yrs ☐ 3 to 4 yrs ☐ >4 yrs ☐

5. Do you ever exchange your bucks with other farmers from other villages?
If no, tick this box ☐
If yes, after how long? >1 yr ☐ 1 to 2 yrs ☐ 3 to 4 yrs ☐ >4 yrs ☐

6. Is there any decrease in the size of your goats over time?
Size is decreasing ☐ Size is increasing ☐ There is no difference☐

If there is an increase or decrease, what factors do you think attribute to that?
………
………
…………………………………………………………………………..

7. What are your sources of buck(s) used in the herd (Tick one or more)

		Common name
Own buck(bred)		
Own buck (bought)		
Buck donated		
Communal area buck		
Artificial insemination		

8. Do you castrate your male goats? Yes ☐ No☐
9. If yes, state reason for castration To control breeding ☐ To improve meat quality ☐ For better temperament ☐ Others (specify). ………………………

E. FLOCK DYNAMICS

1. **How many goats joined your flock (within the last 12 months) by the following categories?**

	Kids	Weaners and Adults			
			Adults		Total
		Weaners (W)	Males	Females	W + A
Born					
Bought					
Donated / Gift					
Exchange					

2. **How many goats exited your flock (within the last 12 months) by the following categories?**

	Kids	Weaners and Adults			
			Adults		Total
		Weaners (W)	Males	Females	W + A
Died					
Sold					
Slaughtered					
Donated/Gift					
Exchange					
Stolen					

3. Did you sell any animals in the last 12 months? Yes ☐ No☐
4. If yes, where were the animal sold? At an auction☐ To a butcher☐ Privately☐ To an abattoir☐

Others (specify) ………………….

5. What are your reasons for culling? (the first column is for the reason, the second is for the rank)

1. Size	Males		Females	
2.Conformation				
3. Colour				
4. Temperament				
5. Health				
6. Body condition				
7. Performance				
8. Old age				
9………………				

Appendix 8.2: Recording sheet for goat flock dynamics

Village…………………………..

Name of household…………………………………..

Month……………………………

	Numbers and Classes	Comments
Entries		
Births (Ezizelweyo)		
Purchases (Ezithengiweyo)		
Gifts-in (Izipho)		
Exchange –in (Ukutshintshisa)		
Entrusted –in (Ukunqoma/Ukusisa)		
Exits		
Sold (Ezithengisiweyo)		
Slaughtered (Ezixheliweyo)		
Died (Ezifileyo)		
Predated upon/stolen/lost (Ezibelixhoba/Ezibiweyo/Ezilahlekileyo		
Gifts out (Ekuphiswe)		
Exchange out (Ekutshintshiswe ngazo)		
Entrusted out (Ukungonywa/ukusiselwa)		
Flock Composition		
Female kids (amathokazi andamatakane)		
Male kids (inkunzi ezingamatakane)		
Adult female (sithokazi elidala)		
Adult males (inkunzi elidala)		

Appendix 8.3: Techniques for parasite assays and identification in faecal samples

8.3.1 Introduction

To diagnose gastro-intestinal parasites of ruminants, the parasites or their eggs/larvae must be recovered from the digestive tract of the animal or from faecal material. These are subsequently identified and quantified. This chapter presents diagnostic techniques within the reach of most laboratories to identify and quantify parasite infections from the examination of faecal material. The following are the main tasks involved in this process:

· Collection of faecal samples

· Separation of eggs/larvae from faecal material, and their concentration

· Microscopical examination of prepared specimens

· Preparation of faecal cultures

· Isolation and identification of larvae from cultures

8.3.2 Collection of faecal samples

Faecal samples for parasitological examination should be collected from the rectum of the animal. If rectal samples cannot be obtained, fresh faecal samples may be collected from the pasture. Several samples should be collected. Samples should be dispatched as soon as possible to a laboratory in suitable containers such as:

· screw cap bottles

· plastic containers with lids

· disposable plastic sleeves/gloves used for collecting the samples

· plastic bags

Each sample should be clearly labelled with animal identification, date and place of collection. Samples should be packed and dispatched in a cool box to avoid the eggs developing and hatching. If prolonged transport time to a laboratory is expected, the following may help to prevent the eggs developing and hatching.

(a) Filling the container to capacity or tightening the sleeve/glove as close to the faeces as possible. This is to exclude air from the container.

(b) Adding 3% formal in to the faeces (5-20 ml, depending on the volume of faeces). This is to preserve parasite eggs. (N.B Formalin-fixed faeces cannot be used for faecal cultures.) When samples are received in the laboratory they should immediately be stored in the refrigerator (4°C) until they are processed. Samples can be kept in the refrigerator for up to 3 weeks without significant changes in the egg counts and the morphology of eggs.

8.3.3 Sedimentation technique (for trematode eggs)

8.3.3.1 Principle

The sedimentation technique is a qualitative method for detecting trematode eggs *(Paramphistomum)* in the faeces. Most trematode eggs are relatively large and heavy compared to nematode eggs. This technique concentrates them in sediments.

8.3.3.2 Application

This is a procedure to assess the presence of trematode infections. It is generally run only when such infections are suspected (from previous postmortem findings on other animals in the herd/flock area), and is not run routinely. The procedure can be used to detect liver fluke *(Fasciola)* and *Paramphistomum* eggs.

8.3.3.3 Equipment

· Beakers or plastic containers

· A tea strainer or cheesecloth

· Measuring cylinder

· Stirring device (fork, tongue blade)

· Test tubes

· Test tube rack

· Methylene blue

· Microslide, coverslips

· Balance or teaspoon

· Microscope

8.3.3.4 Procedure

(a) Weigh or measure approximately 3 g of faeces into Container 1.

(b) Pour 40-50 ml of tap water into Container 1.

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

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

(e) Pour the filtered material into a test tube.

(f) Allow to sediment for 5 minutes.

(g) Remove (pipette, decant) the supernatant very carefully.

(h) Resuspend the sediment in 5 ml of water.

(i) Allow to sediment for 5 minutes.

(j) Discard (pipette, decant) the supernatant very carefully.

(k) Stain the sediment by adding one drop of methylene blue.

(l) Transfer the sediment to a microslide. Cover with a coverslip.

8.3.2 McMaster counting technique (for nematodes)

8.3.2.1 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 will detect 50 or more e.p.g. of faeces.

8.3.2.2 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.

8.3.2.3 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

8.3.2.4 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 = (12 + 15) x 50 = 1350 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: Communal goat production in Southern Africa: A review (Accepted manuscript)