

**GASTRO-INTESTINAL NEMATODE INFECTIONS
AMONG GOAT BREEDS AT THE NATIONAL SEMI-
ARID RESOURCES RESEARCH INSTITUTE, SERERE,
UGANDA**

BY

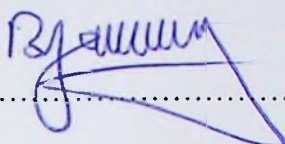
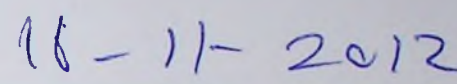
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**A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF
VETERINARY PREVENTIVE MEDICINE OF MAKERERE UNIVERSITY**

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DECLARATION

I, **Charles Byaruhanga**, declare that this is my original research work and has never been submitted for publication or an award to any other university or institution.

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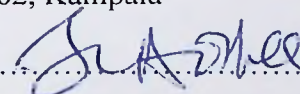
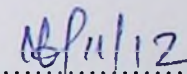
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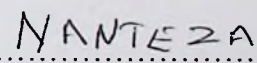
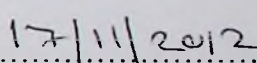
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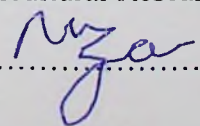
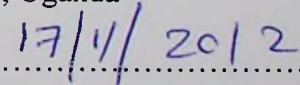
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DEDICATION

I dedicate this work to my loving and caring parents, Mrs. Mary Balongo and the late Joseph Balongo.

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TABLE OF CONTENTS

DECLARATION.....	i
DEDICATION.....	ii
ACKNOWLEDGEMENTS.....	iii
TABLE OF CONTENTS.....	iv
LIST OF TABLES.....	viii
LIST OF FIGURES.....	x
LIST OF APPENDICES.....	xi
ACRONYMS AND ABBREVIATIONS.....	xii
ABSTRACT.....	xiv
CHAPTER ONE: INTRODUCTION.....	1
1.1 Background of study.....	1
1.2 Statement of the study problem.....	3
1.3 Objectives.....	3
1.3.1 General objective.....	3
1.3.2 Specific objectives.....	3
1.4 Hypothesis.....	4
1.5 Justification.....	4
CHAPTER TWO: LITERATURE REVIEW.....	5
2.1 Goat production and importance.....	5
2.2 Goat breeds in Uganda.....	6
2.3 Constraints to goat production.....	7

2.4 Gastro-intestinal nematodes of goats.....7

2.5 The epidemiology of gastro-intestinal nematodes of goats.....8

2.6 The effects of gastro-intestinal nematodes in goats.....10

2.7 Control of gastro-intestinal nematodes in goats.....11

2.8 Relative susceptibility of goat breeds to gastro-intestinal nematode infections.....13

CHAPTER THREE: MATERIALS AND METHODS.....16

3.1 Study site.....16

3.2 Experimental animals.....16

3.3 Care of experimental animals.....18

3.4 Experimental design.....18

3.5 Determination of worm burdens in goats20

 3.5.1 Collection and handling of fecal samples.....20

 3.5.2 Identification of nematode eggs.....21

 3.5.3 Estimation of fecal egg counts.....21

 3.5.4 Larval identification in fecal samples.....22

3.6 Determination of packed cell volume and eosinophil counts.....22

3.7 Determination of body condition score.....22

3.8 Estimation of anemia score.....23

3.9 Estimation of body weight change.....23

3.10 Statistical Analysis.....24

CHAPTER FOUR: RESULTS.....25

4.1 Percentage of goats with gastro-intestinal nematodes across breeds.....25

4.2 Fecal egg counts in goats.....26

4.2.1 Fecal egg counts in male goats of different breeds.....26

4.2.2 Fecal egg counts in female goats of different breeds.....27

4.2.3 Fecal egg counts between male and female goats.....28

4.3 Degree of gastro-intestinal nematode infection in goat breeds.....28

4.4 Changes in fecal egg counts during the study period.....29

4.5 Proportions (%) of gastro-intestinal nematode genera in different goat breeds.....30

4.6 Packed cell volume in goats.....33

4.6.1 Packed cell volume in male goats of different breeds.....33

4.6.2 Packed cell volume in female goats of different breeds.....34

4.7 Eosinophil counts in goats.....34

4.7.1 Eosinophil counts in male goats of different breeds.....34

4.7.2 Eosinophil counts in female goats of different breeds.....35

4.8 Body condition scores in goat breeds.....36

4.8.1 Body condition scores in male goats of different breeds.....36

4.8.2 Body condition scores in female goats of different breeds.....37

4.9 Anemia scores in goats.....37

4.9.1 Anemia scores in male goats of different breeds.....37

4.9.2 Anemia scores in female goats of different breeds.....38

4.10 Body weight changes in goats.....39

4.10.1 Body weight changes in male goats of different breeds.....39

4.10.2 Body weight changes in female goats of different breeds.....39

4.11 Correlations between fecal egg counts, packed cell volume, FAMACHA score and body
condition score in the goat breeds.....40

CHAPTER FIVE: DISCUSSION.....42

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS.....52

6.1 Conclusions.....52

6.2 Recommendations.....52

CHAPTER SEVEN: REFERENCES53

APPENDICES.....71

LIST OF TABLES

Table 1: Grouping of experimental goats used for determining gastro-intestinal nematode infections.....	19
Table 2: Interpretation of fecal egg counts and degree of infection in goats.....	21
Table 3: Percentage of goats with gastro-intestinal nematodes in Boer crosses, Small East African and Mubende breeds.....	25
Table 4: Fecal egg counts in male goats of Boer crosses, Small East African and Mubende.....	26
Table 5: Fecal egg counts in female goats of Boer crosses and Mubende.....	27
Table 6: Fecal egg counts between male and female goats of Boer crosses and Mubende.....	28
Table 7: Packed cell volume in male goats of different breeds.....	33
Table 8: Packed cell volume in female goats of Boer crosses and Mubende.....	34
Table 9: Eosinophil counts in male goats of Boer crosses, Small East African and Mubende....	35
Table 10: Eosinophil counts in female goats of Boer crosses and Mubende.....	35
Table 11: Body condition scores in male goats of Boer crosses, Small East African and Mubende.....	36
Table 12: Body condition scores in female goats of Boer crosses and Mubende.....	37
Table 13: Anemia scores in male goats of Boer crosses, Small East African and Mubende.....	38
Table 14: Anemia scores in female goats of Boer crosses and Mubende.....	38
Table 15: Body weight changes in male goats of Boer crosses, Small East African and Mubende.....	39
Table 16: Body weight changes in female goats of Boer crosses and Mubende.....	40

Table 17: Correlations between fecal egg counts, packed cell volume, FAMACHA and body condition scores in Boer crosses, Small East African and Mubende goats.....	41
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LIST OF FIGURES

Figure 1: Photographs showing Mubende, Boer cross and Small East African goats	17
Figure 2: Photograph showing a goat fecal sample in a plastic bag.....	20
Figure 3: Percentage of goats with various degrees of gastro-intestinal nematode infection in Boer crosses, Small East African and Mubende	29
Figure 4: Changes in fecal egg counts in Boer crosses, Small East African and Mubende goats during the study period.....	30
Figure 5: Photograph showing a recently hatched <i>Haemonchus</i> larva (L ₃).....	31
Figure 6: Proportions (%) of nematode genera in Boer crosses, Small East African and Mubende goats.....	32

LIST OF APPENDICES

Appendix I: Key for the identification of the third stage larvae of some gastro-intestinal nematodes of goats.....	71
Appendix II: FAMACHA© eye color chart for detecting clinical anemia in goats.....	72

ACRONYMS AND ABBREVIATIONS

μm	-	Micrometer
μg	-	Microgram
AIGR	-	American Institute for Goats Research
ANOVA	-	Analysis of variance
BCS	-	Body condition score
BWC	-	Body weight changes
CVMP	-	Committee for Veterinary Medicinal Products
EOS	-	Eosinophil
EPG	-	Eggs per gram
EWP	-	Efficacy Working Party
FAO	-	Food and Agricultural Organization
FAMACHA	-	Anemia guide chart with 5-colour scale
FEC	-	Fecal Egg Count
FECR	-	Fecal egg count reduction
FECRT	-	Fecal egg count reduction test
GIN	-	Gastrointestinal nematodes
GLM	-	General Linear Model
ILRI	-	International Livestock Research Institute
MAAIF	-	Ministry of Agriculture, Animal Industry and Fisheries
MAFF	-	Ministry of Agriculture, Fisheries and Food
MVPM	-	Masters of Veterinary Preventive Medicine

NARO	-	National Agricultural Research Organization
NaSARRI	-	National Semi-arid Resources Research Institute
PROC MEANS	-	Procedure means
SAS	-	Statistical Analysis systems
SD	-	Standard deviation
Se	-	Standard error
SPC	-	Summary of the Product Characteristics
SRNET	-	Small Ruminant Network
STP	-	Strategic Intervention Programme
UBOS	-	Uganda Bureau of Statistics
USDA	-	United States Department of Agriculture
USP	-	United States Pharmacopeia
WAAVP	-	World Association for the Advancement of Veterinary Parasitology
WHO	-	World Health Organization

ABSTRACT

An experimental study was conducted between December, 2010 and April, 2011 at the National Semi-Arid Resources Research Institute, Serere, Uganda, to compare the response of Boer crosses (male = 11, female = 15), Mubende (male = 14, female = 13) and Small East African (only male = 11) goats to gastro-intestinal nematode (GIN) infections. The goats were sampled for blood and feces at four week intervals for a period of 16 weeks and gastro-intestinal nematode prevalence, fecal egg count (FEC) expressed as eggs per gram (EPG), third stage larvae (L₃) count, packed cell volume (PCV) and eosinophil (EOS) count were determined. Simultaneously, the goats were scored for body condition, anemia and body weight changes (BWC). These dependant variables were compared among goats of the same sex across breeds. For each of the three goat breeds, strongyle nematodes were most prevalent (> 80%). FEC did not differ significantly ($p > 0.05$) when male goats of different breeds were compared; although highest in Boer crosses and lowest in Mubende. FEC differed significantly ($P < 0.05$) when female goats of different breeds were compared; higher in Boer crosses than in Mubende. Boer crosses had the highest percentage of goats ($22.6\% \pm 0.94$) with heavy degree of gastro-intestinal nematode infection, while Mubende goats had the lowest proportion ($11.9\% \pm 0.87$). *Haemonchus species* accounted for the highest proportion of nematodes in each of the three goat breeds, with a significant difference ($\chi^2 = 44.48$, $p < 0.05$) in proportions among goat breeds: highest in Boer crosses (96.85%) and lowest in Small East African goats (56.4%). PCV, EOS count, BCS and BWC were significantly different ($p < 0.05$) in goat breeds, but FAMACHA eye scores for anemia was not different. PCV values and BCS were highest in Mubende goats, while EOS count and BWC were highest in Boer crosses. The Small East African goats had the lowest

values for PCV, BCS, body weight gains and EOS count. FEC and PCV were negatively correlated in Boer crosses ($R = -0.106$, $p > 0.05$) and Mubende ($R = -0.09$, $p > 0.05$), but positive for Small East African goats. FEC and FAMACHA eye scores were positively correlated in Mubende ($R = 0.069$), Small East African ($R = 0.115$) and the correlation was significant in Boer crosses ($R = 0.28$, $p < 0.05$). It was concluded that Mubende goats were most tolerant and resilient to GIN infections on the basis of FEC, degree of infection, PCV and BCS. The Boer crosses were least resistant on basis of highest FEC and highest percentage of goats with heavy degree of infection. Small East African goats were least resilient on basis of lowest PCV, BCS, BWC and EOS count.

CHAPTER ONE

INTRODUCTION

1.1 Background of study

Worldwide, goats (*Capra hircus*) are a valuable component among human communities in terms of tangible and intangible benefits (Dossa *et al.*, 2007). They provide valuable products such as meat, milk and skins (Kumba, 2002); and manure for improved crop and fish production (Devendra & Burns, 1983). Currently, Uganda has got a goat population of 12,449,670 (MAAIF, 2010). In most rural communities in Uganda, goats are highly valuable regarding human nutrition, food security, family incomes and socio-cultural needs (Semakula *et al.*, 2010).

Despite the well recognized significance, the current level of goat production in Uganda is low, and yet the potential for further development is enormous given the ever increasing local and regional meat demand (King, 2002). Increasing demand for meat has arisen from the rapid increase in urban populations (King, 2002), and the expansion and emergence of new markets in the great lakes region. There is hence, a greater need than ever to increase both the production and productivity of goats. Unfortunately, development and improvement of goat production in the tropics is *inter alia*, faced with helminthosis as the greatest challenge (Perry *et al.*, 2002).

In the least developed tropical regions of the world, helminth infections of goats are largely responsible for economic losses as a result of reduction in productivity and increased mortality (Perry *et al.*, 2002). Gastro-intestinal nematode helminths are responsible for 25% pre-weaning mortality (Baker *et al.*, 2001), 24-27% reductions in annual off take and 27% loss in meat production (Osaer *et al.*, 2000). The parasites also cause immunosuppression and subsequent

increase in susceptibility to other diseases (Kumba *et al.*, 2003; Githigia *et al.*, 2005). Very high mortalities attributed to acute haemonchosis in breeding Boer goats have been reported in Uganda (Okwee-Acai *et al.*, 2010). Similarly, Lapenga and Rubaire-Akiiki (2009) reported a significant weight loss of 27 kg and poor body conditions of score 1 in helminth affected goats in Uganda. They also observed that helminthosis in goats reduced the dressing percentage and carcass dry matter content by 7.5% and 4%, respectively.

Given the aforementioned, adopting management practices that reduce on helminth infections would improve goat productivity (Githigia *et al.*, 2001). Some of the practices that reduce on worm burdens are: rotational grazing (Torres and Acosta, 2008), keeping worm resistant breeds (Vagenas *et al.*, 2002), keeping stocking rates at recommended levels (Etter *et al.*, 2000) and chemoprophylaxis (Mortensen *et al.*, 2003). However, rotational grazing and keeping stocking at recommended levels are not popular among farmers (Thamsborg *et al.*, 1996; Uriarte *et al.*, 2003). Therefore, chemotherapeutic use of anthelmintics is the mainstay for GIN control programs in many parts of the world (Magona and Musisi, 1999; Taylor *et al.*, 2002; Kumsa and Wossene, 2006). However, this has proved to be costly and its effectiveness has been affected by emergence of drug resistance (Kaplan, 2004; Ram *et al.*, 2007; Kumsa *et al.*, 2010a).

Resistance to all major classes of anthelmintics, which is a major concern, particularly to small ruminant industries occurs in the major nematodes throughout the world (Waller, 2006). Presence of drug residues in food and in the environment is also a big concern (Gentili, 2008).

Therefore, there was need for research into supplementary parasite control methods. One such method would be keeping goat breeds that are relatively resistant to GIN infections. It has been demonstrated that it is feasible to control GIN infections among goats through breeding for resistance (Mandonnet *et al.*, 2001).

1.2 Statement of the study problem

Gastro-intestinal nematode (GIN) infections amongst goats are the most important factor limiting goat productivity. Losses and control costs due to GIN infections can be reduced if farmers kept goat breeds that are less susceptible to nematode infections, while paying particular attention when controlling worms in more susceptible breeds. This requires information on the relative susceptibility of various goat breeds to GIN infections. Baker *et al.* (2001) in Kenya, Chiejina and Behnke (2011) in Nigeria and Rout *et al.* (2011) in India demonstrated a variation in susceptibility of goat breeds to GINs. In Uganda, no earlier study comparing worm tolerance by different breeds (Mubende, SEA, Boer or Boer-crosses) had been done. There was therefore, lack of information on the relative susceptibility of goat breeds to helminth infections.

1.3 Objectives

1.3.1 General Objective

Compare gastro-intestinal nematode infections among Boer crosses, Mubende and Small East African goats at the National Semi-arid Resources Research Institute.

1.3.2 Specific objectives

- i) Determine GIN burdens among Boer crosses, Mubende and Small East African (SEA) goat breeds.
- ii) Determine the clinical effects (PCV, eosinophil count, BCS, anemia and body weight changes) due to GIN infestations among Boer crosses, Mubende, and Small East African goat breeds.

1.4 Hypotheses

- a. There is no difference in GIN burdens in Boer crosses, Mubende and Small East African goat breeds when kept under similar disease challenge.
- b. There is no difference in clinical effects due to GIN infestations in Boer crosses, Mubende and Small East African goat breeds when kept under similar disease challenge.

1.5 Justification

This study compared the relative susceptibility of Boer crosses, Mubende and Small East African goat breeds to GIN infections. Information from the study is of great use in control of helminthoses based on host resistance given its simplicity, low cost and sustainability. The information also creates awareness and urgency of controlling helminthoses among different breeds of goats especially Boer crosses.

CHAPTER TWO

LITERATURE REVIEW

2.1 Goat production and importance

Goats are important in the improvement of income and nutrition of rural communities and to bring those communities into commercial marketing systems (Braker *et al.*, 2002; Lebbie, 2004). They are cheap to buy and easy to sell, multiply very easily and twinning is common (Aziz, 2010; Anon., 2010).

Goats being hardy animals play a key role in the utilization of marginal lands that may not be suitable for crop production (Coffey *et al.*, 2004; Aziz, 2010). They do not easily succumb to disease and can easily be kept by women and children (Lebbie, 2004; Aziz, 2010; Anon., 2010). In Uganda, goats are kept for income generation through sales of the live animals, for meat, milk, insurance, customary norm, wealth accumulation and manure (Semakula *et al.*, 2010).

Goat production systems in Uganda are mainly smallholders characterized by mixing crops with livestock (Mbuza, 1995). The common grazing systems in Uganda are: tethering, extensive, zero grazing and semi-intensive (Anon., 2010).

Uganda has got potential and opportunities for goat farming because of the presence of abundant and largely untapped pastures and shrubs which can be utilized for goat farming. This coupled with the fact that they are browsers, they can be kept with cattle and sheep because they can eat forage that is not commonly eaten by other species. There is also ready market for goat products locally and within the region, which is already being accessed by the private sector (Anon., 2010).

2.2 Goat breeds in Uganda

The major indigenous goat breeds in Uganda include: the Mubende, Kigezi, and the Small East African (SEA) (Mason & Maule, 1960). In order to improve on the productivity of goats, farmers in Uganda have adapted exotic goats such as Boer and Toggenberg and their crosses with indigenous breeds (Kiwuwa, 1992).

The Small East African goat breed is one of the most predominant in Uganda especially in the semi-arid north-eastern parts of Uganda (NARO-ILRI-SRNET, 1995). The coat color ranges from pure white to pure black with intermixes of roan and speckled brown. The adult male weighs 25-30 Kg, and the female weighs 22 Kg. The goats are mainly kept for meat and have got good potential for selection to increase productivity (Anon., 2010).

The Mubende goats are found in the humid southern and central regions of Uganda and particularly in Mubende district where the breed derives its name (NARO-ILRI-SRNET, 1995). The breed is, however, also said to be adapted to sub-humid and warm tropical Savannah climatic conditions found in other districts. They have got a pure black or black and white mixture of hair coat. The adult male and female weigh 25-35 kg and 22-28 kg live weight, respectively (Anon., 2010).

The Boer goats are being adapted by farmers in Uganda as an alternative way of improving the low output of meat among the indigenous goats (Kiwuwa, 1992). The coat color is usually white, with brown spots, as well as red/brown head and neck. The mature body weight in females and males is 50-65 kg and 55-80 kg, respectively (Anon., 2010).

2.3 Constraints to goat production

The common constraints to goat production are lack of access to good breeding stock, disease prevalence, water scarcity, poor infrastructure, lack of veterinary and extension services, lack of credit and access to markets, and deficient inputs (Oluka *et al.*, 2004; De Vries, 2008). Oluka *et al.* (2004) reported additional constraints of prolonged periods of drought which lead to scarcity of quality grazing pastures and forages, and insecurity in eastern Uganda. Kiura *et al.* (2003) reported disease prevalence as a major problem in Kenya; with the most limiting diseases or conditions being helminthosis, ectoparasites and pneumonia in decreasing order of importance.

2.4 Gastro-intestinal nematodes of goats

Gastro-intestinal nematodes refer to the parasites of the phylum nemathelminthes which belongs to helminth parasites and use the gastro-intestinal tract (GIT) as their predilection site (Soulsby, 1968). The most important helminth parasites of goats are the *Trichostrongylids*, nematodes from the abomasum or the small intestine with a direct life cycle. Ruminants are infected by ingestion from pastures of the infective third stage larvae (L3) (Hansen & Perry, 1994).

The strongyle group of nematodes has been identified as the most important and prevalent in goats (Regassa *et al.*, 2006; Rinaldi *et al.*, 2007). The most prevalent genera of GIN in goats are *Haemonchus*, followed by *Trichostrongylus*, *Oesophagostomum* and *Strongyloides* (Magona & Musisi, 2002; Sioned, 2007; Kumsa *et al.*, 2010; Abebe *et al.*, 2010). *Trichuris* nematodes have also been reported in goats (Woldemariam, 2005; Ijaz *et al.*, 2008). The other nematode in goats is of the *Ostertagia* genus (Ijaz *et al.*, 2008). Others have shown *Ascaris* in addition to strongyles and *Strongyloides* (Kumba *et al.*, 2003). *Haemonchus contortus* has been found to be

the most economically important GIN of goats in the different parts of the world (Perry *et al.*, 2002; Mortensen *et al.*, 2003).

5 The epidemiology of gastro-intestinal nematodes of goats

The occurrence and intensity of GIN infections in goats is influenced by a multifactorial system, which comprises the hosts, parasite and environmental effects (Qamar *et al.*, 2009).

Sex of the host can influence the level of helminth infections in which a higher rate of nematode infections in females as compared to male animals has been reported (Regassa *et al.*, 2006; Raza *et al.*, 2009). The difference in prevalence might be due to lowered resistance of female animals on the part of their reproductive events and insufficient/unbalanced diet against higher needs (Raza *et al.*, 2009). In other cases, helminth infections have been found to be higher in males than female animals (Gauly *et al.*, 2006). However, Qamar *et al.* (2009) reported no significant difference in the prevalence of GIN infections between male and female goats.

Age of the animal can affect the level of helminth infection in animals. The kids and lambs have been found to have a significantly higher prevalence rate than older goats and sheep (Magona & Musisi, 2002; Githigia *et al.*, 2005; Regassa *et al.*, 2006 and Qamar *et al.*, 2009). This could be due to the fact that younger animals are more susceptible than adult counterparts. Adult animals may acquire immunity to the parasites through frequent challenge and expel the ingested parasite before they establish infection (Silverman & Patterson, 1960; Shah-Frischer & Fris, 1989). Nevertheless, in some cases high prevalence of GIN have been observed in adult animals than the young ones (Fritsche *et al.*, 1993; Waruiru *et al.*, 2005).

The species and breed of the animal can affect the level of helminth infection. Compared to sheep, goats seem to develop a low immune response against the parasitic nematodes of the

gastro-intestinal tract (Hoste *et al.*, 2008). This could be due to their peculiarities in feeding behavior of goats ('intermediate browsers') which helps them to avoid the infective larvae and by selecting plants with direct anthelmintic properties (Hoste *et al.*, 2008). Between breed and within breed variation in resistance and resilience to GIN in goats has been reported (Mandonnet *et al.*, 2001; Baker *et al.*, 2001). This is the basis of exploiting host resistance in the control of worms which is reviewed in more detail in section 2.8.

The physiological state of the host can influence the level of GIN burdens in the host. Female hosts excrete more parasite eggs around the time of parturition (Faye *et al.*, 2003; Mandonnet *et al.*, 2005). This is described as the peri-parturient relaxation of immunity (PPRI). This relaxation in the host regulation of the parasite biological trait might be related to the nutritional dysbalance occurring at the end of gestation and/or start of lactation. This leads to the diversion of nutrients from the immune response to cover the offspring's needs (Faye *et al.*, 2003; Kahn, 2003).

The consistency of the host faeces can affect the number of nematode eggs produced by the host. Diarrheic feces often contain lower number of eggs per gram than formed feces, due to the effect of dilution (Hansen & Perry, 1994).

Parasitic factors influence the level of helminth infection. Different species of nematodes have different egg-producing capacities. The daily egg production of *Haemonchus* is 5,000-15,000, for *Ostertagia* and *Trichostrongylus* is 100-200. The genus of *Cooperia* produces 1,000-3,000 and *Nematodirus* 50-100. *Oesophagostomum* produces 5,000-10,000 (Hansen & Perry, 1994). The high egg producing capacity of *Haemonchus contortus* gives it an advantage over other parasites in that it can easily contaminate grazing areas and may survive in its small ruminant hosts through frequent and rapid infestations. Some of the gastro-intestinal nematodes can be very adaptable. For example, *Haemonchus* can go into hypo biotic (arrested) state in the

animal to survive poor environmental conditions. It can survive on pasture for a long time under adverse weather conditions (Waller *et al.*, 2004).

Environmental factors influence helminth infection in animals. Higher nematode infection levels occur in the wet than the dry season (Magona & Musisi, 2002; Githigia *et al.*, 2005; Regassa *et al.*, 2006). The higher prevalence in wet than dry season is explained by the difference in humidity and temperature in the seasons. In general warm and moist temperatures are favorable for rapid development, whereas cool and moist conditions are favorable for survival (Hansen and Perry, 1994). The presence of sufficient moisture during the rainy season favors the survival of infective larvae in the pasture and higher probability of uptake of the infective larvae (Magona & Musisi, 2002; Regassa *et al.*, 2006).

4.6 The effects of gastro-intestinal nematodes in goats

Gastro-intestinal nematode infections of goats can cause serious economic losses through reduction in productivity (through impairing weight gains) and increased mortality (Perry *et al.*, 2002; Waller *et al.*, 2004) especially in the young stock (Sartika & Subandriyo, 2002; Waller *et al.*, 2004). This is so especially with *Haemonchus contortus* infection in many resource-poor regions of the world (Perry *et al.*, 2002). Lapenga & Rubaire-Akiiki (2009) reported a significant reduction in weight gain, as well as reduction in body condition score (BCS) and carcass grades due to helminthosis in goats. Other effects can be reduced levels of output of meat, milk and manure (Sartika & Subandriyo, 2002). Economic losses such as low fertility, reduced performance and condemnation in severely infected cases have been reported (Kumsa *et al.*, 2010).

Gastro-intestinal nematode (especially *Haemonchus*) infections in goats are associated with a number of clinical effects. Acute haemonchosis has been reported as the immediate cause of high mortalities due to severe anemia in Boer goats in Uganda (Okwee-Acai *et al.*, 2010). *Haemonchus contortus* (barber pole, wire worm, large stomach worm) is a highly prolific, blood-sucking parasite. With the exception of the L3, all other stages of development of *Haemonchus contortus* feed on blood. This results in a variable degree of anemia which results not only from the blood consumed by the parasites but also due to hemorrhage after the parasites detach from the feeding sites (Waller *et al.*, 2004). However, diarrhea is not common in *Haemonchus* infection unlike other nematode infections (Smith & Sherman, 2009).

Gastro-intestinal nematode infections in goats affect the levels of packed cell volume (PCV) and the leukocytes (Vatta *et al.*, 2002; Kaplan *et al.*, 2004; Mandonnet *et al.*, 2006; Regassa *et al.*, 2006; Sioned, 2007; Kumsa *et al.*, 2010). Goats with higher fecal egg counts have been seen to have lower values of PCV than those with lower fecal egg counts (Chiejina *et al.*, 2010; Rout *et al.*, 2011). The weight gain in animals can also be affected by GIN infection. Correlations between fecal egg counts and growth traits have been found to be negative in goats (Odoi *et al.*, 2008; Rout *et al.*, 2011). This is a result of reduced feed intake (Knox & Steel, 1999), reduced efficiency of feed utilization (Coop & Holmes, 1996) and induced protein deficiency (Yu *et al.*, 2000; Sykes & Coop, 2001).

2.7 Control of gastro-intestinal nematodes in goats

Control of GIN has been mainly by use of broad spectrum anthelmintics (Waller, 1993; Magona & Musisi, 1999). However, the emergence of anthelmintic resistance has become a major threat to this control method (Bakunzi, 2003; Mortensen *et al.*, 2003).

Keeping of stocking rate at recommended levels can reduce the rate of worm infestation. This is achieved by reducing the contamination of pastures by livestock and the levels of infective L₃ on pastures (Thamsborg *et al.*, 1996). Besides, about 80% of the infective larvae can be found on the first two inches of vegetation. Therefore, by keeping stocking rates at relatively low levels, overgrazing and the subsequent possibility of animals grazing closer to the ground will be avoided (Vallade *et al.*, 2000). Also, keeping ruminants at the upper limit of pasture availability interferes with their mechanism of avoiding grazing herbage which is contaminated with feces (Cooper *et al.*, 2000). However, the limitation of this method of control is that it has a long term effect rather than short term consequences (Thamsborg *et al.*, 1996).

Rotational grazing of animals can be a good practice in the control of gastro-intestinal nematodes. This can be done by introducing animals on a paddock only after the populations of infective larvae have dramatically reduced due to natural death (Torres-Acosta & Hoste, 2008), or by withdrawing animals from paddocks before the eggs develop to L₃ (Eysker *et al.*, 2005). This has limitations since the survival and availability of infective larvae varies with climate (Rahmann & Seip, 2006). Therefore, it would need the goat farmers to have a good understanding of the peaks and troughs of infective larvae so that optimal timing for rotating the animals can be determined (Uriarte *et al.*, 2003).

Manipulation of the host nutrition can improve the host response against worms. Protein supplementation to infected goats can improve on the host resilience and, to a lesser extent, on its resistance to parasites (Hoste *et al.*, 2005). The protein supplementation of female goats around parturition has been found to alleviate the periparturient rise and thus reducing on pasture contamination (Houdijk *et al.*, 2000; Kahn, 2003). However, anecdotally, very few farmers can afford to purchase the feeds for supplementation.

Control of GIN can be met by use of medicinal plants. Condensed tannins of tannin-rich legumes have been found to have anthelmintic properties (Hoste *et al.*, 2006). However, woody plants are not as resilient to being eaten as grasses (Kahan *et al.*, 2009). Therefore, the plants must be incorporated into the pasture in strategic locations in order to maximize forage consumption throughout the pasture. Also control of GIN of goats can be achieved through selection of goats both within and between breeds that show less susceptibility to infection (Vagenas *et al.*, 2002). Section 2.8 of this chapter provides a detailed insight into this control method.

2.8 Relative susceptibility of goat breeds to gastro-intestinal nematode infections

The relative resistance of different breeds of goats to GIN infections can be exploited in the control of the nematodes. It is a relatively simple and cheap method of reducing the effects of nematode infestation through selecting and breeding genetically nematode-resistant animals (Baker, 1999; Bishop & Stear, 1999).

Some breeds of goats have been found to be more resistant and /tolerant to gastro-intestinal nematode infections than others. In the Thailand and the Philippines, indigenous goats have been found to be more resistant to internal parasites as compared with the Nubian derived breeds and crosses (Baker & Gray, 2004). The Nigerian West African Dwarf goat, in contrast to other goats in West Africa was seen to be more effective in the control/regulation of *Haemonchus contortus* infections both in laboratory and to naturally acquired infections (Chiejina & Behnke, 2011). Rout *et al.* (2011) reported strong genetic correlations between fecal egg counts at various ages of two Indian goat breeds, suggesting that the traits may be controlled by the same genes.

study by Hoste *et al.* (2001b) revealed that nematode egg excretion was higher in the Angora than the Saanen goats.

The Small East African goat has been found to be more resistant than other goat breeds from the East African region. Baker *et al.* (1998 and 2001) reported higher resistance of Small East African goats than Galla goats to gastro-intestinal nematode infections, as shown by their significantly lower fecal egg counts and higher PCV. Other reports also indicated lower worm infestation rates, a lesser change in body weight and lower mortality rates in Small East African goats compared to the Galla and the Toggenberg crosses in Kenya (Shavulimo, 1989).

Other researchers have reported no breed differences in resistance of goats to gastro-intestinal nematode infections. Chauhan *et al.* (2003) reported no breed differences in fecal egg counts and packed cell volume between two breeds of Indian goats at various stages. Results by Costa *et al.* (2000) showed no variation in fecal egg counts between goat breeds, although there were breed differences in the packed cell volume which was related to resistance to *Haemonchus contortus*.

Even within the same breed, individual goats show differences in susceptibility to gastro-intestinal nematode infections. Very small proportions of animals with moderate to severe nematode infection rates as compared to big proportions of animals with low infection have been reported (Hoste *et al.*, 2001a; Maichomo *et al.*, 2004; Regassa *et al.*, 2006). Mandonnet *et al.* (2001) demonstrated the feasibility of breeding for improved resistance to nematode infections in the Creole goat kids.

Information about the variability in response to gastrointestinal parasitism that could be linked to genetic components is still scarce in goats (Hoste *et al.*, 2008). The genetic factors in goats can influence the size of gastro-intestinal nematode infection by affecting the rate at which acquired resistance develops in the host (Hansen & Perry, 1994). The mechanism for heritability

s not well established. Genes for the major histocompatibility complex of the immune system in sheep have been identified as candidates (Benavides *et al.*, 2002). Some alleles at the microsatellite loci that are associated with fecal egg counts (FEC) have been found to be breed specific in sheep (Benavides *et al.*, 2002).

The genetic trait measured (FEC) may be affected directly by genetic effects on the immune system (Fakae *et al.*, 1999) or indirectly through diet selection for improved nutrition or grazing habits that reduce exposure to infective helminth larvae (Hoste *et al.*, 2001b; Hutchings *et al.*, 2007). For this reasoning, higher nematode fecal egg counts in Angora goats which are mainly grazers than the Saanen goats which are mainly browsers have been reported (Hoste *et al.*, 2001b).

Attwood (2001) in a study on the epidemiology and phylogeography of helminthosis made an explanation on the differences in helminth distribution and infection among animals; as helminths are multicellular organisms with a characteristic sexual reproduction, there are genetic variations among the helminth types. He asserted that this genetic make-up influences host range, pathogenicity and patency of the parasite.

CHAPTER THREE

MATERIALS AND METHODS

1 Study site

The study was carried out at the National Semi-Arid Resources Research Institute (NaSARRI). The Institute is located in Serere district in eastern Uganda. The site lies at longitude 33° 40'E and latitude 01° 40N. It is located at an altitude of 1140 m above sea level, and has got an average rainfall of 1350 mm ranging from 1000 to 1500 mm. The temperature ranges from 22 to 30°C. The climatic conditions produce two wet and two dry seasons. The long wet season occurs between April and June and the short wet season between October and November, while the long dry season occurs between December and March and the short dry season between July and September.

The study site was preferred because it was a Research Station with all the common breeds of goats in Uganda readily available, and whose pure parent stock was used for research purposes. Livestock graze on natural pastures and on fields after crop harvest. The natural vegetation is characteristic of scattered tree grassland savannah with a mixture of grass, trees and various shrub species. The predominant natural pastures include *Imperata cylindrical*, *Hypparrhenia* species, *Cynodon* species, *Panicum* species and *Cymbopogon afronodus*.

2 Experimental animals

The animals used in this study were crosses of Small East African and the Boer, and the indigenous Mubende and Small East African (SEA) goat breeds (Figure 1). The Boer crosses and

Mubende goats were chosen purposively from flocks reared at Serere Research Station for breeding purposes. The Small East African goats were purchased from local farmers in Serere. The breeds were categorized according to physical characteristics as described by Mason & Maule (1960); NARO-ILRI-SRNET (1995) and Oluka (1999). The goats were of both sexes and aged between three and seven months at the start of the experiment. The age of the individual goats was determined from the farm management records and also by use of dentition criteria (Swize, 2000). Each goat was identified using a numbered ear tag.



A: Mubende (*note the pure black color*)



B: Boer cross (*note the white color & a brown head and neck*)



C: Small East African (*note the intermix of white and speckled brown coat color*)

Figure 1: Photographs showing Mubende, Boer cross and Small East African goats

Care of experimental animals

The study goats, together with other goats on the farm were kept under an extensive system of management, whereby, the animals were grazed within the same area on natural pasture and low lands during the day (from 9:00 am to 4:00 pm daily). At night, the goats were kept in houses of plastered brick with concrete floor and mesh ventilated windows. The purchased goats were given a period of four weeks to acclimatize before commencement of the experiment.

At the start of the acclimatization period, it was realized that the small East African goats were infected with coccidiosis. All goats were therefore, treated four weeks prior to the experiment using amprolium soluble powder USP (Coccid[®]) at dosage of 80mg/Kg body weight. The goats were sprayed fortnightly using chlorofenvinphos 1000 GML (Supona extra[®]) for tick control. Water was provided *ad libitum*.

Experimental design

An experiment was set-up to compare GIN infections amongst Boer crosses, Small East African and Mubende goats (Table 1). Boer crosses and Mubende goats were chosen based on availability of those in the age group of three to seven months from a flock reared at the research institute. The number of Small East African goats used in the study was based on ease of buying them from farmers.

Four weeks prior to the experiment, all the goats were dewormed using albendazole 10% (Mebafas[®]) at a dose rate of 0.8 mg/Kg body weight. The treatment was meant to expel most of the worms so that the experiment could commence at a low and leveled level of nematode infection in the goats. After treatment, the goats were allowed to be naturally re-infected by grazing on the natural pastures. Blood and fecal samples were collected from individual goats at

er week intervals for 16 weeks between December, 2010 and April 2011. The period of four weeks is ideal because it represents the lifecycle of nematodes: from ingestion of infective larvae through development of egg laying adults to time of development from egg to infective larvae (Miller, 2000). Gastro-intestinal nematode prevalence, fecal egg counts (FEC) and differential third-stage larvae counts were determined from the fecal samples. Packed cell volume (PCV) and eosinophil counts were established from the blood samples. Simultaneously, body condition score (BCS), FAMACHA score and body weight gain of each goat were determined. Confounding effects were avoided by grazing the goats on the same pastures, housing them in similar structures and stocking densities, and by not sampling pregnant animals. Furthermore, laboratory tests indicated that of the goats had haemoparasites.

Table 1: Grouping of experimental goats used for determining gastro-intestinal nematode infections

Goat breed	Number of goats		
	Female	Male	Total
Local crosses	15	11	26
Small East African	0	11	11
Abendé	13	14	27
Total	28	36	64

Determination of sample size based on purpose and availability of the respective breeds in the age range 7 months. The researcher purchased 13 male and 15 SEA goats. However during the acclimatization period, 2 male and all the female goats were lost due to coccidiosis. Analysis of data was done by comparing parameters in goats of same sex among breeds.

3.5 Determination of worm burdens in goats

3.5.1 Collection and handling of fecal samples

Following prophylactic anthelmintic treatment of all goats on the farm, fecal samples were collected from the study goats at four weekly intervals for a period of 4 months. Using gloved fingers, about 10 grams of feces was obtained from the rectum of each goat and immediately placed in a plastic bag. The bag was tightened by tying as close to the fecal sample as possible to keep off air (Figure 2). Each sample was carefully labeled with the details of the individual goat for identification, and put in a cold box containing ice packs.

The samples were transported to the Veterinary Parasitology Laboratory, Makerere University within 12 hours for analysis. In the laboratory, each sample was split into three equal parts. The first part was used for nematode egg identification, the second for estimation of fecal egg counts (FEC) and the third incubated for larval (L₃) identification.



Figure 2: Photograph showing a goat fecal sample (arrow) in a plastic bag; Note how the bag was tied close to the sample to keep off air

2.2 Identification of nematode eggs

The simple test tube flotation method (Hansen and Perry, 1994) was used in the detection of nematode eggs from each of the samples. Identification of nematode eggs was done in accordance with the standard procedure described by Soulsby (1982).

2.3 Estimation of fecal egg counts (FEC)

Enumeration of fecal eggs was completed a day following collection of fecal samples. Fecal egg counts (FEC) were determined for each sample as number of eggs per gram (EPG) using a modified McMaster technique (MAFF, 1971) as described by Max *et al.* (2006). Sub samples of fecal suspension were examined under a compound microscope at 100 magnifications for both fields of McMaster counting chamber. The detection level of the McMaster method used was 100 eggs per gram.

Depending on the egg counts, nematode infections were categorized as light, moderate or heavy as described by Hansen & Perry (1994) (Table 2). The values for EPG were used as an indirect way of estimating total worm burden (Hansen & Perry, 1994).

Table 2: Interpretation of fecal egg counts and degree of infection in goats

Degree of infection	Fecal egg counts (EPG)
No infection	0
Light	50-800
Moderate	801-1200
Heavy	>1200

Adapted from Hansen and Perry (1994)

4 Larval identification in fecal samples

The positive fecal samples were bulked by goat breed and cultured for larval identification. The samples were incubated at 27° C for seven days. The emerging stage 3 (L₃) larvae were recovered using the Baermann technique (Hansen & Perry, 1994). The larvae were identified to genus level and counted under a compound microscope (at magnification x100) using morphological keys given by MAFF (1971) and van Wyk *et al.* (2004) (Appendix 1).

Determination of packed cell volume and eosinophil counts

Blood samples were collected on the same day as fecal samples. About 3 mls of whole blood were drawn from each goat by external jugular vein puncture using disposable syringes and 20-gauge needles. The blood was immediately transferred into vacutainers (Venosafe®) pre-gelatinized with ethylene diamine tetraacetic acid (EDTA) as an anticoagulant. The vacutainers were labeled with the goat identification details. The samples were transported in cool box filled with ice packs to the Central Diagnostic Laboratory at the College of Veterinary Medicine, Animal Resources and Bio security, Makerere University within 12 hours and analyzed for packed cell volume (PCV) and eosinophil counts. The PCV (%) and eosinophil counts (%) were determined using the micro-haematocrit and haemocytometer techniques, respectively, as described by Schalm *et al.* (1975).

Determination of body condition score

The body condition score was established by as described by AIGR (2000). This was done by visual examination of each goat from a distance of about one meter. The goats were then given scores ranging from one (very poor, emaciated) to five (very good, fat). The scoring was done in

the afternoon hours. This was to avoid the obscurity in the morning and evening hours when the animals have starved over night or on full stomach after grazing, respectively.

3.8 Estimation of anemia score

The anemia score was estimated by use of the FAMACHA[®] technique (Bath *et al.*, 2001; Kaplan & Miller, 2009). One person restrained the goat and pushed the lower eyelid downwards to expose the eye mucus membrane. A second person held the FAMACHA chart (Appendix 2) as close to the mucus membrane as possible. The technique classifies animals with infection into five categories according to eye mucus color, which corresponds to the level of anemia. Category number one is for animals with pink-red eye mucus membranes that are without infection. Category number five is for animals with extremely pale, almost white eye mucus membranes that are near death. The parasite load and fecal egg counts are correlated with a color eye chart (Bath *et al.*, 2001).

3.9 Estimation of body weight change

The body weight of the individual goats in kilograms was determined by means of a suspendable weighing scale. The goat was held in plastic bag which was hooked to the suspended weighing scale by means of two ropes. The weight changes were then established by subtracting the weight at that day from that of the previous four weeks. The weight of the plastic bag was taken into consideration when estimating the weight of the goats.

3.10 Statistical Analysis

Statistical analysis was performed using Predictive Analytics SoftWare (PASW[®] Statistics 18). Descriptive statistics using frequency procedures was used to determine the prevalence of gastro-intestinal nematodes. Chi-square (χ^2) was used to determine the statistical significance of association between categorical variables of prevalence, degree of infection and proportions of gastro-intestinal nematodes among different goat breeds.

Before analysis, data for fecal egg counts (FEC), packed cell volume (PCV), eosinophil count, body condition score (BCS), FAMACHA score and body weight gain have been ($\log(x+1)$) transformed to normalize their distribution. Analysis of variance (ANOVA) and independent samples T test were used to test differences in means of FEC, PCV, eosinophil count, BCS, FAMACHA score and body weight gain among goat breeds. Linear correlation was analyzed between FEC and PCV, FEC and FAMACHA scores, FEC and BCS, and PCV and FAMACHA scores. P-values of less than 0.05 were considered significant.

CHAPTER FOUR

RESULTS

4.1 Percentage of goats with gastro-intestinal nematodes across breeds

The percentage of goats with strongyle, *Strongyloides* and *Ascaris* nematodes in Boer crosses, Small East African and Mubende breeds was as shown in Table 3. For each of the breeds, strongyle nematodes were most prevalent, followed by *Ascaris*. The chi-square test indicated that there was no significant difference in the percentage of goats with strongyle ($\chi^2 = 2.534$, $p > 0.05$), *Strongyloides* ($\chi^2 = 0.748$, $p > 0.05$) and *Ascaris* ($\chi^2 = 1.59$, $p > 0.05$) nematodes between the breeds. Although not statistically significant, the proportion of Small East African goats (95.2%) infected with strongyle nematodes was highest in the three goat breeds and lowest for Mubende goats (86.3%).

Table 3: Percentage of goats with gastro-intestinal nematodes in Boer crosses, Small East African and Mubende breeds

Nematode type	Percentage $\pm$ SD			χ^2 -value	P-value
	Boer crosses (n=26)	Small East African (n=11)	Mubende (n=27)		
Strongyle	96 (89.7% $\pm$ 0.30)	40 (95.2% $\pm$ 0.20)	88 (86.3% $\pm$ 0.30)	2.534	0.282
<i>Strongyloides</i>	7 (6.5% $\pm$ 0.25)	2 (4.8% $\pm$ 0.20)	4 (3.9% $\pm$ 0.20)	0.748	0.688
<i>Ascaris</i>	25 (23.4% $\pm$ 0.42)	7 (16.7% $\pm$ 0.38)	27 (26.5% $\pm$ 0.44)	1.592	0.451

All p-values > 0.05, no significant difference. Samples from the respective number of goats were collected and examined four times at four week intervals.

4.2 Fecal egg counts in goats

4.2.1 Fecal egg counts in male goats of different breeds

No significant difference ($F = 0.462, P > 0.05$) was observed in fecal egg counts in male goats of Boer crosses, Small East African and Mubende goats (Table 4). Although not statistically significant, male goats of Boer crosses experienced the highest fecal egg counts (1147 EPG), and lowest for the Mubende breed (836 EPG). There was no significant variation in fecal egg counts between male goats of the Boer crosses and Small East African ($t = 0.921, p > 0.05$), as well as between male goats of Boer crosses and Mubende ($t = 0.756, p > 0.05$).

Table 4: Fecal egg counts in male goats of Boer crosses, Small East African and Mubende

Goat breed	Fecal egg counts (mean EPG $\pm$ Se)	Fecal egg counts (Log (x+1))	f/t-value	p-value
Boer crosses (n=11)	1147 (258.58)	2.62 (0.12)		
Small East African (n=11)	862 (169.61)	2.44 (0.15)	0.921 (t)	0.359
Mubende (n=14)	836 (110.47)	2.48 (0.14)	0.756 (t)	0.451
Overall breed effect			0.462 (f)	0.63

F-value from comparison of FEC of three goat breeds, $p > 0.05$ from ANOVA.
T-values from comparison of pairs of goat breeds; Boer crosses were used as the reference breed, $p > 0.05$ from two independent samples T test. Samples from the respective number of goats were collected and examined four times at four week intervals.

4.2.2 Fecal egg counts in female goats of different breeds

There was a significant difference ($t = 2.613$, $P < 0.05$) in fecal egg counts (FEC) between female goats of Boer crosses and Mubende (Table 5). The mean FEC from female goats of Boer crosses (551 EPG) was twice that of female goats of Mubende (283 EPG).

Table 5: Fecal egg counts in female goats of Boer crosses and Mubende

Goat breed	Number of goats examined	Fecal egg counts (mean EPG $\pm$ Se)	Fecal egg counts (log $x + 1$)	t-value	p-value
Boer crosses	15	551 (85.67)	2.33		
Mubende	13	283 (41.08)	1.79	2.613	0.01*

**: $p < 0.05$ from independent samples T test. No female goats for the Small East African breed were available. Samples from the respective number of goats collected and examined four times at four week intervals.*

4.2.3 Fecal egg counts between male and female goats

Fecal egg counts were higher in male goats than females, although the difference was only significant in Mubende breed ($p < 0.05$) (Table 6). The mean FEC in eggs per gram from male goats of Boer crosses (1147) was twice that of female goats (838). The mean FEC of male goats of Mubende breed (836 EPG) was three times that of female goats (283).

Table 6: Fecal egg counts between male and female goats of Boer crosses and Mubende

Goat breed	Number of goats examined	Fecal egg counts (Log (x + 1)) ± Se		t-value	p-value
		Male	Female		
Boer crosses	M (11), F (15)	2.62 (0.117)	2.33 (0.12)	1.738	0.085
Mubende	M (14), F (13)	2.48 (1.39)	1.79 (0.164)	3.208	0.002*

* $p < 0.05$, mean FEC were significantly different from independent samples T test.

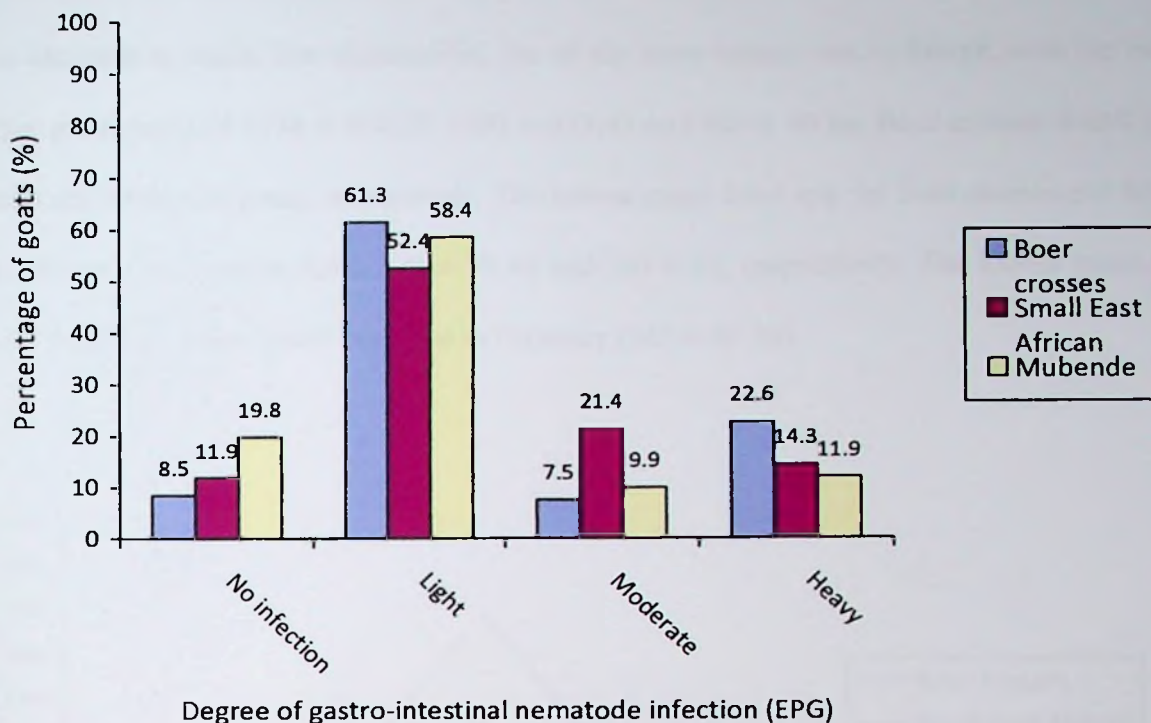
No female goats were available for the Small East African breed.

Samples from the respective number of goats collected and examined four times at four week intervals.

4.3 Degree of infection in goat breeds

A statistically significant difference ($\chi^2 = 14.606$, $p < 0.05$) in degree of infection (EPG) was observed across different breeds of goats studied. The Mubende goats had the highest percentage ($19.8\% \pm 0.87$) of goats with no infection while Boer crosses had the lowest percentage ($8.5\% \pm 0.94$) (Figure 3). In all the breeds, 50-60% of the goats had light infection, i.e. $61\% \pm 0.94$, $52\% \pm 0.88$, and $58.4\% \pm 0.87$ for Boer crosses, Small East African and Mubende goats, respectively.

There was no significant difference ($\chi^2 = 5.025$, $p > 0.05$) in the percentage of goats with heavy degree of infection in the three breeds. The Boer crosses had the highest percentage ($22.6\% \pm 0.94$) of goats with heavy degree of gastro-intestinal nematode infections while Mubende goats had the lowest percentage ($11.9\% \pm 0.87$). There was a significant difference in the proportions of goats with heavy degree of infection between Boer crosses and Mubende ($\chi^2 = 4.19$, $p < 0.05$), but not between Boer crosses and Small East African.



No infection; 0 (EPG), Light; 50-800 (EPG), Moderate; 801-1200 (EPG), Heavy; >1200 (EPG).

N = 26 (Boer crosses), 11 (Small East African) and 27 (Mubende) during study period. Samples from the respective number of goats collected and examined four times at four week intervals.

Figure 3: Percentage of goats with various degrees of gastro-intestinal nematode infection in Boer crosses, Small East African and Mubende

4.4 Changes in fecal egg counts during the study period

The monthly measurements of fecal egg counts (FEC) among Boer crosses, Small East African and Mubende goats were as shown in Figure 4. There was a significant difference in monthly fecal egg counts (FEC) for Boer crosses ($F = 4.08$, $p < 0.05$) and for Mubende goats ($F = 3.51$, $p < 0.05$) but not for Small East African goats ($F = 0.61$, $p > 0.05$).

Generally, there was a decrease in the FEC from January to February, an increase in March and a decrease in April. The highest FEC for all the three breeds was in March, with the mean egg per gram (epg) of 1574 ± 464.27 , 1091 ± 313.47 and 889 ± 46 for Boer crosses, Small East African and Mubende goats, respectively. The lowest mean fecal epg for Boer crosses and Small East African goats was in April, 471 ± 91.49 and 509 ± 91 , respectively. The lowest mean epg was for Mubende goats which occurred in February (385 ± 80.32).

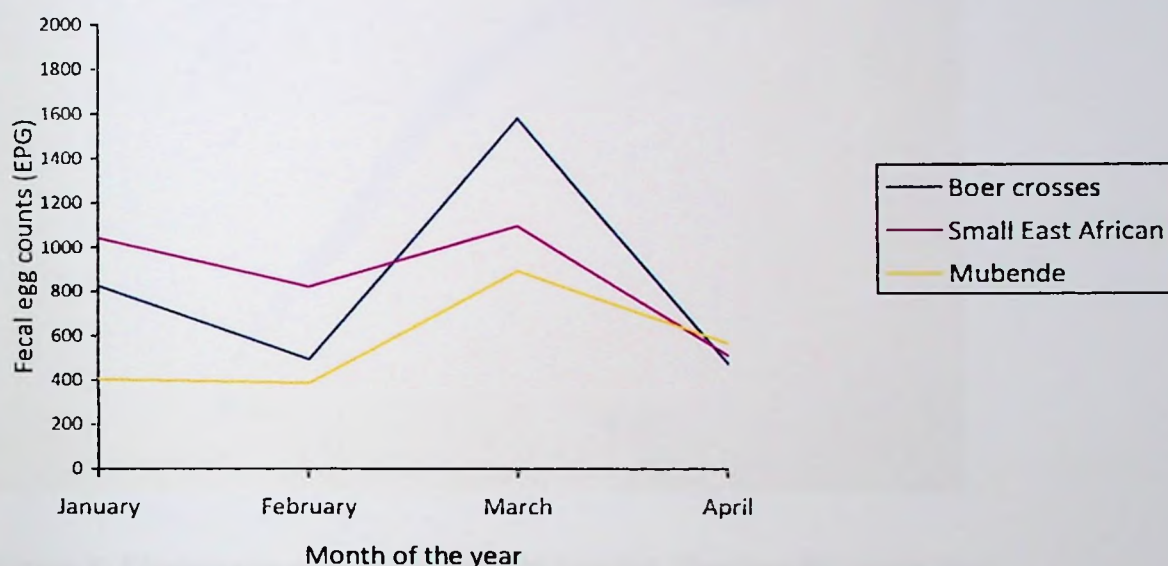


Figure 4: Changes in fecal egg counts in Boer crosses, Small East African and Mubende goats during the study period

4.5 Proportions (%) of gastro-intestinal nematode genera in different goat breeds

Haemonchus (Figure 5) accounted for the highest proportion of nematodes in each of the three goat breeds. As shown in Figure 6, the proportion of *Haemonchus* was highest in Boer crosses (96.85%), followed by the Mubende (72%) and lowest in the Small East African goats

(56.4%). There was a significant difference ($\chi^2 = 44.48$, $p < 0.05$) in proportions of *Haemonchus* among the three goat breeds. *Trichostrongylus* (30%) and *Oesophagostomum* (15.8% and 1.43%) constituted the second highest proportions of worm burdens in Small East African, Mubende and Boer crosses, respectively.



Figure 5: Photograph showing a recently hatched *Haemonchus* larva (L₃)

(Magnification 100x): note the tail of sheath of medium length tapering to a point (arrow)

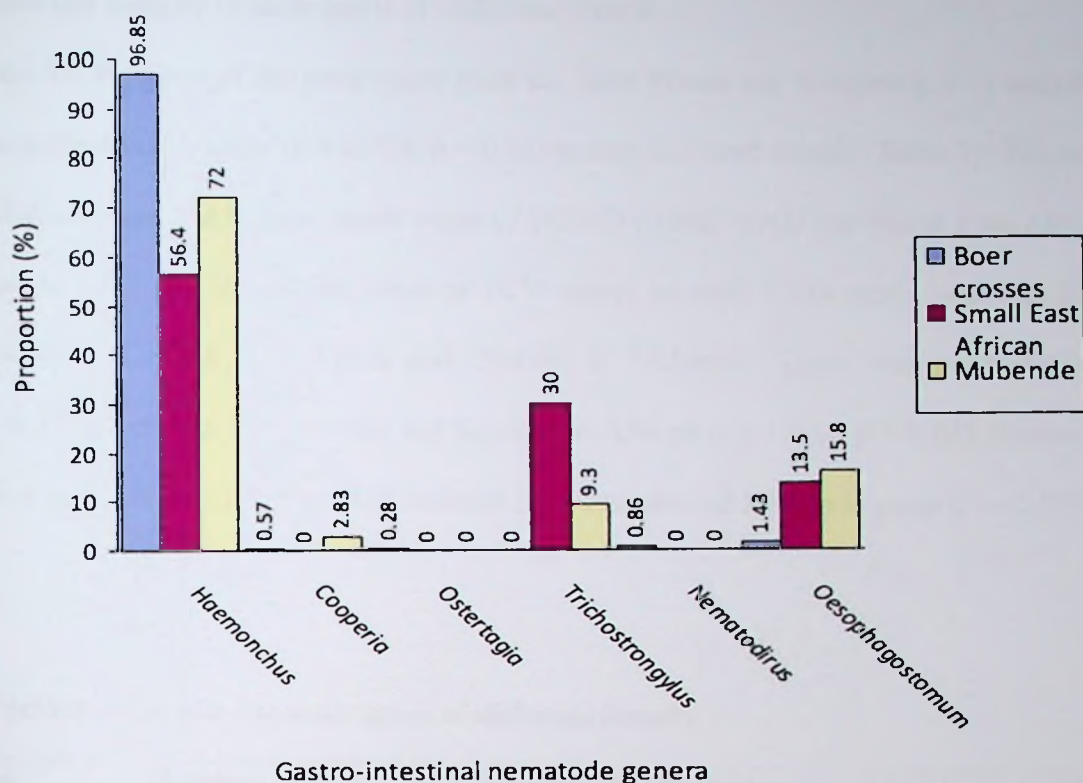


Figure 6: Proportions (%) of nematode genera in Boer crosses, Small East African and Mubende goats

Only *Haemonchus* and *Oesophagostomum* were present in all goat breeds. No *Cooperia* was seen in Small East African goats, and no *Trichostrongylus* in Boer crosses. *Ostertagia* and *Nematodirus* nematodes were only found in Boer crosses.

4.6 Packed cell volume in goats

4.6.1 Packed cell volume in male goats of different breeds

When the PCV values of the male goats from the three breeds are compared, it is seen that there is a significant difference ($F = 6.733$, $p < 0.05$) among the three breeds (Table 7). The male goats of Mubende had the highest mean value of PCV (33.16%) while the Small East African had the lowest value (29.25%). The range of PCV values in male goats was 12-42% in Boer crosses, 14-36% in Small East Africa and 25-49% in Mubende. There was no significant difference in PCV between Boer crosses and Small East African ($t = 1.021$, $p > 0.05$). However, there was a significant difference in PCV between Boer crosses and Mubende goats ($t = -2.539$, $p < 0.05$).

Table 7: Packed cell volume in male goats of different breeds

Goat breed	Number of goats examined**	PCV (mean% $\pm$ SD)	PCV (Log (x+1)) $\pm$ SD	F/t-value	p-value
Boer crosses	45	30.67 $\pm$ 5.42	1.49 $\pm$ 0.086		
Small East African	36	29.25 $\pm$ 4.89	1.47 $\pm$ 0.079	1.021 (t)	0.311
Mubende	49	33.16 $\pm$ 4.00	1.53 $\pm$ 0.051	-2.539 (t)	0.013*
Overall breed effect				6.733 (F)	0.002*

*: $p < 0.05$, PCV values were significantly different.

T-values from independent samples test of two goat breeds; Boer crosses were used as reference breed.

F-value from ANOVA test of all three breeds.

**Represents number of male goats whose PCV was determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.

4.6.2 Packed cell volume in female goats of different breeds

There was a significant difference ($t = -3.97$, $p < 0.05$) in packed cell volume values between female goats of Boer crosses and female goats of Mubende (Table 8). The Mubende goats had a higher mean PCV value (35.3%) than Boer crosses (31.17%). The range of PCV values in female goats was 16-40% in Boer crosses and 19-38% in Mubende.

Table 8: Packed cell volume in female goats of Boer crosses and Mubende

Goat breed	Number of goats examined**	PCV (mean% $\pm$ SD)	PCV (Log (x + 1)) $\pm$ SD	t-value	p-value
Boer crosses	52	31.17 $\pm$ 5.22	1.5 $\pm$ 0.08		
Mubende	46	35.30 $\pm$ 4.28	1.56 $\pm$ 0.057	-3.97	<0.0001*

*: $p < 0.05$, PCV values were significantly different from independent samples T test.

No female goats available for the Small East African breed.

**Represents number of female goats whose PCV was determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.

4.7 Eosinophil counts in goats

4.7.1 Eosinophil counts in male goats of different breeds

There was a significant difference ($F = 4.094$, $p < 0.05$) in eosinophil counts when male goats from different breeds were compared (Table 9). The male goats of Small East African goats had the lowest eosinophil counts (2.14%), while male goats of Boer crosses had the highest mean eosinophil counts (3.89%). There was a significant difference in eosinophil counts between male goats of Boer crosses and Small East African ($t = 2.413$, $p < 0.05$), but not between male goats of Boer crosses and Mubende ($t = 0.074$, $p > 0.05$).

Table 9: Eosinophil counts in male goats of Boer crosses, Small East African and Mubende

Goat breed	Number of goats examined**	Eosinophil counts (mean % $\pm$ SD)	Eosinophil counts (Log (x + 1)) $\pm$ SD	F/t-value	p-value
Boer crosses	45	3.89 $\pm$ 3.56	0.57 $\pm$ 0.35		
Small East African	36	2.14 $\pm$ 2.30	0.38 $\pm$ 0.32	2.413 (t)	0.018*
Mubende	49	3.78 $\pm$ 3.52	0.57 $\pm$ 0.32	0.074 (t)	0.942
Overall breed effect				4.094 (F)	0.019*

*: $p < 0.05$, eosinophil counts were significantly different.
T-values from independent samples test of two goat breeds; Boer crosses were used as reference breed.
F-value from ANOVA test of all three breeds.
**Represents number of male goats whose eosinophil count was determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.

4.7.2 Eosinophil counts in female goats of different breeds

Table 10 shows that there was no significant difference ($t = 1.322$, $p > 0.05$) in eosinophil counts between female goats of Boer crosses and female goats of Mubende. The eosinophil counts were higher in female goats of Boer crosses (5.48%) than those of Mubende (4.64%).

Table 10: Eosinophil counts in female goats of Boer crosses and Mubende

Goat breed	Number of goats examined*	Eosinophil counts (mean % $\pm$ SD)	Eosinophil counts (Log (x + 1)) $\pm$ SD	t-value	p-value
Boer crosses	52	5.48 $\pm$ 4.10	0.707 $\pm$ 0.33		
Mubende	47	4.64 $\pm$ 4.05	0.614 $\pm$ 0.379	1.322	0.189

$p > 0.05$, eosinophil counts were not significantly different from independent samples T test.
No female goats available for the Small East African breed.
*Represents number of female goats whose eosinophil count was determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.

4.8 Body condition scores in goats

4.8.1 Body condition scores in male goats of different breeds

Body condition scores in male goats of different breeds varied significantly ($F = 3.17$, $p < 0.05$) (Table 11). Males goats of Mubende had the highest body condition score (3.21), while the male goats of Small East African had the lowest BCS score (2.98). There no significant difference in body condition scores between male goats of Boer crosses and Small East African ($t = 0.95$, $p > 0.05$), and between male goats of Boer crosses and Mubende ($t = -1.623$, $p > 0.05$).

Table 11: Body condition scores in male goats of Boer crosses, Small East African and Mubende

Breed	Number of goats examined**	Body condition score (mean $\pm$ SD)	Body condition score (Log (x + 1))	F/t-value	p-value
Boer crosses	51	3.06 $\pm$ 0.42	0.606 $\pm$ 0.045		
Small East African	44	2.98 $\pm$ 0.46	0.597 $\pm$ 0.052	0.95 (t)	0.344
Mubende	56	3.21 $\pm$ 0.53	0.621 $\pm$ 0.053	-1.623 (t)	0.108
Overall breed effect				3.17 (F)	0.045*

*: $p < 0.05$, body condition scores were significantly different.

T-values from independent samples test of two goat breeds; Boer crosses were used as reference breed.

F-value from ANOVA test of all three breeds.

**Represents number of male goats whose body condition score was determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.

4.8.2 Body condition scores in female goats of different breeds

No significant difference ($t = -0.321$, $p > 0.05$) in body condition scores of female goats of Boer crosses and Mubende was observed (Table 12). There was slight difference (0.02) in body condition scores between the two breeds.

Table 12: Body condition scores in female goats of Boer crosses and Mubende

Goat breed	Number of goats examined*	Body condition score (mean $\pm$ SD)	Body condition score	t-value	p-value
Boer crosses	60	3.23 $\pm$ 0.53	0.623 $\pm$ 0.055		
Mubende	52	3.25 $\pm$ 0.44	0.626 $\pm$ 0.042	-0.321	0.749

$p > 0.05$, body condition scores were not significantly different from independent samples T test.

No female goats available for the Small East African breed.

****Represents number of female goats whose body condition score was determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.*

4.9 Anemia scores in goats

4.9.1 Anemia scores in male goats of different breeds

As shown in Table 13, there was a slight difference (0.09) in anemia scores in male goats of Boer crosses, Small East African and Mubende breeds. The difference was not significant ($F = 0.338$, $p > 0.05$). Similarly, there was no significant difference in anemia scores between goat breeds.

Table 13: Anemia scores in male goats of Boer crosses, Small East African and Mubende

Goat breed	Number of goats examined*	Anemia score (mean $\pm$ SD)	Anemia score (Log (x+1))	F/t-value	p-value
Boer crosses	53	3.17 $\pm$ 0.61	0.62 $\pm$ 0.066		
Small East African	44	3.09 $\pm$ 0.68	0.606 $\pm$ 0.072	0.666 (t)	0.507
Mubende	56	3.18 $\pm$ 0.61	0.616 $\pm$ 0.065	-0.081 (t)	0.935
Overall breed effect				0.338 (F)	0.714

P values > 0.05, anemia scores were not significantly different.

T-values from independent samples test of two goat breeds; Boer crosses were used as reference breed.

F-value from ANOVA test of all three breeds.

***Represents number of male goats whose FAMACHA scores were determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.*

4.9.2 Anemia scores in female goats of different breeds

The female goats of Boer crosses had a slightly higher anemia score (3.02) than the Mubende goats (2.92) (Table 14). The difference was not significant ($t = 1.044$, $p > 0.05$).

Table 14: Anemia scores in female goats of Boer crosses and Mubende

Goat breed	Number of goats*	Anemia score (mean $\pm$ SD)	Anemia score (Log (x + 1)) $\pm$ SD	t-value	p-value
Boer crosses	60	3.02 $\pm$ 0.47	0.6 $\pm$ 0.052		
Mubende	52	2.92 $\pm$ 0.48	0.59 $\pm$ 0.055	1.044	0.299

p > 0.05, anemia scores were not significantly different from independent samples T test. No female goats available for the Small East African breed.

**Represents number of female goats whose FAMACHA scores were determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.*

4.10 Body weight changes in goats

4.10.1 Body weight changes in male goats of different breeds

Body weight changes in male goats of different breeds were not significantly different ($F = 0.657, p > 0.05$) as shown in Table 15. Although not statistically significant, the male goats of Boer crosses had the highest weight change (1.20 kg), while the male goats of Small East African had the lowest weight change (0.86 kg). There was no significant difference in body weight change between breeds of goats.

Table 15: Body weight changes in male goats of Boer crosses, Small East African and Mubende

Breed	Number of goats examined*	Body weight change (mean kg $\pm$ SD)	F/t-value	p-value
Boer crosses	44	1.20 $\pm$ 1.50		
Small East African	42	0.86 $\pm$ 1.50	1.076 (t)	0.285
Mubende	60	0.97 $\pm$ 1.38	0.837 (t)	0.404
Overall breed effect			0.657 (F)	0.52

P values > 0.05, body weight changes were not significantly different.
T-values from independent samples test of two goat breeds; Boer crosses were used as reference breed.
F-value from ANOVA test of all three breeds.
**Represents number of male goats whose body weight change was determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.*

4.10.2 Body weight changes in female goats of different breeds

Table 16 shows that there was no significant difference ($t=1.903, p>0.05$) in body weight changes between female goats of Boer crosses and female goats of Mubende. However, the mean

body weight change in female goats of Boer crosses (1.5 kg) was higher than in female goats of Mubende (1.1 kg).

Table 16: Body weight changes in female goats of Boer crosses and Mubende

Breed	Number of goats examined*	Body weight change (mean kg ± SD)	t-value	p-value
Boer crosses	60	1.50 ± 1.28		
Mubende	60	1.10 ± 1.00	1.903	0.059

p>0.05 from independent samples T tests, body weight changes were not significant difference. No female goats were available for the Small East African breed.

**Represents number of female goats whose body weight change was determined in 16 weeks taking into consideration repeated measurements at 4 week intervals.*

4.11 Correlations between fecal egg counts, packed cell volume, FAMACHA score and body condition score in the goat breeds

Pearson correlation coefficients indicated that FEC and PCV were negatively correlated in Boer crosses and Mubende goats, but positive in Small East African goats (Table 17). FEC and FAMACHA eye scores were positively correlated in all the three goat breeds, and the correlation was significant ($r = 0.28$, $p < 0.05$) in Boer crosses. The goats showed a significant negative correlation between FEC and BCS in Mubende goats ($r = -0.23$, $p < 0.05$), but positive in Boer crosses and Small East African. Packed cell volume and FAMACHA scores showed a significant negative correlation in Boer crosses ($r = -0.27$, $p < 0.05$) and Mubende goats ($r = -0.33$, $p < 0.05$), but positive and not significant in Small East African goats.

Table 17: Correlations between fecal egg counts, packed cell volume, FAMACHA score, and body condition score in Boer crosses, Small East African and Mubende goats

Goat breed	Correlation coefficients (r)			
	Fecal egg count and packed cell volume	Fecal egg count and FAMACHA score	Fecal egg count and body condition score	Packed cell volume and FAMACHA score
Boer crosses	-0.106	0.28 ^a	0.07	-0.27 ^a
Small East African	0.016	0.12	0.09	0.1
Mubende	-0.09	0.07	-0.23 ^a	-0.33 ^a

Correlations coefficients with superscript, a, are significant ($p \leq 0.05$)

CHAPTER FIVE

DISCUSSION

The most prevalent nematodes encountered in all goat breeds were strongyles. This was consistent with a report by Regassa *et al.* (2006). Gastro-intestinal strongyle infection remains one of the main constraints to goat production (Mandonnet *et al.*, 2003; Rinaldi *et al.*, 2007). Other gastro-intestinal nematodes identified were *Strongyloides* and *Ascaris*. A similar observation had been made by Kumba *et al.* (2003) that *Strongyloides* and *Ascaris* nematodes were present in goats in addition to strongyles. The presence of ascarid eggs could be of spurious occurrence with a possible ingestion of eggs deposited by other animal species. There was no significant difference in prevalence of strongyle nematodes among goat breeds. The goats were grazed within same area and management system. They therefore had equal chances of exposure to infection with infective larvae of nematodes.

No significant difference was observed when FEC in male goats from different breeds were compared, although Boer crosses had the highest FEC, followed by Small East African and lowest in Mubende. A significant difference in fecal egg counts (FEC) was recorded when female goats of different breeds were compared; with female goats of Boer crosses having higher FEC than females of Mubende. Chauhan *et al.* (2003) reported no significant difference in fecal egg counts between Barbari and Jamunapari kids to natural infection with gastrointestinal nematodes in India. In the Thailand and the Philippines, indigenous goats have been found to be more resistant to internal parasites as compared with the Nubian derived breeds and crosses (Baker & Gray, 2004). The Nigerian West African Dwarf goat, in contrast to other goats in West Africa was seen to be more effective in the control/regulation of *Haemonchus contortus*

infections both in laboratory and to naturally acquired infections (Chiejina & Behnke, 2011). Rout *et al.* (2011) reported strong genetic correlations between fecal egg counts at various age stages of two Indian goat breeds. Baker *et al.* (1998 and 2001) reported higher resistance of Small East African goats than Galla goats to gastro-intestinal nematode infections.

In the present study, the indigenous goats had lower fecal egg counts than Boer crosses. This is because they could be adapted to the local production circumstances (Lebbie, 2004) which helped them to develop resistance due to frequent challenge.

However, Chenyambuga *et al.* (2009) reported higher fecal egg counts in local goats than Boer crosses. This was because the goat breeds were reared under different management systems; the system for the local goats exposing them to higher infection rates than the Boer. However, in the present study there was no influence of management system on worm burdens in different goat breeds because they were all kept under the same management system (extensive) and grazing area.

The resistance to helminth infections involves initiation and maintenance of responses provoked in the host to suppress and /or eliminate parasite burdens (Woolaston & Baker, 1996). The mechanism for the differences in fecal egg counts seems to involve genes for the major histocompatibility complex of the immune system as identified in sheep (Benavides *et al.*, 2002).

Male goats had higher fecal egg counts than females. Other researchers have also reported higher fecal egg counts in male than female goats (Chauhan *et al.*, 2003; Gauly *et al.*, 2006). Testosterone seems to play a role in resistance in male animals, since the levels of the hormone have been found to be significantly positively correlated with worm burdens (Gauly *et al.*, 2006). However, these observations disagree with the findings of Regassa *et al.* (2006) and Raza *et al.* (2009) who reported that the helminth infection rate was higher in female hosts compared with

males. Higher infection observed in female animals is due to their reproductive events and insufficient/unbalanced diet against higher needs which lower resistance (Raza *et al.*, 2009). However, in the present study, the goats had not gone through the reproductive phase. It therefore seems that before goats reach maturity, the females are usually more resistant to helminth parasites than the males. This means that female goats at this stage would require less treatment with anthelmintics than males. In contrast, Qamar *et al.* (2009) reported no significant difference in gastro-intestinal nematode infection between male and female animals.

A significant variation was observed when degrees of gastro-intestinal nematode infections were compared among goat breeds. Boer crosses had the highest proportion of goats with heavy infection, followed by Small East African and lowest in Mubende goats. The Mubende goats had the highest proportion of goats with light and no infection. This indicates that Mubende goats were more resistant to gastro-intestinal nematode infections as compared to Small East African and Boer crosses.

The month of the study period significantly influenced fecal egg counts (FEC) for Boer crosses and Mubende goats. The study revealed a decrease in fecal egg counts from January to February, an increase in March and a decrease in April. Costa *et al.* (2000) also reported a variation in fecal egg counts between weeks of exposure in goat breeds. The decrease in fecal egg counts from January to February was because the goats were growing in that period. As animals grow, they acquire immunity to parasites through frequent challenge and expel the ingested parasite before they establish infection (Shah-Fischer and Say., 1989; Silverman & Patterson, 1960). Fecal egg counts increased in March because of the possibility of maturation of hypobiotic larvae (L₄) which usually occurs towards the end of dry seasons (Ng'ang'a *et al.*,

2004). The month of March represents the end of the dry season in the study area. Therefore, strategic deworming would be recommended to control of helminths during that period.

The proportion of worm genera in fecal samples indicated that *Haemonchus* comprised the largest percentage, followed by *Trichostrongylus*, *Oesophagostomum*, *Cooperia*, *Nematodirus* and *Ostertagia*. This concurs with previous findings that the most important and widely prevalent nematodes of goats are *Haemonchus*, *Trichostrongylus* and *Oesophagostomum* (Sioned, 2007; Chenyambuga *et al.*, 2009; Lapenga & Rubaire, 2009; Kumsa *et al.*, 2011). *Haemonchus* is the most economically important gastro-intestinal nematode of goats in the different parts of the world (Perry *et al.*, 2002; Mortensen *et al.*, 2003). *Haemonchus* species has been found to account for 47% (Chenyambuga *et al.*, 2009), 76% (Lapenga & Rubaire, 2009) and more than 95% (Costa *et al.*, 2000) of nematodes counts. However, in Nigeria the most prevalent genera of nematodes were *Strongyloides* (Nwosu *et al.*, 2007). Therefore, it seemed that *Haemonchus* was the most predominant nematode in Uganda, while *Strongyloides* was the most predominant in Nigeria. The high egg producing capacity of *Haemonchus* gave it an advantage over other helminths in that it can easily contaminate grazing areas and may survive in small ruminant hosts through frequent and rapid infestations (Hansen & Perry, 1994; Waller *et al.*, 2004). *Haemonchus* was also very adaptable and could survive on pasture for a long time under adverse weather conditions (Waller *et al.*, 2004). Therefore, efforts should be made to keep goats away from heavily contaminated pastures, until a period when the number of infective larvae has reduced.

Haemonchus species accounted for the highest proportion of nematode species in each of the three goat breeds, and the proportions varied significantly among goat breeds. Boer crosses had the highest proportion, followed by Mubende and Small East African goats. Boer goats are

exotic to Uganda, and therefore, less resistant to nematode infections than indigenous goats (Baker and Gray, 2004).

Only *Haemonchus* and *Oesophagostomum* were present in all goat breeds. *Ostertagia* and *Nematodirus* were observed only in Boer crosses. There was no *Cooperia* in Small East African goats and no *Trichostrongylus* in Boer crosses. Attwood (2001) asserted that since helminths are multicellular organisms with a characteristic sexual reproduction, there are genetic variations among helminth types. This genetic make-up influences host range, pathogenicity and patency of the parasite. This could explain differences in helminth distribution and infection among goats. The diversity of helminth parasites has also been found to be affected by agro ecological zones and farms of origin (Magona *et al.*, 2002). The three goat breeds have originated from different origins (Kiwuwa, 1992; NARO-ILRI-SRNET, 1995). This could affect the distribution of nematode species in goats. It could probably imply goat breeds have got varying degrees of resistance to different genera of gastro-intestinal nematodes.

The overall mean PCV values of Boer crosses (30.9%), Small East African (29.25%) and Mubende (34.2%) were within the normal range of 22-38% (Schalm *et al.*, 1975). Other researchers have also reported normal PCV values ranging from 23 to 25% (Piccione *et al.*, 2010) and 28 to 32% (Chiejina *et al.*, 2010). This probably reflected that the highest percentage of goats in the present study had light gastro-intestinal nematode infections. It had been shown that as worm infestation increases, the PCV values decrease (Chiejina *et al.*, 2010).

PCV values differed significantly ($p < 0.05$) among goat breeds. These observations agreed with those of Baker *et al.* (2001) and Costa *et al.* (2000) who reported significant variation of PCV among goat breeds. However, other researchers had reported no significant breed differences in PCV between goat breeds (Shavulimo, 1989; Chauhan *et al.*, 2003; Makun *et al.*,

2008). In the present study, Mubende goats had the highest value for PCV, followed by Boer crosses and lowest in Small East African. This was in accordance with the observation made for FEC that goats of Mubende breed had the lowest degree of worm infection compared to that in Boer crosses and Small East African. Therefore, Mubende goats were probably more resilient compared to Boer crosses and Small East African. The values of PCV could be an indicator of resilience when gastro-intestinal nematode infection was predominantly *Haemonchus* (Baker *et al.*, 2001); which was the case in this study. Results by Chenyambuga *et al.* (2009) showed that Boer crosses had higher PCV values than local goats in Tanzania. This was due to the difference in management systems of the respective goat breeds.

The male goats of Small East African had lower PCV values than male goats of Boer crosses, despite the fact that Boer crosses had higher FEC than Small East African. This means that Small East African goats showed the least resilience/tolerance to gastro-intestinal nematode infections. This is because of their low genetic potential (Ssewanyana *et al.*, 2004) which hinders them to remain as productive as other breeds in the face of the same parasite challenge.

The present study revealed a significant difference in eosinophil counts among goat breeds. The Boer crosses had the highest eosinophil counts, followed by Mubende and lowest in Small East African. This could be explained by the fact that Boer crosses goats had the highest fecal egg counts when male goats of breeds were compared. Eosinophils are used by the body to protect against parasites, and therefore, higher worm burdens are associated with higher eosinophilic counts (Mandonnet *et al.*, 2006). The Small East African goats had a lower eosinophil counts than Mubende goats, despite having higher worm burdens. This could be due to the breed differences in hematological parameters of goats that have been reported by other researchers (Tambuwal *et al.*, 2002; Daramola *et al.*, 2005). The eosinophil counts in all goats

were within normal range of 1-8% (Anon., 2009) for goats. This was a reflection of the fact that the highest percentage of study goats had light degree of gastro-intestinal nematode infections as compared to those with moderate and heavy degree of infection.

Body condition scores among Boer crosses, Small East African and Mubende goats significantly varied. The Mubende goats had the highest body condition score, followed by the Boer crosses, and lowest in Small East African goats. Helminthosis is known to cause a reduction in body condition score (Lapenga & Rubaire-Akiiki, 2009). Therefore, lower body condition scores are expected in animals with higher nematode fecal egg counts. This explained higher body condition score in Mubende goats which had the lowest fecal egg counts. This inverse relationship was due to a reduction in feed in take (Knox & Steel, 1999), reduced efficiency of feed utilization (Coop and Holmes, 1996) and an induced protein deficiency (Yu *et al.*, 2000; Sykes & Coop, 2001) in animals with higher fecal egg counts.

When body condition scores in male goats were compared, the Small East African had the lowest body condition score, despite having lower fecal egg counts than male goats of Boer crosses. Similarly, female goats of Boer crosses had higher fecal egg counts than female goats of Mubende, and the difference was significant; and yet there was no significant difference in the body condition score between the two breeds. This could have an implication on the performance of the goat breeds in the absence of worm infestation; the Boer goats would perform even much better than the indigenous breeds.

There was no significant difference in anemia scores among male goats of the breeds, and also among female goats of the breeds. This due to the fact that there was no significant difference in fecal egg counts among male goats of the breeds. However, there was a significant difference in fecal egg counts between female goats, with Boer crosses having higher fecal egg

counts than Mubende. This could explain why anemia score of female goats of Boer crosses was higher than that of Mubende, although it was not significant. It has been shown that as worm infestation increased, the level of anemia also increased (Kaplan *et al.*, 2004; Burke *et al.*, 2007).

The mean anemia scores for the three goat breeds were slightly above 3 on the 1-5 FAMACHA[®] score chart. This could be explained by the low proportion of goats with heavy degrees of gastro-intestinal nematode infection; while there was a positive correlation between fecal egg count and anemia score. *Haemonchus* was the main nematode identified from the coprocultures, and the anemia was determined by scoring the pallor of the ocular mucous membrane, an assay for evaluation of anemia caused by *Haemonchus* species (Vatta *et al.*, 2002). Fecal egg counts have been found to be correlated with the number of adult *Haemonchus contortus* in sheep (Le Jambre *et al.*, 1971, Cited by Kaplan *et al.*, 2004)

The body weight changes across goat breeds differed significantly. The weight gain was highest in Boer crosses, followed by Mubende and lowest in Small East African goats. A reduction in body weight gains as a result of high helminth levels has been reported (Lapenga & Rubaire-Akiiki, 2009). Therefore, as worm burdens increase, we expect a decrease in weight gains. However, this was not precisely seen in this study; the Boer crosses had higher weight gains than Small East African and Mubende goats, and yet they had higher fecal egg counts. Therefore, in the event that worms were absent, Boer crosses would even perform much better than seen in this study. Boer crosses goats have been found to have higher weight gains than other breeds (Cameron *et al.*, 2001; Ssewanyana *et al.*, 2004). The Mubende goats had higher weight gains than Small East African goats as expected; as worm burdens were lower in Mubende.

There was a negative correlation between FEC and PCV in Boer crosses and Mubende goats but positive in Small East African goats. Negative correlations between FEC and PCV have been reported by Vatta *et al.* (2002); Mandonnet *et al.* (2006); Sissay (2007); Chiejina *et al.* (2010) and Rout *et al.* (2011), suggesting that animals that contributed least to pasture contamination had high PCV. High worm burdens resulted in loss of blood (Waller *et al.*, 2004) and therefore a reduction in PCV. The positive correlation between FEC and PCV in Small East African goats was explained by the relatively low PCV values seen in the goats, which indicated low resilience in the Small East African goat.

Fecal egg counts and FAMACHA scores were positively correlated in this study. This was consistent with reports by Kaplan *et al.* (2004) and Scheurle *et al.* (2010) who reported a positive relationship between fecal egg counts and FAMACHA eye scores. *Haemonchus* was the main nematode identified in the fecal cultures of the goats; and it consumed blood which resulted in anemia (Waller *et al.*, 2004). Therefore, the level of anemia was expected to increase with worm burdens.

There was a significant agreement between lower haematocrit (PCV) values and paler mucous membranes in Boer crosses and Mubende goats. The results were in agreement with those of Vatta *et al.* (2002) and Sissay (2007). However, the correlation was positive in Small East African goats. PCV and fecal egg counts were correlated with *Haemonchus* burdens (Le Jambre *et al.*, 1971). Furthermore, PCV and worm burden were negatively correlated, while worm burdens were positively correlated with FAMACHA eye-color scores (Kaplan *et al.*, 2004; Scheurle *et al.*, 2010). Therefore, as PCV increased, anemia also decreased. This was what was seen in this study. The positive correlation between PCV and anemia in Small East African goats was due to the relatively low PCV values recorded.

FEC and BCS showed a significant negative correlation in Mubende goats, but positive for Boer crosses and SEA. Coop and Holmes (1996) observed reduced efficiency of feed utilization in animals with high fecal egg counts. Therefore, worm burdens in Mubende goats reduced feed utilization leading to a reduction in body condition score. The positive correlation between worm burdens and BCS in Boer crosses and Small East African goats was due to the characteristic slow and fast growth rates, respectively observed by Ssewanyana *et al.* (2004). This was due to a lower and higher feed conversion rates, respectively (Ssewanyana *et al.*, 2004). This could have an apparent effect of gastro-intestinal infections on body condition.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Results indicated that Mubende goats could be more resistant and resilient to gastro-intestinal nematode infections as indicated by their lowest mean fecal egg count, lowest proportion of goats with heavy infection, and highest mean PCV values. Although Boer crosses had the highest fecal egg counts, they gained more weight gain on average than Mubende and Small East African goats. Therefore, in the event that worms were absent, Boer crosses would even perform much better than seen in this study. Small East African goats were least resilient on basis of lowest packed cell volume, body condition score, body weight gain and eosinophil count.

6.2 Recommendations

Based on the results of the resistance and resilience, the Mubende breed would be more cost effective to keep by farmers as they would require less treatment and would remain more productive in case of parasitic challenge. However, farmers should continue adapting Boer goats, because results of this study show that they can still grow faster than the indigenous goats even in the face of parasitic challenge. However, farmers need to pay more attention to them in the control of gastro-intestinal nematodes since the results of the study show that they higher worm burdens than the indigenous goats.

More studies can be conducted to support the present one with a bigger number of goats of different age groups, and extending over two seasons (wet and dry) of the year.

CHAPTER SEVEN

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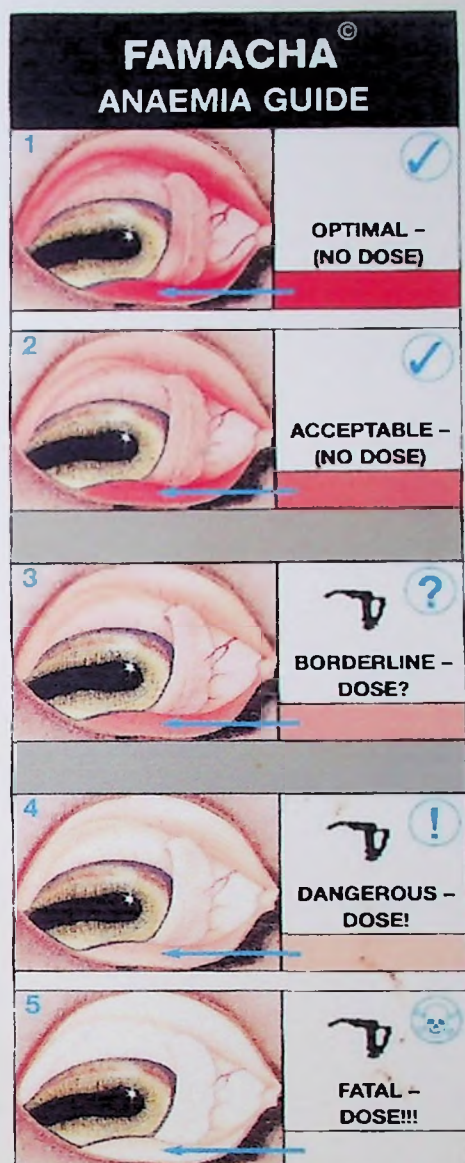
APPENDICES

Appendix I: Key for the identification of the third stage larvae of some gastro-intestinal nematodes of goats

1.	Oesophagus rhabditiform	Free living nematodes
	Oesophagus not rhabditiform	2
2.	Without sheath, oesophagus nearly half the length of the body	<i>Strongyloides</i>
	With sheath, oesophagus less than $\frac{1}{4}$ the length of the body	3
3.	Tail of sheath short or of medium length	4
	Tail of sheath very long	7
4.	Two refractile bodies or a bright transverse band visible between buccal cavity and oesophagus	<i>Cooperia</i>
	Refractile bodies or band absent	5
5.	Slender larva, tail of sheath of medium length tapering to a point and often kinked	<i>Haemonchus</i>
	Tail of sheath very short, conical	6
6.	Larva of medium size or large with distinct rounded tail	<i>Ostertagia</i>
	Small larva, tail bearing one or two tuberosities or indistinctly rounded	<i>Trichostrongylus</i>
7.	Very large larva, 8 gut cells, tail notched, bilobed or trilobed	<i>Nematodirus</i>
	Larva of medium size, 32 pentagonal gut cells, lumen of gut wavy	<i>Oesophagostomum</i>
	Larva of medium size, 32 square gut cells, lumen of gut straight	<i>Chabertia</i>
	Very small larva with 16 gut cells	<i>Bunostomum</i>

Adapted from: Ministry of Agriculture, Fisheries and Food (1971)

Appendix II: FAMACHA[®] eye color chart for detecting clinical anemia in goats



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