

**ON-FARM EVALUATION OF SELECTED INDIGENOUS LOCAL PLANTS FOR THE
CONTROL OF GASTROINTESTINAL NEMATODES BETWEEN DIFFERENT
BREEDS AND SEXES OF GOATS IN BOTSWANA**

MASTER OF SCIENCE IN ANIMAL SCIENCE

(ANIMAL BREEDING AND REPRODUCTION)

PERFECT LECHANI

MAY 2026

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A dissertation submitted to the Department of Animal Sciences in partial fulfilment of the
requirements for the degree of Master of Science (MSc) in Animal Science (Animal Breeding
and Reproduction)

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DECLARATION

I, Perfect Lechani hereby declare that this dissertation submitted by me to Botswana University of Agriculture and Natural Resources for the degree of Master of Science in Animal science (Animal Breeding and Reproduction) is my own independent work and has not been previously submitted by me at another University to obtain any qualification. All references and assistance rendered during the production of this work have been duly acknowledged.

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Preface

Internal parasites are a major hindrance to small ruminants' production and hampers global food security. Conventional drugs remain the primary measure in controlling internal parasites. However, drug resistance and unaffordability have led communal farmers to use other treatments such as locally available indigenous medicinal plants to control internal parasites as an alternative to pharmaceuticals. The study identified ethnobotanical practices used to combat internal parasites in goats in Ngamiland districts. The research project ethical clearance was granted by the Botswana University of Agriculture and Natural Resources Ethical Committee - Reference number: BUAN-AEC-2023-04.

The thesis is structured into 5 chapters

- Chapter 1-General Introduction which gives background information of the research undertaken, motivation and objectives of the study.
- Chapter 2 is a literature review which explores the different methods that have been used to control internal parasites.
- Chapters 3-Participatory inventory of plant-based ethnoveterinary medicine used to control internal parasites of goats in the Ngamiland region of Botswana. The focus of the chapter was to identify local plants used to control internal parasites. This chapter has been published in the South African Journal of Botany.
- Chapter 4-On-farm evaluation of local plants on internal parasites in different goat breeds of Botswana. The chapter looked at the anthelmintic efficacy of most used plants on different goat breeds and sexes. The abstract of this chapter has been accepted for presentation at the 56th SASAS congress, 07-09 July, Capetown, South Africa.
- Chapter 5- General discussion, conclusion and recommendations. The chapter presents the general summary of the findings, scientific contribution, recommendations, future work and limitations of the study.

GENERAL ABSTRACT

Two objectives were set for this study, first; to identify local plants used to control internal parasites in goats in the Ngamiland district of Botswana and secondly; to determine the anthelmintic efficacy of most commonly used plants to treat different breeds and sexes of goats. To carry out the first objective, a total of 120 communal farmers were randomly identified from six villages and interviewed using a structured questionnaire consisting of demographic parameters and ethnobotanical information. The qualitative data was analyzed using SPSS software and the most popular plants were identified using fidelity levels. Most of the respondents were secondary educated males of 50 to 60 years and relied on livestock for their livelihoods. About 13 local plant species from 11 families were used for the treatment of intestinal parasites in goats and the most popular was family Fabaceae (27.3%). *Terminalia sericea* and *Gnidia capitata* plant species recorded the highest fidelity levels, scoring 89.3% and 88.0%, respectively. The roots (76.9%) were the most frequently used plant part while decoction (46%) was popular in medicinal preparations. To carry out objective 2, a total of thirty goats from two breeds; 15 Tswana and 15 Boer goats, aged 18-21 months were used. The study was carried out at Ngocho farmstead, with the goats allowed to graze and browse naturally in the veld from morning to evening. The goats were randomly allocated to three treatment groups; Treatment 1 and 2 were given *Terminalia sericea* and *Gnidia capitata* extracts. The extracts were prepared by soaking in water (infusion) for 24 hours and were given to the goats orally, respectively, while Treatment 3 animals were given Ivermax 1% under the skin (subcutaneously). The animal sexes were allocated across all treatments with each treatment having 6 females and 4 males. The body condition score (BCS) and faecal egg count were performed at the beginning of the trial (day 0) and at days 30, 60 and 90. The data were analyzed using statistical analysis system (SAS). At day 0 the animals recorded a body condition score of 2 (emaciated) and improved post treatment to a score of 4 at day 60. Generally, faecal egg count decreased across the goat breeds and sexes after treatment with plant remedies. Tswana goats recorded an overall better reduction in faecal egg counts compared to Boer goats. At day 60, males had lower faecal egg count than females for both plant remedies with males treated with *Gnidia capitata* plant extract showing a better response. The studied plants contain some phytochemical compounds responsible for their anthelmintic properties. It is important to

incorporate these local plants in flock health management to improve animal productivity, food security and livelihoods.

Keywords: Breed, fidelity level, *Gnidia capitata*, plant efficacy, *Terminalia sericea*

DEDICATION

This work is dedicated to my dear family for support, encouragement and commitment.

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First and foremost, I would like to thank God for the strength to make this study a success.

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TABLE OF CONTENTS

Preface.....	i
General Abstract.....	ii
Dedication.....	iii
Acknowledgement.....	iv
Table of contents.....	v
List of Tables.....	ix
List of Figures.....	x
List of abbreviations.....	xi
CHAPTER 1.....	1
General Introduction.....	1
1.0 Background.....	1
1.1 Problem Statement.....	2
1.2 Justification.....	3
1.3 Main Objectives.....	3
1.3.1 Specific Objectives.....	3
1.4 Research Questions.....	4
1.5 References.....	5
CHAPTER 2.....	7
Literature Review.....	7
2.1 Introduction.....	7
2.2 Internal parasites and their effects on goats.....	7
2.3 Prevention and control measures of internal parasites in goats.....	9

2.3.1 Pasture management.....	9
2.3.2 Feeding management.....	10
2.3.2.1 Vitamin A.....	11
2.3.2.2 Zinc.....	11
2.3.2.3 Alternative forages.....	12
2.3.3 Breed effect.....	12
2.3.4 Biological control.....	13
2.3.5 Use of commercial drugs.....	13
2.4 Use of indigenous knowledge to combat internal parasites.....	14
2.5 Efficacy of local plants in controlling internal parasites in livestock.....	15
2.6 Conclusion.....	15
2.5 References.....	17
CHAPTER 3.....	24
Participatory inventory of plant based ethnoveterinary medicine used to control internal parasites of goats in the Ngamiland region of Botswana.....	24
3.1 Abstract.....	24
3.2 Introduction.....	25
3.3 Methodology.....	27
3.3.1 Ethical statement.....	27
3.3.2 Study site.....	27
3.3.3 Data collection.....	28
3.3.4 Data analysis.....	29
3.4 Results.....	29
3.4.1 Demographic data.....	28

3.4.2 Ethnobotanical information.....	32
3.4.3 Fidelity level of different plants.....	34
3.5 Discussion.....	35
3.6 Conclusion.....	38
3.7 Conflict of interest.....	39
3.8 References.....	40
CHAPTER 4.....	46
On- farm evaluation of local plants on internal parasites in different goat breeds and sexes of Botswana.....	46
4.1 Abstract.....	46
4.2 Introduction.....	47
4.3 Methodology.....	48
4.3.1 Ethical statement.....	48
4.3.2 Study site.....	48
4.3.3 Collection and preparation of plant extracts.....	49
4.3.4 Animal selection and management.....	50
4.4 Data collection.....	50
4.4.1 Body condition score.....	50
4.4.2 Faecal collection.....	50
4.4.3 Parasitology test.....	51
4.4.4 Statistical analysis.....	51
4.5 Results.....	52
4.5.1 Body conditon score.....	52
4.5.2 Faecal egg counts.....	53

4.6 Discussion.....	55
4.7 Conclusion.....	57
4.8 References.....	59
CHAPTER 5.....	65
GENERAL DISCUSSION, CONCLUSSIONS AND RECOMMENDATIONS.....	65
5.1 General Discussion.....	65
5.2 Conclusions.....	67
5.3 Recommendations.....	68
5.4 References.....	69
APPENDIX.....	71

LIST OF TABLES

Table 3.1: Summary of demographic characteristics of respondents in the Ngamiland region...	28
Table 3.2: Total number of livestock kept by respondents across six villages in the Ngamiland region.....	30
Table 3.3: Frequency of administration of plant remedies by different farmers.....	31
Table 3.4: Ethnobotanical information on local plants used to control internal parasites in goats in the Ngamiland region.....	32
Table 3.5: Fidelity levels indices of local plants used to control internal parasites in goats.....	35
Table 4.1: Average body condition score of goats over 90 days study period for three treatments.....	51
Table 4.2: The mean ($\pm$ SE) faecal egg count and Coccidial oocysts of goats under various treatments according to different times.....	52
Table 4.3: The effect of goat breeds on faecal egg counts and Coccidial oocysts (mean $\pm$ se) under various treatments.....	53
Table 4.4: The effect of goat sex on faecal egg counts and Coccidial oocysts (mean $\pm$ se).....	54

LIST OF FIGURES

Figure 2.1: General life cycle of a nematode.....	8
Figure 3.1: Map- Ngamiland region of Botswana.....	27
Figure 3.2: Reasons for keeping goats as stated by respondents in the Ngamiland region.....	30
Figure 3.3: Methods used in controlling internal parasites and commercial drugs used by respondent in the Ngamiland region.....	31
Figure 4.1: <i>Gnidia capitata</i>	48
Figure 4.2: <i>Terminalia sericea</i>	48

LIST OF ABBREVIATIONS

BCS	Body Condition Score
BUAN	Botswana University of Agriculture and Natural Resources
CIOMS	Council for International Organization of Medical Sciences
DDGS	Dried Distilled Grain with Solubles
EPG	Egg per gram
FAO	Food and Agriculture Organisation
FEC	Faecal Egg Counts
FECRT	Faecal Egg Count Reduction Test
FL	Fidelity Level
GIN	Gastrointestinal Nematodes
LIMID	Livestock Management and Infrastructure Development
NARDI	National Agricultural Research and Development Institute
SAS	Statistical Analysis System
SPSS	Statistical Package for Social Sciences
WAD	West African Dwarf

CHAPTER 1

GENERAL INTRODUCTION

1.0 Background

Smallholder farmers in rural areas of Botswana depend mostly on small stock for their livelihood. The advantages of rearing small stock include, short gestation period, less investment input such as housing structures and feeding, as well as their ability to withstand drought compared to cattle (Aganga and Aganga, 2015). Small stock provide capital and protein-rich diets contributing to food security, employment and cultural value in terms of social status. Ecologically, small stock contributes to soil improvement through manure, which enhances soil structure, water retention, and nutrient recycling (Xing et al., 2025). The most popular small stock production in Botswana is goat with a population of about 1 271 407 million and sheep are a little under 323 279 (Statistics Botswana, (2025). Although popular, about 95% of goat production occurs under traditional management system, where there are less financial inputs, inadequate record keeping and lack of flock health program (Monau et al., 2018). These aspects contribute negatively to the efficiency of goat production, impairing animal performance, leading to low offtakes, poor reproduction efficiency, low carcass weight, and ultimately, poor returns.

Internal parasites are among the major challenges in the traditional management system hindering goat productivity in Botswana due to poor housing structures, poor pasture management, and inaccessibility to commercial pharmaceutical remedies (Mungube et al., 2006). Ademola (2016) observed that grazing animals are at risk due to high degrees of larval contamination in pastures. Internal parasites have direct negative effects on goat production by causing low fertility, rough coat, low appetite, and low body weight resulting in death and low productivity (Molefe et al., 2012). The global economic losses in livestock due to internal parasites (e.g. organ condemnation at the abattoir, mortality, and costs of treatment) is approximately US\$3.2 billion per year (Abebe et al., 2011). However, in a commercial goat farming setup, which constitute about 5% of goat production in Botswana, internal parasites are controlled by conventional drugs that are costly to the resource-constrained farmers and has possible product contamination as well as anthelmintic resistance (Clark et al., 1996). The small-

scale farmers have therefore, resorted to ethnoveterinary medicine which has a lot of potential as cheap, readily available and efficient anthelmintics (Akhtar and Malik, 2000).

Ethnoveterinary medicine is the application of indigenous knowledge including the use of plants in treating livestock diseases (Athanasaidou et al., 2007; Khan et al., 2012). Most goat farmers practice ethnoveterinary with the belief that some indigenous plants contain pharmacological active chemicals (Coetzee, 2000). A study on ethnoveterinary practice carried out in South Africa identified nine indigenous plants used to control internal parasites in goats, with *Aloe ferox* plant being the most common (Sanhokwe et al., 2016). In Botswana, Kweneng district, Setlalekgomo and Setlalekgomo (2013), documented 13 plant species (*Aloe* species dominating) used in treating diseases and controlling internal parasites in goats. However, this district does not represent the wide variation that occurs in the country. It is, therefore, important to document ethnoveterinary practices in other regions of Botswana and create new strategies that will result in the long-term reduction of internal parasites in goats. Again, since the antiparasitic activity of these plants is based on anecdotal observations, there is a need to investigate the potential efficacy of these plants and other pharmacological and toxicological parameters. As a sustainable measure, it is also important to consider animal breed on controlling parasites, since the effectiveness of ethnoveterinary practices often depends on the specific plant's bioactive compounds and the animal's innate resistance or resilience. This may involve an integrated strategy that incorporates parasite treatment, and goat breeds that are parasite resistant.

1.1 PROBLEM STATEMENT

Internal parasites threaten animal welfare, food security, food and environmental safety and profit margins of goat communal production systems. In most parasitism, the economic losses are not attributable to mortality but to decreased productivity of animals. Gastrointestinal nematodes prevalence is expected to increase due to climate change. Commercial pharmaceutical remedies are used to control internal parasites under farm management systems; however, these remedies are costly, and their residues pollute the environment and food products of goat origin. The prolonged use of commercial remedies in goat production system results in the emergence of internal parasites strains that are resistant to these remedies. Therefore, there is a need for alternative parasite control strategies that will be cost effective, sustainable and environmentally

friendly. The use of indigenous knowledge of local plants to control internal parasites has been recommended as an environmentally safe alternative strategy. In Botswana, goat production is mostly practiced under communal environments characterized by elevated levels of infestation by internal parasites. There has also been some paucity of information in Botswana about the evaluation of breed responses to treatment using plants to control gastrointestinal parasites. For instance, the Tswana goat superior resistance to internal parasites has not been explored in the use ethnoveterinary medicine. Therefore, it is important to provide an integrated strategy in combating internal parasites.

1.2 JUSTIFICATION

This study is motivated by some of the Food and Agriculture Organisation strategic objectives, which is to help reduce rural poverty and to make agriculture more productive and sustainable in the next centuries (FAO, 2021). Botswana has a vast amount of indigenous knowledge on the use of local plants to control internal parasites that has not been documented and/or evaluated. Most of the farmers in rural areas especially in the Ngamiland district depend on small stock for food and income generation and do not have much income to buy commercial drugs to treat internal parasites. The understanding of ethnoveterinary medicine and breed effect on the treatment of internal parasites of goats will assist in developing sustainable management strategies that will improve goat productivity and food security.

1.3 MAIN OBJECTIVES

The main objective of this study are to document local plants that are used to control internal parasites in the Ngamiland district and determine their efficacy as remedies for GINs in different goat breeds and sexes.

1.3.1 SPECIFIC OBJECTIVES

The specific objectives of this study are to:

- Identify local plants used by goat farmers to treat and control gastrointestinal parasites in goats in the Ngamiland district.

- Document local plants used by goat farmers of Ngamiland district to control and treat gastrointestinal parasites of goats.
- Determine the efficacy of plant extracts on different goat breeds and sexes in controlling internal parasites in the Ngamiland district.

1.4 RESEARCH QUESTIONS

- Do Ngamiland farmers use local plants to control internal parasites in goats?
- What are the common local plants used by Ngamiland farmers to control internal parasites in goats?
- Are local plants useful and effective in controlling internal parasites in goats?
- Is there breed effect or sex effect on local plants efficacy against internal parasites?

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Goat farming in Africa is a crucial, low-maintenance, and climate-resilient socio-economic activity that supports poverty alleviation, food security, and rural livelihoods. Despite the economic importance of goats, the prevalence of helminthiasis causes a reduction in production and profitability due to high treatment costs, improper management and climate variability. Goats are more susceptible to helminth infections compared to sheep and cattle, possibly due to foraging behaviour (Hoste et al., 2010). There are several interventions that can be used to manage internal parasites which include nutrition, breeding, pasture management, and indigenous knowledge of local plants as dewormers. The aim is to review the literature on the effect of internal parasites on goats and alternative ways that can be used by farmers to manage internal parasites in small ruminants.

2.2 Internal parasites and their effects on goats

Gastrointestinal nematodes (GIN) that infect goats include *Haemonchus contortus*, *Trichostrongylus colubriformis*, *Teladorsagia circumcincta*, *Cooperia* species, *Oesophagostomum*, *Trichuris ovis*, *Strongyloides papillosus*, and *Bunostomum* (Craig, 1996). They are commonly called roundworms due to their wormlike appearance (Taylor et al., 2007). Trichostrongyloidea is a superfamily of two nematodes under the order Strongylida, and in this family, several genera, such as *Haemonchus*, *Oesophagostomum* and *Trichostrongylus* are of major relevance to ruminant production (Nginyi et al., 2001; Pandey et al., 1994). Trichostrongylids are frequently found in the gastrointestinal tract and are monoxenous, i.e. they make use of one host in their life cycle (Andersson, 2000). The life cycle of other nematodes consists both of external stages (outside the host) and internal stages (in host) (Taylor et al., 2007) as shown in Figure 2.1 below;

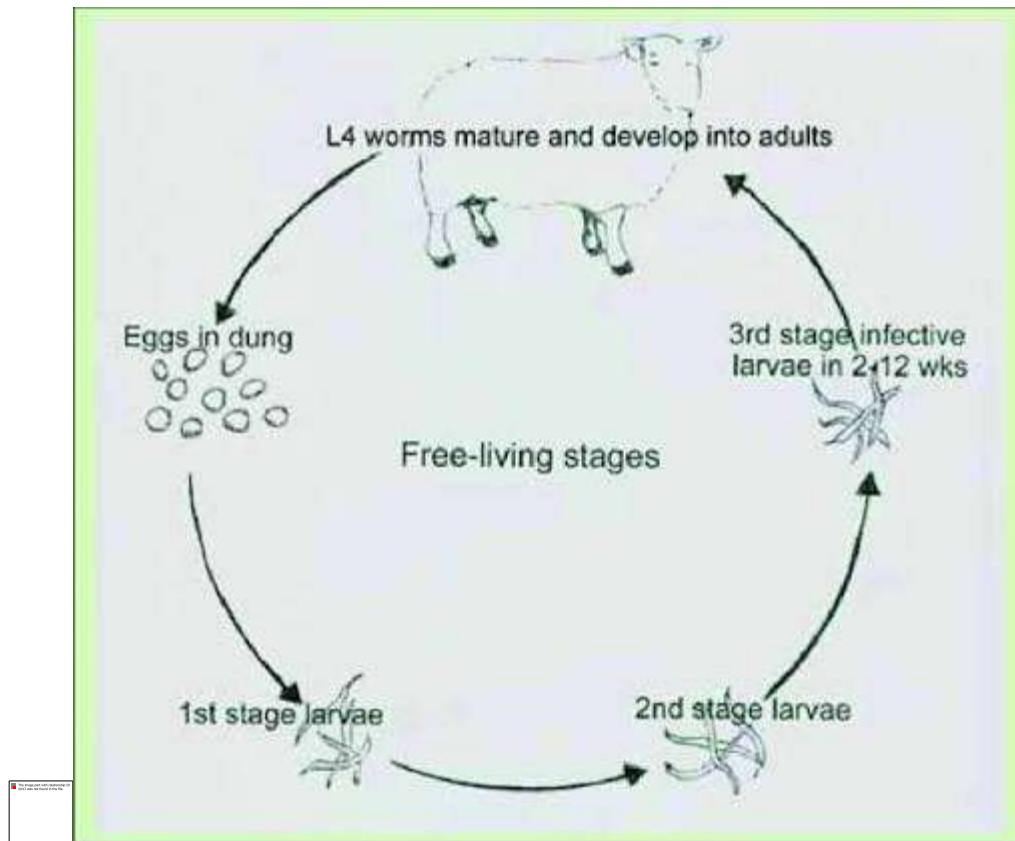


Figure 2.1: General life cycle of a nematode (Abbott et al., 2007)

Environmental factors such as temperature, moisture, soil, and pasture growth are critical elements for nematodes development, survival and transmission or migration (Banks et al., 1990; Waller, 2006; Salem et al., 2025). For instance, without significant rainfall, green pasture can retain enough moisture for eggs to mature into a different larval stage (Besier and Dunsmore, 1993). According to Wilson et al. (2024) soil moisture is critical for free-living stages of most nematode eggs/larvae and enables development and movement, while soil temperature regulates the speed at which the nematode develops (Amarasingha et al., 2024). In a laboratory setting, Besier et al. (2016) found that the normal development of infective larval stage is at the temperature range of 10°C – 40°C. Craig (2018) stated that a more ideal temperature range for optimal development of gastrointestinal parasites is 22.2°C – 26.1°C with 100% humidity and beyond these ranges, parasite hatchability and survivability decreases. The development of nematodes is more rapid during the summer seasons even though their life expectancy is short due to heat and sunlight (Delling and Dauschies, 2024). Nsoso and colleagues (2001) studied

the effect of season on internal parasites burden on indigenous goats kept under traditional management and observed that faecal egg counts (FEC) significantly decreased during the winter and increased during summer and fall.

Small ruminants are more susceptible to significant output losses from parasitic gastrointestinal nematode infections than cattle (Craig, 1996). In the southern region of Botswana, Sharma and Busang (2013) reported helminthic infection rates of 16.2% in young ruminants with a high percentage in small stock. The larvae tear the mucosa during development, resulting in hemorrhages, edema, and loss of protein (de Oliveira et al., 2025). In a clinical setting, this typically manifests as weight loss, diarrhea and death particularly if the animals are severely infected and emaciated (Taylor et al., 2007). A study by Kagira and Kanyari (2001) reported mortality rate of 26% in goats and 32% in sheep in Kenya due to helminthosis. Egualé et al. (2007) stated that gastrointestinal nematode infections cause 8% weight loss and 28% death in sheep, especially in developing nations with low management techniques. The clinical signs cause infected animals to produce lower-quality wool, meat, and milk (Iqbal et al., 2001) which results in an economic loss of revenue. In order to increase production and small-holder farmers' standard of living, it is crucial to sustainably manage internal parasites in goats.

2.3 Prevention and control measures of internal parasites in goats

2.3.1 Pasture management

Internal parasites in grazing animals can be effectively managed through pasture management (Stuedemann et al., 2004). To maximize output, animals should be permitted to graze on fresh or clean pasture. According to Younie et al. (2004) clean or new pastures include those that have not been grazed on for six to twelve months, pasture fields that have had hay or silage crops removed, pasture fields that have rotated with field crops and pastures that have just had tillage renovations. One of the ways of managing pasture is through pasture rotation, whereby pasture lands are divided into different-sized land areas known as paddocks and regularly shifting animals from one paddock to another (Wells, 1999). The primary goal of pasture rotation is to keep animals out of the same field until the risk of infection has decreased. Theoretically, increasing the number of land pieces and rotation time will result in low parasitism. According to

Kumar et al. (2013) the infectious stage of parasites typically has a longer lifespan than the amount of time needed between grazing times to maximize grass usage. Therefore, for an infected pasture to revert to a low level of infectivity, a rest is necessary.

Comprehensive epidemiological knowledge of the parasites' development both inside and outside of the hosts may be the first step towards understanding how pasture management affects internal parasite control (Barger, 1999). Uriarte et al. (2003) examined the seasonal variations in parasitic nematode loads in sheep and discovered three generations of parasites throughout the experiment. The animals that continued to grow in the spring were the offspring of the first generation of larvae. In winter, the absorbed larvae on the pasture produced the subsequent generation, which was the primary cause of newly acquired infections in lambs and frequently resulted in clinical signs. Although the final generation, which was seen in the fall, had minimal effect on the animals, it was found to be the primary cause of pasture contamination in the next season. This experiment demonstrates crucial epidemiological knowledge in effective grazing management. However, pasture management may not be viable solution to small scale farmers in Botswana due to shortage of land, hence the need to consider other feeding management.

2.3.2 Feeding management

The rate at which immunity develops may be influenced by the host's nutritional status, this effect is probably most noticeable in internal parasite infections, where the complexity of immunity development is highest (Kumar et al., 2013). For instance, increasing the amount of metabolizable protein in diet during periods of protein scarcity has been reported in the literature to help animals establish immunity to illnesses and to make them more resistant to parasite infection (Shea-Donohue et al., 2017). It has been discovered that a number of protein supplements, such as fish meal, soybean meal, cottonseed meal urea, and dried distillers' grain with solubles (DDGS), can lower the number of faecal eggs over an extended period of time (Barkley, 2023). The vulnerability of an animal to internal parasites can also be influenced by vitamins and minerals, such as vitamins A, D, and B. According to Hughes and Kelly (2006), minerals such as zinc, iron, cobalt, sodium, potassium and phosphorus are also crucial for the development of effective immunity against parasites.

2.3.2.1 Vitamin A

Vitamin A deficiencies cause disruptions to the intestinal immune system, which likely weakens the host's defense against intestinal parasites (Coop and Kyriazakis, 1999). The significant alterations in the regulation of immune cell activity result from the profile of cytokine production by cells from animals deficient in vitamin A (Kumar et al. 2013). Additionally, through the primary oxidative metabolite retinoic acid, vitamin A polarizes the immunological response in favor of Th2 (Stephensen, 2001). Villamor and Fawzi (2005) stated that vitamin A is important in improving intestinal epithelial integrity. Therefore, it is important for farmers to consider vitamin A supplementation in order to strengthen the intestinal immune system.

2.3.2.2 Zinc

The T helper cell function and cell-mediated cytotoxicity are both compromised in zinc-deficient animals (Kumar et al., 2013). Scott and Koski (2000) examined zinc deficiency on immune responses against parasitic nematode infections at intestinal and systemic locations. The authors observed that parasites can live longer in zinc-deficient hosts than in animals with adequate nutrition. The authors further discovered that the spleen of zinc-deficient animal produces less interleukin-4, which results in lower levels of Immunoglobulin E (IgE), Immunoglobulin G1 (IgG1), and eosinophils as well as compromised T cell and antigen-presenting cell activity. Cook-Mills et al. (1990) also looked at the involvement of zinc in the hazardous oxygen metabolites that mononuclear phagocytes produce that destroy *Trypanosoma cruzi*. The authors found that zinc-deficient animals had poor Natural Killer (NK) cell activity and macrophage phagocytosis, which could be due to a decreased oxidative burst capacity. Zinc should therefore be included in the animal diets to increase productivity and aid in the battle against parasitic infections. Since the majority of goats are kept under extensive communal grazing systems in Botswana, to make up for the mineral deficits in pastures, the animals should constantly have access to vitamin supplements and mineral blocks. However, this can be quite unaffordable to the small-holder farmers hence other interventions such as supplementing with alternative forages can assist.

2.3.2.3 Alternative forages

The pasture plants with condensed tannins provide anthelmintic qualities in addition to vitamins and minerals (Min et al., 2004). According to the literature (Butter et al., 2000; Madibela and Jasen, 2003), animals eating tannin-rich forages had less faecal egg counts. The tannin may slow the growth of larvae in faeces and the pace at which parasite eggs hatch (Kumar et al., 2013). Tannins often reduce faecal egg counts by inhibiting female worm fecundity, reducing egg hatchability and lowering adult worm burdens (Max, 2010). The use of an indigenous parasitic herb (*Viscum verrocosum*) to lower faecal egg counts in female Tswana goats was studied by Madibela and Jasen (2003). Goats were fed the tannin-containing fodder plant (*V. verrucusom*) and showed a 20% decrease in faecal egg counts. The effects of continued consumption of condensed tannins on parasitized sheep were also evaluated by Anthanasiadou et al. (2000). The authors discovered that the faecal egg count decreased within two days of tannin administration, a time frame comparable to that following anthelmintic medication treatment. The resource-constrained goat producers of Botswana can utilize such knowledge of feeding tannin rich forages as well as keeping an adaptable breed for sustainable farming.

2.3.3 Breed effect

Animal genes are the most effective long-term defense against internal parasites in animals (Kumar et al., 2013). Chiejina and Behnke (2011) examined the resistance and resilience of gastrointestinal nematode infections on different breeds of goats and discovered that the Nigerian West African dwarf goats were highly resistant. Baker et al. (2016) investigated the genetic resistance to gastrointestinal nematode in three sheep breeds: Red Maasai, Dorper, a cross between Red Maasai and Dorper. The authors observed that the Red Maasai ewes were more resistant to gastrointestinal nematode infections than the Dorper ewes based on significant lower faecal egg count. The Red Maasai reduced faecal egg counts from 378 to 288, Dorper from 525 to 354 while their cross recorded an increase of 376 to 437 faecal egg counts. The figures were obtained during mating and three months post mating. In order to improve goat productivity, reduce poverty and costs associated with anthelmintics drugs, farmers can keep goat breeds that are resistant to internal parasites and in most cases the local adapted goats.

An animal that is resistant to internal parasites either inhibits the establishment of parasites within its body or, if they occur, inhibits the worms' ability to lay eggs (Coffey and Hale, 2012).

A stronger herd will be produced by breeding more resilient animals over time. For instance, Eady et al. (2003), discovered that Merino sheep selected for resistance averaging a 224-day period showed a 69% decrease in fecal egg counts (FEC). Selecting for resistance and using biological controls such as nematophagous fungi will lead to less pasture pollution and more productivity.

2.3.4 Biological control

According to Grønvold et al. (1996), biological control is the use of a single living organism to control the targeted organism, lowering the pathogen population below a threshold level where it cannot cause clinical issues or financial losses in animals. In the context of parasite management, it typically refers to the application of naturally occurring agents to reduce parasitic burden that would result in losses to animal productivity. Several authors; Paraud et al. (2003); Waghorn et al. (2003); Jansson et al. (2004) have suggested that nematophagous fungi can be used as a biological control for internal parasites. Waller and Thamsborg (2004) stated that the fungi, *Duddingtonia flagrans* is often used to manage gastrointestinal parasites in grazing animals due to its cultivation easiness. According to Siddique et al. (2025), fungal spores are picked by animals from pasture, excreted in faeces, where they germinate to trap and kill nematode larvae. This mechanism directly disturbs the nematode life cycle at the environmental stage, thus reducing the number of infective larvae on pasture. Previous study by Persson (1974) revealed that earthworms are residents of the soil that feed on organic matter that has been deposited on the soil's surface. They play a major role in the biological control of nematodes by either digesting eggs and larvae or moving them to deeper soil levels where their chances of reaching the surface as infectious larvae are extremely low (Grønvold et al., 1996). The use of biological agents by local farmers can be a difficult exercise due to the possibility of contamination of the environment (particularly if a lot has been scattered on the ground), hence there is a need to consider other measures such as commercial anthelmintic drugs or ethnoveterinary medicine.

2.3.5 Use of commercial drugs

The anthelmintic drugs are chemotherapeutic agents that are frequently employed either therapeutically to treat current infections or prophylactically, where the timing of treatment is

determined by an understanding of the epidemiology (Worku et al., 2017). Most of the species of gastrointestinal parasites have been successfully treated using a variety of medication classes, including piperazine, benzimidazoles, salicylanilides, macrocyclic lactones (such as ivermectin), and imidazothiazoles (Getachew et al., 2007). Despite their effectiveness, certain nematode species have developed resistance due to prolonged use, improper handling, and underdosage (Chartier et al., 2001), resulting in significant production losses (Wolstenholme, 2004). Again, the anthelmintic drugs can be costly particularly to small scale farmers hence animals die from acute illness. Effective, long-lasting alternative or supplemental treatment approaches are desperately needed such as the use of native plants to treat internal parasites. This could assist farmers in finding less expensive substitutes, thus improving and increasing their flock.

2.4 Use of indigenous knowledge to combat internal parasites

Ethno-veterinary medicine is another term for using traditional knowledge to cure illnesses in animals (Khan et al., 2012; Gabalebatse et al., 2013). It is an indigenous animal healthcare system that incorporates the customs, knowledge, abilities, techniques, and beliefs of a particular community (Yineger et al., 2008). Plant materials and their derivatives have occasionally been used extensively in health therapies for both humans and animals. For instance, during an exceptional health pandemic brought on by the new coronavirus disease, derivatives and herbal formulations were suggested to lessen COVID-19 symptoms in a number of nations worldwide (Syta et al., 2021). The active substances to be extracted, the mode of administration, and the medical purpose (therapeutics or prophylactic) all influence the modality used in the creation of ethnoveterinary medications (Mathias, 2004). The methods of preparation such as infusions, decoctions, powders, drops, fumes, pastes, and ointments made from therapeutic plants, animals, minerals, and other non-plant materials are often used by livestock owners and herders in ethnoveterinary practices (Gabalebatse et al., 2013).

Maphosa and Masika (2010) in the Eastern Cape Province of South Africa, conducted a survey on plants utilized in the ethnoveterinary management of gastrointestinal parasites in goats. According to the survey, 28 plant species from 20 families were frequently used to cure goats' gastrointestinal parasites, with 21.4% of the plants belonging to the Asphodelaceae family and Aloe species (50%) being the most used (Maphosa and Masika, 2010). For the benefit of future

generations, it is important to document and evaluate efficacy of local plants that can help farmers in Botswana to control internal parasites. This can lead to increased livestock output, poverty reduction and improved livelihoods.

2.5 Efficacy of local plants in controlling internal parasites in livestock

Majority of the evidence on the antiparasitic activity of local plants is based in anecdotal observation and there is a growing number of controlled studies that aim to scientifically verify, validate and quantify such bioactivity. However, some of these studies have been inconsistent with the reports of traditional herbalist and researchers. Such differences might be as a result of the variations in the locality, season, method of harvesting and storage of plant materials, experimental models as well as other methodological limitations (Ignacio, et al., 2001). Two main approaches have been used in the efficacy studies against helminthics. The first one is through feeding plants or their parts to naturally or experimentally to infected animals. The second one is by testing extracts and concoctions from medicinal plants via *in vitro* systems. For example, Mazhangara et al. (2020), used an *in vitro* method to evaluate the efficacy of roots extracts of *Elephantorrhiza elephantina* against *Paramphistomum cervi* worms in goats. The authors reported high efficacy of 96.7% on ethanol extracts at 15 mg/mL concentration. On the other hand, in *in vivo* evaluations, Băieș et al. (2024) in Romania evaluated the effect of *Allium sativum* L. and *Artemisia absinthium* L. against gastrointestinal parasites in swine. The authors reported the anthelmintic potential of both *A. sativum* and *A. absinthium* against gastrointestinal parasites in pigs, with their effectiveness mainly attributed to the presence of compounds like polyphenols, tocopherols, flavonoids, sterols, sesquiterpene lactones, and sulfoxide. However, it will be unfair to directly extrapolate *in vitro* findings into live animals since during *in vitro* experiments active compounds are introduced at target points.

2.6 Conclusions

The review has provided several strategies used to manage internal parasites in livestock. These methods include the use of pharmaceutical remedies, pasture management practices and enhancing host resistance through nutrition and biological control, breeding and selection of animals that are more parasite-resistant and through protein supplementation. However, the study

will focus on plant remedies as the key methods of controlling goats' internal parasites by resource-limited farmers. In many developing countries, including Botswana, medicinal plants are the most commonly used method to control internal parasites due to their easy accessibility and affordability.

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CHAPTER 3

Participatory inventory of plant-based ethnoveterinary medicine used to control internal parasites of goats in the Ngamiland region of Botswana.

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3.1 Abstract

The effect of internal parasites on goats is of major concern, particularly in the tropics where there are limited resources and financially constrained farmers. The ethnic knowledge on controlling and treating internal parasites is of value to sustainable and organic product production which are essential for long-term prosperity of goat farmers. Using farmers participatory approaches, this study identified and documented popular plants used to control internal parasites in goats in the Ngamiland region of Botswana. A total of 120 communal farmers were interviewed using a structured questionnaire consisting of demographic parameters and ethnobotanical information. The data were analyzed using Statistical Package for the Social Sciences (SPSS) and the most popular plants were identified using fidelity levels (FL). Most of the informants were secondary educated males of 50 to 60 years and relied on livestock for their livelihoods. It was recorded that a total of 13 local plant species from 11 families are commonly used in the treatment of intestinal parasites in goats. The plant family Fabaceae (27.3%) was common among the farmers. The roots (76.9%) were the most frequently used plant part while decoction (46%) was popular in medicinal preparations. The prepared plant-based medicine is often administered orally. The highest FL values were found for the following plant species; *Terminalia sericea*, *Gnidia capitata* and *Aloe ferox* each scoring 89.3%, 88.0% and 86.3%, respectively. The safety and efficacy of these plants should be validated to inform strategic utilization and alternative cost-effective strategy in managing internal parasites in Botswana.

Key words: Ethnoveterinary; indigenous knowledge; internal parasites: Livestock

3.2 Introduction

Goat production plays a significant role in both developing and developed nations. It contributes significantly to the promotion of human health by providing animal protein of high value in the form of meat and milk (Sujon et al., 2008). There are more than one billion goats in the world, and most have adapted to challenging conditions of different production systems (FAO, 2021). Africa is a host to about 423 million goats, with southern Africa contributing about 35 million (Mataveia et al., 2021). Most of the goats in the continent are kept by resource-limited farmers where they are used in alleviating poverty, improving living standards, contributing to gender equity (Monau et al., 2020). For example, in Botswana, there are approximately 22 000 female goat holdings compared to 36000 male goat holdings. Although there is quite a difference between genders but there is growth compared to 9000 of female cattle holdings and 26000 male cattle holdings (Statistics Botswana, 2019). Compared to other livestock species, production efficiency of goats lags behind, particularly in developing countries including Botswana. Several reasons have been attributed to this effect, such as poor management, low financial input, diseases, and parasites (Monau et al., 2018) and lack of organized markets.

Goat production cycle is relatively short, with 5 months gestation and 4 months to wean a kid (Peaker, 1978). Therefore, it is possible to take 2 years to produce 3 kiddings and when combined with high litters size (twins or triplets) it means meat production is increased many folds and is achieved within a relative short span of time. However, these good attributes of goat production in the tropics and subtropics are often stifled by internal parasites. This is due to adverse climatic conditions, inadequate husbandry practices and poor control measures (Zvinorova et al., 2016). According to a study by Sharma and Busang (2013), several parasitic gastrointestinal parasites have been reported in goats in Botswana, with eight genera of strongylid nematodes, namely *Trichostrongylus*, *Haemonchus*, *Oesophagostomum*, *Cooperia*, *Chabertia*, *Bunostomum*, *Trichuris* and *Strongyloides* species, one species of trematode *Paramphistomum* and proglottids of *Moniezia* species, a cestode being identified. The impact of internal parasites includes reduced feed intake, increased age at puberty and treatment costs (Molefe et al., 2012; Roeber et al., 2013). The internal parasites can further contribute to a decrease in animal weight gains (Hogberg et al., 2023) and a negative economic impact on the production systems (Tachack et al., 2022). The common method of controlling internal parasites

consists of synthetic anthelmintic medications whose active ingredients include benzimidazoles, levamisole and macrocyclic lactones (N'guessan et al., 2021). However, the use of synthetic anthelmintic medications may pose risks including the development of drug resistance (Besier 2007; Tsotetsi et al. 2013), soil micro and macrofauna destabilization (Lumaret et al., 2012), and increased human consumption of chemical residues in meat and milk (Jayathilake et al., 2012). In marginalized areas of sub-Saharan Africa, the use of anthelmintic medications has been impractical due to incorrect dosages, inadequate supply of drugs by government institutions, inability to reach veterinary shops and ever-increasing drug prices (Ndlela et al., 2022).

In this context, cutting-edge interventions, such as the use of local knowledge of ecological resources for veterinary care becomes necessary. The plant kingdom is renowned for offering a wide variety of secondary metabolites which possess chemical structures that are not present in synthetic compounds and play a significant role in controlling diseases and parasites (McGaw et al., 2020). Currently, most pastoralists and agricultural communities in the southern African region practice plant based ethnoveterinary medicine in goats. For instance, in South Africa, KwaZulu Natal Province, twelve (12) plant species were commonly used to control internal parasites in goats, with *Cissus quadrangularis* Linn. being the most predominant (97%) (Ndlela et al., 2022). In Botswana, Kweneng region, about 17.65% aloe plant species have been reported to control internal parasites in goats (Setlalekgomo and Setlalekgomo, 2013). This study, however, does not represent ethnoveterinary practices in other regions of Botswana hence the need for further documentation. Moreover, ethnoveterinary medicines differ from one ethnic group to the other as well as from region to region. Comprehending the utilization of plant based ethnoveterinary medicine creates a basis for future scientific interventions that are relevant for sustainable resource management practices and goat productivity. The objective of this study was to identify and document local plants used to control internal parasites in goats in the Ngamiland region of Botswana. The Ngamiland region has about 80 000 goats (Statistics Botswana, 2019) and possess a vast diverse range of plant species that serve as an important medical resource for plant based ethnoveterinary is mostly practiced. The habitat is quite unique compared to other regions in Botswana. This region also obtains the least annual rainfall and possesses diverse wildlife animals which affect crop production. Livestock production is key to

livelihoods of farmers in this region and any intervention that helps improve livestock productivity will directly improve livelihoods of these communities.

3.3 Methodology

3.3.1 Ethical Statement

All the data collection methods used in this study were conducted in accordance with relevant guidelines and regulations provided by the Botswana University of Agriculture and Natural Resources Ethical Committee (Reference number: BUAN-AEC-2023-04). Informed consent which ensured anonymity, protection, privacy, dignity, and integrity of the participants in the study was carried out before data collection, and the objectives of the study were thoroughly explained. The consent was obtained through signatures for literate participants and verbally for the illiterates. The verbal consent form was carried out with the presence of the Botswana University of Agriculture and Natural Resources Ethical Committee member. All participants were informed that they are free to drop from the study at any time.

3.3.2 Study site

The study was carried out in Ngamiland region which is in the Northwest part of Botswana between latitudes 20°00'00 S and 22°30'00 E (Figure 1) and possess a total surface area of 129 130 square km (Mcfarlane and Eckardt, 2004). Ngamiland is situated within the sand-veld and its vegetation is largely characterized by savannah with tall grasses, bushes, and trees such as *Colophospermum mopane* and *Terminalia sericea* (Tedder, 2012). The area experiences 490 mm of rain on average each year with most rains in the summer (Moses, 2019). The average minimum and maximum temperatures are 16.4°C and 31.5 °C, respectively (World climate Guide, 2020). The human population of the region is about 193 725 (Statistics Botswana, 2022) and the ethnic groups include Batawana, Baherero, Bahambukushu, Bayeyi and Basarwa (Larson, 1989). Most of the households are active in livestock production, for instance, there are about 2075 female goat households and 3086 male goat households (Statistics Botswana, 2019). The most prevalent livestock diseases in the study area are both internal and external parasites, foot-and-mouth disease and dermatophilosis (Gabalebatse et al., 2013).

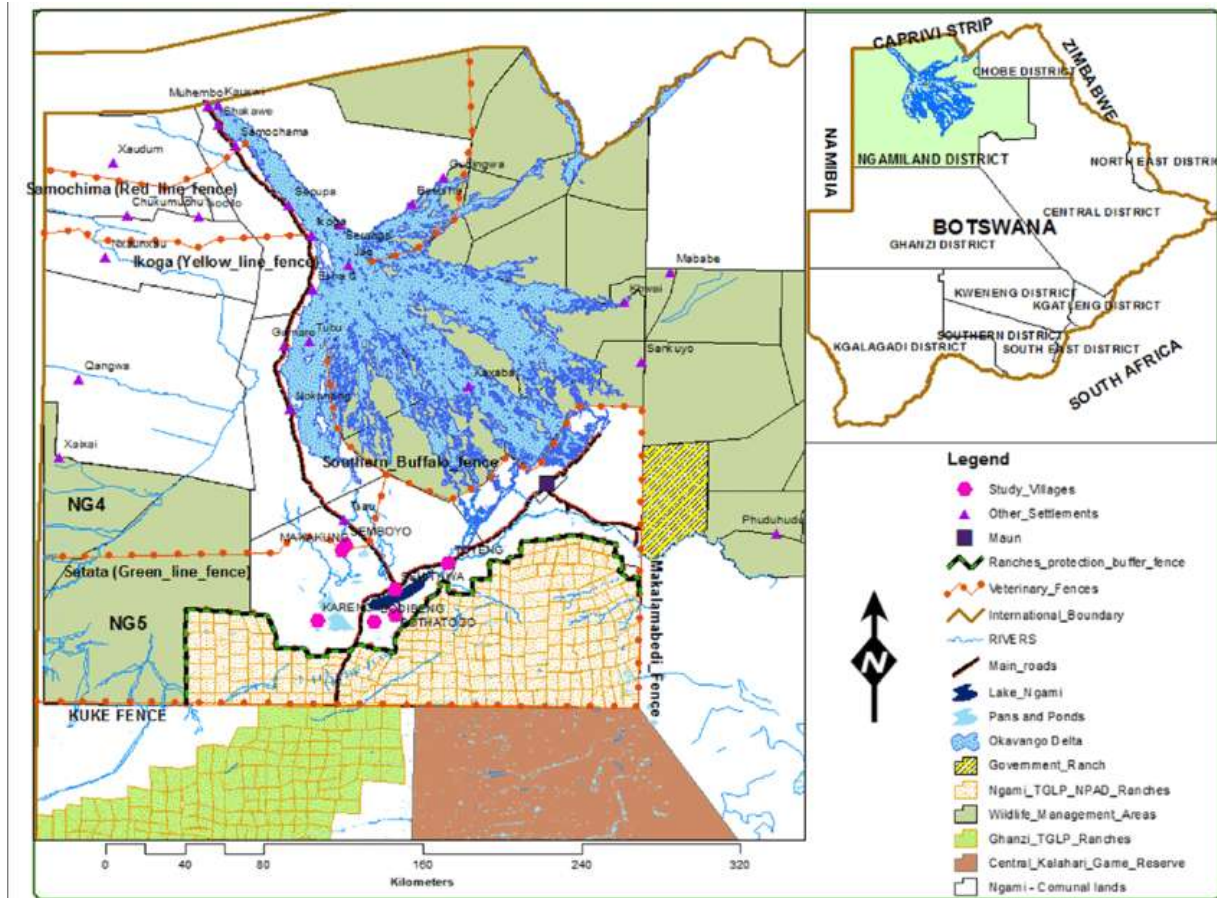


Figure 3.1- Ngamiland region of Botswana- Study area (source- Ministry of Agriculture, Botswana, 2017)

3.3.3 Data collection

Six villages were randomly selected from the Ngamiland region, namely Ghani, Chukumuchu, Mohembo, Tsau, Semboyo, and Makakung (Figure 1). A snowball sampling approach (Patton 1990) was used to select goat farmers. According to Patton (1990), snowball sampling is a method for identifying key informants who are rich in information, contacting them for interviews, and those individuals can recommend to the interviewer other possible respondents. A structured questionnaire was used to collect data. The questionnaire included demographic data such as gender, age, and source of income. The ethnobotanical information gathered included local name of plant used, plant parts utilized, method of preparation and dosages rates for different plants and undesirable effects. Other information gathered included information

source, and other ways of managing internal parasites. Consent of farmers was acquired before administration of the questionnaire. The survey was conducted orally using both English and Setswana.

3.3.4 Data analysis

The data were analyzed using Statistical Package for the Social Sciences (SPSS) software, version 28.0.1 (SPSS, 2022). The most popular plants in the region were identified using fidelity level (FL) values, which was a sign of a plant's potential effectiveness. The fidelity level was calculated using the formula,

$$FL = (Na / N) \times 100$$

where Na is the number of respondents who use a specific plant for the treatment of internal parasites and N is the total number of respondents who use plant species for the treatment of internal parasites (Alexiades, 1996). The data analysis also focused on generating descriptive statistics (frequencies/percentages) related to participants' demographics, livestock species kept and ethnoveterinary practices.

3.4 Results

3.4.1 Demographic data

A total of one hundred and twenty (120) informants were interviewed in six villages (n=20 each) of the Ngamiland region. The majority of the informants were males (71%) and females were in the minority at 29% (Table 3.1). The most represented age groups were 51-60 (36.7%) followed by 61-70 (20%) and 41-50 years (15%). The majority of informants acquired secondary education (43%) whilst a total of 20% never went to school. Regarding their upkeep, most of the informants depended on the sale of livestock and crops (Table 3.1). Most of the informants acquired knowledge on ethnoveterinary medicine orally from their elderly parents (93,3%) (Table 3.1). All the respondents owned livestock, which included cattle, sheep, goats, chicken, pigs, donkeys, and horses as shown on Table 3.2. Most livestock kept are cattle and goats whilst pigs are in the minority (Table 3.2).

Table 3.1: Demographic characteristics of the respondent in the Ngamiland region

Characteristics	Total Participants	Percentages
	(n=120)	
Gender		
Male	85	70.8
Females	35	29.2
Age		
20-30	04	3.3
31-40	16	13.3
41-50	18	15.0
51-60	44	36.7
61-70	24	20.0
71-80	10	8.3
81 and above	04	3.3
Level of Education		
Primary	34	28.3
Secondary	51	42.5
University/College	11	9.2
Informal education	24	20.0
Source of income		
Crop sales	92	76.7
Livestock sales	120	100
Salary/wages	45	37.5
Pension	22	18.3
Social grants	63	52.5
Source of information		93.3
Elderly people	112	3.3
Books	04	1.7
Internet	02	

Traditional doctors	02	1.7
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The purpose of keeping goats as articulated by informants in the Ngamiland region is shown in Figure 3.2. All the informants kept goats for meat (100%) and about 92% of the informants kept goats for income generation (Figure 3.2).

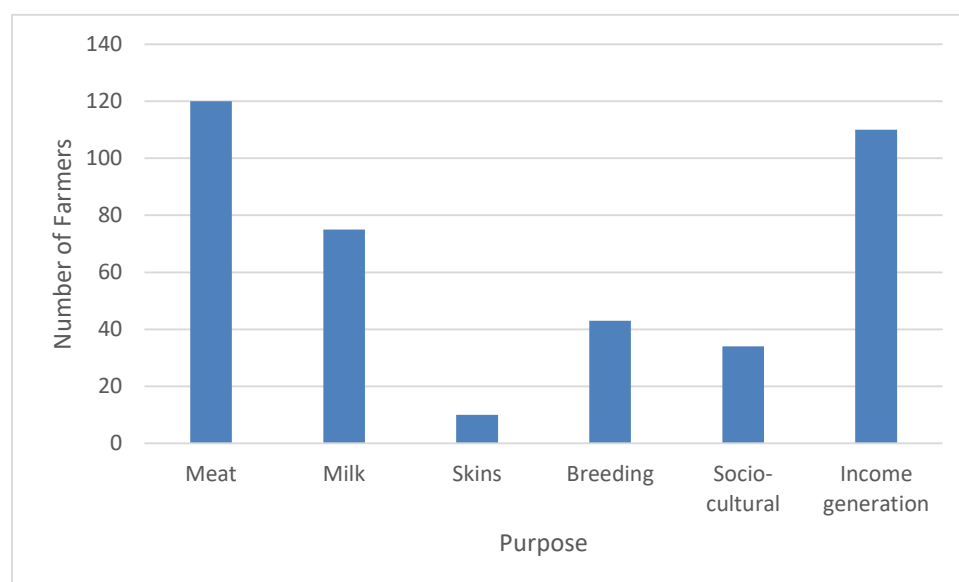


Figure 3.2 Reasons for keeping goats as stated by respondents in the Ngamiland region.

Table 3.2: Livestock kept by respondents across the six villages in the Ngamiland region.

Village	Number of livestock						
	Cattle	Goats	Sheep	Donkeys	Horses	Chickens	Pigs
Ghani	1010	710	210	234	104	98	00
Chukumuchu	988	568	198	232	98	40	00
Mohembo	906	668	201	237	178	62	18
Tsau	1084	690	188	240	115	78	00
Makakung	1034	700	204	250	160	44	10
Semboyoy	1062	677	207	229	111	100	26

Total	6084	4013	1208	1422	766	422	54
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3.4.2 Ethnobotanical information

The majority (65%) of respondents use local plants, while 25% use commercial drugs and 10% use both medicinal plants and commercial drugs to treat and control internal parasites in goats (Figure 3.3A). The common commercial drug used by respondents was Ivermax 1% (ivermectin) injectable solution (Figure 3.3B). Majority of the respondents administered plant remedies once a year, while a few gave plant remedies thrice a year (Table 3.3).

Most of the medicinal plants are found in the wild. Fabaceae is the most frequently mentioned plant family (Table 3.4). The common plant parts used in preparing the remedies are roots (76.9%) followed by leaves (69.2%) and bark (15.4%). In preparing ethnoveterinary medicine, a total of 46% respondents uses decoctions, while 31% use infusions and 23% use both decoctions and infusions methods. Fresh and dried plant parts are used in preparing concoctions.

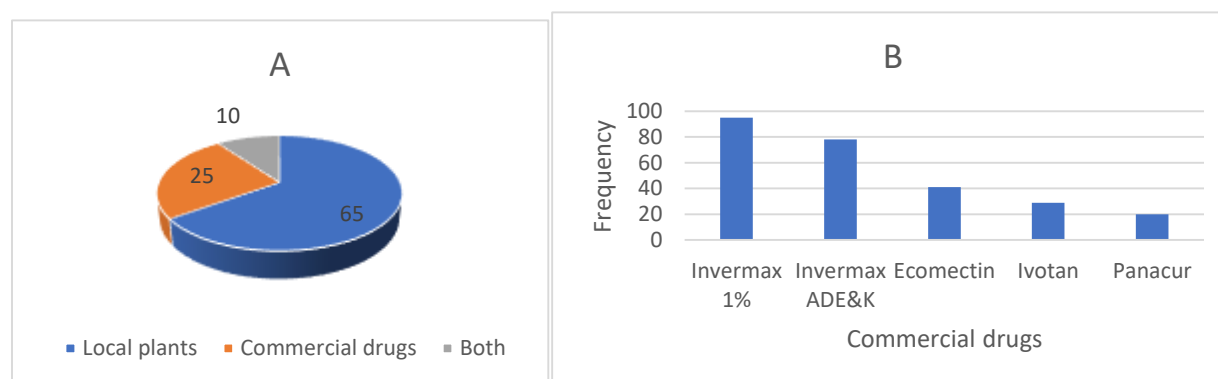


Figure 3.3 Methods used in controlling internal parasites and commercial drugs used by respondent in the Ngamiland region.

Table 3.3: Frequency of administration of plant remedies by different farmers

Frequency of Administration	Number of Respondents
Once a year	50
Twice a year	36
Thrice a year	10

Others	24
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Table 3.4: Ethnobotanical information on local plants used to control internal parasites in goats in the Ngamiland region.

Family	Scientific	Setswana	Parts	*Method of	Route	Dosage
name	name	name	used	preparation		(ml)
Capparaceae	<i>Boscia</i>	Motlopi	Leaves	Decoction	Oral	100
	<i>albitrunca</i>		Roots			
Fabaceae	<i>Colophospermum</i>	Mophane	Bark	Infusion	Oral	100
	<i>mopane</i>		Leaves	Decoction		
Rhamnaceae	<i>Ziziphus</i>	Mokgalo	Roots	Decoction	Oral	50
	<i>Mucronata</i>		Leaves	Infusion		
Malvaceae	<i>Grewia</i>	Motsotsojane	Leaves	Infusion	Oral	100-300
	<i>Flavescens</i>		Roots			
Combretaceae	<i>Terminalia</i>	Mogonono	Roots	Infusion	Oral	100-200
	<i>sericea</i>					
Asphodelaceae	<i>Aloe</i>	Mokgwapha	Leaves	Infusion	Oral	150
	<i>ferox</i>					
Thymelaceae	<i>Gnidia</i>	Mokaikai	Roots	Decoction	Oral	100-200
	<i>capitata</i>		Leaves	Infusion		
Orchidaceae	<i>Asenllia</i>	Palamela	Roots	Decoction	Oral	200
	<i>africana</i>					
Solanaceae	<i>Solanum</i>	Makgonatsotlhe	Roots	Infusion	Oral	200

	<i>nigrum</i>					
Compositae	<i>Tarchonanthus</i>	Moologa	Roots	Infusion	Oral	50-100
	<i>camphoratus</i>					
Fabaceae	<i>Elephantorrhiza</i>	Mositsane	Leaves	Decoction	Oral	100
	<i>Elephantina</i>					
Apocynaceae	<i>Acokanthera</i>	Serekolo	Leaves	decoction	Oral	200
	<i>oppositifolia</i>					
Fabaceae	<i>Peltophorum</i>	Mosetlha	Roots	Decoction	Oral	100
	<i>africanum</i>		Leaves			
			Bark			

*Decoction is a method of extracting plant materials by boiling to dissolve the chemicals of the material. Infusion is a process of extracting chemical compounds from plant material by soaking in water.

3.4.3 Fidelity level of different plants

The highest FL values were found for the following plant species; *Terminalia sericea*, *Gnidia capitata* and *Aloe ferox* each scoring 89.3%, 88.0% and 86.3%, respectively. The table (Table 3.5) shows that the plants with high fidelity levels were mostly used.

Table 3.5: Fidelity level indices of local plants used to control internal parasites in goats.

Plant species	Fidelity Level (%)
<i>Terminalia sericea</i>	89.3
<i>Gnidia capitata</i>	88.0
<i>Aloe ferox</i>	86.3
<i>Grewia flavescens</i>	55.8
<i>Peltophorum africanum</i>	55.0

<i>Elephantorrhiza elephantina</i>	42.5
<i>Solanum nigrum</i>	37.5
<i>Tarchonanthus comphoratus</i>	36.7
<i>Boscia albitrunca</i>	28.3
<i>Ansellia africana</i>	20.8
<i>Ziziphus mucronata</i>	19.2
<i>Colophospermum mopane</i>	8.3
<i>Acokanthera oppositifolia</i>	6.7

3.5 Discussions

Ethnoveterinary medicine is part of community-based approach that provide animal health care that is cheaper, easier, and more sustainable (Mkwanazi et al., 2020). It is important to conserve ethnoveterinary knowledge since it is vulnerable and at risk of extinction due to lack of recording and documentations, lifestyle changes and technological developments. In this study, the male dominance observed on the demographic characteristics could be due to cultural or religious beliefs. In the African culture males are trained at a younger age to be the head of the household by doing certain roles such as herding of goats, performing spiritual and traditional healing. Women are often associated with family care through cooking and nurturing of children. Similar findings have been reported by Adeniran et al. (2020) in Nigeria, Ndlela et al. (2022) in South Africa and Eiki et al. (2022) in Namibia. However, in other parts of the world such as China and Romania women were predominant in practicing plant-based ethnoveterinary medicine (Shen et al., 2010; Bartha et al., 2015).

The present study has shown that the plant-based ethnoveterinary practice is limited to the elderly as compared to the younger generation. The youth tend to migrate to urban areas and foreign countries seeking better employment opportunities. Similar phenomena have been reported by several authors (Bartha et al., 2015; Jambwa and Nyahangare, 2020; Luo et al., 2022; Ndlela et al., 2022). This trend indicates that transmission of information on plant based ethnoveterinary medicine will eventually decline resulting in extinction through death and

unsustainability. Therefore, documentation, conservation of information and sustainable management of these plants is vital in the control of internal parasites in livestock.

Domesticated animals continue to play a significant role in the lives of farmers in this study due to lack of employment, poverty and cultural beliefs. In most African societies people believe that owning livestock is a sign of wealth. The farmers kept livestock as a source of food, income and to buy other commodities for the household. Similar findings have been reported by Monau et al. (2018). The study further revealed that farmers attained some form of formal education which is important in the documentation of medicinal plants. The farmers should be encouraged to document and adopt such remedies for future reference. Our findings are, however, different from ethnoveterinary practitioners of Omusati and Kunene regions of Namibia who reported that majority of the respondents had no formal education (49%) (Eiki et al., (2022).

The frequent use of medicinal plants for the treatment of internal parasites observed in this study is attributed to their cheapness, and easy accessibility. Herbal plants are broad-spectrum and have low chances of drug resistance (Marandure, 2015). Similar findings have been reported by Moreki, et al. (2010). The frequent use of the Fabaceae plant family in this study was similar to McGaw, et al. (2020) in South Africa, Eiki et al., (2022) in Omusati and Kunene Regions of Namibia and Adeniran et al., (2020) in the north-central region of Nigeria. The Fabaceae family has broad plant species that are renowned for treating illness associated with respiratory infections (Alhaji and Babalobi, 2015) and diarrhoea (Aremu et al. 2012; Offiah et al., 2012). However, in other regions of Botswana, Kweneng district, Lentsweletau area, Asphodelaceae was reported as the dominant plant family in treatment of internal parasites in goats (Setlalekgomo and Setlalekgomo, 2013).

The frequent utilization of roots noted in this study was similarly observed by Gabalebatse et al. (2013) in Toteng village of Botswana and by Birhanu and Abera (2015) in western Ethiopia. This is mainly attributed to the fact that roots remain in the soil and are easily accessible even during extended dry seasons. Roots are also broad-spectrum and have various bioactive molecules which display curative possibilities (Das et al., 2014). However, the use of roots is often not advocated for, due to harmfulness and unsustainable harvesting methods, ultimately leading to plant extinction (Moyo et al., 2015). The results are different with other studies as

Setlalekgomo and Setlalekgomo, (2013) observed that the use of plant leaves was highly favoured in other areas of Botswana, such as the Kweneng district. Sanhokwe et al. (2016) also noted that most farmers prefer to use fresh plant parts particularly leaves, especially during the rainy season in the Eastern cape, South Africa. The use of leaves in preparation of herbal remedies reduces loss of plants from the natural habitats as it does not destroy the whole plant.

The preference of decoction process observed in this study was similar to what Maphosa and Afolayan (2003) reported in South Africa but different from a report by Gabalebatse et al. (2013) in Toteng village of Botswana where infusion preparation method was preferred for treating internal parasites in different livestock species. This is mainly because decoction helps extract water-soluble polar compounds and the high temperature helps in reducing the toxicity of thermolabile compounds that may be poisonous to the animals (Djoueche et al., 2011). Farmers prefer oral administration, which is a simple and non-invasive form of treatment. The route enables sufficient curative power to be delivered along with quick absorption and distribution of the prepared medications (Teklay et al., 2013). The most popular method of treating and controlling internal parasites across many African cultures is oral administration of medicinal plants because it ensures quick and direct interaction with various plant compounds at the site of action (Chakale et al., 2022; Gradé et al., 2009; Yineger et al., 2007).

High fidelity level (FL) values are highly important in the selection of specific plants for further search of bioactive chemicals (Assefa and Bahiru, 2018). In this study three plant species, *Terminalia sericea*, *Gnidia capitata* and *Aloe ferox* scored the highest fidelity values and should be subjected to further phytochemical and pharmacological investigation to determine their medicinal efficacy. The results agree with Moreki et al. (2010) and Gabalebatse et al. (2013) who reported that *Terminalia sericea* was used for the treatment of internal parasites in livestock in Chobe district, and Toteng village in the Ngamiland district, respectively. Setlalekgomo and Setlalekgomo (2013), also reported the use of *Aloe ferox* for the control of intestinal parasites in goats in Lentsweletau village. According to Mwale et al. (2006), *Aloe vera* leaf and juice may be used internally or externally in animals. This agrees with the present study where respondents infused *Aloe ferox* leaves in water to control internal parasites infection. The findings differ with findings by others who found high fidelity in other Aloe species including Eiki et al. (2022) in Namibia who reported *Aloe esculenta* with high fidelity level, whilst Sanhokwe et al. (2016) in

South Africa reported high fidelity levels in *A. ferox*, *A. oppositifolia*, *A. setosa* and *E. elephantina*. *Aloe ferox* has been reported to contain a wide range of phytochemical compounds, including anthraquinones, chromones, anthrones, phenolic compounds, flavonoids, tannins, steroids and alkaloids, all of which contribute to its various pharmacological activities (Nalimu et al. 2021). Alkaloids and phenolic compounds are probably the two most important phytochemical compounds that are of medicinal value (Singh et al. 2021). *Terminalia sericea* has also been phytochemically investigated for its chemical constituents, and a diverse group of phytochemicals, namely, pentacyclic triterpenoids, phenolic acids, flavonoids, steroids, and alkaloids have been reported from their plant parts (Nair et al. 2018). Pharmacological studies of *Gnidia* spp have also revealed that they contain certain compounds i.e. diterpene esters, coumarins, flavonoids, chromones, lignans, and neolignans which are of medicinal value (Bhandurge et al. 2013).

The farmers used clinical signs and symptoms to identify internal parasites infection in goats. Some of these clinical signs include weight loss, loss of appetite, rough skin, swelling throat, breathing problem, diarrhoea, and dehydration (Chakale et al., 2022). Therefore, the effectiveness of these plant remedies is based on the disappearance of clinical signs and symptoms. Thus, there is a great need to discover new biologically active compounds from these plants species and develop novel drugs. Few studies are available about ethnoveterinary medicinal plants and their constituents with antimicrobial activities (Chakale et al., 2021), and these indigenous plants may contain pharmaceutically essential compounds. Therefore, it is important to document and conserve these plant species for sustainable treatment of helminthiasis in goats.

3.6 Conclusions

The study revealed that there were 13 local plant species that Ngamiland goat farmers use to control internal parasites based on indigenous knowledge. Despite the gradual sociocultural change over the years, the locals have retained some remarkable knowledge about plants and their current applications. This shows that the Ngamiland people's use of plants to manage internal parasites in goats is still deeply rooted in their culture. However, there is a need to go a

step further and conduct safety, efficacy and optimization trials to verify farmers' claims that the plants are safe and effective.

3.7 Conflict of Interest

The authors declare that they have no competing interests.

Acknowledgement

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CHAPTER 4

On-farm assessment of breed and sex variations in response to selected indigenous plant-based anthelmintics in goats in Botswana

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4.1 Abstract

The aim of this study was to evaluate the efficacy of *Terminalia sericea* and *Gnidia capitata* plants on faecal egg counts of different goat breeds and sexes. A total of 15 Tswana and 15 Boer goats, aged 18-21 months were randomly allocated to three treatment groups comprising of 10 goats each. For the sexes 6 females and 4 males were randomly selected for each of the three treatments. The animals were selected from two different farmers at Ngocho farmsteads. The leaves of *Gnidia capitata* and the roots of *Terminalia sericea* plants were sun dried, crushed into powder and 150g of each powdered sample was mixed with 2 litres of water. The extracts were prepared by soaking in water (infusion) for 24 hours and were given to the goats orally, respectively, while Treatment 3 animals were given Ivermax 1% under the skin (subcutaneously). The body condition score and faecal egg counts based on modified McMaster technique were performed at the beginning of the trial and on days 30, 60 and 90. The data were analyzed using SAS. The results revealed an increase from 2 to 4 in the animal's body condition score across all treatments over the 90-day period. The optimum efficacy against nematodes was on the 60th day and *Gnidia capitata* had the highest efficacy of 76% followed by Ivermax with 71% and *Terminalia sericea* with 65%. *Terminalia sericea* plant mixture was more efficient on reducing coccidia oocysts with an efficacy of 80% and 89% on days 60 and 90, respectively. Tswana goats treated with both *Terminalia sericea* and *Gnidia capitata* plant remedies showed a significant reduction in the mean egg counts of nematodes at day 60. Boer goats given *Terminalia sericea* plant mixture had significantly lower number of coccidia oocyst compared to Tswana goats at days 30, 60 and 90. At day 60, males had lower nematodes egg counts than females for both plant remedies with males treated with *Gnidia capitata* plant extract showing a

higher significant response. These plants should be preserved and further studies conducted to determine their active compounds and specific mechanisms of action.

Keywords: Breed, efficacy, faecal egg count, plant extracts

4.2 Introduction

Internal parasites pose significant challenges to goat health and productivity in Botswana. They cause significant health constraints such as weight loss, anemia, stunted growth, and in severe cases death (Roeber et al., 2013). These effects translate into reduced fertility, meat, milk, and fiber production as well as socio-cultural needs, leading to substantial economic consequences for livelihoods and food security. A study in Ethiopia revealed that internal parasites can cause up to 28% kid mortality and 8% weight loss, translating to national losses exceeding US\$400 million annually (Sissay et al., 2008). The control of internal parasites has for many years relied solely upon anthelmintic treatment, which has led to emergence of resistant worms, poor biodegradation and high financial expenditures (Johansson 2018; Lagos et al., 2023). The countries combating anthelmintic resistance in ruminants has estimated the parasitic worm cost at €1.8 billion per year, with drug-resistance costing at least €38 million per year in production losses and treatment costs (Charlier et al., 2020).

Herbal remedies and local plants have emerged as promising alternatives to conventional anthelmintics, offering sustainable and affordable options in controlling internal parasites in goats. The plant based bioactive compounds such as tannins, alkaloids, saponins, and glycosides from *Chenopodium ambrosioides* (epazote), *Azadirachta indica* (neem), and *Allium sativum* (garlic) have been observed to impede the growth and multiplication of internal parasites in livestock, providing possible solutions to anthelmintic resistance among ruminants (Salem et al., 2011; Carvalho et al., 2012; Kristianto et al., 2023). In Botswana, several local plants have been utilized by farmers to prevent a range of animal illnesses, including internal parasites in goats (Moreki et al., 2010; Gabalebatse et al., 2013; Setlalekgomo and Setlalekgomo, 2013; Lechani et al., 2024). However, the efficacies of these plants are yet to be scientifically proven.

The efficacy of local plants dewormers is of importance for development of therapeutically effective drugs, sustainability and commercialization. The efficacy of plant-based treatments can,

however, vary considerably among different goat breeds and sexes. For instance, indigenous breeds like the West African Dwarf (WAD) and the Kenyan small east African goats are known for their resilience against parasitic infections, potentially due to their adaptive immunity (Baker et al., 1998; Chiejina and Behnke 2011). Therefore, utilizing animals with robust immune responses may respond favorably to plant treatments, exhibiting greater weight gain and lower faecal egg counts (Matika et al., 2003). Sex has also shown to influence parasites susceptibility, for example, male goats have been reported to be significantly more susceptible to gastrointestinal nematodes than female goats (Haile et al., 2002), due to androgen hormones that regulate various facets of host immunity (Klein, 2000). Therefore, it is anticipated that using male animals in efficacy tests will yield a marked and variable response (Onzima et al., 2017).

The sustainable alternative internal parasites control strategies include a combination of indigenous knowledge, epidemiology of infection and management practices. This underscores the practicality of integrating plant-based treatments into flock health management. While the use of plants is advantageous due to affordability, low toxicity and reduced risk of drug resistance, the variation in different goat breed responses necessitates careful monitoring and adjustment of treatment regimens (Cavalho et al., 2012; Alawa et al., 2003; Muthee, 2018). There has been an increase in research on identifying different local plants that farmers use to combat internal parasites with a major gap on efficacy. Therefore, the aims of this study were to evaluate the efficacy of *Terminalia sericea* and *Gnidia capitata* in reducing faecal egg counts on two different goat breeds and sexes in Botswana. The two plants were selected based on the farmers survey carried out in the Ngamiland district by Lechani et al. (2024).

4.3 Methodology

4.3.1 Ethical Statement

The present study complied with requirements of Botswana University of Agriculture and Natural Resources' Animal Care and Ethics Committee (Reference number: BUAN-AEC-2023-04).

4.3.2 Study site

The study was carried out on farm in the Ngamiland district of Botswana at Ngocho cattle farmstead. The farmstead is located at latitude of S19°22'27.11568" and a longitude of E22°9'48.23244. The vegetation is mainly savanna with tall grasses and bushes. The annual mean rainfall ranges from 400 to 600 mm and mostly falls in summer, from October to April (Bhalotra, 1987). The annual temperatures range from 13°C to 38°C and the soil is predominantly sandy loam and sandy clay (Bhalotra, 1987).

4.3.3 Collection and Preparation of Plant Extracts

The leaves of *Gnidia capitata* (Figure 4.1) and the roots of *Terminalia sericea* (Figure 4.2) plants were collected in the wild areas of Qurube and Ghani villages of the Ngamiland district, in November 2024. To get a representative sample, at least five samples of each plant were collected. The plants were randomly selected by skipping five plants then sampling the sixth plant in a row. The fresh leaves of *Gnidia capitata* were collected from five different shrublets. The roots of *Terminalia sericea* were collected by digging the plant and cutting off the roots from five different plants. The plant specimens were then taken to Botswana University of Agriculture and Natural Resources herbarium for identification and authentication. The samples, i.e. the roots (*Terminalia sericea*) and leaves (*Gnidia capitata*) were sun dried then mixed and crushed into powder using the traditional wooden mortar and pestle. Both plant remedies/ extracts were prepared according to the farmer's method by soaking 150 grams of powder of each sample in 2 liters of water and left to stand for 24 hours (Infusion). The mixtures for both plants were then sieved with a tea strainer to collect the plant extracts. Both extracts were then kept in 2L bottles at room temperature, while waiting to be given to the animals.



Figure 4.1; *Gnidia capitata*



Figure 4.2; *Terminalia sericea*

4.3.4 Animal selection and management

The goats used in the study had not received any anthelmintic treatment for at least 90 days prior to the commencement of the study. A total of thirty goats from two breeds; 15 Tswana and 15 Boer goats, aged 18-21 months were used in this study. The Tswana and Boer goats were physically identified based on phenotypic characteristics described by Nsoso et al. (2004) and by Talukder and Choudhury (2018), respectively. The animals were aged based on the farmers' information and observations on the eruption and wear of lower incisors as described by Greenfield and Anold (2008). The goats were randomly allocated to three treatment groups comprising of 10 goats each, with each group having 5 Tswana and 5 Boer goats. For the sexes 6 females and 4 males were randomly selected for each of the three treatments. The animals were selected from two different farmers. The goats were tagged with different colour tags for group identification. The animal sexes were balanced for each treatment group. Treatment 1 and 2 groups were respectively given *Terminalia sericea* (TS treatment) and *Gnidia capitata* (GC treatment) plant remedies orally at a dose of 100ml per goat as recommended by farmers. The positive control group (treatment 3) was given a synthetic commercial anthelmintic product Ivermax 1% (IVM 1% treatment) at the recommended dosage rate of 1ml per 50kg live mass, subcutaneously. The animals were treated once. The treatments were given to the animals in the morning before grazing. The animals were allowed to graze naturally from the veld, from 0900 to 1700 hours with water provided *ad libitum*.

4.4 Data collection

4.4.1 Body condition score

The body condition score (BCS) was recorded at the beginning of the trial (day 0) and at different phases of the experiment, that is at day 30, 60 and 90. BCS was determined by palpating the spinous and transverse processes of the lumbar vertebrae, fat thickness over the loin and loin shape (Edmonson, 1989). The BCS assessment of the animals was expressed as a numerical score typically ranging from 1 – 5, with 1 indicating very poor condition (i.e. emaciated) and 5 representing excessive fat deposition (i.e. obese) (Hutu and Onan, 2020).

4.4.2 Faecal collection

At the beginning of the trial the animals were screened for the presence of gastrointestinal nematodes by examining faecal samples obtained before administering any treatment. The faecal samples for each animal were collected from the rectum and placed in the labeled universal bottles. They were then refrigerated at 4°C for 24 hours before being taken to the laboratory for analysis as the lab was far away from the sampling area. This was done to prevent bacterial growth and changes in the sample that could affect test results. The faecal egg counts were performed on day 0, 30, 60 and 90 between the months of December 2024 and March 2025.

4.4.3 Parasitology test

The parasitology laboratory at National Agricultural Research and Development Institute (NARDI) in Maun was used for analyzing the samples. The collected faecal samples were quantitatively examined for nematode eggs and coccidia oocysts by using the modified McMaster technique. Two grams of faeces were weighed and crushed in a mortar and 28 ml of distilled water was added to the faecal material and mixed thoroughly. The mixture was sieved, and the filtrate was centrifuged for 3 minutes at 1500rpm. The supernatant was poured off, the residue was agitated and then 30 ml of saturated salt solution was added and the sample mixed by shaking. Using a pipette, the sample was withdrawn and both sides of the McMaster counting chamber were filled, placed under a compound microscope and allowed to stand for five minutes to allow the eggs to float before examination. Using 10x objective (X10) lens, the total eggs were counted and multiplied by 50 to obtain eggs per gram (EPG) of faeces. The efficacy of different treatments was determined by faecal egg count reduction test following the formula below by Sujon et al. (2008):

$$\text{Efficacy} = \frac{\text{EPG}_{\text{prior to treatment}} - \text{EPG}_{\text{post - treatment}}}{\text{EPG}_{\text{prior to treatment}}} \times 100$$

EPG prior to treatment

Where EPG is the Eggs per gram

4.4.4 Statistical Analysis

The mean body condition scores were evaluated using the Friedman statistical test. To evaluate the differences in efficacy based on fecal egg count between Tswana and Boer goats over time, the following model was used in SAS (SAS, 2003).

$$Y_{ijk} = X_{ijk} + \mu + A_i + B_j + Y_k + (AB)_{ij} + \varepsilon_{ijk}$$

Where Y_{ij} is the j th observation at the day of sampling on i th animal breeds, X_{ij} is the effect of initial count as a covariate, μ is the overall mean effect, A_i is the effect of treatment, B_j is the j th fixed effect of the goat breed, Y_k is the k th day of sampling (30, 60, 90) effect when measurement was taken, $(AB)_{ij}$ is the interaction effect between the i th treatment level and the j th level of breed, and ε_{ij} is the random error. A statistically significant association was considered with $P \leq 0.05$.

Furthermore, SAS model was also used to evaluate the efficacy between males and females over time. The formula below was used for analysis:

$$Y_{ijk} = X_{ijk} + \mu + A_i + B_j + Y_k + (AB)_{ij} + \varepsilon_{ijk}$$

Where Y_{ij} is the j th observation at the day of sampling on i th animal breeds, X_{ij} is the effect of initial count as a covariate, μ is the overall mean effect, A_i is the effect of treatment, B_j is the j th fixed effect of the goat sex, Y_k is the k th day of sampling (30, 60, 90) effect when measurement was taken, $(AB)_{ij}$ is the interaction effect between the i th treatment level and the j th level of breed, and ε_{ij} is the random error. A statistically significant association was considered with $P \leq 0.05$.

4.5 Results

4.5.1 Body Condition Score (BCS)

There was an increase in the animal's body condition across all treatments over the 90-day study period (Table 4.1). Initially, all animals had a mean BCS of 2 and on day 30, the mean BCS increased to 3, and at days 60 and 90, the BCS further increased to 4. Statistical analysis using the Friedman Chi-Square test yielded an F-statistic of 9.0 and a p-value of 0.0293, indicating a statistically significant difference in BCS over time.

Table 4.1: Average body condition score of goats over 90 days study period for three treatments

Treatment	Days			
	0	30	60	90
Treatment group 1 (<i>Terminalia sericea</i>)	2±0.2	3±3.16	4±0.0	4±0.0
Treatment group 2 (<i>Gnidia capitata</i>)	2±0.2	3±3.16	4±0.0	4±0.0
Treatment group 3 (Ivermax 1%)	2±0.2	3±3.16	4±0.0	4±0.0

4.5.2 Faecal Eggs Counts

At the beginning of the trial (day 0) treatment 1 (*Terminalia sericea*) had higher significant mean nematode eggs and coccidia oocysts compared to other treatments (Table 4.2). *Terminalia sericea* and *Gnidia capitata* plant extracts significantly reduced nematodes worm egg counts and coccidia oocysts with an efficacy of approximately 40% to 46% on the 30th day. The commercial drug (Ivermax.) had an efficacy of 60% and 70% against nematodes egg count and coccidia oocysts, respectively on the 30th day. On the 60th day, *Gnidia capitata* plant extract had the highest efficacy against nematode of 76% followed by Ivermax with an efficacy of 71% and *Terminalia sericea* with 65%. Generally, *Terminalia sericea* plant extract was more efficient on coccidia oocysts reduction throughout the study period with an efficacy of 80% and 89% on day 60 and 90, respectively. The optimum efficacy against nematodes was observed on day 60 and the increase of nematodes infection in all treatments occurred on day 90. There was no reinfection for coccidia oocysts on the 90th day of the experiment in all treatments.

Boer goats were initially significantly loaded with nematodes eggs and lower coccidia oocysts in all treatments. On the 30th day, treatment 1 and 2 (*Terminalia sericea* and *Gnidia capitata*) had a minimal efficacy of 40% in treating nematodes in both breeds. Tswana goats treated with both *Terminalia sericea* and *Gnidia capitata* plant remedies were responsive to nematodes infection on the 60th day with some reduction in nematode infection. Boer goats given *Terminalia sericea* plant extract had significantly lower number of coccidia oocyst compared to Tswana goats at days 30, 60 and 90. Although the commercial drug reduced the coccidia oocysts at days 30 and 60, there was a reinfection at day 90 and the Boer goat was highly affected. Generally, at day 90, the plant treatment remedies had significantly lower reoccurrence of coccidia oocyst but higher

nematodes reinfection in both breeds. There was no significant interaction ($P>0.05$) between the day of sampling and the breed (Table 4.3).

At the beginning of the treatment, the male goats were heavily infected ($P<0.05$) with nematode eggs compared to female goats in all treatments. At day 30, females in treatment 1 were more responsive and males were more responsive in treatment 2. At day 60, males had lower nematodes egg count than females for both plant remedies with males in treatment 2 (*Gnidia capitata* extract) showing significant response (16.6 ± 2.20) than males in treatment 1 (26 ± 6.0). At day 30, the males treated with plants extract had lower coccidia oocysts than males treated with commercial drug. The females in treatment 1 and 3 had significantly lower coccidia oocysts at day 60. The male goats given *Terminalia sericea* extract and the female goats given *Gnidia capitata* extract had significantly lower ($P<0.05$) coccidia oocysts at day 90. On day 90, there was significant ($P<0.05$) increase to nematode egg counts across all treatments except for males in treatment 3. Females in treatment 1 and 3 had a significantly ($P<0.05$) higher reinfection than males in the same groups. Comparatively, goat sexes given plant remedies had lower coccidia oocysts reinfection than those given the commercial drug. There was no significant interaction ($P>0.05$) between day of sampling and goat sex.

Table 4.2: The mean ($\pm$ SE) faecal egg count and Coccidial oocysts of goats under various treatments according to different times

Treatments	Days			
	0	30	60	90
Nematodes				
Treatment 1 (<i>Terminalia sericea</i>)	92.3 $\pm$ 3.4 ^a	55.4 $\pm$ 4.4 ^a	32.5 $\pm$ 3.5 ^a	42.1 $\pm$ 3.8 ^a
Treatment 2 (<i>Gnidia capitata</i>)	75.9 $\pm$ 4.4 ^b	43.4 $\pm$ 3.5 ^b	18.5 $\pm$ 2.1 ^b	43.6 $\pm$ 2.2 ^a
Treatment 3 (Ivermax 1%)	65.6 $\pm$ 6.3 ^c	25.5 $\pm$ 3.6 ^c	18.9 $\pm$ 2.4 ^b	22.6 $\pm$ 2.4 ^b
Coccidia oocysts				
Treatment 1 (<i>Terminalia sericea</i>)	63.1 $\pm$ 3.7 ^a	38.1 $\pm$ 2.0 ^a	12.0 $\pm$ 2.8 ^a	6.9 $\pm$ 1.1 ^a
Treatment 2 (<i>Gnidia capitata</i>)	43.0 $\pm$ 4.5 ^b	23.8 $\pm$ 3.7 ^b	10.5 $\pm$ 2.1 ^a	9.1 $\pm$ 1.7 ^b
Treatment 3 (Ivermax 1%)	31.4 $\pm$ 4.1 ^c	9.3 $\pm$ 1.8 ^c	8.4 $\pm$ 1.2 ^a	6.2 $\pm$ 2.4 ^a

*Values with a different superscript in a column have a significant difference at ($P<0.05$).

Table 4.3: The effect of goat breeds on faecal egg counts and coccidial oocysts (mean $\pm$ se) under various treatments

Faecal Eggs	Breed	Days			
Nematodes		0	30	60	90
Treatment 1 (<i>Terminalia sericea</i>)	Tswana	89.6±4.2 ^a	52.0±6.8 ^a	25.4±4.7 ^a	44.0±3.9 ^a
	Boer	95.0±5.5 ^b	58.8±5.8 ^b	38.0±4.4 ^b	40.2±6.8 ^a
Treatment 2 (<i>Gnidia capitata</i>)	Tswana	77.2±8.1 ^c	43.6±6.1 ^c	17.4±2.8 ^c	44.2±4.2 ^a
	Boer	74.6±4.6 ^d	43.2±4.2 ^c	19.6±3.3 ^d	43.0±2.2 ^c
Treatment 3 (Ivermax 1%)	Tswana	64.4±10.0 ^e	25.6±7.0 ^d	20.0±5.0 ^d	20.8±3.1 ^d
	Boer	66.8±8.3 ^e	25.4±2.9 ^d	17.8±5.8 ^c	24.4±3.9 ^e
Coccidia oocysts					
Treatment 1 (<i>Terminalia sericea</i>)	Tswana	64.8±3.4 ^a	40.2±1.4 ^a	13.2±3.5 ^a	6.6±2.5 ^a
	Boer	61.4±6.5 ^b	36.0±3.5 ^b	10.8±4.4 ^b	5.8±2.1 ^a
Treatment 2 (<i>Gnidia capitata</i>)	Tswana	44.8±7.2 ^c	26.6±9.7 ^c	9.8±2.3 ^b	6.4±2.7 ^a
	Boer	41.2±5.3 ^d	21.0±4.0 ^d	11.2±3.0 ^b	7.4±3.8 ^b
Treatment 3 (Ivermax 1%)	Tswana	30.2±6.1 ^e	10.6±3.4 ^e	6.4±0.9 ^c	9.0±1.9 ^c
	Boer	32.6±5.6 ^e	8.0±1.3 ^e	10.4±1.9 ^b	11.0±2.7 ^d

*Values followed by the same letter in one column show no significant difference

Table 4.4: The effect of goat sex on faecal egg counts and Coccidial oocysts (mean ±se)

Treatment	Sex	Days			
Nematodes		0	30	60	90
Treatment 1 (<i>Terminalia sericea</i>)	Male	90.0±4.0 ^a	61.5±3.6 ^a	26±6.0 ^a	32.8±5.3 ^a
	Female	93.8±5.2 ^a	51.3±6.7 ^b	36.8±3.6 ^b	48.3±3.5 ^b
Treatment group 2 (<i>Gnidia Capitata</i>) extract	Male	76.8±5.6 ^b	44.0±2.1 ^c	16.6±2.2 ^c	43.8±3.9 ^c
	Female	75.0±7.4 ^b	42.8±7.2 ^c	20.4±3.5 ^d	43.4±2.6 ^c
Treatment group 3 (Ivermax 1%)	Male	72.8±8.6 ^c	30.8±12.4 ^d	21.8±4.2 ^d	21.4±2.9 ^d
	Female	58.4±8.8 ^d	20.2±3.9 ^e	16.0±2.3 ^c	23.8±4.1 ^d
Coccidia oocysts					
Treatment 1 (<i>Terminalia sericea</i>)	Male	62.3±3.3 ^a	30.0±3.9 ^a	13.5±5.3 ^a	5.3±1.6 ^a
	Female	63.7±5.8 ^a	38.5±3.7 ^b	11.0±3.0 ^a	6.8±2.4 ^a
Treatment 2 (<i>Gnidia capitata</i>)	Male	34.4±4.6 ^c	19.8±1.8 ^c	8.2±2.5 ^b	9.6±1.5 ^b
	Female	46.2±8.1 ^d	27.8±6.7 ^d	12.8±2.7 ^a	4.2±2.2 ^c
Treatment group 3 (Ivermax 1%)	Male	35.8±6.6 ^c	12.4±2.8 ^e	10.2±1.8 ^a	10.4±3.7 ^b
	Female	27.0±4.0 ^e	6.2±1.3 ^f	6.6±1.2 ^b	7.8±2.3 ^c

*Values followed by the same letter in one column show no significant difference

4.6 Discussion

Body condition score (BCS) is critical for assessing the general health of the animal (Bessel et al., 2018). It is generally considered the best and simplest indicator of available fat reserves which can be used by the animals in periods of high energy demand, stress or sub-optimal

nutrition (Detweiler et al., 2008). The low body condition scores observed at the beginning of the study could probably be attributed to internal parasite infection. The loss of considerable quantities of animal protein into the gastrointestinal tract and consequent changes in protein synthesis in host tissues are cardinal features of all helminth infections which ultimately manifest in the body condition of the host (Holmes, 1993). The present findings concur with those of Idika et al. (2012) who reported a decrease of body condition scores in Nigerian West African Dwarf sheep infected with internal parasites. The observed improved BCS post treatment in this study is consistent with Bessell et al. (2018) in Tanzania who reported improved BCS in goats after treatment with anthelmintics. The improved body condition score may be due to reduced competition for nutrients, particularly the absorption of essential nutrients necessary for fat and muscle development between the host animal and gastrointestinal nematodes (Praveen et al., 2024).

The mean egg counts for the commercial drug were generally lower compared to local plant remedies even though they failed to achieve 100% efficacy. This may be due to their standardized and extensively tested nature of commercial drug compared to low potency of herbal remedies. In addition, according to a study by Ramabu et al. (2020), on the evaluation of nematode infection and levels of anthelmintic resistance in small-holder goat flocks across Modipane, Kopong and Gakuto villages in Botswana. The authors found that infection increased in some flocks in Kopong post injection with Ivermectin and these might have been due to anthelmintic resistance. A similar study was carried out by Hassan et al. (2021) in Egypt using Egyptian local plants, namely *A. herba-alba*, *B. aegyptiaca* and *A. sativum* against a standard drug Albendazole. The authors reported that the standard drug had a higher effect in reducing *Haemonchus contortus* in Baladi sheep compared to local plants due to their low potency. Another study in Kenya, Munthe (2018) reported an 87% decrease of faecal egg counts with Albendazole drug in sheep compared to 59%, -11% and -31% for *Myrsine africana*, *A. anthelmintica*, and *E. schimperi*, respectively. Nevertheless, plants remedies used in this study reduced faecal egg counts with immunity lasting for about 60 days. Chandrawathani et al. (2013) reported that Neem leaves have the potential to reduce faecal egg counts of gastrointestinal parasites in goats with immunity lasting for two weeks. Abdul-Rahman et al. (2023) also reported a decrease in faecal egg count in Djallonke goats when fed some garlic powder once in

four weeks. Madibela and Kelemogile (2008) reported a decrease in coccidia oocysts in goats within a week in a three week experiment, when using *Melia azedarach* fruits. The decrease was attributed to the presence of condensed tannins and other compounds which binds to the intestinal mucosa causing autolysis or unavailability of free proteins to the oocysts (Abo-Shedada and Abo-Farieha, 2003). The studied local plant remedies are a prolific source of ecological bioactive compounds capable of reducing internal parasites in goats. They are a promising potential source for new, effective and safe anti-helminth treatments.

The pre- treatment results from this study showed that Boer goats were more infected with nematodes compared to Tswana goats. The results agree with Burikukiye et al. (2022), who reported that Boer goats are more susceptible to gastrointestinal parasites. This variation between breeds may be due to genetic differences in resistance and resilience against nematodes. Furthermore, the observed high responsiveness of Tswana goats to local plants remedies could be attributed to genetic variations influencing drug or plant extract metabolism. Landau et al. (2010) carried out an experiment on Damascus and Mamber goat breeds (both local breeds) using *Pistacia lentiscus* as an anthelmintic. The authors reported that Damascus kids showed lower faecal egg counts than their counterparts, Mamber. However, Githiori et al. (2004) documented findings that diverged from the present study, reporting differing responses to treatment among Dorper and Red Maasai lamb breeds. The authors discovered that all the 6 local plants extract (*H. abyssinica*, *O. varafricana*, *A. squamosa*, *A. comosus*, *D. angustifolia*, *H. sepalosa*) did not reduce any faecal egg counts on these breeds and there was no significant difference between the breeds.

The observed sex variation in this study may be due to a combination of several factors i.e. hormones, genetic make-up and physiological or environmental. The low infection rate of females at the beginning of the trial may be due to their production of estrogen that stimulates an immune response (Lashari and Tasawar, 2011). Our findings were inconsistent with the previous studies that reported no significant difference between male and female goats on reduction of faecal egg counts when treated with *Salix babylonica* extract (Salem et al., 2015). Abdul-Rahman et al. (2023) outlined that sex had no influence on Djallonke goats when treated with garlic extract and albendazole drug. The inconsistencies could be due to parasites susceptibility or burden which is often influenced by sex hormones (Mpofu et al., 2022). Hormones generally

modulate the immune system, for example testosterone hormone often increase susceptibility to parasites by suppressing the immune response (Roberts et al., 2001). Further research is however, needed to understand the complex interplay between sex hormones and immune response.

4.7 Conclusions

The plant remedies studied have potential to reduce internal parasitism in goats for at least 60 days. Tswana goats showed a very strong reaction to both local plants treatments compared to Boer goats. Although there was sex variation, overall, there was a higher decrease in mean faecal egg counts in males compared to females across treatments with a slight difference in between. A better understanding of the specific mechanism of action of these plant remedies in the animal and the immune system could lead to future solutions to control internal parasites in small ruminants.

4.8 References

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CHAPTER 5

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General Discussion

Ethnoveterinary encompasses beliefs and abilities related to healthcare and animal management. Traditional treatment methods have been used for ages to keep animals healthy and transmitted orally from generation to generation. Despite their crucial function in the livestock population, the knowledge of ethnomedicinal plants is on the verge of irreparable extinction and is deteriorating, hence the need for documentation. Herbal preparations have the potential to reduce worm burden or prevent disease conditions from getting worse or even death of the animals (Murugaiyah et al. 2006). One of the main reasons for poor livestock performance in Botswana is parasitism, which results in a growing disparity between the supply and demand of livestock products.

The first objective of this study was to document plants which are commonly used in controlling internal parasites of goats in the Ngamiland district of Botswana. The study documented 13 plant species belonging to 11 families. The most frequently used plant family was the Fabaceae. Hassan and Yuguda, (2021) and Abrha et al. (2021) also reported that Fabaceae family represents the most abundant ethnoveterinary plant family. The most frequently used plants in this study, according to Fidelity levels (FL), were *Terminalia sericea* and *Gnidia capitata*. Roodt (1998) reported that a decoction of *Terminalia sericea* roots administered orally can help cure a cow suffering from a retained placenta. Some of the plants including *Terminalia arjuna*, *Terminalia bellirica*, and *Terminalia chebula* were found to be used in treating different health issues, like gastrointestinal problems, skin issues, and respiratory ailments (Pelthadka et al., 2025). It is important to document plants used in controlling internal parasites in other regions of Botswana for knowledge and plants conservation, livestock productivity and future research.

The second objective of this study was to determine the efficacy of *Terminalia sericea* and *Gnidia capitata* plants in reducing faecal egg counts in goats. These plants reduced faecal egg count in goats indicating that they may contain specific phytochemicals or a combination of them through similar or different pathways. *Terminalia sericea* is known to contain a source of secondary metabolites including cyclic triterpenes and their derivatives, flavonoids, tannins, and

other aromatics (Nair et al., 2018). According to Isah et al. (2016), the cyclic triterpenes normally disrupt metabolic processes of internal parasites and modulates the host's immune system. The presence of these metabolites in plants can have a direct effect on internal parasite treatment (Nair et al., 2018). According to Paolini et al. (2003) tannins can have a direct impact on the reduction of faecal egg counts in goats. Tannins reduce faecal egg counts by inhibiting female worm fecundity, reducing egg hatchability and lowering adult worm burdens (Max, 2010). *Gnidia capitata* on the other hand contains flavanoids and glycosides necessary for treatment of gastrointestinal parasites (Bhandurgesa et al., 2013). Flavonoids and their glycosides usually act as phytoalexins which normally disrupt life cycles, vitality and development of internal parasites (Marmouzi et al., 2021). However, it should be noted that some of these phytochemicals can have contradicting effects on animals if given on high doses. For example, the excessive consumption of tannins can lead to reduced feed intake and digestibility, impairment of rumen metabolism and mucosal toxicity (Rittner and Reed, 1992; Dawson et al., 1999).

The study also evaluated the breed effect as well as sex effect on plant efficacy. These results should be interpreted with caution due to a small sample size. Nonetheless, the results indicated variation between the breeds in response to treatment, possibly due to the influence of certain genes. Further research on the understanding of the genes and mechanisms involved would assist in the selection of breeds which respond positively to treatment with these plants. This may lead to vast epidemiological benefits, accelerating genetic gain and goat productivity that is both cumulative and permanent.

Regarding goat sex, it can be noted that one sex can be more vulnerable to infection than the other due to innate host-related characteristics. These host-related factors include behavioral influences that have been linked to variations in exposure and susceptibility, and physiological impacts including sex hormones and immunity-related factors (Wesolowska, 2022). The effect of sex hormones on the immune system is the main cause of variations in susceptibility (Badaso and Addis, 2015). Testosterone is a powerful immunological suppressant though essential for the development of secondary sexual features in males (Klein, 2004). Males from this study have shown high prevalence of internal parasites than females and have responded better to treatment than their counterparts. On the contrary, Sharma and colleagues (2009) have reported results

where females had higher internal parasites infection than males, associating it with reduced immune function during pregnancy cycle, parturition and lactation. The observed findings could be viewed as preliminary and further research should be carried out to validate these hypotheses over a period of time with a larger sample size.

Although the two plants reduced faecal egg count on goats, it is important to consider methodological aspects, *in vitro* vs *in vivo* in the interpretation on these results. The study used *in vivo* methodology which examines the efficacy of treatments in a natural context with the outcome completely reflecting how treatment interacts with a living system; immune responses and metabolic processes (Shelar et al., 2024). The results based on this methodology may have confounding effects of the environment interaction, physiological state of the animal and host immune system. On the other hand, *in vitro* methodology provide detailed data on specific cellular mechanisms because some of the confounding factors present in a whole organism are not present (Pastorino et al., 2024). However, *in vitro* studies cannot fully replicate the complex interactions and environment occurring within the animals as cultured cells can behave differently from cells in their natural environment (Pastorino et al., 2024).

5.2 Conclusions

Ngamiland district is endowed with a vast medicinal plants that are of importance to the general health of animals and 13 families have been documented in relation to internal parasites treatment. The study proved that *Terminalia seriea* and *Gnidia capitata* plants were effective in reducing faecal egg counts in both breeds and sexes of goats. The efficacy of these plants means that the Ngamiland farming community can use cheap, reliable methods in controlling internal parasites of goats. The study has further revealed that breeds such as Tswana have some genetic traits that can effectively influence these anthelmintic treatments. Breeding goats that are more reliant on plant remedies to control gastrointestinal parasites is more viable because of reduced production costs and easier accessibility. The study has provided baseline data that is relevant for biotechnology in relation to drug development and future research. By incorporating these local plants in flock health management, animal productivity, food security and improved livelihoods can be achieved.

5.3 Recommendations

The current study recommends the following;

1. There should be some concerted efforts by relevant people to educate the people of Ngamiland district to conserve these medicinal plants and traditional knowledge.
2. Further studies should be carried out on a large sample size of different breeds, sexes and at different seasons of Botswana.
3. It is also important to identify the prevalent nematode in goats before and after treatment.
4. Studies based on in vitro methodology should be carried out to provide knowledge on the effect of these plants at cellular level.
5. *Terminalia sericea* and *Gnidia capitata* plants should be evaluated further to determine the bioactive compounds and their mode of action.

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APPENDIX

Questionnaire administered to farmers in Ngamiland district



QUESTIONNAIRE

ENUMERATOR NAME: _____

The overall objective of the survey is to obtain reliable information on some of the local plants used by farmers to control gastrointestinal parasites in goats in Ngamiland district of Botswana. The survey will enable us to find cheaper alternatives for farmers in controlling internal parasites due to rising prices of anthelmintics drugs. This will also help document and preserve information for future use by other generations.

1.0 DEMOGRAPHIC INFORMATION

1.1 Name of the farmer: _____

1.2 Gender

M	F
---	---

1.3 Age: 20-30yrs

31-40yrs

41-50yrs

51-60yrs

61-70yrs

71-80yrs

81 and above

1.4 Highest education level: *(tick where appropriate)*

No formal education	
Primary	
Secondary	
Tertiary	

1.5 Land holding/ farm size: _____

1.6 Land ownership: own

lease
other

specify _____

1.7 What is your major source of income? (Tick and rank, 1= most important)

source	tick	rank
Crop sales		
Livestock sales		
Salary/ wages		
Pension		
Social grants		
Other (specify)		

1.8 What type of livestock do you keep? (Rank, 1= most important)

Species	cattle	sheep	goats	chicken	pigs	Other (specify)
Number						
rank						

2.0 PRODUCTION MANAGEMENT

2.1 Production system (tick)

Intensive ☐

Extensive ☐

other ☐ specify _____

2.2 Purpose of keeping small stock (Tick and rank, 1= most important)

Purpose	Meat	Milk	Skins	Breeding	Manure	Socio-cultural	Cash from sales	Other (specify)

Tick								
Rank								

2.3 Members of the household who own small stock (tick one or more)

member	Head/ father	spouse	Head/ spouse together	sons	daughter	Other(specify)
Tick						

2.4 Type of housing of small stock(tick)

type	kraal	none	Other (specify)
tick			

2.5 Feeding regime (tick one or more)

Regime	Grazing/ browsing	Bought complete ration	Home- made ration	Stover	Grain	Other (specify)
Tick						

3.0 HEALTH

3.1 Access to veterinary services (*tick where appropriate*)

☐

Government vet

☐

Private vet

☐

Veterinary drug supplier

☐

Extension service

☐

None

3.2 Prevalent disease that normally occur (diseases seen by the farmer on goats)

If **none** tick this box

☐

Local name or symptoms of disease

Are goats treated when sick

(Rank, most common first) rank

1 _____

2 _____

3 _____

4 _____

5 _____

3.3 Vaccination/ preventive treatment given

If **none** tick this box

☐

Local name or symptoms of disease

(Rank, most common first)

rank	done routinely	done when need arise (tick)	
1 _____			
2 _____			
3 _____			
4 _____			
5 _____			

3.4 Do you have parasites problems (circle the appropriate)

External: YES/ NO

Internal: YES/ NO

3.5 How do you think internal parasites are spread from one animal to the other?

3.6 How do you tell the animal has internal parasites?

1. Worms in faeces
2. Worms observed after slaughter
3. Flukes in the liver
4. Bottle jaw (swollen jaw)
5. Loss of body condition
6. Diarrhoea
7. Pale gums, eyes
8. Ruffled coat
9. Other

(specify)

3.7 Internal parasite control

Method (tick)

	Done routinely	Done when need arises
none		
Vaccination		
Dosing		
Traditional		

If traditional method specify _____

Any local plant used: YES/ NO (circle where appropriate)

3.7.1 Local plant name: _____

3.7.2 state of the plant: (tick)

Dry	☐	specify _____
Fresh	☐	
Other	☐	

3.7.3 Plant parts used: (tick one or more)

Roots	☐	specify _____
Leaves	☐	
Bark	☐	
Other	☐	

3.7.4 Method of Preparation:

3.7.5 dosage:

3.7.6 method of administration: (tick)

1. orally	☐	
2. intravenous	☐	
3. intramuscularly	☐	
4. subcutaneous	☐	
5. other	specify	

3.7.7 Source of knowledge:

3.7.8 Target Parasites:

3.8 Have you ever used commercial drugs (*tick where appropriate*)

Yes ☐ No ☐

3.9 How many sheep and goats have been treated with commercial drugs in the past year?

1.0 Which class of sheep and goats were treated for interna parasites? (*Tick one or more where appropriate*)

1. Kids	☐
2. Does	☐
3. Ewes	☐
4. Bucks	☐
5. Rams	☐
6. None	☐
7. All classes	☐

1.1 Commercial drugs given

List of drugs used

Done routinely (tick)

Done when need arises (tick)

1. _____	☐	☐
2. _____	☐	☐
3. _____	☐	☐
4. _____	☐	☐
5. _____	☐	☐

