Prevalence and clinical relevance of *Haemonchus contortus* infections in Zambian goat herds

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Prevalens och klinisk relevans av Haemonchus contortus-infektioner hos getter i Zambia

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Abstract

Zambia is home to 5.5 million goats, owned by 700,000 households, making them the most widely owned livestock in the country. Nearly 90% of these goats are raised by small-scale farmers that own fewer than fifteen goats per household. For many of these households, goats represent their sole source of income, leaving them vulnerable to unpredictable challenges. Among these challenges, disease is the highest reported threat facing goat-farmers in Zambia, leading to high economic losses. Internal parasitism is the most significant health issue amongst goats, with *Haemonchus contortus* in the leading role.

Globally, *Haemonchus contortus* is recognized as the parasite with the greatest economic impact. Its clinical signs include high mortalities, reduced production, weight loss and edema resulting from anaemia and hypoproteinaemia. While primarily considered a tropical parasite, *H. contortus* has through its high biotic potential and ability to ecological adaptation developed mechanisms to expand into arid environments. Zambia's tropical to subtropical climate, with extended droughts that are exacerbated by climate change, creates a suitable environment for this parasite. Although *H. contortus* is prevalent in other African countries, its presence and relevance have not recently been studied in Zambia. The aim of this study was therefore to investigate the prevalence of *Haemonchus contortus* in Zambian goat herds.

A total of 195 faecal samples were collected from goats across the Southern Province (100 samples) and the Central Province (95 samples). The samples were obtained from 20 randomly selected farms in various villages within these provinces. Each sample was pooled with groups of 3-4 individuals from the same herd, then analysed using the McMaster egg count technique and cultivated for ten days before microscopic identification. All goats included in the study were over one year old and of a local mixed breed.

The results revealed a prevalence of *H. contortus* of 17% in the Southern Province and 85% in the Central Province, with an overall prevalence of 49% among pooled samples. Parameters such as body condition score (BCS), anaemia score (using the FAMACHA scoring system), age and sex were documented, but no significant difference were observed between the two provinces. The average BCS was 2.67 (all BCS summarized/number of individuals) and average FAMACHA score was 3.5 across all goats studied.

Keywords: intestinal parasites, endoparasites, Africa, FAMACHA, anaemia

Sammanfattning

I Zambia finns över 5,5 miljoner getter, ägda av över 700 000 djurägare. Majoriteten utgörs av småskaliga bönder med färre än 15 getter per ägare. För många djurägare och deras familjer är getterna den enda inkomstkällan och fungerar som en ekonomisk buffert vid krissituationer. Zambia är ett land som präglas av långa torrperioder, vilka förvärras årligen på grund av klimatförädningar. Getter är både billiga och tåliga under knapra förhållanden och är därför de mest använda boskapet i landet. Den största utmaningen som getägare rapporterat är sjukdom hos djuren. Trots detta finns det ett talesätt i Afrika som lyder ”getter blir inte sjuka”, vilket bidrar till att många sjukdomssymptom förbises och leder till onödiga dödsfall. Det största sjukdomsproblemet hos getter i Zambia är interna parasiter. Detta beror på flera faktorer: det tropiska till subtropiska klimatet som gynnar parasiternas livscykel, brist på möjlighet till profylaktisk alternering av beten, begränsad tillgång till eller kunskap om avmaksningsmedel, samt att getterna är mer känsliga för interna parasiter än andra idisslare. Parasiten med störst global ekonomisk påverkan är *Haemonchus contortus*. Frågeställningen i denna studie är därför vilken förekomst och betydelse *H. contortus* har i Zambiska getbesättningar. Infektion med *H. contortus* kan leda till anemi och hypoproteinemi, vilket yttrar sig som plötsliga dödsfall, nedsatt produktion, minskad tillväxt samt utveckling av ödem. Parasiten har påvisats ha hög prevalens i samtliga afrikanska länder där studier genomförts och mycket tyder på att den även förekommer i Zambia. I småskaliga studier för ca 30 år sedan påvisades förekomesten av *H. contortus* i Zambia, men förekomsten i dagsläget är okänd.

I denna studie analyserades 195 träckprover från getter i södra (n=100) och centrala (n=95) provinserna i Zambia. Först utfördes en McMaster äggräkning och sedan odling för att artbestämma larverna i mikroskop. Proverna poolades med material från 3-4 individer från samma besättning. Resultatet visade att 17 % av de poolade proverna från den södra provinsen (n=30) och 85 % av de poolade proverna från den centrala provinsen (n=27) var positiva för *H. contortus*. Totalt sett var 49 % av de analyserade poolningarna (n=57) positiva. FAMACHA-score, ålder och kön noterades för samtliga individer, men ingen tydlig koppling mellan dessa faktorer och förekomsten av *H. contortus* kunde observeras. Det sågs heller ingen tydlig skillnad mellan de två provinserna.

Nyckelord: intestinala parasiter, endoparasiter, Afrika, FAMACHA, anemi

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Abbreviations

Abbreviation	Description
BCS	Body Condition Score
EPG	Eggs per gram
FAMACHA	Faffa Malan Chart
FAO	Food and Agricultural organisation of the United Nations
FEC	Faecal egg count
GDP	Gross Domestic Product
L	Larvae
PCV	Packed cell volume
WHO	World Health Organisation

1. Introduction

Goats play a vital role in rural households across Zambia, providing nutritional support and economic stability. The animals act as a cushion against unpredictable events such as crop failures or climate variations, ensuring resilience for many communities (Homann *et al*. 2007; Swanepoel *et al.* 2010; Pradère 2014; Namonje-Kapembwa & Chiwawa 2019). Approximately 70% of Africa's rural population depends directly on animal husbandry for their livelihoods. Smallholder farmers in Zambia dominate the livestock sector (Namonje-Kapembwa & Chiwawa 2019; Republic of Zambia: Ministry of Fisheries and Livestock 2024). According to the 2023 livestock survey report, the goat population in Zambia stands at 5.5 million, surpassing the cattle population of 5.1 million, making goats the most widely owned livestock in the country (Republic of Zambia: Ministry of Fisheries and Livestock 2024).

For many people in Zambia goats are their only source of income (Ahmadu & Lovelace 2002). However, a common misconception that goats do not get sick hampers proper understanding of necessary health measurements. This misinformmation increases the risk of preventable losses for livestock owners. The 2023 livestock survey report of Zambia reported disease as the most significant constraint faced by goat-raising households, affecting 37% of respondents (Republic of Zambia: Ministry of Fisheries and Livestock 2024). Among diseases in goats, internal parasitism remains the leading issue impacting animal productivity and welfare (Miller *et al.* 2012:1). Globally *Haemonchus* spp. are the nematode parasites with the highest economic impact (Craig 2009; Jacobs *et al*. 2016:391). *Haemonchus contortus* is the species that primarily infect small ruminants, making it a key parasite of concern in Zambia. Zambia's tropical and subtropical climate provides a favourable environment for the parasite's life cycle, making the country highly susceptible to its presence (Jacobs *et al*. 2016:389).

Despite *Haemonchus contortus* significance, no recent studies have examined the prevalence in Zambia. Given its clinical consequences, such as sudden death, weight loss, reduced production and growth, the threat posed by this parasite cannot be overlooked (Craig 2009). The first step to managing haemonchosis effectively is to assess the current prevalence.

2. Literature review

2.1 About the Republic of Zambia

Zambia is situated in Southern Africa, with an area of approximately 75 million hectares, and experiences a climate ranging from tropical to subtropical (Chileshe 2001). The nation's population is rapidly expanding, currently exceeding 21 million inhabitants (Worldometer 2024). The country is divided into ten provinces: Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, Muchinga, North-Western, Southern and Western province.

2.1.1 Climate and agro-ecological zones in Zambia

Zambia experiences three distinct climatic seasons: the hot dry season (September to November), the warm wet season (November to April) and the cool dry season (May to September), with October typically being the hottest month (Nations Online Project n.d.). During the dry season, humidity levels frequently drop below 20%, and the country experiences severe drought. In 2024, Zambia experienced its longest drought to date, with no rainfall recorded from January to late October (ReliefWeb n.d.). Climate change has further exacerbated these conditions, with the average annual rainfall decreasing by 1.9 mm per month per decade since 1960, and a 1.3 °C rise in average annual temperature over the same period (Irish aid 2018; World Bank Group 2024). The southern part of Zambia experiences longer periods of drought and the southern province is on its way to turn into a desert. The central and northern regions of Zambia are generally more humid year-round (Zambia Climate: Weather Zambia & Temperature by Month 2024).

Zambia is categorized into three agro-ecological zones, as illustrated in figure 1, along with the sample areas for this study (Nalubamba 1994). These zones are primarily defined by annual rainfall patterns. Zone I, located in the southernmost part of the country, is the hottest and driest region, receiving less than 800 mm of annual rainfall. Zone II, situated in central Zambia, receives between 800 mm and 1,000 mm of rainfall annually and is characterized by its fertile soils, making it the most suitable zone for agriculture (Mtambo *et al*. 2007; Zambia - Global yield gap atlas n.d.). Zone III, the high-rainfall region, receives over 1,000 mm of rainfall annually.

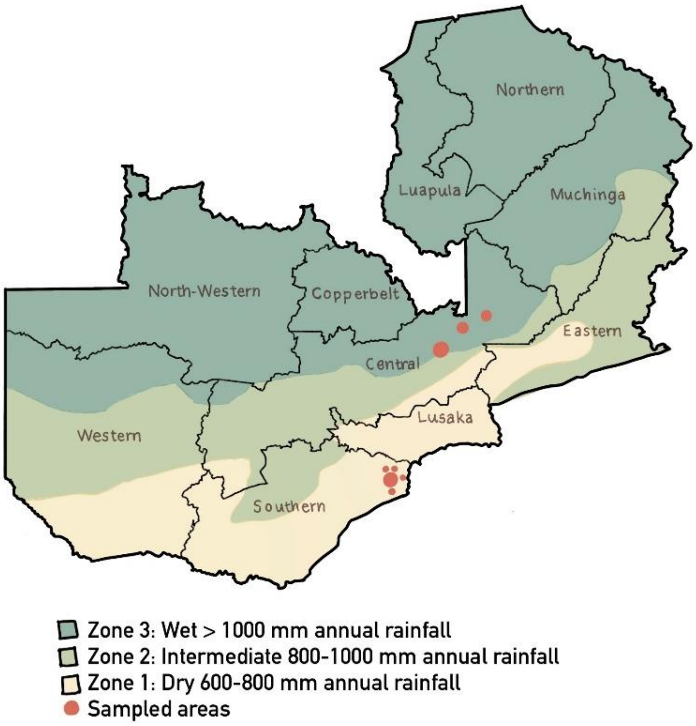

Figure 1. Map over the climate regions of Zambia, the provinces and the sampled areas. Author's marking of the regions on a map from https://sv.wikipedia.org/wiki/Fil:Zambia_provinces_named.png with permission to use according to GNU Free Documentation License.

2.1.2 Small ruminant sector and livelihood in Zambia

The small ruminant sector in Zambia presents high potential for growth and enhanced efficiency in its development (Republic of Zambia: Ministry of Fisheries and Livestock 2020). To advance production and productivity, the Zambian government has implemented the Eight National Development Plan, which prioritizes improvements in livestock breeds, infrastructure, and disease control measures (Ministry of Fisheries and Livestock 2024).

Increasing land constraints in Zambia have limited income opportunities from field crops, making small livestock rearing a more viable livelihood strategy for rural farming households (Namonje-Kapembwa & Chiwawa 2019). The livestock sector accounts for over 40% of Zambia's agricultural Gross Domestic Product (GDP), making it one of the fastest-growing agricultural sub-sectors (Republic of Zambia: Ministry of Fisheries and Livestock 2024). This growth is included within what has been described as a "livestock revolution", characterized by factors such as population growth, urbanisation, and a substantial increase in demand driven by rising incomes (Swanepoel *et al*. 2010). Consequently, livestock has emerged as an increasingly vital contributor to livelihood security in the country.

2.1.3 Challenges in goat management

Goats are considered more resilient and cost-effective livestock due to their ability to utilise a wide range of resources and adapt to resource-constrained environments (Namonje-Kapembwa & Chiwawa 2019). Despite their adaptability, disease remains the most significant challenge in goat management, with limited access to veterinary care due to high costs. In 2022, the number one health threat to goats in Zambia was gastrointestinal parasites (Livestock consensus 2022). Among these, the nematode with the highest economic impact globally is *Haemonchus contortus*, especially in warm climates such as Zambia's (Craig 2009; Jacobs *et al*. 2016:391).

2.2 *Haemonchus contortus*: Morphology, lifecycle, and adaptive Mechanisms

The genus *Haemonchus* spp., first described in 1803, includes hematophagous nematode helminths and is taxonomically classified under the superfamily Trichostrongylidae (Soulsby 1982). *Haemonchus* spp. are globally distributed, highly pathogenic helminths capable of infecting all ruminant species. Among its species, *Haemonchus contortus* primarily infects small ruminants, such as sheep and goats, whereas *Haemonchus placei* predominantly infects large ruminants, particularly cattle (Besier *et al.* 2016b; Arsenopoulos *et al*. 2021). The disease caused by this parasite is termed haemonchosis (Craig 2009), which is categorized into three general syndromes – hyperacute, acute, and chronic – depending in the parasite load and the host's immune response (Urquhart *et al*. 1996:19–21; Besier *et al.* 2016b:101).

2.2.1 Morphology

Morphologically, *Haemonchus contortus* measures 1-3 cm in length, making it larger than other abomasal trichostrongylid nematodes. Females are larger than males, consistent with the majority of nematode species (Van Wyk & Mayhew 2013; Jacobs *et al*. 2016:389). The fifth stage larvae (L5) and adult larvae possess a small lancet in their buccal cavity, which enables the extraction of blood from the host (Ehsan *et al*. 2020). Identification of the larval stage (L3) is based on the morphology of the caudal extremities. Microscopically, the L3 tail measures approximately 67-70 µm (Van Wyk & Mayhew 2013; Jacobs *et al*. 2016:384). Macroscopically, female worms exhibit a characteristic "candy cane" or "barber's pole" appearance, resulting from the intertwining of the red, blood-filled intestine with the white reproductive tract.

2.2.2 Life cycle

Haemonchus spp. have a direct life cycle, eliminating the need for intermediate hosts. Adult worms inhabit the mucosal lining of the abomasum, where they consume up to 0.05 mL of blood per worm per day (Urquhart *et al*. 1996:19; Besier *et al*. 2016b:101). High parasite loads can result in significant blood loss, leading to fatal haemorrhagic anaemia (Jacobs *et al*. 2016:389). The reproductive capacity of *H. contortus* is high, with females producing up to 6,000 eggs per day, resulting in rapid environmental and pasture contamination (Craig 2009).

The lifecycle begins with eggs developing into the first larval stage (L1) within the faeces on the pasture (Craig 2009). L1 feeds on mould and bacteria in the faeces, moulting into the second larval stage (L2). L2 feeds in the same way to develop into the infectious third stage (L3), retaining the protective sheath from the previous stage. The development from egg to L3 requires 5-10 days under favourable conditions (Craig 2009). L3 larvae are non-feeding and rely on stored glycogen for energy and movement, employing a swimming motion through ground moisture to exit the faeces. This process, known as translation, is essential for the larvae to be ingested by a suitable host to progress in their lifecycle (Jacobs *et al*. 2016:376).

Within the host, L3 larvae exsheath in the rumen and migrate to the abomasum, where they burrow into the mucosa in gastric pits to moult into the fourth larval stage (L4) (Craig 2009; Jacobs *et al*. 2016:376). L4 develops into L5, which feeds on blood and matures into sexually reproductive adults. Fecundated female worms then begin producing eggs, completing the lifecycle. The prepatent period – the interval between infection and egg production – is approximately three weeks (Jacobs *et al.* 2016:384). Adult worms can persist in the host’s abomasum for several months.

2.2.3 Adaptive mechanisms

Haemonchus species exhibit remarkable adaptions to survive adverse environmental conditions. During periods of drought or winter, infective L3 larvae can remain ensheathed and inactive within faecal pellets to conserve energy (Craig 2009). Additionally, *Haemonchus* spp. have developed a mechanism known as hypobiosis or facultative arrested development. In this state, L4 penetrate the abomasal wall and enters an arrested state until conditions improve (Wray & Tucker 2022). This adaptation in nematodes allows the parasite to persist during unfavourable periods within the host or environment and can extend significantly the prepatent period (Besier *et al*. 2016b:97). Resumption of development under more favourable conditions results in a rapid increase in egg output, ensuring the species’ survival (Gibbs 1986). This adaptive capacity enables *H. contortus* to survive in both temperate and tropical regions where the external environment is disadvantageous.

In tropical and subtropical regions with dry climates, L3 larval populations increase seasonally following the rainfall pattern (Sissay *et al*. 2007; Besier *et al*. 2016b:98). For instance, in a report from the tropical areas of Nigeria, hypobiosis correlates with arid conditions, with L4 larvae remaining latent in the abomasum during drought and resuming development during the rainy season (Ogunsusi & Eysker 1979). Similarly, a study conducted in Senegal revealed that the number of inhibited L4 larvae in sheep peaked between November and April, with December accounting for 49% of the total amount of larvae (Vercruysse 1985). In conclusion, the direct lifecycle, high reproductive potential, and adaptive mechanisms of *H. contortus* lead to its capacity to persist in diverse environmental conditions, contributing to its pathogenicity and global distribution.

2.3 Clinical signs

Clinical signs associated with haemonchosis are primarily linked to the anaemia that develops as a result of the parasite's blood-sucking activity (Urquhart *et al*. 1996; Besier *et al*. 2016b). As previously mentioned, *H. contortus* can rapidly increase in population under favourable conditions, leading to a sudden onset of disease. The key clinical signs include anaemia and hypoproteinaemia, which quickly weaken the host and can result in the development of edema. In more chronic cases, there may be a decrease of growth, production, and significant weight loss (Craig 2009). Anaemia typically becomes evident 10-12 days after infection, and other clinical manifestations can include ascites, bottle jaw (intermandibular edema), and soft faeces.

The disease is presented differently depending on the parasite burden and the host's immune response. Goats, in particular, have a lower innate immune response, making them highly susceptible to gastrointestinal parasites and leading to potentinally substantial production losses (Pomroy *et al*. 1986; McKenna & Watson 1987). The peracute form of haemonchosis is characterised by sudden death, occurring due to rapid and severe decrease in packed cell volume (PCV). Acute haemonchosis is evident in a larger proportion of the herd with clinical signs such as pale mucous membranes, bottle jaw (caused by hypoproteinaemia), and general weakness. In the chronic form, anaemia becomes unresponsive due to depleted iron levels, and affected hosts show signs of weight loss and poor fur quality (Craig 2009).

2.4 Ecology and epidemiology of *Haemonchus contortus*

Haemonchus contortus is predominantly recognized as a tropical parasite. However, due to its ecological adaptation and high biotic potential, the parasite has become increasingly widespread globally. Its expansion into areas previously considered low risk is further facilitated by climate change and an escalating level of anthelmintic resistance (Kaplan & Vidyashankar 2012). Its high biotic potential allows it to take advantage of short periods of favourable environments for the development of its free-living stages. The abovementioned survival of the infective L3 and hypobiosis of L4 inside the host are further survival mechanisms (Peter & Chandrawathani 2005). *Haemonchus contortus* is dependent on warm and moist external environments for the free-living stages to survive, the prevalentce of the parasite is therefore highest in the tropical climatic zones between 23.5 °N and 23.5 °S (O'Connor *et al*. 2006), which includes Zambia. Nevertheless, *H. contortus* is found in nearly all regions where small ruminants are present, regardless of the climatic zone. In warm climate, temperature supports larval development, with moisture being the critical limiting factor. In subtropical environments, such as Zambia, seasonal variations in rainfall largely dictate the timing and severity of haemonchosis outbreaks, determining whether larval development is sporadic or constant (Veglia 1916; Swan 1970).

2.4.1 Epidemiology of *Haemonchus contortus* in neighbouring countries

The prevalence of *H. contortus* in goats has not been recently studied in Zambia, updated data on the parasite's occurrence are therefore missing. However, recent studies in other African countries consistently report *H. contortus* as a prevalent parasite. In Rwandan goat herds (2018), a prevalence of over 70% was observed in faecal samples (Mushonga *et al.* 2018). In Ethiopia (2012), approximately 50% of faecal samples showed strongyle-type parasites present, including *H. contortus* (Terefe *et al*. 2012). Similarly, a study in Haramaya, Ethiopia (2015) revealed an overall gastrointestinal strongyle prevalence of 92%, with *H. contortus* accounting for 83% of infections (Yimer *et al*. 2015). In South Africa, 59% of goats were infected with strongyle parasites, where *H. contortus* was identified, with higher prevalence observed in sub-humid to humid environments and lower prevalence in arid climates (Mpofu *et al*. 2020). Comparable findings were reported in Benin, where *H. contortus* prevalence reached 80% during the wet season and 36% in the dry season among sheep and goats (Attindehou *et al*. 2012). These results also demonstrated a strong correlation between worm burden and anaemia scores using the FAMACHA method, with seasonal variation being a significant factor.

In other studies, goats in Cameroon exhibited a *H. contortus* prevalence of 18% (Malla *et al*. 2021), while in Malawi, the parasite was identified as the most abundant gastrointestinal parasite found in goats (Airs *et al.* 2023). In Moroccan sheep herds, *H. contortus* prevalence was 24%, with higher infection rate observed in older animals and those with lower body condition scores (Nabukenya et al. 2014; Brik et al. 2019). Seasonal variation was also noted, with higher prevalence during spring and autumn (approximately 35%) compared to summer (approximately 3%).

2.4.2 Prevalence and historical studies of *Haemonchus contortus* in Zambia

In Zambia, although no recent studies of the prevalence in goats have been made, earlier research suggests the parasite has been prevalent. A 1989 study reported *H. contortus* as one of the most common nematode species in faecal samples from goats (Wilson & Azeb 1989). Similarly, a 1994 study identified *H. contortus* and *Trichostrongylus* spp. as the predominant nematodes in goat herds in the central province of Zambia (Nalubamba 1994). In 2001, a survey on anthelmintic resistance in sheep in Lusaka found *H. contortus* present both before and after treatment with levamisole, ivermectin, and albendazole (Gabrie *et al.* 2001).

In other species, studies on *Haemonchus* spp. are limited but indicate the prevalence of *Haemonchus contortus* in Zambia. For example, a 14-month study of captive wild impala in Lusaka showed the presence of the parasite, with the lowest faecal egg counts during the hot dry season (Nalubamba *et al*. 2012). Additionally, post-mortem examinations of cattle in the southern province showed gastrointestinal nematode infections in all animals, of which 76% included *Haemonchus* spp. (Phiri 1998).

2.5 Economic impact

Haemonchus contortus is widely regarded as the most economically significant endoparasite affecting small ruminants, owing to its potential to cause severe mortality and reduced production (Perry 2002; Waller & Chandrawathani 2005; Miller *et al.* 2012; Besier *et al*. 2016b). Gastrointestinal parasites are associated with numerous detrimental effects, including mortality, anaemia, reduced milk production, decreased weight gain, weight loss, diminished reproductive capacity, and increased veterinary treatment expenses (Jacobs *et al.* 2016:63; Mushonga *et al.* 2018). The impact is particularly pronounced in low-income countries, where livestock mortality can be up to ten times higher than in high-income countries, making the health of livestock crucial for economically sustainable production systems (Pradère 2014; Fischer 2020).

Goats represent a primary source of income for many households in Zambia. Consequently, the health of these animals is vital for economic stability and survival, especially for families whose livelihoods depend entirely in livestock (Swanepoel *et al.* 2010). The economic burden of treating *H. contortus* has been studied in other regions, with annual treatment costs estimated to $26 million in Kenya in 1999 (Waller & Chandrawathani 2005) and $46 million in South Africa 1971 (Horak 1971). However, no estimations have been made more recently for these countries or Zambia (Arsenopoulos *et al*. 2021). For context, Kenya had approximately 9.8 million goats in 1999 (Ahuya & Okeyo 2006).

There are no recent data existing for African livestock industries, but studies from Europe highlight the economic burden of helminth infections. In 2020, a study across 18 European countries estimated the combined annual cost for helminth infections (including gastrointestinal nematodes, *Fasciola hepatica* and *Dictyocaulus viviparus)* in ruminants at € 1.8 billion (Charlier *et al*. 2020). However, it is important to note that the livestock industry in Europe operates under significantly different conditions than in Africa, making comparisons to the industry in Zambia difficult.

2.6 Diagnostic methods for haemonchosis

2.6.1 Clinical signs and herd-level diagnostic tools

The diagnosis of haemonchosis involves evaluating clinical signs, post-mortem findings, laboratory analysis and results from molecular methods. It is crucial to confirm or exclude a diagnosis of haemonchosis since its symptoms, such as sudden death or decreased productivity, are often nonspecific (Besier *et al*. 2016a:183). Prompt and accurate diagnosis is necessary to prevent further losses and to minimize parasitism while avoiding excessive use of chemical treatments. To manage the parasitic burdens in herds, goat owners can use herd-level tools as indicators. The Goat Production Manual of Zambia (2019) recommends a monthly five-point worm check as a practical tool to manage worm burdens in a herd (Els *et al.* 2019:42). These five points include:

1. Eyes – Using the FAMACHA (Faffa Malan Chart) scoring method.
2. Nose – Checking for nasal discharge, which may indicate *Oestrus ovis* (nasal bot fly)
3. Jaw – Identifying “bottle jaw” caused by hyperproteinaemia.
4. Back – Checking overall body condition
5. Tail – Observing signs of diarrhoea

2.6.2 The FAMACHA scoring system

One of the most accessible diagnostic methods is examining the colour of the conjunctival membrane for anaemia caused by haemonchosis. The FAMACHA scoring system, developed in South Africa (Malan *et al*. 2001), facilitates the identification of sheep infected with *H. contortus* by comparing the membrane colour to a standardized chart with five grades ranging from reddish pink to pale white. Red to dark pink is considered normal, pale pink means signs of anaemia, and white indicates terminal anaemia, see Figure 2 (Malan *et al.* 2001). This method can be used on a herd level where anthelminthic treatments are put in when a certain number of individuals fall below a threshold value, or to identify animals with the highest worm burdens (Malan *et al*. 2001; Van Wyk & Bath 2002; Molento *et al.* 2004). The FAMACHA approach requires frequent monitoring and manual labour input with a recommendation of inspection every 7-10 days (Besier *et al.* 2016a). In South African sheep herds the chart has been used successfully as a method for controlling haemonchosis, where scores 4-5 indicated the need for treatment (Van Wyk & Bath 2002; Ejlertsen *et al.* 2006). A study conducted in Kenya in 2006 confirmed that the FAMACHA system can also be effectively applied to managing haemonchosis in goats (Ejlertsen *et al*. 2006). The same results were shown in a study conducted in South Africa, showing that the FAMACHA method can be a tool to manage *H. contortus* in goats for resource-constrained farmers (Vatta *et al*. 2001).

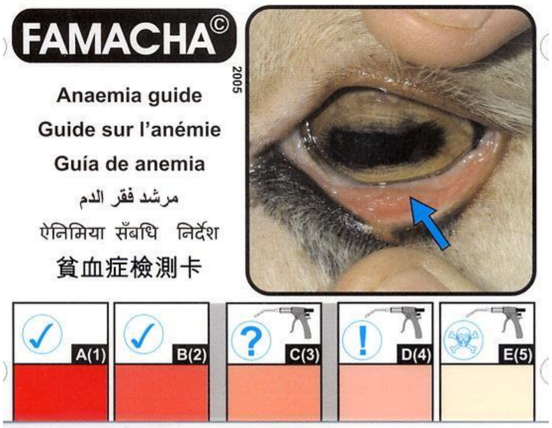

Figure 2. FAMACHA, FAffa MAlan CHArt, scoring chart (Malan et al. *2001).*

2.6.3 Laboratory-based diagnostic techniques

For more precise diagnosis of haemonchosis, laboratory-based faecal egg counts (FEC) followed by larval cultivation to identify L3 larvae are considered the most reliable methods. Techniques such as McMaster flotation can detect most parasitic dispersal stages, including nematode eggs, cestode eggs and coccidian oocysts, but cannot usually differentiate *H. contortus* eggs from those shed by the majority of other stongylid nematodes, since they produce very similar eggs (Thienpont *et al.* 1979; Craig 2009). Despite this limitation, quantitative tests like McMaster provide an estimate of parasite burden in hosts, offering insight into whether the parasite load is likely to cause disease. Although there is no linear correlation between egg counts and the number of adult worms in a host, faecal egg counts exceeding 4,000 eggs per gram are often indicative of haemonchosis (Craig 2009:7). In herds, approximately 20% of animals typically harbour 80% of the total parasite population. Sampling 10-20% of the herd can provide sufficient information about the group's overall parasite burden (Wray & Tucker 2022).

To confirm *H. contortus* specifically, larval culture of faecal samples followed by microscopic examination is required. Fresh faecal samples are incubated for 10 days at room temperature (~20°C) to develop into the infectious L3 stage. *Haemonchus contortus* can then be identified through microscopic observation of key morphological features, such as the head, internal structures, total length, and tail length (Great Britain, Ministry of Agriculture, Fisheries and Food 1986). The tail (from the end of the intestine to the end of the tail), "c" in Figure 3, is 67-70 µm. Typically, 100 larvae or three microscopic slides are examined before results are deemed negative; identification of even a single *H. contortus* larva is considered a positive test. In recent years, advanced molecular diagnostic methods, such as PCR (Ljungström *et al.* 2017) and droplet digital PCR (Elmahalawy *et al.* 2018), have been developed and are occasionally used in routine diagnostics.

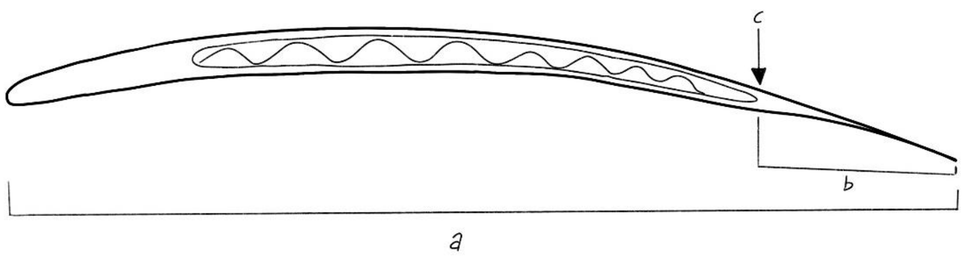

Figure 3. Diagram of a nematode infective larva: (a) total length, (b) sheath tail extension and (c) end of intestine and beginning of tail. Illustration based on observations by the author and information from Borgesteede & Hendriks (1974).

2.6.4 Post-mortem examinations as a diagnostic tool

Post-mortem examination is another rapid and reliable diagnostic method and is typically conducted when an animal dies naturally. The parasite can be seen in the abomasum with its characteristic barber's pole appearance, along with petechiae on the gastric mucosa (Besier *et al.* 2016b; Arsenopoulos *et al*. 2021).

2.7 Treatment

Effective treatment and prevention of haemonchosis are critically important due to its potentially severe clinical consequences. However, determining the most appropriate anthelmintic drug and optimal timing for treatment is not always straightforward. Numerous factors must be considered: economic constraints, labour requirements, the risk of anthelmintic resistance, environmental conditions, the age of the host, the parasite's life cycle and more (Besier *et al*. 2016a).

Currently, over six single-active classes of anthelmintics are used in practice against *H. contortus,* alongside several combination therapies. However, the availability of these drugs varies greatly across countries. Notably the occurrence of strains of *H. contortus* resistant to all major anthelmintic drug classes have been described, making treatment challenging. (Kotze & Prichard 2016:398)

2.7.1 Anthelmintic drug classes

Benzimidazoles were the first broad-spectrum anthelmintics and continue to be used today (e.g. albendazole, oxfendazole). However, their long-standing availability and widespread use have led to high levels of resistance, rendering them rarely effective against dominant strongylid species in many regions (Kaplan & Vidyashankar 2012; Besier *et al*. 2016a:194). In endemic zones for *Haemonchus* spp. benzimidazoles are only effective when used in combination with other drugs.

Another early class of anthelmintics are anticholinergics, such as imidazothiazoles (e.g. levamisole), which has also lost efficacy due to widespread resistance in endemic areas (Kaplan & Vidyashankar 2012; Besier *et al*. 2016a:194). Macrocyclic lactones (e.g. ivermectin), introduced in 1980s, initially showed broad efficacy against all stages of nematodes (in most species) and some ectoparasites (Campbell *et al*. 1978). Within this class, moxidectin has in field studies shown to be more effective against *Haemonchus* spp. than ivermectin, although resistance is emerging. In endemic zones, resistance to ivermectin is particularly pronounced. Although moxidectin has a longer-lasting effect against *H. contortus*, its efficacy will be reduced or eventually be ineffective as resistance to macrocyclic lactones continues to develop (Leathwick *et al*. 2000).

2.7.2 Combination therapies

To prevent resistance and maintain effectiveness, anthelmintics are often used in combination, allowing efficacy even when parasites have developed resistance to one of the drugs (Anderson *et al.* 1988). Resistance develops more slowly when combination treatments are employed, although resistance has been reported even with combinations of three or more drugs (Playford *et al*. 2014; Besier *et al.*

2016a). For all anthelmintic treatments proper dosage and treatment frequency are crucial, as underdosing or overly frequent treatments aid the development of resistance (Baudinette *et al.* 2022). After every anthelmintic treatment a faecal egg count should be performed to evaluate its effectiveness, monitor resistance, and assess parasitic pressure on pastures (Wray & Tucker 2022). This approach saves costs for producers and improves herd management.

2.7.3 Challenges in goat treatment

The goat industry faces several challenges in treatment of gastrointestinal parasites. Goats retain a slightly different drug metabolism compared to other ruminants, resulting in lower plasma concentrations of anthelmintics when administrated the same doses (Baudinette *et al*. 2022). Therefore, goats require higher dosages to achieve the desired therapeutic effect. The high presence of anthelmintic resistance in goat helminths can therefore be partly explained by underdosing.

Since *H. contortus* has developed resistance to all available anthelmintic drug classes, treatment strategies must extend beyond pharmacological measures. The *Goat Production Manual of Zambia* recommends regular rotation of dewormers and the use of the FAMACHA chart as a management method (Els *et al*. 2019).

2.7.4 Prophylactic strategies

Prophylactic measures to reduce pasture contamination are critical for controlling *Haemonchus* spp. prevalence. High stocking rates (overcrowding) increases both pasture contamination and larval exposure rates, while inadequate nutrition heigh-tens susceptibility to infection (Miller *et al.* 2012). Breeding strategies to breed goats with greater ability to withstand *H. contortus* infections could reduce the prevalence of severe haemonchosis infections (Bath *et al.* 2001:54).

Different groups of goats require tailored treatment protocols. For example, kids, as well as pregnant or lactating does, are particularly vulnerable and should receive special attention. If separation is not possible, the entire herd should be treated based on the needs of the most susceptible group (Bath *et al*. 2001:81–82).

Rotational grazing and pasture resting are also essential to breaking the parasite's life cycle (Bath *et al.* 2001:81–82). Allowing pastures to rest for extended periods ensures that free-living larvae die, thereby reducing reinfection risks. The time needed varies with the climate, season, weather and parasitic species, but a rule of thumb is at least 3 months resting. When animals are moved to rested pastures, excessive deworming should be avoided. To minimise the development of resis-tance to anthelmintic drugs, treatment should be limited to as few animals as necessary. The FAMACHA scoring system can be used to identify the individuals with heavy worm burdens and leave the rest untreated.

Pastures can also be alternated with other species, such as cattle or horses, which do not acquire *H. contortus* infections. These animals contribute to reducing the worm burden on pastures by ingesting larvae without becoming infected themselves. Consequently, the population of infectious larvae capable of reinfecting goats is reduced. (Bath *et al*. 2001:83)

3. Method

3.1 Selection of farms

The samples were collected in two districts in the southern province (Chirundu & Lusitu) in early September and in three districts in the central province (Serenje, Mkushi & Kabwe) in late October to early November. The two provinces and the districts were selected for an ongoing unpublished longitudinal study of diseases in Zambian goat herds through a stakeholder consultation a few years ago. The individual households were selected through snowball sampling since there are no records of the active livestock owners. Amongst the households found through snowball sampling in the longitudinal study, this study selected 10 households randomly from each province.

3.2 Sampling in the field

A total of 195 goats were randomly selected from 19 farms in two provinces of Zambia, 100 goats from 10 farms in the southern province, and 95 goats from 10 farms in the central province, see fig-2. Faecal samples were collected rectally with lubrication from 10 randomly selected goats over one year on each farm, except from Chimupati who only had 3 goats. Age was determined by looking at the rings of the horns or the number of teeth. Anaemia score was determined using the FAMACHA scoring method, by looking at the conjunctiva, giving a score from 1-5 and body condition score using a scale from 1.0-5.0, by using "Body Condition Scored in Goats" by Langston University and the American Intitute for Goat Research (Villaquiran *et al.* 1977). We asked every household owner about the routines for deworming: with what product and how often.

In the southern province the samples were collected over four days (9th to 13th of September) in the Chirundu (refer to fig-2. map) area. The environment was arid and hot, during the day the released goats had access to the Zambezi River. Each faecal sample was placed in a separate plastic container with a lid and were stored in the truck without cooling until midday and then put in a refrigerator that unfortunately did not have electricity the whole day. The temperature was between 30 and 37°C.

In the central province samples were collected over six days (29th of October to 3rd of November) around three different areas: Serenje, Mkushi and Kabwe. The rainfall had just started, making the environment more humid than the southern province, but the season was still arid and dry with a temperature around 30°C.

The samples were kept cold throughout the day and stored overnight in a properly functioning refrigerator.

3.3 Faecal egg count using McMaster

3g faeces was used for McMaster to count helminth eggs, pooled with equal amounts from 3-4 individuals. 3g faeces plus 42 ml water was mixed and then filtered through a wire mesh sieve into a tube filled up to 1 cm from the top. Samples were centrifuged for 2 minutes 214 x g and then the supernatant was discarded. The tube was shaken and filled with saturated sodium chloride up to 1 cm from the top and mixed carefully 5 times with a pasteur pipette. From the centre of the tube a pasteur pipette was filled and immediately transferred to the two McMaster chambers, leaving to sit for 5 minutes. The dilution factor (D) is 3g + 42 ml = 15. The volume (V) of each McMaster chamber square is 150 mm^3. Each egg count is therefore (D/V) 100 eggs per gram of faeces (EPG). Both chambers are filled which makes D/V = 15/0,3 = 50. Which makes every counted egg = 50 EPG. The parasitic stages counted are helminth eggs from trichostrongylid nematodes, *Nematodirus* spp., *Moniezia* spp., *Trichuris* spp. and *Eimeria* spp. oocysts. (Thienpont *et al.* 1979; Rinaldi *et al*. 2011)

3.4 Cultivation of gastrointestinal nematodes to L3 stage

This is a qualitative analysis method to hatch eggs of gastrointestinal nematodes to identify L3 larvae such as *H. contortus*. Pooled samples of 3-4 individuals were used (pooled 3, 3, 4 from each farm), 3g from each goat. The samples were pooled with the same individuals in both the egg count and the cultivations. A total of 9 g of faeces in the container plus 10 g of vermiculite was mixed with a mortar and then set in a dark incubator at 25 degrees for 8 days with an arid lid on top. The moisture was checked every two days, if dry the samples were sprayed with water with a spray bottle.

After incubation the container was filled with tap water up to the brim. Covered with a petri dish and turned upside down. The edges of the petri dish were filled with tap water and left at room temperature for 24 hours, so the larvae can swim from the faeces out in the petri dish. Then, with a pasteur pipette, the fluid from the petri dish was collected into a test tube and centrifugated for 3 min 214 x g. The supernatant was removed until 1 cm remaining from the bottom and the surfactant transferred to four glass microscopic slides using a Pasteur pipette plus 1 drop of iodine to kill the larvae (Van Wyk & Mayhew 2013).

3.5 Microscopical examination

Haemonchus contortus was identified using a microscope to identify and measure the tail of the larvae. *H. contortus* tail is 67-70 micrometres long, from the end of the intestine tract to the end of the tail. Four microscopic slides from each sample were examined until the sample was considered negative. A sample was considered as positive as soon as one L3 was identified as *H. contortus* (Van Wyk & Mayhew 2013).

4. Results

4.1 Egg count and detection of *Haemonchus contortus*

In this study, *Haemonchus contortus* was detected in 15 out of 20 farms (75%) across the surveyed regions. In the southern province, *H. contortus* was identified in 5 out of 30 pooled samples (17%), as presented in Table 1. The positive samples contained low numbers of L3 larvae. The McMaster egg count revealed minimal egg presence, with only a single trichostrongylid egg identified in six pooled samples. In the central province, the results from the McMaster egg count were significantly higher compared to the southern province. Among the pooled samples from the central province, 23 out of 27 (85%) tested positive for *H. contortus*, as detailed in Table 2. These samples contained substantially higher numbers of L3 larvae, along with evidence of other L3 species. The data regarding egg counts, deworming routines, and *H. contortus* positivity rates are presented in Table 1. The mean value of EPG per farm in the southern province was 30 EPG (300/10), with a range from 0 to 50. In the central province the mean value was 695 EPG per farm (6950/10), with a range from 100 to 1750 EPG per farm.

Table 1. Results from egg count and cultivation from all 20 households, including the deworming routines.

Season	Province	Village	Deworming	Egg count EPG	Number of Haemonchus positive pooled samples / total number of pooled samples
Hot and Dry Early September	Southern	Mulambinda	Nothing	50	2/3
		Kapululila 1	Every month, product not specified	0	1/3
		Kapululila 2	Albendazole every 3rd month	50	1/3
		Farao	Ivermectin every 3rd month	0	0/3
		Sikongo	Albendazole every 4th month	50	0/3
		Chamba Chabota	Albendazole + Ivermectin every 6th month	50*	1/3
		Sialyabwanda	Ivermectin every month	0	0/3
		Kapungira	Nothing	0	0/3
		Mutena	Ivermectin every 6th month	50	0/3
		Hachaka	Nothing	50	1/3
Hot and Dry/Rainy Early November	Central				
		Chibale	Albendazole every 3rd month	550	1/3
		Kamena	Albendazole once a year	100	1/3
		Chimupati**	Piperazine once a year	500	1/1
		Ntetete 1	Ivermectin every 4th month	1150	3/3
		Chigae	Nothing	450	2/2
		Ntetete 2	Levamisole twice a year	1750	3/3
		Mapanga	Ivermectin twice a year	700	3/3
		Kasapu	Ivermectin once a year	600	3/3
		Mubanga	Ivermectin twice a year	800*	3/3
		Malawo	Nothing	350	3/3

* *Other eggs than trichostrongylid found:* Monezia expansa *and* Monezia benedeni.
***Only 3 goats sampled*
EPG calculated: the total number of eggs found in McMaster for the whole farm times 50.

The overall prevalence of *H. contortus* among all examined farms (n=20) was 75%, considering a farm positive if at least one samples tested positive for *H. contortus*. When evaluated at the pooled sample level (n=57), the overall prevalence was 49%, as detailed in Table 2.

Table 2. Prevalence of Haemonchus contortus *in pooled samples. Total number of positive pooled samples divided by total number of samples for each province.*

Province	*Number of Haemonchus positives pooled samples (%)*	*Number of negative pooled samples (%)*	*Total number of pooled samples*
Southern	5 (17)	25 (83)	30
Central	23 (85)	4 (15)	27

4.2 Body Condition Score (BCS) and FAMACHA

The average BCS in the southern province was 2.72 (all BCS summarized/number of individuals: 272/100), range 2.5 (difference between the highest and the lowest), with the highest BCS of 4, and lowest 1.5, see Table 3. FAMACHA average score in the southern province was 3.57 (357/100), range 2.0, with 5 being the highest and 3 the lowest score. Nine percent of the examined goats (n=100) were male, and all goats were above 1 year and of a local mixed breed. Average BCS in the central province was 2.62 (249,5/95), range 2.5, and average FAMACHA score was 3.44 (327/95), range 3.0, with 5 being the highest and 2 the lowest score. Chi-square test for BCS showed a p-value of 0,56 and for FAMACHA score the p-value was 0,046, which shows a significant variation where the southern province gave significant higher FAMACHA scores. These values are put in relation to positive or negative for *H. contortus* in Table 4. Twenty percent of the examined goats (n=95) were male, and all goats were above 1 year and of a local mixed breed.

Table 3. Mean value of BCS (1-5) and FAMACHA score (1-5) in the pooled samples (all scores of the individuals in the pooling summarized, then divided by the total number of individuals). Chi2 test shows P-value BCS: 0,56, and FAMACHA score p-value 0,046.

Province	Number of pooled samples with mean BCS ≤2.75 (%)	Number of pooled samples with mean BCS >2.75 (%)	Number of pooled samples with mean FAMACHA score ≤ 3 (%)	Number of pooled samples with mean FAMACHA score > 3 (%)	Total number of pooled samples
Southern	20 (67)	10 (33)	2 (7)	28 (93)	30
Central	16 (59)	11 (41)	7 (26)	20 (74)	27

Table 4. Number of pooled samples in different categories. Mean value of the individuals in the pooled samples

Category	*Haemonchus Positives pooled samples (%)*	*Negative pooled samples (%)*	*Total number of pooled samples*
Southern province	5 (17)	25 (83)	30
Central province	23 (85)	4 (15)	27
BCS ≤ 2.75	19 (50)	19 (50)	38
BCS > 2.75	9 (47)	10 (53)	19
FAMACHA score ≤ 3	7 (58)	5 (42)	12
FAMACHA score > 3	21 (47)	24 (53)	45
Total	28 (49)	29 (51)	57

5. Discussion

There is a notable lack of recent studies on the prevalence of *Haemonchus contortus* in Zambian goat herds, leaving the current prevalence unknown. Given Zambia's tropical to subtropical climate and the high prevalence of *H. contortus* reported across various African countries, it is reasonable to assume that the parasite persists in Zambia. Studies conducted in Zambia three to two decades ago confirm its presence, and despite the increased drought, it is likely that *H. contortus* continues to exist in the country.

The free-living larval stages of *H. contortus* rely on moisture for movement from faeces to pasture to be eaten by a host. During sampling period in Zambia, the country experienced its most prolonged drought in decades, with no rainfall since January. Sampling occurred between September and November, during an exceptionally dry period. Such arid conditions inhibit the movement of free-living *H. contortus* larvae, making it difficult for them to survive outside the host. Faecal samples reveal the presence of eggs shed by adult female worms. As previously mentioned, *H. contortus* has adapted to survive in arid environments by entering latent stages in the host's abomasum (L4) or in the faeces on pasture (L3) until favourable conditions, such as rainfall, resume. This mechanism may result in false-negative faecal samples during periods of drought when active, egg-producing adults are inactive. These findings align with the results of Brik *et al*. (2019), who documented seasonal variations of *H. contortus* in Moroccan sheep herds, reporting a prevalence of 35% in spring and autumn compared to 3% in the arid summer. In Zambia, Nalubamba *et al*. (2012) showed that the faecal egg count from impalas was lowest in the arid season, and Wilson & Azeb (1989) reported that EPG in goat samples peaked in the rainy season (February) and decreased in the dry season (staring in May). In South Africa, Mpofu *et al.* (2020) conducted a study on gastrointestinal parasites in goats across different agro-ecological zones, similarly to this study. Their results indicated that parasite prevalence was highest in sub-humid to humid environments, such as the central province, and significantly lower in arid climates, such as the southern province.

Wilson & Azeb (1989) reported that egg counts in faecal samples from Zambian goat herds peaked in February, coinciding with the rainy season, and started to decrease in May, marking the onset of the dry season. Similarly, a study conducted in South Africa found that the prevalence of *H. contortus* in goats was highest in sub-humid to humid environments and lowest in arid regions (Mpofu *et al*. 2020). These findings collectively support the observation that *H. contortus* prevalence is generally lower in arid areas and demonstrates significant seasonal variations.

In this study, sampling in Zambia's southern province during September occurred under extremely arid conditions. By contrast, sampling in the central province in November coincided with the onset of rainfall, resulting in a less arid environment. Additionally, the sampled areas in the central province are located within agro-ecological zone 3, which provides a more humid environment throughout the year compared to the sampled areas in the southern province, located in zone 1. The difference in environmental conditions likely contributed to the variation in *H. contours* prevalence between the two provinces. However, further sampling across diverse regions of Zambia and throughout an entire year, encompassing all seasons, is necessary to provide a more comprehensive understanding.

Previous Zambian studies by Nalubamba *et al.* (2012), Phiri (1998), and Wilson & Azeb (1989) demonstrated high *H. contours* prevalence in impalas, cattle and goats. Given the absence of evidence for any nationwide elimination programs, the expectation was that this study would yield similar results, as *H. contours* is a resilient parasite unlikely to disappear without intervention. Indeed, the overall prevalence in this study was 49%, with significant regional differences: 85% in the central province and 17% in the southern province. The central province prevalence aligns with findings from Rwanda (Mushonga *et al*. 2018) where goat herds exhibited a prevalence of 70%, and Ethiopia (Yimer *et al*. 2015), where the overall prevalence of strongyles was 92%, of which 83% were *H. contortus.* In contrast, the low prevalence observed in the southern province is comparable to findings from Cameroon's northwest region (Malla *et al*. 2021), where the prevalence was 18% in goats. This region is characterized by arid, hot, desert-like conditions (International Monetary Fund. African Dept. 2024), which are similar to the environmental conditions in Zambia's southern province.

The low prevalence in the southern province may be because of the severe drought. Despite the access to the Zambezi River, where more humid pastures might support larval development and transmission, the extremely arid conditions likely played a significant role. Another factor may be the handling of faecal samples, as high temperatures (35-39°C) during sampling potentially caused eggs to hatch prematurely, leading to larval death and lower egg counts. Although efforts were made to keep samples cool, power outages and prolonged exposure to heat compromised refrigeration, thereby affecting sample integrity. Despite these challenges, some *H. contortus* were identified in the southern province, confirming the parasite's presence, although without reliable prevalence estimates. Further studies should include seasonal sampling, improved sample preservation methods, and broader geographic coverage for a more accurate assessment of *H. contortus* prevalence. This study is limited by its reliance in a single sampling event. Consequently, comparing the prevalence between the two provinces is difficult, as the study does not account for seasonal variations.

In the central province, higher prevalence of *H. contortus* and higher egg counts could be attributed to the more humid conditions favourable to the parasite's larval stages, as well as improved sample handling. The central province is situated in agro-ecological zone 3, whereas the southern province is located in zone 1, which receives less annual rainfall. Also, the larval cultures were prepared whilst out in the field to eliminate as much time as possible for the eggs to hatch prematurely.

The mean egg count in the southern province was 30 EPG per farm, with a range from 0 to 50 EPG across the sampled farms. The few eggs detected in this province could indicate that the samples became too warm during handling, potentially allowing the eggs to hatch before laboratory analysis began. In contrast, the central province exhibited a substantially higher mean egg count of 695 EPG per farm, with a range of 100 to 1,750 EPG across farms. Compared to the southern province, the central province not only had significantly more eggs but also a higher number of larvae following cultivation. It is possible that the severe drought in the southern province induced an arrested development state in the parasites within the host, rendering them dormant in the abomasum and thus reducing egg-laying activity detectable in faecal samples. However, goats in the southern province showed greater signs of anaemia compared to those in the central province. This finding may suggest that high levels of active *H. contortus* are present in the abomasum, consuming blood and causing anaemia. For the parasite to induce anaemia, it must be actively feeding on the host's blood. However, it is important to note that the FAMACHA anaemia scoring system was originally developed for sheep and may not be entirely optimal for use in goats.

The effectiveness of anthelmintic treatment in managing *H. contortus* was challenging to assess due to inconsistent and unclear treatment routines reported by goat owners. Response bias may have influenced the accuracy of the information provided, as some farmers might have reported what they believed to be the expected answer, potentially reflecting advice previously given by their local veterinarian, who translated the questions for us. Interestingly, in a similar ongoing study conducted a year earlier, the same farmers were asked identical questions about their deworming routines, and their responses differed significantly from those provided in the current study. There are no standardized guidelines for antiparasitic treatment in Zambia, which may contribute to the uncertainty and confusion among goat owners. To effectively manage a herd's parasitic burden a solid understanding of the parasite and its life cycle is required. However, in Zambia, limited access to resources such as the internet, books, reports, and affordable veterinary services often makes it challenging for goat owners to acquire this crucial information.

Anthelmintic resistance of *H. contortus* in sheep in Zambia has previously been documented by Gabriel *et al*. (2001). They found resistance to benzimidazoles and macrocyclic lactones, while levamisole remained effective. However, resistance to levamisole has since been reported in other African countries, and the study's small scale (6 farms) and age leave the current resistance pattern uncertain. In this study we found that regardless of the treatment protocol, *H. contortus* was present on 75% of farms, indicating limited impact of current anthelmintic practices. Treatment regimens ranged from monthly to annual applications, often involving entire herds and potentially promoting resistance through improper dosing or lack of drug rotation. As previously mentioned, certain groups within a herd require greater attentions and should be treated individually. If the entire herd is routinely treated together, the dosage and choice of drug should be based on the needs of the most susceptible group. However, in this study it was not possible to verify whether this practice was implemented. Future studies would benefit from detailed questionnaires on treatment routines and on-site demonstrations of implementation. The overall impression was that it is remarkably challenging for goat owners to monitor their herds at an individual level. This difficulty arises because the animals must be released during the day to forage for food, as there are insufficient financial resources to provide them with feed.

All goats in this study grazed communally, with no controlled pasture system or breeding strategies to inhibit *H. contortus* infections. The FAMACHA scoring system or other diagnostic tools for selective treatment were not in use by the farmers. The observed clinical signs of *H. contortus* infections, including high FAMACHA score (3-5), low BCS, soft faeces, weakness, and poor fur quality, were consistent across both provinces. However, no intermandibular edema or ascites was seen and no information about sudden deaths was obtained. Despite the apparent differences in prevalence between provinces, no significant differences in BCS were observed. However, even though the centrale province had a higher prevalence, that province had a higher percentage of number of pooled samples with a mean FAMACHA score under or equal to 3 (see Table 3). Most goats had a high FAMACHA score (greater than 3), indicating severe anaemia; however, the high mean value of pooled samples did not correspond to a higher prevalence of *H. contortus*, see Table 4. Even though the FAMACHA scoring system was originally designed for sheep, studies have shown that it can be applied to goats as well, but further studies are needed (Ejlertsen *et al*. 2006; Van Wyk & Bath 2002). The lack of significant statistical relationships may stem from the compromised reliability of southern province data. The Chi-square test for BCS between the two provinces yielded a p-value of 0.56, which exceeds the threshold of 0.05, indicating no statistically significant difference. Consequently, the study found that province had no effect on BCS. In contrast, the Chi-square test for FAMACHA scores produced a p-value of 0.046, which is below the 0.05

threshold, demonstrating a statistically significant difference between the two provinces. Specifically, goats in the southern province showed significantly higher FAMACHA scores compared to those in the central province, suggesting greater signs of anaemia. Despite these findings, this study reported a lower prevalence of *H. contortus*. This discrepancy raises concerns about the reliability of the prevalence results for the southern province, potentially due to inadequate sample handling.

To gain a more comprehensive understanding of *H. contortus* prevalence, its clinical relevance, and economic impact in Zambia, future studies should include post-mortem examinations, data from veterinary clinics and slaughterhouses, and sampling across multiple provinces and seasons.

5.1 Conclusion

There are no recent studies of the prevalence and clinical relevance of *Haemonchus contortus* in Zambia. Goats, as the most widely owned livestock, play a critical role as a primary source of income for many rural households. In this study, 195 faecal samples were collected from the southern province and from the central province of Zambia during the arid and hot season, with conditions being drier in the southern province. Among the samples, 49% (n=28) tested positive for *H. contortus*, with 17% (n=5) of positive pools identified in the southern province and 85% (n=23) in the central province. The actual prevalence in the southern province may be underestimated due to the lack of controlled refrigerated storage for the samples during this study. The clinical relevance of the parasite is significant in Zambia, particularly given its impact on the rural sector, where small-scale farmers predominate. The high prevalence observed in this study, coupled with the severe clinical effects associated with the parasite, underscores the urgent need for effective management strategies. Given the minimal profit margins within this farming sector, controlling *H. contortus* infections is essential to safeguarding the livelihoods and economic stability of these rural communities.

References

Ahmadu, B. & Lovelace, C.E.A. (2002). Production characteristics of local Zambian goats under semi-arid conditions. *Small Ruminant Research*, 45 (2), 179–183. https://doi.org/10.1016/S0921-4488(02)00098-6

Ahuya, C.O. & Okeyo, A.M. (2006). *Sustainable genetic improvement of goat meat and milk production in Kenya: A case of the Meru and Tharaka-Nithi Dairy and Animal Healthcare community-based Breeding Programme*. A paper presented at the Tanzania Society for Animal Production, Morogoro, Tanzania. https://scispace.com/pdf/sustainable-genetic-improvement-of-goat-meat-and-milk-3oajns5xva.pdf

Airs, P.M., Ventura-Cordero, J., Mvula, W., Takahashi, T., Van Wyk, J., Nalivata, P., Safalaoh, A. & Morgan, E.R. (2023). Low-cost molecular methods to characterise gastrointestinal nematode co-infections of goats in Africa. *Parasites & Vectors*, 16 (1), 216. https://doi.org/10.1186/s13071-023-05816-y

Anderson, N., Martin, P.J. & Jarrett, R.G. (1988). Mixtures of anthelmintics: A strategy against resistance. *Australian Veterinary Journal*, 65 (2), 62–64. https://doi.org/10.1111/j.1751-0813.1988.tb07355.x

Arsenopoulos, K.V., Fthenakis, G.C., Katsarou, E.I. & Papadopoulos, E. (2021). Haemonchosis: A challenging parasitic infection of sheep and goats. *Animals*, 11 (2), 363. https://doi.org/10.3390/ani11020363

Attindehou, S., Salifou, S., Biaou, C.F., Bassa, O., Adamou-N'Diaye, M. & Pangui, L.J. (2012). Epidemiology of haemonchosis in sheep and goats in Benin. *Journal of Parasitology and Vector Biology.* 4 (2), 20-24. DOI: 10.5897/JPVB12.012

Bath, G.F., Hansen, J.W., Krecek, R., Van Wyk, J. & Vatta, A.F. (2001). Sustainable approaches for managing haemonchosis in sheep and goats. *Final Report of Food and Agriculture Organisation (FAO): Technical Cooperation Project in South Africa,* No TCP/SAF/8821(A). https://www.researchgate.net/publication/288266753_Sustainable_approaches_for_managing_haemonchosis_in_sheep_and_goats

Baudinette, E., O'Handley, R. & Trengove, C. (2022). Anthelmintic resistance of gastrointestinal nematodes in goats: A systematic review and meta-analysis. *Veterinary Parasitology*, 312, 109809. https://doi.org/10.1016/j.vetpar.2022.109809

Besier, R.B., Kahn, L.P., Sargison, N.D. & Van Wyk, J.A. (2016a). Diagnosis, Treatment and Management of Haemonchus contortus in Small Ruminants. In: Gasser, R.B. & von Samson-Himmelstjerna, G. (eds.) *Advances in Parasitology.* Elsevier. 181–238. https://doi.org/10.1016/bs.apar.2016.02.024

Besier, R.B., Kahn, L.P., Sargison, N.D. & Van Wyk, J.A. (2016b). The Pathophysiology, Ecology and Epidemiology of Haemonchus contortus Infection in Small Ruminants. In: Gasser, R.B. & von Samson-Himmelstjerna, G. (eds.)

Advances in Parasitology. Elsevier. 95–143. https://doi.org/10.1016/bs.apar.2016.02.022

Borgesteede, F.H.M & Hendriks, J. (1974). Identification of infective larvae of gastrointestinal nematodes in cattle. *Tijdschrift Diergeneeskunde,* 99, 103-113.

Brik, K., Hassouni, T., Elkharrim, K. & Belghyti, D. (2019). A survey of Haemonchus contortus parasite of sheep from Gharb plain, Morocco. *Parasite Epidemiology and Control*, 4, e00094. https://doi.org/10.1016/j.parepi.2019.e00094

Campbell, N.J., Hall, C.A., Kelly, J.D. & Martin, I.C.A. (1978). The anthelmintic efficacy of non-benzimidazole anthelmintics against benzimidazole resistant strains of Haemonchus contortus and Trichostrongylus colubriformis in sheep. *Australian Veterinary Journal*, 54 (1), 23–25. https://doi.org/10.1111/j.1751-0813.1978.tb00265.x

Charlier, J., Rinaldi, L., Musella, V., Ploeger, H.W., Chartier, C., Vineer, H.R., Hinney, B., von Samson-Himmelstjerna, G., Băcescu, B., Mickiewicz, M., Mateus, T.L., Martinez-Valladares, M., Quealy, S., Azaizeh, H., Sekovska, B., Akkari, H., Petkevicius, S., Hektoen, L., Höglund, J., Morgan, E.R., Bartley, D.J. & Claerebout, E. (2020). Initial assessment of the economic burden of major parasitic helminth infections to the ruminant livestock industry in Europe. *Preventive Veterinary Medicine,* 182, 105103. ttps://doi.org/10.1016/j.prevetmed.2020.105103

Chikowo, R. (n.d.). *Zambia. Global yield gap atlas.* https://www.yieldgap.org/zambia [2024-12-09]

Chileshe, A. (2001). *FOSA Country Report - Zambia.* https://www.fao.org/4/ac428e/AC428E02.htm [2024-11-03]

Climate Data (2024). *Climate: Zambia.* https://en.climate-data.org/africa/zambia-192/ [2024-11-03]

Craig, T.M. (2009). Helminth parasites of the ruminant gastrointestinal tract. In: Anderson, D.E. & Rings, D.M. (eds.) *Food Animal Practice*. 5th ed. Elsevier. 78–91. https://doi.org/10.1016/B978-141603591-6.10022-3

Ehsan, M., Hu, R.-S., Liang, Q.-L., Hou, J.-L., Song, X., Yan, R., Zhu, X.-Q. & Li, X. (2020). Advances in the development of anti-Haemonchus contortus vaccines: Challenges, opportunities, and perspectives. *Vaccines*, 8 (3), 555. https://doi.org/10.3390/vaccines8030555

Ejlertsen, M., Githigia, S.M., Otieno, R.O. & Thamsborg, S.M. (2006). Accuracy of an anaemia scoring chart applied on goats in sub-humid Kenya and its potential for control of Haemonchus contortus infections. *Veterinary Parasitology*, 141 (3–4), 291–301. https://doi.org/10.1016/j.vetpar.2006.05.020

Elmahalawy, S.T., Halvarsson, P., Skarin, M. & Höglund, J. (2018). Droplet digital polymerase chain reaction (ddPCR) as a novel method for absolute quantification of major gastrointestinal nematodes in sheep. *Veterinary Parasitology*, 261, 1–8. https://doi.org/10.1016/j.vetpar.2018.07.008

Els, C., Doyer, T. & van Vuuren, R. (2019). *Goat Production in Zambia.* University of Africa. https://prospero.co.zm/app/uploads/2023/04/Goat-Production-Manual-2019.pdf

Fischer, K., Lysholm, S., & Wensman, J.J. (2020). Factors Enabling Sustainable Goat Production in Zambia. *SIANI Policy brief.* https://www.siani.se/wp-content/uploads/2021/01/Factors-Enabling-Sustainable-Goat-Production-in-Zambia-Policy-Brief.pdf

Gabrie, S., Phiri, I.K., Dorny, P. & Vercruysse, J. (2001). A survey on anthelmintic resistance in nematode parasites of sheep in Lusaka, Zambia. *The Onderstepoort Journal of Veterinary Research,* 68 (4), 271–274.

Gibbs, H.C. (1986). Hypobiosis in parasitic nematodes – An update. *Advances in Parasitology*. Elsevier. 129–174. https://doi.org/10.1016/S0065-308X(08)60343-7

Great Britain, Ministry of Agriculture, Fisheries and Food (1986). *Manual of Veterinary Parasitological Laboratory Techniques*. 3rd ed. H.M. Stationery Office.

Homann, S., Rooyen, A.V., Moyo, T. & Nengomasha, Z. (2007). *Goat production and marketing: Baseline information for semi-arid Zimbabwe.* http://oar.icrisat.org/id/eprint/397

International Monetary Fund. African Dept. (2024). Climate Change in Cameroon: Key Challenges and Reform Priorities. *IMF Staff Country Reports*, 2024 (052), A003. https://doi.org/10.5089/9798400268243.002.A003

Irish Aid (2018). *Zambia Country Climate Risk Assessment Report.* Resilience and Economic Inclusion Team, Policy Unit. https://www.iied.org/sites/default/files/pdfs/2023-11/22096g.pdf

Jacobs, D., Fox, M., Gibbons, L. & Hermosilla, C. (2016). *Principles of Veterinary Parasitology.* Wiley-Blackwell. https://www.wiley.com/en-us/Principles+of+Veterinary+Parasitology-p-9780470670422

Kaplan, R.M. & Vidyashankar, A.N. (2012). An inconvenient truth: Global worming and anthelmintic resistance. *Veterinary Parasitology*, 186 (1), 70–78. https://doi.org/10.1016/j.vetpar.2011.11.048

Kotze, A.C. & Prichard, R.K. (2016). Anthelmintic Resistance in Haemonchus contortus. In: Gasser, R.B. & von Samson-Himmelstjerna, G. (eds.) *Advances in Parasitology.* Elsevier. 397–428. https://doi.org/10.1016/bs.apar.2016.02.012

Leathwick, D.M., Moen, I.C., Miller, C.M. & Sutherland, I.A. (2000). Ivermectin-resistant Ostertagia circumcincta from sheep in the lower North Island and their susceptibility to other macrocyclic lactone anthelmintics. *New Zealand Veterinary Journal*, 48 (5), 151–154. https://doi.org/10.1080/00480169.2000.36183

Ljungström, S., Melville, L., Skuce, P.J. & Höglund, J. (2017). Comparison of four diagnostic methods for detection and relative quantification of Haemonchus contortus eggs in feces samples. *Frontiers in Veterinary Science*, 4, 239. https://doi.org/10.3389/fvets.2017.00239

Malan, F.S., Van Wyk, J.A. & Wessels, C.D. (2001). Clinical evaluation of anaemia in sheep: early trials. *The Onderstepoort Journal of Veterinary Research*, 68 (3), 165–174. https://pubmed.ncbi.nlm.nih.gov/11769347/

Malla, M.E., Payne, V.K., Cedric, Y., Nadia, N.A.C., Leonelle, M. & Rosine, M. (2021). Prevalence of gastrointestinal parasites in sheep and goats of Bui and Donga-Mantung Divisions of the North West Region of Cameroon. *Asian Journal of Research in Animal and Veterinary Sciences,* 4 (2), 161–175. https://doi.org/10.9734/ajravs/2021/v4i2149

McKenna, P.B. & Watson, T.G. (1987). The comparative efficacy of four broad spectrum anthelmintics against some experimentally induced trichostrongylid infections in sheep and goats. *New Zealand Veterinary Journal*, 35 (11), 192–195. https://doi.org/10.1080/00480169./1987.35443

Miller, J.E., Kaplan, R.M. & Pugh, D.G. (2012). Chapter 6 - Internal Parasites. In: Pugh, D.G. & Baird, A.N. (eds.) *Sheep and Goat Medicine.* 2nd ed. W.B. Saunders. 106–125. https://doi.org/10.1016/B978-1-4377-2353-3.10006-X

Molento, M.B., Tasca, C., Gallo, A., Ferreira, M., Bononi, R. & Stecca, E. (2004). Famacha guide as an individual clinic parameter for Haemonchus contortus infection in small ruminants. *Ciência Rural*, 34 (4), 1139–1145. https://doi.org/10.1590/S0103-84782004000400027

Mpofu, T.J., Nephawe, K.A. & Mtileni, B. (2020). Prevalence of gastrointestinal parasites in communal goats from different agro-ecological zones of South Africa. *Veterinary World*, 13 (1), 26–32. https://doi.org/10.14202/vetworld.2020.26-32

Mtambo, J., Madder, M., Van Bortel, W., Chaka, G., Berkvens, D. & Backeljau, T. (2007). Further evidence for geographic differentiation in R. appendiculatus (Acari: Ixodidae) from Eastern and Southern provinces of Zambia. *Experimental and Applied Acarology*, 41 (1–2), 129–138. https://doi.org/10.1007/s10493-007-9049-2

Mushonga, B., Habumugisha, D., Kandiwa, E., Madzingira, O., Samkange, A., Segwagwe, B.E. & Jaja, I.F. (2018). Prevalence of Haemonchus contortus infections in sheep and goats in Nyagatare District, Rwanda. *Journal of Veterinary Medicine*, 2018, 1–9. https://doi.org/10.1155/2018/3602081

Nabukenya, I., Rubaire-Akiiki, C., Olila, D., Muhangi, D. & Höglund, J. (2014). Anthelmintic resistance in gastrointestinal nematodes in goats and evaluation of FAMACHA diagnostic marker in Uganda. *Veterinary Parasitology,* 205 (3–4), 666–675. https://doi.org/10.1016/j.vetpar.2014.07.019

Nalubamba, K.S. (1994). *The epidemiology of gastrointestinal nematodes in goats in the traditional grasslands of Zambia*. Diss. University of Zambia. http://dspace.unza.zm/handle/123456789/1742

Nalubamba, K.S., Mudenda, N.B. & Malamo, M.R. (2012). A seasonal survey of gastrointestinal parasites in captive wild impala antelope on a game facility south of Lusaka, Zambia. *Journal of Helminthology*, 86 (4), 418–425. https://doi.org/10.1017/S0022149X11000617

Namonje-Kapembwa, T., Chiwawa, H. & Sitko, N. (2019). Value chain analysis of goats in Zambia: Challenges and opportunities of linking smallholders to markets. In: *Feed the Future Innovation Lab for Food Security Policy,* Research Paper 139. Copyright: Michigan State University & Indaba Agricultural Policy Research Institute. https://www.canr.msu.edu/fsp/publications/research-papers/rp%20139%20ac.pdf

Nations Online Project (n.d). *Administrative Map of Zambia.* https://www.nationsonline.org/oneworld/zambia.htm [2024-11-03]

O'Connor, L.J., Walkden-Brown, S.W. & Kahn, L.P. (2006). Ecology of the free-living stages of major trichostrongylid parasites of sheep. *Veterinary Parasitology*, 142 (1–2), 1–15. https://doi.org/10.1016/j.vetpar.2006.08.035

Ogunsusi, R.A. & Eysker, M. (1979). Inhibited development of trichostrongylids of sheep in northern Nigeria. *Research in Veterinary Science*, 26 (1), 108–110. https://doi.org/10.1016/S0034-5288(20)30952-8

Perry, B.D., Randolp, T.F, McDermott, J.J, Sones, K.R., Thornton, P.K. (2002). *Investing in Animal Health Research to Alleviate Poverty.* Nairobi: ILRI. https://hdl.handle.net/10568/2308

Phiri, D. (1998). *Gastrointestinal nematodes in traditional cattle of Zambia: seasonality and relationship between faecal egg counts and worm burden*. Diss. University of Zambia. http://dspace.unza.zm/handle/123456789/1734

Playford, M., Smith, A., Love, S., Besier, R., Kluver, P. & Bailey, J. (2014). Prevalence and severity of anthelmintic resistance in ovine gastrointestinal nematodes in Australia (2009–2012). *Australian Veterinary Journal*, 92 (12), 464–471. https://doi.org/10.1111/avj.12271

Pomroy, W.E., Lambert, M.G. & Betteridge, K. (1986). Comparison of faecal strongylate egg counts of goats and sheep on the same pasture. *New Zealand Veterinary Journal,* 34 (3), 36–37. https://doi.org/10.1080/00480169.1986.35272

Pradère, J.-P. (2014). Improving animal health and livestock productivity to reduce poverty. *Revue Scientifique et Technique (International Office of Epizootics),* 33 (3), 735–744, 723–734. https://pubmed.ncbi.nlm.nih.gov/25812201/

Republic of Zambia: Ministry of Fisheries and Livestock (2024). *2023 Livestock Survey Report.* Zambia Statistics Agency. https://www.mfl.gov.zm/wp-content/uploads/2024/08/2023-Livestock-Survey-Report.pdf

Republic of Zambia: Ministry of Fisheries and Livestock (2020). *National Livestock Development Policy*. https://faolex.fao.org/docs/pdf/zam214177.pdf

ReliefWeb (n.d). *Zambia: Drought – Jan 2024*. https://reliefweb.int/disaster/dr-2024-000018-zmb [2024-11-03]

Rinaldi, L., Coles, G.C., Maurelli, M.P., Musella, V. & Cringoli, G. (2011). Calibration and diagnostic accuracy of simple flotation, McMaster and FLOTAC for parasite egg counts in sheep. *Veterinary Parasitology*, 177 (3–4), 345–352. https://doi.org/10.1016/j.vetpar.2010.12.010

Rushton, J., Uggla. A., Magnusson. U. (2017). *Animal Health in Development: Its Role for Poverty Reduction and Human Welfare.* Expertgruppen för Biståndsanalys. https://eba.se/en/reports/animal-health-in-development-its-role-for-poverty-reduction-and-human-welfare/5381/

Sissay, M.M., Uggla, A. & Waller, P.J. (2007). Epidemiology and seasonal dynamics of gastrointestinal nematode infections of sheep in a semi-arid region of eastern Ethiopia. *Veterinary Parasitology*, 143 (3–4), 311–321. https://doi.org/10.1016/j.vetpar.2006.08.026

Soulsby, E.J.L. (1982). *Helminths, Arthropods and Protozoa of Domesticated Animals*. 7th ed. London: Baillière Tindall. https://doi.org/10.1016/0035-9203(84)90110-X

Swan, R.A. (1970). The epizootiology of Haemonchosis in sheep. *Australian Veterinary Journal,* 46 (10), 485–492. https://doi.org/10.1111/j.1751-0813.1970.tb09169.x

Swanepoel, F., Stroebel, A. & Moyo, S. (eds) (2010). *The Role of Livestock in Developing Communities: Enhancing Multifunctionality*. SunBonani Media. https://doi.org/10.18820/9781928424819

Terefe, D., Demissie, D., Beyene, D. & Haile, S. (2012). A prevalence study of internal parasites infecting Boer goats at Adami Tulu Agricultural Research Center, Ethiopia. *Journal of Veterinary Medicine and Animal Health*. 4 (2), 12–16. DOI:10.5897/JVMAH11.046

Thienpont, D., Rochette, F. & Vanparijs, O.F.J. (1979). *Diagnosing Helminthiasis by Coprological Examination.* 1st ed. Janssen Animal Health. https://www.researchgate.net/publication/283924775

Urquhart, G.M., Armour, J., Duncan, J.L., Dunn, A.M. & Jennings, F.W. (1996). *Veterinary Parasitology*. 2nd ed. Blackwell Publishing.

Van Wyk, J.A. & Bath, G.F. (2002). The FAMACHA system for managing haemonchosis in sheep and goats by clinically identifying individual animals for treatment. *Veterinary Research*. 33 (5), 509–529. https://doi.org/10.1051/vetres:2002036

Van Wyk, J.A. & Mayhew, E. (2013). Morphological identification of parasitic nematode infective larvae of small ruminants and cattle: A practical lab guide. *Onderstepoort Journal of Veterinary Research,* 80 (1), 14 pages. https://doi.org/10.4102/ojvr.v80i1.539

Vatta, A.F., Letty, B.A., van der Linde, M.J., van Wijk, E.F., Hansen, J.W. & Krecek, R.C. (2001). Testing for clinical anaemia caused by Haemonchus spp. in goats farmed under resource-poor conditions in South Africa using an eye colour chart developed for sheep. *Veterinary Parasitology,* 99 (1), 1–14. https://doi.org/10.1016/S0304-4017(01)00446-0

Veglia, F. (1916). *The anatomy and life-history of Haemonchus contortus (Rud.).* Third and Fourth Reports of the Director of Veterinary Research, 1915, pp. 347-500. http://hdl.handle.net/2263/10471

Vercruysse, J. (1985). The seasonal prevalence of inhibited development of Haemonchus contortus in sheep in Senegal. *Veterinary Parasitology*, 17 (2), 159–163. https://doi.org/10.1016/0304-4017(85)90102-5

Villaquiran, M., Gipson, T.A., Merkel, R.C., Goetsch, A.L., Sahlu, T. (1977). *Body Condition Scores in Goats*. American Institute for Goat Research. Langston University. https://onpasture.com/wp-content/uploads/2015/03/goat-bcs_factsheet.pdf

Waller, J.P. & Chandrawathani, P. (2005). Haemonchus contortus: parasite problem No. 1 from tropics - Polar Circle. Problems and prospects for control based on epidemiology. *Tropical Biomedicine*, 22 (2), 131–137. https://pubmed.ncbi.nlm.nih.gov/16883278/

Wilson, R.T. & Azeb, M. (1989). African Small Ruminant Research and Development. *Proceedings of a conference held at Bamenda, Cameroon,* 18-25 January 1989. Addis Ababa, Ethiopia: ILCA. https://hdl.handle.net/10568/16464

World Bank Group (2024). *Climate Change Knowledge Portal.* https://climateknowledgeportal.worldbank.org/ [2024-11-03]

Worldometer (2024). *Zambia Population 2024*. https://www.worldometers.info/world-population/zambia-population/ [2024-12-10]

Wray, E.M., Tucker, C. & Powell, J. (2022). Managing Haemonchosis in Sheep and Goats. *University of Arkansas System: Division of Agriculture.* https://www.uaex.uada.edu/publications/pdf/FSA3160.pdf

Yimer, M., Chalchisa, N. & Bezabih, M. (2015). Prevalence of gastrointestinal strongyles parasites of small ruminants in and around Haramaya, Ethiopia. *Middle East Journal of Scientific Research,* 23, 2833–2840. https://doi.org/10.5829/idosi.mejsr.2015.23.12.101134

Populärvetenskaplig sammanfattning

Cirka 70 % av Afrikas rurala befolkning är direkt beroende av boskapsdjur för sin överlevnad. I Zambia är getter det vanligaste boskapsdjuret och hålls framför allt av låginkomsthavare eftersom de är billigare att hålla än nötkreatur. Landet har över 5,5 miljoner getter, varav de flesta ägs av bönder med färre än 15 djur per hushåll.

I Afrika finns det ett uttryck som lyder "getter blir inte sjuka" vilket ligger till grund för att det nu görs stora satsningar för att undersöka förekomst av olika sjukdomar hos getter i Afrika. Trots att getter anses vara tåliga och anpassningsbara djur rapporterar många djurägare att sjukdomar är den största utmaningen. I Zambia har inre parasiter en betydande negativ påverkan på getter. Getter är mer mottagliga mot gastrointestinala parasiter än andra djur och resulterar snabbare i en minskad produktion. Dessutom tillhör Zambia subtropiskt till tropiskt klimat vilket främjar parasiternas livscykler och gör dem ännu mer relevanta. Parasiten som har störst ekonomisk påverkan globalt är stor magmask (*Haemonchus contortus*) och är därför den parasiten som undersöks i denna studie. Förekomst av stor magmask har inte undersökts i Zambia de senaste 30 åren. Parasiten kan orsaka blodförlust, plötsliga dödsfall, viktminskning och minskad tillväxt hos många getter, och därför ha stod betydelse för getbönder.

Stor magmask är en mag-tarmparasit som drabbar små idisslare. Den är 2-3 cm lång och borrar in sig i magsäckens slemhinna, där den suger blod för att utvecklas till vuxen larv som kan börja utsöndra ägg. Äggen kommer ut med värddjurets avföring och kläcks på fältet. Med hjälp av en fuktig omgivning mognar larven och rör sig fram på betet för att bli uppäten av ett nytt värddjur. I värddjuret kan varje mask suga 0.05 ml blod per dag. Eftersom värddjuret kan hysa tusentals maskar kan blodbrist snabbt utvecklas och bli påtaglig på djuret efter 10-12 dagar efter infektion. Parasiten har tidigare hittats med hög förekomst i många afrikanska länder. Stor magmask har en unik förmåga att anpassa sig till torka, vilket tyder på att den borde finnas i Zambia.

För att undersöka förekomsten av stor magmask i Zambia provtogs 195 getter via rektalt träckprov, 100 getter i södra provinsen och 95 getter i centrala provinsen i olika byar. 20 olika gårdar ingick i studien och valdes ut slumpvis i de två provinserna. Proverna undersöktes mikroskopiskt genom att räkna antal ägg och sedan odla fram larver för att kunna artbestämma parasiterna. Proverna togs under september till november månad, vilket är precis innan regnsäsongen börjar och således när miljön är som torrast. När studien utfördes hade Zambia dessutom sin värsta torka någonsin, utan nedbörd från januari till november. Torkan påverkar södra provinsen så hårt att det håller på att utvecklas till en öknen. Eftersom parasitens frilevande stadier är beroende av fukt är det sannorlikt att torkan har en påverkan på resultaten. Larverna kan vid torska ligga vilande i magslemhinnan tills miljön är mer gynnsam och utsöndrar under den perioden inga ägg. Detta medför att trots att djuren är infekterade går det inte att påvisa i träckprover.

Resultatet i den här studien visar att 75 % av de provtagna gårdarna hade förekomst av stor magmask i sina getbesättningar. Förekomsten var högre i den centrala provinsen jämfört med den södra, vilket kan bero på det fuktigare klimatet i den centrala provinsen, eller på grund av att träckproverna från den södra provinsen inte kunde hållas tillräckligt kylda innan det laborativa arbetet påbörjades. Det gör att äggen kan ha kläckts i förtid innan de undersöktes. I den centrala provinsen hade regnperioden börjat vid provtagningstillfället och klimatet är året runt mer tropiskt jämfört med den södra provinsen, vilket gör marken mer gynnsam för parasiten.

Studien visar att stor magmask är ett utbrett problem för Zambias getter och understryker vikten av att förstå parasitens påverkan. Detta för att utveckla bättre strategier för att stödja småskaligaa rurala bönder som dominerar sektorn i Zambia.

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