

**THE EXTENT OF ANTHELMINTIC RESISTANCE ON NEMATODES IN
COMMUNALLY GRAZED SHEEP AND GOATS IN A SEMI-ARID AREA OF
NORTH-WEST PROVINCE (RSA)**



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**Submitted in fulfilment of the requirements for the degree of Masters of Science in
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Agriculture, Science and Technology at North-West University (Mafikeng
Campus)**

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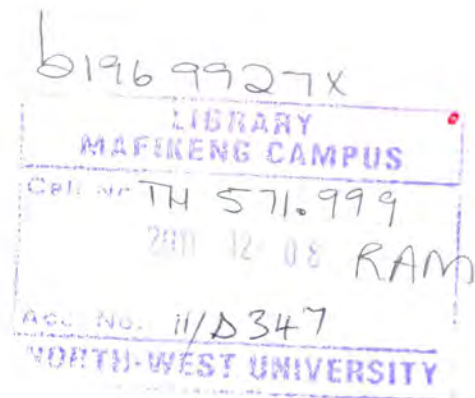
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DECLARATION

I, **Tebogo Stanley Ramotshwane**, the undersigned hereby declare that the work on which this thesis is based is original, and neither the whole nor any part of it has been, or is to be submitted for another degree at this or any other university.

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ABSTRACT

A survey was conducted to investigate the occurrence of anthelmintic resistance of nematodes in communally grazed sheep and goat herds in the Zeerust area of the North-West Province, Republic of South Africa. The fecal egg count reduction test (FECR%) tests were used to assess the sheep and goat small holder farmers. Efficacy of albendazole, ivermectin and closantel was done on both the treatment and control animals. Anthelmintic efficacy of 80% was considered a threshold for anthelmintic resistance. The FECR % showed that all drugs tested more than 80% effective in most instances, but there were some notable exceptions. For instance in sheep ivermectin and closantel were 78% and 71% effective respectively. In goats, albendazole was 78% and ivermectin was 76% effective. A significant reduction ($P < 0.01$) in epg in all sheep and goat herds was observed 2 weeks post-treatment with anthelmintics as compared to the control groups where the epg remained high. The relative efficacies of the 3 drugs on each farm and on different farms showed no significant differences ($P > 0.05$) except with few drugs. The occurrence of anthelmintic resistance in the small holder sheep and goat farming sector is a cause of concern. Steps should therefore be taken by policy makers to prevent its further spread and to avoid the development of a situation as on commercial sheep farms where resistance is rampant.

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CHAPTER ONE

1. INTRODUCTION

Anthelmintic resistance is said to have been established when previously effective drug ceases to kill exposed parasitic population at the therapeutically recommended dosages (Jabbar *et al.*, 2006). Resistance in nematodes of the digestive tract of ruminants is probably one of the biggest challenges confronting veterinarians and breeders (Humbert *et al.*, 2001). Anthelmintic resistance crisis of gastrointestinal nematodes has become a global problem for sheep and goat industry (Chandrawathini *et al.*, 1999). Anthelmintics have been used as the primary method for controlling parasitic gastrointestinal nematodes of small ruminants in Kenya and South Africa for many years and it appears that continuous and intensive use of benzimidazole and levamisole has led to the selection for resistant *H. contortus* (Waruiru *et al.*, 1998; Van Wyk *et al.*, 1999).

Resistance to anthelmintic drugs amongst the major nematode parasites of sheep and goats has now reached alarming proportions throughout the world and threatens the future viability of continued small ruminant production in many countries (Waller, 1999). In most parts of the world benzimidazole resistance is too widespread in ovine nematodes for a change in the definition of resistance to be relevant (Papadopoulos *et al.*, 2001). Drug resistance in *H. contortus* is widespread throughout the world in sheep and goats (Čerňanská *et al.*, 2006). Any single new anthelmintic group will bring a temporary relief to the resistance crisis, unless the present practice of excessive drenching is reduced considerably (Van Wyk *et al.*, 1999). Little thought was given to the possibility that anthelmintic resistance could

become a serious problem presumably because it was assumed that new drugs would continue to be developed (Van Wyk *et al.*, 2006). If resistance to other new compounds follows same trend as ivermectin, we may reach a crisis despite integrated control such as provision of safe pastures and many farmers might have to abandon sheep farming under such conditions (Van Wyk *et al.*, 1987).

1.2 AIM AND OBJECTIVE

The aim of the study was to investigate the level of anthelmintic resistance in communally grazed goats and sheep by using the faecal egg count reduction tests(FECR%). Then after, the objective was to allow a basis for advising communal farmers and government sectors on how to dose goats and sheep effectively at low cost to reduce emergence of anthelmintic resistance.

CHAPTER 2

LITERATURE REVIEW

2.1 Anthelmintics Resistance world wide

Anthelmintic resistance is an important issue in most sheep-producing areas (Vatta *et al.*, 2001). Therefore, it is important that means have to be found to reduce this anthelmintic resistance as farmers do rely more and more on usage of anthelmintics to control gastrointestinal parasites (Waller, 2006). The occurrence and the degree of resistance of *Haemonchus spp.* of sheep and goats to the available anthelmintics in South Africa (S.A) indicate that small ruminant production is entering a crisis situation (Van Wyk *et al.*, 1999). The aim of parasitic control is to ensure that parasite populations do not exceed levels compatible with economic production (Arece *et al.*, 2004).

The control of gastrointestinal trichostrongylosis in small ruminants is now severely impaired by the increasing development of anthelmintic resistance (Hoste *et al.*, 2002). Where anthelmintic drugs have been used as the sole means of control, these drugs are failing due to the emergence of resistant strains of helminths (Wanyangu *et al.*, 1996). The diagnosis of multiple anthelmintic resistance was first made when the cause of poor lamb growth rates was investigated, typically after terminal sire cross lambs had failed to reach slaughter weights by 6months (Sargison *et al.*, 2007). Drug resistance however can also be selected at lower treatment frequencies, especially when the drug is used over many years (Jabbar *et al.*, 2006).

Small ruminant (sheep and goat) production in Ethiopia is affected by many factors including animal health constraints, inadequate nutrition and ineffective management systems (Sissay *et al.*, 2006). Recently there have been increasing reports from all parts of the world, on the occurrence of anthelmintic resistance of trichostrongyle nematodes in small ruminants (Waruiru *et al.*, 1998, Boersema and Pandey, 1997). Resistance of sheep helminths to chemotherapeutic agents have become an important issue throughout the sheep farming world over the last three decades, particularly in the Southern hemisphere (Farais *et al.*, 1997). The resistance of gastrointestinal nematodes of small ruminants (sheep and goat) to benzimidazole anthelmintic drugs seems to be primarily due to a single mutation in the isotype 1 *b*-tubulin gene (Silverter and Humbert, 2002). Due to the widespread resistance to benzimidazole and the emergence of resistance to ivermectin, the situation is becoming a cause of concern, and the current repeated use of ivermectin could lead to a situation where digestive-tract strongyles are no longer controlled (Bentounsi *et al.*, 2007).

For the vast majority of grazing livestock industries, anthelmintics will always remain the cornerstone of effective control programmes (Waller, 2006). The development of anthelmintic resistance poses threats to the future welfare and production of grazed animals (Coles, 2005). It is alarming that gastrointestinal nematodes (Gin) of small ruminants have resistance against all major groups of anthelmintics and there is need for search of other alternatives to control gastrointestinal nematodes with use of plant products (Jabbar *et al.*, 2006). The exceptional resistance spectra of the two strains of *H. contortus* suggest that resistance to anthelmintics in South Africa is far by outstripping speed at which new compounds are

becoming available (Van Wyk *et al.*, 1997). In the South central and South eastern United States (US) the most important helminth of small ruminants is *H. contortus* (Zajac and Gibson, 2000). In the Southern United states and throughout much of the warm temperate, subtropical and tropical regions of the world *Haemonchus contortus* is the parasite species of primary concern in sheep and goats (Kaplan *et al.*, 2007). Approximately 50% of sheep farms have showed resistance to the benzimidazole which is one of the commonest anthelmintic groups used by owners of small ruminants in Malaysia (Chandrawathani *et al.*, 1999). *Haemonchus* in Kenya affects all members of a flock of sheep and lambs and result in deaths of numerous lambs and ewes 1-6 week after the onset of clinical signs (Gatongi *et al.*, 1997). Infection with gastrointestinal nematodes (GIN), particularly *Haemonchus contortus*, is the biggest constraint to profitable goat production in the United States of America (USA) (Shaik *et al.*, 2006). It is becoming increasingly evident that gastrointestinal parasite control programs based on dewormers are failing because of increased dewormer resistance; thus, alternative control strategies are necessary (Nguyen *et al.*, 2005).

There is no single requirement more crucial to the rational and sustainable control of helminth parasites in grazing animals than a comprehensive knowledge of the epidemiology of the parasite as it interacts with the host in a specific climatic, management and production environment (Barger, 1999). The epidemiology of parasitic diseases is affected by the changes in climate, land usage and husbandry methods (Learmount *et al.*, 2006). Vast majority of sheep producers continue to use anthelmintics in control of internal parasites (Waller *et al.*, 1996). However recent surveys in Argentina indicate that a substantial proportion (40%) of farmers claim to not use anthelmintics

and only recognize parasite disease to be a problem when associated with clinical manifestations of haemonchosis (Waller *et al.*, 1996). As with bacteria and antibiotics, or with insects and insecticides, the trichostrongylid nematode parasites of domestic small ruminants (sheep and goats) have acquired resistance to anthelmintics (Humbert *et al.*, 2001). The prevalence of ivermectin (IVM) resistance within the UK is still comparatively unknown with no specific surveys having been undertaken (Bartley *et al.*, 2006). Traditionally, anthelmintics have been the most popular and widely-used means of controlling helminth parasites (Magaya *et al.*, 2000). On their experiments, Miller *et al.*, (2006) found that anthelmintic treatment did remove infections as evidenced by the relatively high efficacy. However, of particular note is the observation that efficacy declined from year to year which indicated that even with the combination of three anthelminitics, evidence of resistance was observed (Miller *et al.*, 2006).

Injectable and oral ivermectin had an efficacy of over 99% against *H. contortus* whereas, the mean worm counts for levamisole, benzimidazole and rafoxanide treated groups were higher than that of the control group, indicating the lack of efficacy of these drugs (Waruiru *et al.*, 1998). Knowledge of what is happening in other countries may be taken as a warning for others (Coles, 2005). Research has indicated that some of one or more of the anthelmintic chemical classes are common on more than 50% of farms (Nguyen *et al.*, 2005). Attempts to expand sheep and goat production by replacing traditional village production system, which rarely involve anthelmintic treatment, with large-scale intensive commercial enterprises invariably induces complete reliance on anthelmintics to control nematodes parasites (Waller, 1997). In Malaysia sheep and goat owners rely

heavily on anthelmintics with increasing awareness of the hazards associated with this approach (Chandrawathani *et al.*, 1999). It is critically important to convince farmers of the need for them to incorporate various alternative methods into the control of nematode parasites (Chandrawathani *et al.*, 1999). Benzimidazole compounds are far the most frequently used anthelmintics due to zero milk withdrawal period and there is an obvious lack of alternative from other anthelmintic families (Chartier *et al.*, 1998). Frequent and continuous use of a single drug leads to the development of resistance (Jabbar *et al.*, 2006). There is no doubt that the development and widespread of high level of anthelmintic resistance represents the greatest single threat to the control of gastrointestinal parasitism of small ruminants in the humid regions of the developing world (Waller, 1997).

2.2 Anthelmintic Resistance in Southern Africa

In South Africa on the farms situated mainly on the Highveld of Mpumalanga, Western Cape, few properties in Kwazulu-Natal, Limpopo, and the Free State, (Van Wyk *et al.*, 1997) indicate that about 90% of sheep farms in South Africa house worm strains that are resistant to drugs from at least one anthelmintic group. Multiple resistances of *haemonchus* were found in Zimbabwe in all farms and the situation has been provoked by the very high frequency of anthelmintic treatment (Boersema and Pandey, 1997). The occurrence and high level of resistance in South Africa makes it difficult and virtually impossible for anyone to advise farmers effectively on worm control on any farm without knowledge of the susceptibility status of the worm strains on the farm concerned (Van Wyk *et al.*, 1999). As close communication with informed advisors is generally limited, there is a danger

that Sustainable Integrated Parasite Management Programme (SIPM) will remain a theoretical concept without alternative modes of communication (Van Wyk *et al.*, 2006). Once resistance has become severe it will often be too late to avoid losses as to implement effective remedial measures (Van Wyk *et al.*, 2006). This problem of timely acceptance by farmer of the potential economic impact of an apparent problem further complicates worm management extension (Van Wyk *et al.*, 2006). What is often lacking is effective communication and back-up service to convince farmers not only to adopt, but more particularly to persist with non chemotherapeutic alternatives and adjuncts to parasite control (Waller, 1999).

2.3 Anthelmintic Resistance in communally grazed areas

In South Africa sheep owners traditionally graze their livestock extensively on communally managed range land (Bakunzi and Serumaga-Zake, 2000). This leads to low anthelmintic resistance in goats and sheep in addition to infrequent dosing by resource-poor farmers (Bakunzi, 2003; 2008). However emerging farmers often buy animals at auctions supplied by commercial farms on which anthelmintic resistance may be present, and in this way resistant nematode populations or strains may be disseminated (Bakunzi, 2003; 2008). In Semi-Arid areas of Kenya, communal sheep and goat owners traditionally treat their flocks for helminthes during rains when a disease is already evident (Gatongi *et al.*, 1997). Sheep farmers treat their animals with anthelmintics only when they believe treatment is needed, due to clinical signs such a scruffy hair, weight loss and the presence of pot belly (Torres Acosta *et al.*, 2003). According to Maingi *et al.*, (1997) majority of communal farmers in Kenya underdose lambs and adult sheep due to

reliance on estimation of drenching weights using visual perception rather than actual weighing and dosing according to the average weight of the animals in a flock and this tends to create resistance. In eastern Ethiopia, livestock production is mainly pastoral or agro-pastoral, and the farmers or pastoral communities are entirely dependent on their communal pastures, and animals are exposed to less infective larval stages continuously throughout the year and thus less resistance (Sissay *et al.*, 2006). In some cases animals are not provided with supplementary feed because resource poor farmers cannot afford to buy commercial feeds and these animals lose natural immunity and become drug resistant (Magaya *et al.*, 2000). In the Nigerian humid zone, as in other similar agro-climatic zones in the tropics, which rely heavily on small-scale, traditional system of livestock production, formal parasite control is frequently lacking (Chiejina *et al.*, 2005). Where it is practiced at all it is based entirely on the sporadic use of the cheapest available drugs of varying degrees of efficacy which eventually leads to anthelmintic resistance (Chiejina *et al.*, 2005).

2.4 The impact of parasites on production

Gastrointestinal helminthoses play a major role in decreasing livestock productivity in sub-Saharan Africa, particularly in young and growing animals (Magaya *et al.*, 2000). Helmenthosis is the one major constraint in the successful wool and mutton industry (Jabbar *et al.*, 2006). Gatongi *et al.*, (1997) states that production level in goats and sheep are lower because of number of factors which include poor nutrition, diseases, parasitism and poor management. Sheep and goats constitute a major source of protein for a human nutrition in tropical regions (Gatongi *et al.*, 1997). Nematodosis

can cause direct losses due to drop in production and deaths of animals (Jabbar *et al.*, 2007). Lamb production is small in Sao Paulo state, which forces the state to be a large importer of sheep meat from other Brazilian as well as from other countries (Amarante *et al.*, 2004). The small ruminant sector can make a sizeable contribution to meeting this demand, particularly if the predominantly–small holder producers of the developing world can overcome current constraints to production (Wanyangu *et al.*, 1996). The purpose of drenching particularly ewes before introduction of the rams, is to increase their fertility, which may be reflected in an increase in the number of lambs born per ewe, or in the number of animals that conceive or both (Van Wyk *et al.*, 1990). When comparing dairy goats from other studies conducted it has been discovered that, the high producing animals within a flock were less resistant and resilient to nematode infections than does with a low level of milk production (Hoste *et al.*, 2006). Current published information on whether resistant to parasites compromises the productive performance in sheep suggests that potential interactions may vary according to breeds and age (Liu *et al.*, 2005). The temporary depression of immunity also makes the ewe more susceptible to the effects of parasitism (Romjali *et al.*, 1997).

2.5 Nematode Resistance to anthelmintics

Anthelmintic resistance monitoring is a key requirement for sustainable livestock nematode management programs (Kotze *et al.*, 2006). Anthelmintic resistance (AR) among parasites of sheep and goats has been known to occur at least for four decades (Várady *et al.*, 2007). Sustainable control is threatened by the development of anthelmintic resistant nematodes

(Torres Acosta *et al.*, 2003). Anthelmintic resistance is almost cosmopolitan in distribution and has been reported in almost all species of domestic animals and even in some parasites of human being (Jabbar *et al.*, 2006).

Anthelmintic resistance is rapidly increasing in parasites of small ruminant nematodes in Kenya (Wanyangu *et al.*, 1996). In the last two decades anthelmintic resistance has progressed from being of academic interest to a major threat to the small ruminant industries in many countries of the world (Waller, 1999).

High levels of multiple resistances to albendazole, tetramisole, both separately and in combination, as well as to ivermectin were recorded in all the goat flocks (Sissay *et al.*, 2006). The resistance of trichostrongylid nematode communities to benzimidazoles is a world-wide problem in sheep and goat farming and has led to many studies designed to determine the molecular basis of this phenomenon (Silvester and Humbert, 2002). The development of anthelmintic resistance in ovine nematodes poses a major threat to the continued welfare and productivity of the world, particularly in the southern hemisphere (Papadopoulos *et al.*, 2001). Control of such highly resistant helminth strains is problematic, without effective anthelmintic to back up other methods of control and intensive farming probably has but small chance of success (Van Wyk *et al.*, 1997).

Data can give a warning that if different approaches for worm control are not adopted animal welfare or productivity may be seriously compromised by loss of all anthelmintic activity (Coles, 2005). Prophylactic mass treatment of domestic animals have contributed to the widespread development of anthelmintic resistance in helminths (Jabbar *et al.*, 2006). A single treatment

with closantel/ albendazole mixture revealed that closantel could effectively prevent establishment of adult *Haemonchus contortus* in goats for up to 3 weeks (Waruiru, 2002). Inhibition in the abomasal mucosa is an important mechanism which enables nematode populations to survive when conditions on pasture are adverse (Sargison *et al.*, 2007).

2.6 Common causes of anthelmintic resistance and prevention

2.6.1 General overview

Few UK sheep farmers routinely weigh their lambs and ill thrift problems are only identified during the late autumn when it is apparent that insufficient numbers have reached slaughter weights (Sargison *et al.*, 2007). This approach may result in failure to diagnose anthelmintic resistance when investigating the underlying cause of ill thrift due to parasitic gastroenteritis (Sargison *et al.*, 2007). According to Bentousi *et al.*, (2007) pilot farms in Algeria are used for demonstration purposes for stock selection, and indicate that they may be a source of resistance since low-income smallholders buy selected sheep. In many cases the anthelmintic dose rates are lower in Southern Latin America than dose rates elsewhere in the world and may predispose to selection of anthelmintic resistance in nematode parasites (Waller, 1996). Consequently, the development of alternative means to control gastrointestinal nematodes (GIN) has become imperative (Burke and Miller, 2006).

Relative lack of use of dewormers may also reflect relative lack of access to chemicals or willingness to pay cash for health inputs by resource poor

smallholder farmers (Ancheta *et al.*, 2004). It is much easier to abandon an anthelmintic when it is not effective and use a different one than to pay for tests and let others know the extent of the problem on a particular farm, which may reduce animal values (Coles, 2005). The basic epidemiology and principles of control of gastrointestinal nematodiasis have been evaluated for the major cheap and cost-effective control when used in accordance with the body of accumulated knowledge (Barger, 1993).

The advent of highly effective and very safe anthelmintics during the 1960s to 1980s resulted in the extensive use of these chemicals to the virtual exclusion of other approaches (Bath *et al.*, 2005). The control of gastrointestinal nematodes of small ruminants is performed almost exclusively with anthelmintics leading to continual development of anthelmintic resistance (Assis *et al.*, 2003). Agreeing with statement by Assis *et al.*, (2003), Liu *et al.*, (2005) also state that the control of GI parasites is currently based largely on treatments with anthelmintics (drenches). In Mexico control of gastrointestinal nematode infections of sheep is mainly based on anthelmintics (Torres Acosta *et al.*, 2003). The negative effects of nematodes in small ruminants can be reduced by use of dewormers but their effectiveness is increasingly limited by the emergence of anthelmintic resistance (Ancheta *et al.*, 2004). A small number of surviving worms, which are the most resistant component of the population, then contaminate the pasture with a majority of resistant offspring for subsequent generations which lead to development of a resistance due to selection pressure (Jabbar *et al.*, 2006). To maintain the production benefits of intensive livestock production systems the efficacy of available

compounds must be maintained so that worm control measures remain effective (Taylor *et al.*, 2002).

Sissay *et al.*, (2006) states that to achieve eradication also requires action to be taken against the free living populations as well as the parasitic stages within the animals. Use of pasture rotation, harrowing, regular manure removal, and “deworm and move” programs can be of help in parasite control (Nguyen *et al.*, 2005). The use of grazing management strategies, combined with anthelmintic treatment, may well result in better parasite control at less cost, but may not reduce significantly the selection pressure for the development of resistance (Waller, 2006). After dosing, sheep should be withheld from pastures for 48h, sufficient time to ensure that any viable nematode eggs are voided, before turning onto contaminated pasture to ensure dilution of any surviving resistant nematode eggs and larvae (Sargison *et al.*, 2007). Effective quarantine drenching and annual drench checks may, therefore, prove to be more important than practices which might reduce the rate of emergence of multiple anthelmintic resistances within the flocks (Sargison *et al.*, 2007). Common problems identified in any small ruminant production system is that farmers inadequately dose animals, and uses their visual appreciation to determine doses and also use their visual assessment to calculate weight of the animals (Torres Acosta *et al.*, 2003).

Effective monitoring of resistance is vital in order to maintain a high efficacy of currently available anthelmintics and prevent further selection for resistance, especially in areas where it is present in only a small proportion of the worm population (Várady *et al.*, 2007). Due to the high prevalence

of anthelmintic resistance in goats, there is a need to explore novel approaches to control nematodes and to reduce the exclusive reliance on chemotherapy which is strongly demanded in this host species (Paolini *et al.*, 2005). Selective treatment has effectively been carried on many cattle farms where only first year animals are treated with anthelmintic and calves are allowed to graze on pasture used previous year by older animals (Coles, 2005). This could explain the low levels of resistance in the UK (Coles, 2005). To slow down the development of anthelmintic resistance within worm populations is to favour targeted anthelmintic treatments instead of their systemic use (Hoste *et al.*, 2006). Generic products of substandard quality, repacked and /or reformulated products, and expired drugs are widespread in pharmacies and general markets and these products may contribute to development of anthelmintic resistance (Jabbar *et al.*, 2006). A factor common to all farms in Kenya is that drugs are either paid for by Government or donated by manufacturers, and removal of the economic basis for decisions on frequency of drenching is a likely contributory factor to the existence of anthelmitic resistance (Wanyangu *et al.*, 1996). This is partly because AR usually only becomes evident once efficacy drops below 50% and partly because farmers simply switch to another group or use combination drugs when problems emerge until eventually no effective drugs remain (Bath, 2006).

In Paraguay a major problem that exists is the counterfeit anthelmintics (Waller *et al.*, 1996). There are no government controls or surveillance operations to monitor drug quality and because all sheep meat is consumed locally and often only on the farms where sheep are raised, there is little incentive to introduce the necessary control measures (Waller *et al.*, 1996).

It is reasonable to assume that genetic variation to worm infection is likely to be even greater between breeds, than within breeds of small ruminants (Waller, 1999). The formidable combination of malnutrition, environmental stress, long-term and often massive larval challenge and limited relief by way of effective anthelmintic treatment, would have imposed the harshest conditions for selection, resulting in survival of the fittest (Waller, 1999). When goats are kept intensively at high stocking rates and forced to graze, rather than allowing their natural habit to browse, problems with nematode parasites can be particularly severe, and under these relatively newly contrived management systems, managers of goat flocks tend to resort to very frequent use of anthelmintics and thus development of resistance (Sissay *et al.*, 2006).

Over the centuries, many of the indigenous breeds of sheep and goats in the tropics and subtropics have been unwittingly exposed to strong survival pressure for parasite resistance (Waller, 1999). Due to expansion in organic farming sector, a greater number of goat owners allow their animals to graze (Paraud *et al.*, 2004). When giving out the resistance surveillance, Coles, (2005) briefly states that data can give a warning that if different approaches for worm control are not adopted, animal welfare or productivity may be seriously compromised by loss of all anthelmintic activity. Current trend suggests that farmers are increasing the use of anthelmintics, particularly macrocyclic lactones (MLs), to try to maximize production which will almost inevitably result in the development of resistance (Coles, 2005). From the 1950s new classes of highly effective and safe anthelmintics were introduced to the market at the rate of about one per decade, and livestock production targets were based on the improved parasites control made

possible by these drugs (Van Wyk *et al.*, 2006). Any single new anthelmintic group will probably bring but temporary relief to the resistance crisis, unless the present practice of excessive drenching is reduced considerably (Van Wyk *et al.*, 1999). Prospect of slowing down the development of severe anthelmintic resistance against the commonly used groups of anthelmintics in communally grazed sheep is needed (Bakunzi, 2008). Extension personnel and veterinarians who suggest alternative treatment regimes to producers must also emphasize that they represent only temporary solutions in the face of existing parasites (Zajac and Gipson, 2000). In order to preserve the full potential of closantel and to control mixed nematode infections, it is recommended that administration of the drug be used in full and in combination with broad-spectrum anthelmintic (Waruiru, 2002). Strategic use of this combination would ensure that incoming larvae from pasture are killed before establishment (Waruiru, 2002). If resistance does not persist long in a population of trichostrongyloid population after discontinuing treatment, use of levamisole in an annual or biannual rotation of anthelmintics may help maintain its efficacy (Zajac and Gibson, 2000).

2.6.2 Effect of weather on the growth of production

Gastro-intestinal nematode parasitism imposes severe economic constraints on sheep and goat production on rangeland in the tropics (Matika *et al.*, 2003). The anthelmintic efficacy of *Sericea lespedeza*(SL) hay was highest against *H.contortus*, but also significantly reduced numbers of *T.colubriformis*, with a greater effect on female than male nemaotodes of each species (Shaik *et al.*, 2006). During the rainy season (December to

March), environmental conditions were ideal for the development and translation of infective larvae on herbage (Magaya *et al.*, (2000). It is during this period that faecal egg counts began to rise, reaching their highest peaks between March and May (Magaya *et al.*, 2000). The faecal egg counts declined from June, reaching their lowest level in July (Magaya *et al.*, 2000). This decline may be attributed mainly to the dry conditions prevailing and the low temperatures, which are unsuitable for the development of the free-living stages (Magaya *et al.*, 2000). The rate of emergence of resistance varies geographically in accordance with the prevailing climate, parasite species and treatment regimes adopted in the region (Jabbar *et al.*, 2006). Supplementation with urea reduced the effects of parasitic infection and improved the productive performance of sheep (Knox and Steel, 1996). It is vitally important that the right advice is given in relation to anthelmintic usage, both in terms of maximizing production and, limiting the development of further resistance (Tylor *et al.*, 2002).

2.6.3 Use of biological control and vaccines to control resistance

Effective helminth control is a major element ensuring the sustainability of animals production, especially as part of nationalistic visions of increasing the volume of locally produced livestock products now being embraced by many countries (Waller, 1997). Biological control for any target pest organism is aimed at exploiting their natural enemies so as to reduce the number of the pests in the environment to level less than what would have occurred in the absence of the biological control organisms(s) (Waller, 2006). It is argued that a vaccine of moderate efficacy measured in terms of economic benefits, may well be effective in the field (Waller, 1999). This is

achieved by priming the host for progressive development of immune regulation of parasites and thus reducing the overall rate of parasite population increase in the flock (Waller, 1999). However in the broadest sense, any means by which animals are separated from their faeces (thus the free living stages of parasites) constitutes a form of biological control (Waller, 2006). Young animals could be stimulated via appropriate antigens and vaccination protocols into acquiring immunity at the same rate and to lesser extent as adults and most of the debilitating effects of infection could be avoided, with little or no requirement for anthelmintic treatment (Barger, 1993).

According to Waller, (2006) evasive parasite control brought about by movement of animals so as to avoid the peak periods of larval pick-up from pasture is an excellent, albeit indirect form of biological control. Like wise the sale of, often-young susceptible livestock to the slaughterhouse deprives parasites of susceptible hosts in which they may readily complete their life cycles (Waller, 2006). One activity of man, which could be more justifiably called biological control, is the practice of dung collection in the developing world for the use as fuel and building material, thus breaking the life cycles of parasites (Waller, 2006). A variety of birds rely heavily on coprophagous invertebrates as a food source and in seeking these, they tear bovine dung apart thus destroying the environmental buffering capacity of these large faecal masses (Waller, 1997). Control of snail intermediate hosts by foraging flocks of ducks has shown to be of practical value in the control of *Fasciola gigantica* infections of ruminants raised in the rice –producing areas of South-East Asia (Waller, 1997). Waller, (1999) states that tethered husbandry and night housing with stall feeding are common management

procedures in the tropics/subtropics particularly for small ruminants. The system allows administration of low cost supplementation of nitrogen and essential minerals by way of feed blocks and plant by products to enhance the supply of nutrients without greatly increasing the cost to the farmer (Waller, 1999).

2.6.4 Knowledge dissemination to farmers about the use of anthelmintics

Famacha is a method used to test clinical anaemia caused by *Haemonchus* spp. in goats farmed under resource-poor conditions in South Africa (Vatta *et al.*, 2001) and advantage of it is that it can be successfully applied by generally illiterate people, and thus be a valuable tool for resource poor farmers in developing countries (Van Wyk *et al.*, 2006). Farmers in Yucatan (Mexico) did not select their anthelmintics according to the drug rotation criteria, and most have not been informed about the need to rotate drug every year and thus resistance develops in the flocks (Torres Acosta *et al.*, 2003).

2.6.5 Introduction of sustainable integrated parasite management

Strategies to optimize refugia can involve leaving animals on helminth – contaminated pasture after drenching with an effective anthelmintic or leaving some animals in a group untreated so that are genetically diluted by mating with unselective worms originating from pasture (Van Wyk *et al.*, 2006). However, if the nematode population in refugia is small, then the offspring of resistant nematodes will constitute a larger proportion of the

next generation (Sargison *et al.*, 2007). The rate to which resistance develops will be affected by whether resistant worms are as fit or less fit than the susceptible worms and said fitness include all those properties that enable more worms to complete their life cycle including egg laying rate, persistence of worms in the host, survival on the pasture, ability to migrate on herbage and infectivity when ingested (Coles, 2005).

2.6.6 Pasture management

Safe pastures are generally those that have been mown and temporarily 'rested' for grass regrowth and to a lesser extent, those grazed by adult cattle, sheep, or horses (Williams, 1997). In modern pastoral farming system the main emphasis for nematode control is to limit the number of infective larvae on pasture (Coles *et al.*, 2006). This is commonly achieved by regular use of anthelmintics and other manipulations of grazing management such as treating and moving animals from contaminated sites to clean pasture (Coles *et al.*, 2006). The treatment of young animals at weaning, in conjunction with a move to a spelled pasture, is almost universal in commercial small ruminant production systems, even though the spelled pasture may be provided more for nutritional than parasitological reasons (Barger, 1999).

2.6.7 Use of anthelmintics by farmers under intensive grazing

Under intensive grazing conditions worms are controlled exclusively by frequent drenching with anthelmintics, often without alternation of the compounds or with alteration of chemically related compounds (Van Wyk *et*

al., 1987). Selection pressure is caused because the anthelmintics are dosed as often as every 3 weeks at times of peak transmission, and this pressure may be increased when the first signs of resistance occur (Van Wyk *et al.*, 1987). Preventive drenching is most important for forestalling excessive contamination of the pasture with free living stages of the worms, and thus minimizing the expense of susceptible hosts to verminosis (Van Wyk *et al.*, 1990). Mixing of sheep and cattle on the same pasture could result in low infective larvae affecting sheep because of cattle consuming large amount of infective larvae that could affect sheep negatively (Torres Acosta *et al.*, 2003).

2.6.8 Does nutrition play a major role in relieving animals from parasite burden?

Increasing stocking rate must of course be accompanied by providing more feed to the animals for them to remain productive (Waller, 2006). It is well known that the plane of nutrition is an important determinant of the response by animals to parasitism by affecting the development and establishment of parasite and also influencing the magnitude of their pathogenic effects (Waller, 1997). Feed supplementation, particularly with quality protein, is often necessary to maintain adequate productivity of livestock on such poor quality feed, but the cost involved makes this option quite unrealistic for the majority of livestock owners in the developing world (Waller, 1997).

2.6.9 Does the gathering of animals on the same kraal have effect on the spread of resistant parasites?

Typically, clean plots or paddocks of pasture will be contaminated naturally or artificially with known numbers of eggs of known species at specified intervals throughout the year, and the resulting populations of eggs and /or larvae monitored by direct recovery from soil or pasture samples, or by use of 'tracer''sheep (Barger, 1999). Outbreaks of helminth infections were associated with heavy rains that diluted the levels of urine in the pens and allowed the survival of eggs and free-living larvae (Bath *et al.*, 2005). According to Jacquet *et al.*, (1992) very few animals (a maximum of only 19.5% in the rain season) are infected and so may seed the pastures or the periphery of the wells where animals are concentrated for drinking. Resistant survivors of such treatments are immediately diluted by incoming larvae that have not been exposed to selection, thus diminishing their opportunity to contribution to the genetic basis of future worm populations on that pasture (Barger, 1999).

2.6.10 Farmers' attitudes and knowledge with the existence of resistance

From the farmer's perspective, the following are most pertinent: worms are usually not uppermost in the farmer's mind, and other priorities usually take precedence since they are seen to be more urgent or important (Bath, 2006). The extraordinarily high prevalence of resistance to benzimidazoles ,levamisole and morantel in nematode parasitizing sheep has stimulated the formulation and, to a surprisingly large extent, adoption by farmers of strategic control programmes aimed at preserving the useful life of

ivermectin (Barger, 1993). It is also clear that farmers are generally more willing to pay for drugs than for advice (Bath, 2006). This is a problem of perceived value and is the inevitable result of valuable advice being given away free for decades in many countries (Bath, 2006). Advice not paid for is often advice ignored (Bath, 2006). In UK cereal farmers were aware about the consequences of relying on chemicals to control agronomic pests and had responded to the emergence of insecticide resistance by adopting natural control methods, while accepting a reduced level of production (Sargison *et al.*, 2007).

2.6.11 Do the drug manufactures have any inputs in the growing of anthelmintic resistance?

According to Bath, (2006), pharmaceutical companies and distributors must also accept a share of the blame for development of anthelmintic resistance. The major drug companies have huge advertising budgets and field forces and can therefore exert a significant influence on farmer thinking and behaviour when it comes to parasite control. This can apply to the thinking and advice of veterinarians in the field as well. The driving force in these firms is sales volume, usually related to projected targets and budgets, therefore, they continue to advocate and encourage reliance on drugs, blanket treatments and excessive treatments which are certainly good for short-term. Sales staff has little choice but to sell, even if this is against their better judgment. This has been exacerbated by the proliferation in the number of generic anthelmintic products often of dubious drug substitution and adulteration (Waller, 1997).

2.6.12 Anthelmintic Resistance with Animal Production (threat)

Small ruminants are an important resource for poor farmers who keep their animals for cash income, savings, meat, fertilizer and employment of family members (Ancheta *et al.*, 2004). Healthy livestock represents one of Man's valuable and renewable resources (Waller, 1997). They provide high quality edible protein, fibres of all types, leather and a range of useful by-products, as well as providing an important way of generating and storing wealth, supplying motive power and fuel in developing countries (Waller, 1997). The parasite infection reduces the protein utilization efficiency for wool production (Liu *et al.*, 2005). It is widely believed by farmers that nematode parasites are more important to the sheep industry than to the cattle industry and this is probably a consequence of the ability of pathogenic species such as *Haemonchus contortus* and, to a lesser extent, *Trichostrongylus colubriformis* to cause the death of large numbers of sheep, whereas deaths of cattle attributable to nematode infection are less common (Barger, 1993).

The changes that are being brought to bear on the livestock industries throughout the world will make producers either change entrenched practices of chemical dependence to control nematode parasites in their flocks and herds or force them to get out of livestock production (Waller, 1999). *Oesophagostomum columbianum* has been a special problem, and in the past it was recognized as a major cause of poor production of small ruminants, but frequent drenching on most commercial farms has led to the elimination of this species (Bath *et al.*, 2005). The capsule-treated ewes weaned around 50% greater total weight of lambs under both dryland and

irrigated conditions, and the lambs from such ewes produced up to 20% more wool (Barger, 1999).

The main interest of small ruminant exploitation is the production of meat for feeding rural low-income populations (Assis *et al.*, 2003). We have to learn to farm with the presence of parasites, trying to prevent only the unacceptable production losses while simultaneously breeding animals fit for the environment, rather than making the environment fit for the existing animals (Bath, 2006). Stock owners habitually suffer crippling financial losses both in terms of mortality and reduced long term productivity of their animals due to uncontrolled parasitism (Waller, 1997). The development of anthelmintic resistance has resulted in lowered animal productivity due to heavy nematode burden (Jabbar *et al.*, 2006).

2.7 Alternatives to normal chemotherapy

Accepting that even the most efficacious anthelmintic drug will not be 100% effective, against 100% of parasites, in 100% of the treated animals, in 100% of times that is used then this literally means that the only parasite control strategy that does not select for the resistance does not entail the use of anthelmintics (Waller, 2006). The apparently prolonged action of copper wire oxide particles (COWP) against *H. contortus* could prove to be enormous benefit in restoring some measure of control in those regions of the world where this parasite predominates and anthelmintic resistance is rampant (Waller, 1999).

The rate of development of resistance is determined by the contribution that those nematodes surviving chemotherapy make it to the next generation of worms (Papadapoulos *et al.*, 2001). The reduction in the development of *T.Colubriformis* larvae after administration of *Duddingtonia flagrans* at the dose rate of 5×10^5 spores/kg BW/day ranged from 86 to 96% when compared to the control group not receiving the spores (Paraud *et al.*, 2004). The antiparasitic effects of tanniferous forages are achieved at lower condensed tannin (CT) -levels in the abomasums than in the small intestine (Heckendorn *et al.*, 2007). Currently available long acting boluses for sheep are designed to act therapeutically and kill the existing burden of parasites and then act prophylactically to block the establishment of new patent infections in the host by continuing to release about 10% of a standard single dose of active ingredient per day for about 100days (Coles *et al.*, 2006). The anthelmintic efficacy of SL(*Sericea lespedeza*) hay was highest against *H.contortus*, but also significantly reduced numbers of *Trichostrongyls circumcincta* and *Trichostrongylus colubriformis*, with a greater effect on female than male nematodes of each species (Shaik *et al.*, 2006).

The relatively high cost of developing new drugs and increasing concern about their ecological impact, indicate a need for alternative control strategies (Miller *et al.*, 2006). Multipurpose trees are of central importance in rural economy of many arid and semi-arid regions in the world (Nguyen *et al.*, 2005). Browse plants are important for animal production during periods of the year when both the quantity and quality of pasture is limited (Nguyen *et al.*, 2005). *D. flagrans* which grows on forages has ability to survive gut passage of ruminants, as resting spores, they then rapidly

germinate and spread on fresh dung and capture infective larvae before they migrate to the pasture (Waller, 1999).

The worm burdens of *Oesophagostomum dentatum* and *Hyostrongylus rubidus* in tracer pigs on a pasture, where animals had been fed supplement containing *D.flagrans chlamydospores*, were significantly lower compared to those of tracers on untreated, control pasture (Larsen, 1999). Although there is a large and diverse range of herbal de-wormers used throughout the world, particularly in the Asian and African countries, generally there is a lack of scientific validation of the purported anthelmintic effects of these products (Waller, 2006). Birdsfoot trefoil (*Lotus Corniculatus*) reduced adult *H.contortus* parasite burden, faecal egg counts and total daily faecal egg output consistently by about 50% compared to the control animals (Heckendorn *et al.*, 2007).

Recent studies in Vietnam have reported that anti-parasitic agents extracted from plant material for the control of parasites in goats were successful and have been introduced into practice like *Citrullus vulgaris* for tapeworms, *Gliricida sepium* and *Artocarpus heterophilus* for common intestinal worms, and *Areca catechu* for liver fluke. Alternative forages of Mimosa, Papaya, *Leucaena leucocephala*, Goava leave, *Mimisa* sp. and *Flemingia macrophylla* have efficacy against larvae of *Haemonchus* in vitro (Nguyen *et al.*, 2005). Heckendorp *et al.*, (2007) discovered that condensed tannin (CT) affected the female worms more severely than the male worms. Condensed Tannin containing forages have the potential to help control anthelmintic resistant gastrointestinal parasites and they have been shown to

reduce faecal egg counts in sheep and goats and may also decrease hatch rate and larval development in faeces (Nguyen *et al.*, 2005).

Mixed grazing or alternate grazing of sheep and other species such as horses and cattle has been recommended as a means of worm control and was practised on the majority (70%) of the farms in Nyandarua District (Kenya), (Maingi *et al.*, 1997). This is likely to reduce pasture infectivity due to host specificity of the predominant parasites such as *Haemonchus* and intestinal *Trichostrongylus* species (Maingi *et al.*, 1997).

2.8 Anthelmintic Resistance in sheep and goats due to metabolic difference

There is high frequency of treatments required in goats because of the poor ability of goats to develop an immune response to nematodes (Hoste *et al.*, 2002). Reduced efficacy of anthelmintic in goats may be the results of a faster metabolism of drugs in goats (Vatta *et al.*, 2001). The difference in anthelmintic metabolism between sheep and goats effectively resulted in underdosing when the sheep dose rate was applied to goats and consequently, failure to control susceptible population of nematodes occurred (Charles *et al.*, 1989). According to Jabbar *et al.*, (2006) there are some indirect field evidence supporting the statement that says: variation in bioavailability in different host species is crucial in making correct dose decision. Animals with a high level of immunity are likely to cause faster development of resistance when drenched than the non-immune stock (Nguyen *et al.*, 2005). There is evidence from other studies that the use of anthelmintic drench to remove parasites in a field situation delays the

development of immunity to reinfection in sheep that are selected for resistance to worms (Eady *et al.*, 2003).

Gopal *et al.*, (1999) reports that the lower mean LD₅₀ (ng/ml) values in goats compared with sheep might be due to a difference in the immune status of the two host species. Hoste *et al.*, (2006) discovered a contradiction of findings with data acquired in goats that the mean quantity of milk produced by dairy goats is nearly twice those produced by ewes. It is suspected that the nutritional demands in ewes is less important than in goats (Hoste *et al.*, 2006). Jabbar *et al.*, (2006) also reports that lambs must also receive sufficient exposure to parasites to develop an effective immunity against infection, while avoiding excessive larval intake. If anthelmintics are being metabolized, either by the host or the parasite, then concentrations may fall below the recommended dosages (von Samson-Himmelstjerna and Blackball, 2005). New infections may then be exposed to suboptimal doses, which would further contribute to the development of resistance (von Samson-Himmelstjerna and Blackball, 2005).

2.9 Seasonal effect of rainfall on Anthelmintic Resistance

The rate of emergence to resistance varies geographically in accordance with the prevailing climate, parasite species and treatment regimes adopted in the region (Jabbar *et al.*, 2006). Treatment either before or during the rains significantly reduces the faecal output, improves body weight and packed cell volume (Gatongi *et al.*, 1997). The benefit of treatment in reducing mortalities was strongly evident in the young stock (Gatongi *et al.*, 1997). In marginalized areas of Kenya the benefit of treating animals after rains can be

short lived as animals can be immediately reinfected from pastures already contaminated with infective larvae (Gatongi *et al.*, 1997).

During their research in Zimbabwe, Magaya *et al.*, (2000) reported this : the control and cottonseed meal (CSM) groups had high eggs per gram of faeces (epg) during the period of the study, with peaks occurring in October and January rainy months. The epg declined towards the end of the rainy season. All animals lost weight during the dry season and gained during the rainy season. During the dry season and part of the rainy season (August to January) the faecal egg count in the bolus –treated groups was virtually zero, and only started to increase slowly in February. Warm, humid climatic conditions, which occur during the summer months in the northern united states, and during spring, summer, and fall in the southern, are ideal for growth and development of the free living (eggs, larvae) stages of parasites on pasture (Shaik *et al.*, 2006). A similar situation can arise with the larvae of cold-sensitive species such as *H.contortus* or *Oesophagostomum columbianum*. Larvae of *H.contortus* cannot survive extreme cold such as occurs in a northern continental winter and therefore treatment of housed sheep or goats in winter should be very effective in controlling this species (Barger, 1999).

In temperate areas, eggs deposited over prolonged periods in winter, spring or early summer may result in large numbers of larvae being available to grazing animals in spring, summer or autumn, respectively, depending on the temperature-rainfall relationships (Barger, 1999). Eggs deposited on wet tropical pastures hatch and develop to infective larvae very rapidly, resulting in peak infectivity on pasture in a week or so (Barger, 1999). The major

requirement for parasite control, namely a long enough rotation length that most infective larvae originating from previous grazing have died off, is probably not achievable in temperate climates, given that substantial declines in pasture infectivity may take from 3 to 9 months to occur, depending on the climate and time of the year (Barger, 1999).

2.10 Drenching programs for summer and winter rainfall

Management and medication have an important influence on parasite concentration and productivity in small ruminants (Nguyen *et al.*, 2005). Although there are differences between the programs for summer and winter rainfall zones in terms of drench timing and use of narrow –spectrum compounds such as closantel, all programs share a similar philosophy like: they emphasize the minimal use of effective drenches, integration of chemotherapy with the minimal use of effective drenches, integration of chemotherapy with grazing management, avoidance of under dosing, annual rotation of anthelmintic families, the importance of adequate nutrition, monitoring of faecal egg counts and drench efficacy, and above all, introducing to farmers the notion that broad-spectrum anthelmintic are a valuable and extremely limited resource that should not be squandered by excessive and unnecessary use to emergency of resistance (Barger, 1993). From the literature cited above anthelmintic resistance (AR) in communal areas has not been fully surveyed in summer rainfall areas of South Africa except that done by (Vatta *et al.*, 2001) and (Bakunzi 2003; 2008). This study will survey the extent of anthelmintic resistance in communally grazed goats and sheep around Zeerust area of North-West Province, in South Africa.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 ANIMALS USED IN THE STUDY

This research was conducted in NorthWest Province, about 50 km radius from Zeerust from January to March 2008. Eight (8) small-holder goat farmers and 8 of sheep farmers with varying numbers of animals from 40 upwards grazing on communal rangelands were randomly chosen. In the preliminary phase, farmers were asked questions about collection of data and this provided the researcher with the idea as to how often individual farmers dosed their animals and the type of animal breeds. The goats were of mixed breed (indigenous) but the commonest breeds seen were the Boer goat. The sheep also were of the mixed breeds and the prominent breeds were the Dorper and Merino breeds. These goats and sheep also grazed freely with cattle on the same communal rangelands. On the first visit to the farmers goats and sheep were randomly assigned treatment 4 groups of 10 animals each, three treated and one control as shown in Table 1 and 2 below.

3.2 EXPERIMENTAL DESIGN FOR GOATS

TABLE 1: Treatment groups on 8 goat farmers

Groups of treated goats

Farmer	Albendazole	Ivermectin	Closantel	Control	Total
1	10	10	10	10	40
2	10	10	10	10	40
3	10	10	10	10	40
4	10	10	10	10	40
5	10	10	10	10	40
6	10	10	10	10	40
7	10	10	10	10	40
8	10	10	10	10	40
TOTAL	80	80	80	80	320

3.3 EXPERIMENTAL DESIGN FOR SHEEP

TABLE 2: Treatment groups in 8 sheep farmers

Farmer	Groups of treated goats				Total
	Albendazole	Ivermectin	Closantel	Control	
1	10	10	10	10	40
2	10	10	10	10	40
3	10	10	10	10	40
4	10	10	10	10	40
5	10	10	10	10	40
6	10	10	10	10	40
7	10	10	10	10	40
8	10	10	10	10	40
TOTAL	80	80	80	80	320

3.4 METHODOLOGY

3.4.1 EXPERIMENTAL PROCEDURE

Forty goats and forty sheep from each farmer and were eartagged, weighed and then vaccinated with pulpy kidney vaccine oil emulsion a week before the collection of samples. The drench makes the gastrointestinal tract (git) environment suitable for growth of enterobacteria which cause pulpy kidney. The animals were therefore vaccinated before drenching to boost their immunity for protection purposes. Faecal samples were collected directly from the rectum into plastic containers before dosing. The first group of treated animals was then dosed with albendazole (Prodose green, Virbac Animal Health) as an oral drench at a dose of 7.5mg/kg live mass. The second group was treated with ivermectin (Ivomec®) oral drench at a dose of 0.2mg/kg live mass, while the third group was treated with closantel, (Prodose yellow, Virbac Animal Health) as an oral drench at a dose of 5mg/kg live mass. The fourth group was not treated and served as a control. After 2 weeks, faecal samples were again collected from the same eighty animals (40 goats and 40 sheep) and analysed for nematode eggs. The faecal samples were always transported in an ice-cooled box and stored in the laboratory at 4°C until analysis on the same day of collection. Faecal worm egg counts were done using a modification of the McMaster technique (Reinecke, 1983). Two grams of faeces were weighed in a weighing boat and 58 ml of salt solution were added. To make a saturated salt solution, 400 grams of sodium chloride were dissolved in 1 litre of water. The faeces and salt solution were emulsified in the blender and placed in a 100ml glass beaker and 4 to 5 drops of amyl alcohol were added to break up any air bubbles in the emulsion. The required volume of emulsion was transferred

to a counting chamber of Mc-Master slide by means of a wide mouthed pipette and each chamber of the slide was filled separately until 6 chambers were all filled with specimen. The slide was then allowed to stand for 10-15 minutes to allow the eggs to rise to the surface, and examined microscopically under low power. Egg counts were calculated by multiplying obtained figure by 200 to get eggs per gram of faeces (epg) (Reinecke, 1983). The arithmetic means of individual counts before and after treatment were calculated for each group. The faecal egg count reduction percent (FECR) was calculated according to the equation: $(FECR\% = (1 - T_2/T_1 \times C_1/C_2) \times 100$ where T and C are the arithmetic means of egg counts of the treated and control groups respectively (Boersema and Pandey, 1997). The subscripts 1 and 2 describe the counts before and after treatment respectively. In this study, the threshold for efficacy was considered to be 80%, according to Kettle *et al.*, (1983) as the threshold at which an anthelmintic is considered effective. Pooled faecal samples using the same amount of faeces from all 40 treated goats and sheep after the first visit were incubated at 25 °C in a Labotec incubator for 5 days and the 3rd-stage nematode larvae (L₃) were harvested to differentiate which trichostrongylid genus was most dominant, using the method developed by Van Wyk *et al.*, (2004).

3.5 STASTICAL ANALYSIS

Statistical analysis was done on a SPSS program 13.0 and mixed procedures of SAS (2003). Analysis of variance was done to determine whether the use of different types of anthelmintics have an effect on the total number of nematodes 2weeks post treatment with the anthelmintics under study and also the effect within the drugs. In the analysis of variance the following factors and their interactions were considered: species, farm and anthelmintics. The T- test was done within sampling groups to see if the groups differed significantly. The Probability was set at 5% level of significance or less. The raw egg count data was log transformed prior to the analysis of variance.

CHAPTER FOUR

4.1 RESULTS

Tables 3 and 5 below show the mean eggs per gram of faeces (epg) for both sheep and goats respectively while Tables 4 and 6 show the corresponding faecal egg count reduction percent (FECR%) for sheep and goats respectively. On considering farmer effect, species effect yielded no significant differences ($P=0.55$) between sheep and goats on the first visit, with the mean epg of albendazole being 2447, ivermectin 2531, closantel 2543 and control 2272 in sheep (Table 3). In goats albendazole had an epg of 2622, ivermectin 2608, closantel 2722 and control 2470 (Table 5). There was also no significant ($P=0.32$) interaction differences between species epg before treatment. There were overall significant ($P<0.01$) differences between drugs in the second visit in both sheep and goats (Tables 3 and 5) as compared to the controls where the epg remained high. Comparing drug X farmer effects, there were no significant differences ($P>0.05$) in epg with most drugs except a few (Table 3 and 5). For instance in goats, closantel and ivermectin showed an epg of 511 on farms 2 and 7 respectively while closantel showed an epg of 760 and 720 in sheep farms 3 and 4 respectively. These eggs were significantly higher ($P<0.05$) as compared to the other drugs. The drug efficacies were based on faecal egg count reduction percent (FECR %) for albendazole, closantel and ivermectin for all the 8 sheep farmers used in the study. The efficacy percent shown in table 4 based on FECR% for albendazole varied from 82%-90%. Ivermectin based on FECR% showed an efficacy of 78%-90% while closantel varied from 71%-91% in efficacy.

Table 3: Mean egg per gram (epg) with standard error of the mean (sem) in sheep for the 1st and 2nd visits

MEAN AND OVERALL MEAN EPG FOR SHEEP

FARM	VISIT	ALBENDAZOLE	IVERMECTIN	CLOSANTEL	CONTROL	Overall Mean for Farmers
1	1 ST VISIT	1500 ^a ± 489 ^w	1850 ^a ± 611 ^w	2360 ^a ± 503 ^w	1875 ± 237 ^w	1896 ^a ± 232
	2 ND VISIT	450 ^b ± 350 ^w	375 ^b ± 70 ^w	560 ^b ± 146 ^w	3050 ± 833 ^x	1109 ^b ± 350
2	1 ST VISIT	2550 ^a ± 899 ^w	2875 ^a ± 1105 ^w	2320 ^a ± 520 ^w	1925 ± 991 ^w	2418 ^a ± 879
	2 ND VISIT	450 ^b ± 207 ^w	500 ^b ± 151 ^w	640 ^b ± 160 ^w	3175 ± 736 ^x	1191 ^b ± 311
3	1 ST VISIT	2650 ^a ± 648 ^w	2600 ^a ± 1063 ^w	2400 ^a ± 340 ^w	1925 ± 345 ^w	2393 ^a ± 599
	2 ND VISIT	500 ^b ± 261 ^w	500 ^b ± 282 ^w	760 ^b ± 172 ^x	3600 ± 1121 ^y	1340 ^b ± 459
4	1 ST VISIT	2025 ^a ± 688 ^w	3125 ^a ± 1002 ^w	2840 ± 511 ^w	2350 ± 905 ^w	2585 ^a ± 875
	2 ND VISIT	400 ^b ± 185 ^w	500 ^b ± 185 ^w	720 ^b ± 135 ^x	3550 ± 1240 ^y	2585 ^b ± 1292
5	1 ST VISIT	2525 ^a ± 827 ^w	2400 ^a ± 1014 ^w	2500 ^a ± 856 ^w	2800 ± 985 ^w	2556 ^a ± 473
	2 ND VISIT	500 ^b ± 239 ^w	600 ^b ± 261 ^w	500 ^b ± 151 ^w	3125 ± 631 ^x	1181 ^b ± 321
6	1 ST VISIT	2500 ^a ± 925 ^w	2440 ^a ± 386 ^w	2325 ^a ± 575 ^w	2300 ± 565 ^w	2391 ^a ± 613
	2 ND VISIT	450 ^b ± 256 ^w	520 ^b ± 135 ^w	450 ^b ± 256 ^w	3850 ± 826 ^x	1318 ^b ± 368
7	1 ST VISIT	2700 ^a ± 534 ^w	2680 ^a ± 257 ^w	2625 ^a ± 766 ^w	2400 ± 925 ^w	2601 ^a ± 621
	2 ND VISIT	575 ^b ± 361 ^w	560 ^b ± 74 ^w	450 ^b ± 381 ^w	3150 ± 918 ^x	1184 ^b ± 434
8	1 ST VISIT	3125 ^a ± 785 ^w	2280 ^a ± 338 ^w	2975 ^a ± 831 ^w	2650 ± 639 ^w	2757 ^a ± 648
	2 ND VISIT	650 ^b ± 232 ^w	520 ^b ± 120 ^w	500 ^b ± 185 ^w	3700 ± 338 ^x	1343 ^b ± 219
Drugs overall means	Overall mean for 1st Visit	2447 ^a ± 724 ^w	2531 ^a ± 722 ^w	2543 ^a ± 662 ^w	2272 ^a ± 699 ^w	2448 ^a ± 702
	Overall mean for 2nd visit	497 ^b ± 261 ^w	509 ^b ± 160 ^w	573 ^b ± 336 ^x	3400 ^b ± 830 ^y	1245 ^b ± 397

^{a,b} Means in a column carrying different letters are significantly different between visits in a farm (P < 0.05)

^{w,x,y,z} Means in a row carrying different letters are significantly different between drugs

TABLE 4: FECR % FOR THE 8 SHEEP FARMERS

DRUG	FARMER	1	2	3	4	5	6	7	8
ALBENDAZOLE		82	89	90	87	82	89	84	85
IVEMECTIN		88	89	89	89	78	90	88	84
CLOSANTEL		85	84	91	71	82	88	87	88

Table 5: Mean egg per gram (epg) with standard error of the mean (sem) in goats for the 1st and 2nd visits

MEAN AND OVERALL MEAN EPG FOR GOATS						
FARM	VISIT	ALBENDAZOLE	IVERMECTIN	CLOSA TEL	CONTROL	Overall Mean for Farmers
1	1 ST VISIT	2800 ^a ± 529 ^w	2977 ^a ± 1983 ^w	2866 ^a ± 721 ^w	2088 ± 625 ^w	2682 ^a ± 965
	2 ND VISIT	488 ^b ± 145 ^w	577 ^b ± 233 ^w	688 ^b ± 226 ^x	3311 ± 301 ^y	1266 ^b ± 225
2	1 ST VISIT	2533 ^a ± 1019 ^w	2933 ^a ± 866 ^w	2977 ^a ± 880 ^w	2488 ± 895 ^w	2733 ^a ± 915
	2 ND VISIT	311 ^b ± 145 ^w	377 ^b ± 210 ^w	511 ^b ± 247 ^x	3444 ± 829 ^y	1161 ^b ± 356
3	1 ST VISIT	2600 ^a ± 741 ^w	2711 ^a ± 860 ^w	3044 ^a ± 455 ^w	2680 ± 756 ^w	2759 ^a ± 703
	2 ND VISIT	711 ^b ± 333 ^w	644 ^b ± 296 ^w	622 ^b ± 233 ^w	3400 ± 707 ^x	1344 ^b ± 392
4	1 ST VISIT	3088 ^a ± 1685 ^w	2333 ^a ± 104 ^w	3088 ^a ± 831 ^w	2440 ± 219 ^w	2737 ^a ± 700
	2 ND VISIT	844 ^b ± 497 ^w	600 ^b ± 331 ^w	466 ^b ± 331 ^w	3080 ± 641 ^x	1248 ^b ± 450
5	1 ST VISIT	2555 ^a ± 798 ^w	2155 ^a ± 881 ^w	2577 ^a ± 696 ^w	2600 ± 707 ^w	2472 ^a ± 770
	2 ND VISIT	422 ^b ± 210 ^w	577 ^b ± 494 ^w	466 ^b ± 264 ^w	3729 ± 1007 ^x	1299 ^b ± 494
6	1 ST VISIT	2666 ^a ± 1053 ^w	2644 ^a ± 926 ^w	2288 ^a ± 943 ^w	2355 ± 1038 ^w	2488 ^a ± 990
	2 ND VISIT	533 ^b ± 316 ^w	555 ^b ± 343 ^w	488 ^b ± 284 ^w	3311 ± 788 ^x	1222 ^b ± 433
7	1 ST VISIT	2466 ^a ± 974 ^w	2444 ^a ± 1013 ^w	2333 ^a ± 583 ^w	2600 ± 264 ^w	2461 ^a ± 709
	2 ND VISIT	355 ^b ± 194 ^w	511 ^b ± 301 ^x	355 ^b ± 88 ^w	3688 ± 491 ^y	1227 ^b ± 269
8	1 ST VISIT	2266 ^a ± 888 ^w	2666 ^a ± 509 ^w	2600 ^a ± 583 ^w	2511 ± 648 ^w	2511 ^a ± 659
	2 ND VISIT	533 ^b ± 244 ^w	488 ^b ± 226 ^w	400 ^b ± 141 ^w	3351 ± 1400 ^x	1193 ^b ± 503
Drugs overall means	Overall mean for 1st Visit	2622 ^a ± 961 ^w	2608 ^a ± 891 ^w	2722 ^a ± 712 ^w	2470 ^a ± 644 ^w	2606 ^a ± 802
	Overall mean for 2 nd visit	525 ^b ± 261 ^w	541 ^b ± 304 ^w	500 ^b ± 227 ^w	3414 ^b ± 657 ^x	1245 ^b ± 262

^{a,b} Means in a column carrying different letters are significantly different between visits in a farm (P < 0.05)

^{wxyz} Means in a row carrying different letters are significantly different between drugs

TABLE 6: FECR % FOR THE 8 GOAT FARMERS

DRUG	FARMER	1	2	3	4	5	6	7	8
ALBENDAZOLE		89	91	78	78	88	86	90	83
IVEMECTIN		87	90	76	80	81	85	85	87
CLOSANTEL		84	87	80	88	87	85	89	90

Based on FECR% as shown in table 6 above in all the 8 goat farmers the efficacy of albendazole varied from 78% to 91%. Ivermectin based on FECR% varied from 76% to 90% while closantel showed an efficacy of 84% to 90% based on FECR%. When the mean efficacies of the 3 drugs were compared between goat and sheep farmers, there was no statistical significance ($P>0.05$) on all the drugs used. For instance the probability of sheep versus goats was:

Albendazole : $P = 0.39$

Ivermectin : $P = 0.95$

Closantel : $P = 0.13$

On examination of L_3 larvae in both sheep and goats, the most prevalent genus was *Haemonchus* spp, followed by *Trichostrongylus* spp and *Oesophagostomum* spp.

CHAPTER FIVE

5.1 DISCUSSION

Generally all the 3 drugs used in sheep and goats significantly ($P < 0.01$) reduced the epg after 2 weeks as compared to the control groups where there was no significant ($P > 0.05$) difference between the epg in the first and second visits (Tables 3 and 5). This was expected because the 3 drugs used (albendazole, ivermectin and closantel) come from the most commonly used potent drug groups of benzimidazole, avermectins and salicylanides respectively (Van Wyk *et al.*, 1990). The 3 drugs used had efficacies of more than 80% which places them in group A anthelmintics (Van Wyk *et al.*, 1990). There was no significant ($P > 0.05$) effect in epg between the first and second visits in the control animals because no drug was administered to suppress the nematodes. When the effectiveness of the 3 drugs on epg was compared on the same farm (i.e. farmer X drug interactions), there was no statistical significance ($P > 0.05$) between them (Table 3 and 5). Almost similar potency was exerted on the nematodes by the 3 drugs highlighting the factor that all these drugs come from same anthelmintic classification of group A. Comparing drug X farmer effects, there were also no significant differences ($P > 0.05$) in lowering the epg with most drugs, showing again that the drugs are from the same group A of potency (Tables 3 and 5). However, there was an exception indicated by closantel and ivermectin in goats and sheep where their epgs were significantly higher ($P < 0.05$) (Tables 3 and 5). Closantel exerted significantly higher epg in sheep of 760 and 720 in farmers 3 and 4 respectively. While in goats it had an epg of 511 in farmer number 2. Closantel has been reported to be more effective on blood sucking parasites like *Haemonchus* (Papadopoulos, 2008) which was

predominant in the present study and not on none blood sucking parasites like *Oesophagostomum* and *Trichostrongylus* spp which were found in the pretreatment larval cultures. Hence this effect might have contributed to the high epg indicated by closantel in both goats and sheep in those farms. The significantly higher epg indicated by ivermectin on farmer number 7 in goats is not clear but it could have probably been due to high drug metabolism in the gastrointestinal tract in the goat species (Papadopoulos, 2008). More research need to be conducted in drug metabolism in communal environments in goats.

On examination of the L₃, the most prevalent genus was *Haemonchus* spp, followed by *Trichostrongylus* spp. and *Oesophagostomum* spp. Similar prevalence has been reported in communally grazed sheep and goats probably due to free grazing of sheep and goats on communal rangelands (Bakunzi 2003, 2008). In summer rainfall areas *Haemonchus* has also been reported to be the most prevalent genus as shown in this study (Van Wyk, 1990).

Overall, all drugs used had almost similar efficacies in both goats and sheep (Tables 4 and 6). Goats have been reported to be more resistant to anthelmintics due increased drug metabolism in their gastrointestinal tract (Papadopoulos, 2008). Because of this increased metabolism in goats the dose given to goats is usually doubled relative to that used in sheep. In this study the same dose was used for both sheep and goats and therefore less efficacy would have been displayed in goats than sheep which was not the case in this study. The reason for this is not clear in this region and more research is needed to be done on drug metabolism in sheep and goat raised under communal rangelands for conclusive results.

The efficacies of drugs obtained in the present study were generally above 80%, considered to be the cut off point (Kettle *et al.*, (1983) for anthelmintic resistance in both sheep and goats (Tables 4 and 6), suggesting that the level of anthelmintic resistance may not be as high as on commercial sheep farms in Southern Africa (Van Wyk *et al.*, 1999). The reasons for low resistance in communally grazed goats and sheep in this study is probably due to infrequent dosing by resource-poor farmers. There may therefore still be the prospect of slowing down the development of severe anthelmintic resistance in communally grazed sheep and goats in this region. However, there were notable exceptions in some farms displaying some degree of resistance to some drugs in this study in both sheep and goats. For instance, on farm number 3,4 in goats the efficacies of albendazole were 78% and ivermectin displayed an efficacy of 76% on farm number 3. In sheep ivermectin had an efficacy of 78% on farm number 5 while closantel showed an efficacy of 71% on farm number 4. The above results indicate presence of resistant nematode populations in those goats and sheep farms.

The anthelmintic resistance noticed in this survey in communally grazed sheep and goats may be due to under dosing as result of limited financial resources (Van Wyk *et al.*, 2006). This was especially so on farm number 3,4 in goats where it was mentioned on investigation that the animals were dosed with small amounts to both sick and healthy animals due to lack of money. In addition to under dosing emerging farmers often buy animals at auctions supplied by commercial farmers on which anthelmintic resistance may be present, and in this way resistant nematode populations or strains may be disseminated.

5.2 Conclusion and Recommendations

The present study indicated a mild degree of anthelmintic resistance in both sheep and goats raised under communal systems. However some degree of resistance was noticed on few sheep and goat farms, indicating the presence of resistant nematode strains. This is a bit concern in the emerging farmers and the stakeholder must take some measures to stop spread of anthelmintic resistance as has been observed on most commercial sheep farms. The following should be some of the adaptations which can be put in place to minimize the spread of anthelmintic resistance in small stock:

- i). Increasing the number of untreated animals on the farm by using the FAMACHA system to identify anemic animals to be treated.
- ii). Quarantining of new animals
- iii). Breeding tolerant animals
- iv). Introducing nematophagus fungi and plants containing condensed tannins as alternative to chemotherapy.
- v). Improving quality of nutrition by supplementing protein

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